DISTINCTIVE FEATURE ANALYSIS OF TELUGU CONSONANTS

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CERTIFICATE

This is to certify that the dissertation entitled "Distinctive Feature Analysis of Telugu Consonants" is the bonafide work in part fulfilment for the degree of M.Sc., (Speech and Hearing) of the student with the register number:11

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This is to certify that this dissertation entitled "Distinctive Feature Analysis of Telugu Consonants" has been prepared under my supervision and guidance.

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DECLARATION

I hereby declare that this dissertation entitled "Distinctive Feature Analysis of Telugu Consonants" is the result of my own study undertaken under the guidance of Mr. N.P.Nataraja, Reader in Speech Science, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for **any** other diploma or degree.

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CHAPTER - I

INTRODUCTION

INTRODUCTION

The of the fundamental properties of language is that there exists a code whose elements called the distinctive features form the smallest units of language and from which meaningful entities are constructed. The code underlying a given utterance is sometimes viewed as a sequence of units or segments, each of which consists of a set of distinctive features.

The distinctive features can be referred to as the building blocks of the unit or segment which in turn is an element of the code. In other words language is built up of words, words of sounds or phonemes and phonemes of features which are distinctive from each other.

Speech/Language pathologists are interested not only in the combination of various features in the phoneme but also in the way each of these 'features' are acquired, maintained and lost during pathology. According to Hanson (1983)"..... Distinctive feature theory, has viable applications to developmental, evaluative and treatment aspects of articulation disorders.....".

A number of studies support the use of distinctive features in studying the (l) developmental aspects of language (Menyuk, 1968; Leonard, 1973; Panagos and Associates, 1979; Singh and Associated, 1981).

(2) Evaluation (Oiler, 1973? McKeynolds and Huston, 1971? McKeynolds and Elbert 1981) and

(3) Treatment (Pollack and Reese, 1972; McKeynolds and Bennet, 1972; Winitz, 1975; Costello and Onstine, 1976;? Ruder and Bnnce, 1981) of articulation disorders.

Further, the application of distinctive features in the studies of speech reception have proved to be useful. The feature approach helps us to find dimensions that are more important for perception of speech sounds. The workers in the field of speech perception have employed feature frame work to study speech perception in normals (Singh, 1968?; Tonnahill and McKeynolds, 1972? Singh and Blackman,1974; Binnie et al, 1974; Danhauver et al 1978; Miller and Nicely, 1955) and in deaf individuals (Singh et al 1974; Danhauer and Singh,1975; Doyle et al 1981). Danhauer and Singh, (1975) pointed but that hearing impaired subjects used different perceptual strategy and derive comparable amount of feature information from minimal cues available.

On the contrary, there have been few critical reviews on distinctive features, questioning its conceptual reality and theoretical basis (LaRiviere et al, 1974; Retterman and Freeman, 1974; Parkey,1976). Some have even questioned the clinical applicability of distinctive features due to its limitation of not accounting for co-articulation, prosody and dialect (Walsh, 1974; Leonard, 1974; Lund and Duchan, 1978). Despite the limitations, distinctive feature approach is promising tool to speech pathologists and audiologists in handling various speech and hearing problems.

Various approaches to establish feature system in a language have been reported. Acoustic method, Articulatory method and Perceptual method are few of the major methods.

The establishment of the feature system may be apriori or aposteriori. Apriori method involves defining or proposing a feature system before acoustics articulatory or perceptual analysis Here the system proposed forms the basis for analysis of data (Miller and Nicely, 1955).

Aposteriori method involves analysis of plathora of sample and then by various analysis techniques like fine analysis of spectrograms of multidimensional scaling analysis of perceptual data, the features are teased out (Jeter and Singh, 1972).

Apriori method lacks flexibility but it is comparitively less time consuming and simpler. In this study, apriori method has been used to establish the features and thus the present study has the inherent limitations of using apriori method.

In this study an attempt has been made to establish a disti: tive feature system for consonants in Telugu language. Two experiments have been carried out in order to identify acoustic correlates of the proposed feature system and to find out the information carried by each feature perception of speech. Further a cross linguistic study has been carried out in order to test universality of the proposed feature system. The perceptual responses of Telugu and non-Telugu speakers have been compared.

Need for the present study:

Speech Pathology deals with the understanding and treatment of speech language disorders. It has been shown that, distinctiv feature theory has viable application to the developmental, evaluative and treatment aspects of articulation disorders. The Speech/Language Pathologist needs to have a good understanding of the problem as suchas in addition the language to be taugh Somasundaram(1972) states that "... The situation in India, with its multiplicity of linguistic groups, necessitates the study of language. Present additional problems is that the speech clinicin may have to work with languages non-native to him". This clearly indicates the need for the distinctive feature analysis in differs languages and hence in Telugu.

430 words pairs were made using the 31 phonems of Telugu and were randomly presented through headphones in a quiets. situation to 30 Telugu listeners were recorded and later analyse by the experimenter. Confusion matrices were constructed for both the groups and the information content of each feature was determined.

30 words were spectrographically analysed and acoustic characteristics were detected.

Statement of the problem:

To establish a distinctive feature system for consonants in Telugu by perceptual and acoustic methods respectively.

Hypotheses:

1. It is possible to propose a distinctive feature system in Telugu based on phonetic description.

2. Consonants in Telugu are made up of the following features:

   a) Voicing (b) Nasality (c) Continuent (d) Anterior (e) Coronal f) Stridency (g) Aspiration (h) Lateral.

3. Information carried by each feature varies.
4. Each feature has distinctive acoustic characteristics.
5. No significant differences will be found in the listening performance of Telugu and non-Telugu speakers when word pairs are presented in a quiet situation.

Limitations of the present study:

1. Apriori analysis has been used, and hence the study has the inherent limitation of using this method.
2. Only experimenter served as the judge in the present study.
3. Only a limited number of listeners (30+30 in each group) were used due to time constraint.
4. Distinctive feature system has been proposed only for consonants.

CHAPTER-II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Language is built of words, words of sounds or phonemes and phonemes of features which are distinctive from each other. Thus a sound is composed of several parameters which are termed as featured. Those features which provide us with the information about the various distinctive between these speech sounds are called distinctive features. In essence the distinctive features can be referred to as building blocks of the phoneme. The 'Distinctive feature theory' has viable applications to developmental evaluative and treatment aspects of speech disorders. This aspect has more pertinence to the speech specialists, who seek to understand the reasons for the speech deviations in individuals and to discover if any error patterns are present, the understanding of which might facilitate their elimination and replacement by normal adult speech.

Untill, 1939, it was believed that a phoneme is the smallest unit of language and that cannot be further divided. In 1949 Roman Jacobson wrote 'on the identification of phonemic entities' in which for the first time all the phonemes in a language (French) were treated systematically in tens of features. The first complete description of the acoustic properties of distinctive features appeared in Jakobson, Faut and Halle's book 'Preliminaries to speech Analysis published in 1952. The authors asserted that there are a limited number of distinctive features that can be used to describe all the languages of the world.

In the early days of prague phonology, (The prague school studied the structure of language, particularly in terms of features that served to distinguish one phoneme from another), Trebetzkoy and his colleagues looked at phonemes as basic units of opposition. Their examination of phonemes, however, led them to the conclusion that the complexity of language precludes any phoneme having any other phoneme as its only opposite. The next step then was to apply the concept of opposition to the features of phonemes which Jacobson did in 1932. Since then a binary approach to the analysis of features has remained the most frequently used procedure among linguists as well as among speech and language pathologists. In binary approach, the presence of one member of opposing features is marked with a +, and the absence of the contrasting member with a -. Any consonant for eg. can be defined as + consonantal and/or and- non consonantal.

The parameters or the constituent properties of the phoneme are called '<u>Features</u>'. The parameters which distinguish two phonemes of a language are known as 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 Jacobson, Fante and Halle (1952) the distinctive features are the ultimate distinctive entities of language. The distinctive features combine into one simultaneous or concurrent bundle to form a phoneme.

Jacobson (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 motorically produced acoustic properties. A chord is heard as one element and yet is made up of other elements. This transformation, a shift in emphasis from the unit to its subcomponents was the goal of distinctive feature theory.

According to Fant (1973) distinctive features are really distinctive categories or classes within 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 and these phonetic facts on various levels have lent their name to the features.

Blacke (1978) defines a distinctive feature as systematic property that separates a subset of elements from a group.

The definition given by various authors reveal the articulatory, acoustic and perceptual facets of the distinctive features.

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.

First, phonemic theory implies the existence of nondistinctive features, which not only adds unnecessary formal apparatus to the theory and makes the set of distinctive features potentially infinite, but also the concept of nondistinctive feature is not precisely definable.

Second, it allows for the possibility of language specific distinctive features, which makes comparisons among different languages in terms of distinctive features impossible.

Third, it imposes the conditions of linearity and biuniqueness on the relation between the phonemic and phonetic levels of representation, even though these conditions can be shown not to hold, and

Fourth, the assumptions on which the phonemic theory are based are not valid; namely that there is a direct correspondence between phonemes and the speech speakers actually produce and hear in speech (Packer, F, 1976).

Discrepancy between the abstract linguistic system and physical speech signal led Chomsky and Halle (1968) to propose a different concept of phonology. Generative phonology seeks to discover the principles or rules that determine pronunciation in a language, and to the extent these principles are universal.

Chomsky and Halle (1968) in their theory excluded the one to one relationship between phonological segments and speech segments with its conditions of linearity and biuniqaeness. Since there is no theory of phonemics operating in generative. Phonology, it is based on a system of universal phonetics. Chomsky and Halle (1968) state that the features are identical with the set of phonetic properties that can be in principle controlled in speech, representing the phonetic capabilities of man and therefore the same for all languages. Limiting the distinctive features to phonetic properties that are independently controllable in speech makes the selection of distinctive features empirical than arbitrary.

Generative theory (Chomsky and Halle 1968) defines the phonemes of a given language, because they are not directly observable they must be arrived by a discovery process, which are nothing more than alogirthms set up of this purpose. Enumerationof phonemes of a given language is a function of the alogirthm 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. And they recognize 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 matric to yield the phonetic matrix and vice versa. 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 a substitute theoretical framework, based on a concept of the distinctive feature as a definer 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 - Speech Sound Perception:

The role of distinctive features in perception of phonemes has been considered as Vital Singh (1976). The features are the underlying attributes of perceptual processing thus speech sound perception and speech sound discrimination can be measued. and quantified based on distinctive features.

Speech sound perception in normal hearing individuals has been studied extensively. A number of studies on speech sound perception under different conditions (eg. 1) under various signal to noise ratio (2) stimuli present only in (a) auditory mode (b) only in visual mode (c) in combined mode etc) have been reported (Singh, 1968; Tannahill and McKeynolds (1972); Singh and Blackman, 1974; Binnie, Montgomery and Jackson, 1974? Danhauver et al 1978; Miller and Nicely 1955).

The results of these studies reveal that:

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

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

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.

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 occured most frequently between classes distinguished by a single feature and they have concluded that in the initial position, confusions generally arise due to manner of articulation, and in the final position confusions 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 pecception, of Hindi consonants in clipped speech. Effect of peak clipping on intelligibility of individual consonants was found and 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 as follows: 1) place of articulation (2) nasality (3) flapped liquids (4) liquids (5) continuants (6) voicing (7) frication (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 both recognising. And reproducing the same.spectrographic studies showed that aspirates and unaspirated /h/ was different.

Speech sound perception in hard of hearing individual has also been subjected to investigation. Studies on hearing impaired population points to an inference that hearing impaired individuals 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 features voicing nasality and sonorancy.

Danhaver and Singh (1975) studied perceptual processing of CVCV type of stimuli in deaf subjects. From their results, they deduced 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 totheir 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, Danhauer 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, frication and sibilancy were salient features in perception of speech sounds for both groups of listeners. This sugested that both groups use similar pecceptual 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 the groups formed by this analysis correlated with different hearing loss groups. For high frequency loss cases, the feature sonorant was dominantly used. The authors attribute this as due to low frequency formant in sonorant feature. For flat hearing loss the feature sibilance was the dominant dimension, normals used both these features equally. Even Bilger and Wang (1976) found significant correlation between audiometric configuration and consonant confusions.

Blood, I.M, Blood, G.W., and Danhaver (1978) studies 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 weer 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.

Acquisition of speech sound perception:

The classic report on infant perception of speech like stimuli was published in 'Science' in 1971 by Eimas, Siqueland, Jusczky and Vigorito. They monitored Infants sucking a parifier wired to a transducer which recorded infant responses to synthetic speech sounds differing by 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 continua within the same general categories as do adults.

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 question that results from the increasing evidence of infant perceptual abilities is whether infants are innately tuned to detect linguistically significant contrasts, or whether the distinctions they perceive are a result of chaacteristics of the auditory system, Without reference to language. More information is needed on what distinctions infants universally make despite language environment and, further, how language learning affects the perceptual abilities of infants.

Latin 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 prevocalic stop consonants from synthetic prevocalic stop consonants from synthetic speech. The stimuli differed with respect to acoustic cue-voice onset time. Identification functions for labial, apical aHd velar stops were plotted. 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 Perecption:

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 cut 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 beings the interesting question of how perception of one's own speech may relate to perception of speech of others.

Aungst and Frick (1964) found that there was a low correlation correctness of /r/ production and the ability to discriminate phonemes in other's speech. Children with /r/ misarticulation had no problem perceiving the misarticulations of others but failed to detect their own errors.

Kornfeld (1971) showed that children may produce /w/ sounds in (gwzes) for glass and (gwzes) for grass which seem the same to adult listeners. There are spectrographic differences, however, which may reflect the basis on which the children make distinctions.

On the contrary, Locke and Kutz (1975) found that of 75 children who said (Win) 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.

McReynolds, Kohn and Williams (1975) found that children with misarticulations are worse at discriminating their own error sounds than their error free sounds.

Kumudavalli (1973) studied the relationship between articulatory performance and discrimination in school going children and the results revealed that production always preceded 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, with production and self perception developing in parallel as motor maturity permits* The time course of perception - production interaction remains unclear, and 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:

A classic study in the neurophysiology of speech perception was Kimura's (1961) study of cerebral dominance by use of dichotic stimuli. Kimura (1961) used spoken digits and found that subjects made fewer mirrors 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, shew that the right ear to have a small but consistent advantage. Steady state vowels, however, show no consistent ear advantage. Vowels, being more accessible auditory analysis by virtue of their longer duration and higher intensity may be held longer in auditory memory, are less categorically perceived, and yield a weaker right ear advantage. Stop consonants, beipg less accessible to auditory analysis due to their brevity and relativaly low intensity, may be held only briefly in auditory memory, are categorised immediately, and yield a stronger gight ear advantage. These results have been explained by positing a speech processor inthe 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.

BlumStein, 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 that 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 might be explained on either a phonetic or an auditory ievel.

Hayden, Kirstein and Singh (1979) evaluated the role of distinctive featuees 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.

The different studies reported in literature leads to the belief that something special is happening in the left hemisphere when one listens to speech, whether it is some kind of auditory analysis of transient, difficult stimuli, or whether it is some form of linguistic analysis, such as the extraction of features or phoneme 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, Faut 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) examined the articulation tests of 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.

Panagos 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 (l) 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 descending 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. Defnite 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).

Landuage

b) Use of D.F. system in evaluation of Speech/Disorders:

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 McKeynolds 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: (l) 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 occured 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 (l) 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.

The use of D.F. system:

(c) Treatment:- Phonological principles have considerable utility in speech and language disorder intervention. One of the earliest references to the utilisation of distinctive features in speech/language pathology is an article by Pollack and Reese (1972). The authors accomplished two important purposes, First, they introduced speech clinician to distinctive features and motivated them to become better acquainted with the clinical value of feature approach. Second, they provided a model for the application of distinctive features theory to the evaluative process.

Positive results concerning generalisation of distinctive features training to untreated phonemes were found by McReynolds and Bennett (1972). They analysed the articulation patterns of three children using chomsky and Halle's distinctive feature system, and trained the children using the following procedures.

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. The contrasting of the feature was in step two, wherein the children learned 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.

McReynolds and Benett (1972) found that trained features generalised across several phonemes to varying degrees among the three children.

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 intructional 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 therough the use of distinctive features. For one child instruction was given on the production of the /s/ and /k/ phonemes to determine whether corrected features of those two sounds might generalise to another phoneme, the /t/ which contains no features that are not present in the other two phonemes. As predicted, training on /k/ and /s/ did lead to imitative production of the target sound /t/ . Also affected positively were the productions of /f/ and /ts/.

The second child received training on three phonemes /b/, /s/ and /k/ (consecutively, not concurrently). Training on the /b/ generalised to the /in/ and /I/. Training on the /k/ generalised to the /p/, /h/, /d/, and /r/ and training on /s/ the child produced another 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 train-

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 another 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).

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Weiner and Bernethal (1978) based on their clinical experience sugested several criteria for selection of a feature for training. These criteria are (1) redumdancy (2) number of features in error (3) Ease of articulation (4) Acoustic contrast (5) More visibility (6) Higher frequency of usage (7) physiological readiness.

From the review, it is clear that a number of studies support the value of feature analysis.

Advantages and criticisms 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? McKeynold 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.

Damien 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 evaluatien 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, 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, end seeks principles that have general application within and across languages? the latter strives for completeness and clarity in his description of a speech pattern.

Leonard (1973b) argues that co-articulatory influences so shape a phoneme in connected speech that to assign plus or minus values to them is unrealistic. In other words, phonemes in context defy dichotomisation.

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 a11 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, aurmur, lax voice, 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(l980) 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 had 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 phonohical patterns in clients with multiple defective sounds and in clients demonstrating language.delay in combination with articulatory defects".

Different methods of analysis of distinctive features have been used to arrive at the features. Acoustic method has been used by Jakobson, Fant and Halle (1952). They have proposed twelve binary, universal features using acoustic terms based on the spectrographic analysis. They have demonstrated clear acoustic distinction between consonants and vowels. They believe that in no language all these features 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 and 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.

The periodic, harmonically structure 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 relatively steady state 6f the vowels and nasals. Some dipthongs glide as much as any semivowel, but the glides are generally more rapidly changing 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, inten-sity and timing.

The acoustic cues for 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 F1. - F2 acoustic, space, with F1 frequency indicating tongue height or mouth opening and F2 frequency indicating place of maximum approximation of the tongue with the walls of the vocal tract. Semivowel production's mainly reflected in the frequency changes in F2. The semivowel / j / begins with the highest F2, with / r / and /l/ in the middle frequencies, and/w/ relatively low. F3 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 F2 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 is palatal or velar. The F2 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 /ʃ/, it is more often 2500 Hz. If the friction covers a wide band of frequencies, it is more likely to be /f/, /f/, 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 F2 transitions. Acoustic 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 abscence 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 affiicates 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 can cue the perception of differences in voicing, with voweis of longer duration perceived to be followed by a voiced consonant and vowels of shorter duration perceived to be followed by a voicelss consonant.

Chomsky and Halle (1968) describe the articulatory features of universal sounds. The features are binary and are defined by autonymus adjectives. The vocal mecanism 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 term, 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 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 of 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(l969), Singh (1968), Wickelgren(1966) Shepard (1972); Singh and Woods (1971). Singh (1975) describes these perceptual methods as (l) 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, method, the experimenter determines how and based on how many dimensions the data will be analysed prior to analysis. 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. Conditions of acoustic distortion noise and filtering of the stimuli(Miller and Nicely 1955).
2. Cross linguistic settings (Singh and Black, 1966)
3. Recall in short term memory (Wickelgren, 1966).
4. The utlisation 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; 8ingh 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 thet(l) it leaves to choose 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 aposterior , 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 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 articularoty 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, Lawan and Biuce (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 Ghomsky and Halle. After the data entry is complete (about 50,000 words) the program could calculate to 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 times that the plus and minus aspects of a feature used in correctly.

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 feature systems have 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 consanants 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 interms 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(l) Vocalic, (2) Consonantal, (3) Compact/diffuse, (4) Grane/Acute, (5) Plat/Plain, (6) Nasal/Oral, (7) Tense/Lax, (8) Interrupted/continuant, (9) Strident/Mellow, (10) Checked/ Unchecked, (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 temary 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. in completeness. 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 frication for affrication and adding three additional features, liquid, glide and retroflex. Singh made place quaternary by dividing'mid' into midfront and midback. His system is particularly well suited for application in the analysis and treatment planning of disorders of articulation (Hanson, 1983).

In 1968. Chomsky and Halle published their 13 feature approach to analysis. Their features are all defined in articulatory terms and are all binary. They are:

1. Vocalic: The liquids (/r/&/l/) and all the vowels.
2. Consonantal: All the consonants including liquids.
3. Rounded: All vowel sounds that require a rounding of the lips.
4. Tense: The /i/ /u/ and diphthongs.
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 /i/, /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 pathologists. 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 noteworthy 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 be 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).

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

Valantine (1977) proposed a system for classifying phonological segments (of Maiayalam 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 air 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 were 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. Around the same time, Venkatesh (1983) studied the distinctive feature system in Kannada language using both articulatory and acoustic methods. Eight features were found to be present namely, voicing, nasality. Aspiration, Anterior, Coronal, Continuancy, stridency and lateral.

Thus the review of literature indicates the need for studying distinctive features of a language. Not many Indian languages have been subjected for such an analysis. Information regarding the distinctive features of two south Indian languages (Kannada and Malayalam) by experimental analysis are available. However, no information regarding the distinctive features of Telugu consonants by experimental analysis were available to the present investigator. Therefore, it was felt necessary to analyse Telugu consonants to obtain distinctive features. Further in order to develop suitable articulation tests in Telugu and provide the basis for developing therapy material in Telugu, it was intended to carry out the present study.

CHAPTER - III

METHODOLOGY

METHODOLOGY

The present study was undertaken to establish a distinctive feature system for the consonants in Telugu and to establish the acoustic correlates for the proposed features.

The distinctive feature system proposed for describing the consonants in Telugu language consists of the following features (1) Voicing (2) Nasality (3) Continuent (4) Anterior (5) Coronal (6) Stridency (7) Lateral (8) Aspiration. This set of distinctive features are based on distinctive features system proposed by Chomsky and Halle (1968) who in their attempt to establish an universal system of phonology proposed an inventory of binary distinctive features appropriate for describing a large number of languages.

The Telugu consonants considered in the present study are based on the phonetic classification in terms of manner and place of articulation of consonants in Telugu language (Venkateswara Sastry, 1972; See Appendix..2...)

Construction of the word pairs list:

430 word pairs using the 31 consonants in Telugu were constructed. Each consonant was given the chance of being

contrasted with every other consonant considered in the present study.

For eg: Paga - baga, palli - talli, padi - tadi....

In certain cases, a meaningful contrast was not available, and such contrasts were not considered. The word pairs were such that, the consonant in question would differ between the two words, which may occur in initial or medial position (for eg. Pata - bata, Kalla - kajja). But for majority of the word pairs, the initial contrast was maintained. It was attempted as far as possible to have the most familiar words while forming the list (See appendix..3. for the list of word pairs).

Recording:

Recording was done in a quiet 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 simultaneously fed to a Cosmic Tape recorder ( ) and the word pairs were recorded on Philips cassette. A gap of approximately one second was given between words of a pair and a gap of approximately five seconds was present between two successive word pairs.

Speaker:

An adult male native speaker of Telugu served as the speaker for the recording of the word pairs list.

The following experiments were conducted to establish the distinctive features (l) Perceptual analysis and (2) Acoustic analysis.

1) Perceptual Analvsis:-

This experiment was divided into two parts.

Part-l:

Subjects:-

The group comprised of 30 listeners (15 males and 15 females) who were native speakers of Telugu. These subjects could read and write Telugu well. Their age ranged from 18 to 23 years and the mean age was 19 years. The subjects had no history of speech and hearing problem.

Procedure:

The tape recorded word pairs were played through earphones to each listener in a quiet room. The following instructions were given in Telugu.

" ఇప్పుడు మీరు కొన్ని పదజోడీలను వింటారు
దయచేసి సరిగ్గా వినండి. ప్రతి ఒక్క పదజోడిని
విన్న వెంటనే, దానిని మరు విన్న రీతిలో తిరిగి
చెప్పండి."

" You will hear several Telugu word pairs. Please listen to them carefully. As soon as you hear the word pair repeat the word pair as you have heard ".

The responses of the listeners were recorded using a National Panasonic tape recorder for scoring and analysis. It took nearly 30 minutes to record the responses of each listener.

Scoring:

The responses of each subject was scored as correct or incorrect on the response sheet by the experimenter. A response was considered as correct, if the spoken response was same as the presented stimulus. A response was considered incorrect when the spoken responses was different from the presented stimulus.
The incorrect responses were further analysed to find out the sounds for which substitutions were made.

Part - 2:

Subjects:

This group comprised of 15 males and 15 females who did not have Telugu as their mother tongue nor were they native speakers of Telugu. (The group consisted of 15 Kannada speakers, 8 Tamil speakers and 7 Malayalam speakers). They ranged in age from 18 to 25 years, and the mean age was 22 years. The subjects had no history of speech and hearing problem.

Procedure:

The instructions were given either in English, or in Tamil or in Kannada according to the subjects language*. The essence of instructions was the same as that given for the Telugu speakers. In addition here the subjects were told not to bother about the meaning of the words they are going to hear as, it is in a language non-native to them.

The responses of the listeners were recorded using a National Panasonic Ttperecorder for scoring and analysis.

Scoring:-

The spoken responses of all the 30 subjects were scored as in Part-1.

Acoustic Analysis:

Stimuli:

30 words were selected from the master spool in such a way.

that acoustic correlates for the eight features proposed could be established.

Equipment:-

Speech spectrograph (VIC MK 700) which has prevision for continuous recording and to analyse speech sample of 2.4 second duration at a time was used.

Procedure:

Wide band spectrograms were taken for each word using speech spectrograph (VIC MK 700). The spectrograms thus obtained were analysed to note the following characteristics (1) Presence of periodic or aperiodic energy (2) Formant transition (3) Frequency at which concentration of energy is seen (4) Voice lag or voice lead.

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CHAPTER-TV

RESULTS & DISCUSSIONS

RESULTS AND DISCUSSIONS

The results of the two experiments conducted provide the acoustic correlates for the distinctive feature system proposed for the consonants in Telugu and also the amount of information carried by each distinctive feature.

The proposed distinctive feature system for consonants in Telugu consists of the following eight features:- I) Voicing 2) Nasality (3) Aspiration (4) Anterior (5) Coronal (6) Stridency (7) Continent (8) Lateral.

Perceptual Analysis:

Part-1:

Analysis:

The responses of 30 Telugu listeners to 860 words have been analysed using a confusion matrix (See Table-1).

A confusion matrix is a matrix in which the stimuli and responses are portrayed. 31 consonants presented to 30 listeners as they occured in 860 words are presented in the vertical axis of the matrix, as stimuli. The same 31 consonants are by 30 listeners and the spoken out responses are represented on the horizontal axis, as response. The matrix is made up of 860 observations of 30 listeners making it 24120 observations totally.

The number written in each cell is the frequency of occurence of the sound in the response column for the sound shown in the corresponding column of the stimuli. The row sum gives the total frequency of stimuli presented and column sum gives the total frequency of responses which occured.

Further, the confusion matrix for 31 consonants in Telugu was subdivided in voice communication network of eight component binary channels of linguistic features, based on eight features proposed. Confusion matrices were formed for each of these linguistic feature. These matrices were four fold matrices,

Eg:

		Response	
		Voiced	Voiceless
Stimuli	Voiced		
	Voiceless		

In all the confusion matrices thus formed, the sum of numbers in a diagnal line indicates the number of correct responses, and the numbers scattered around the 'diagnal' indicates error response.

A measure of co-variance based on information theory (Shannon and Weawer, 1963) was employed to calculate information transmission for a composite phoneme channel and for eight linguistic distinctive features.

The formula used:

$$T_{(x,y)} = -_{ij} P_{ij} \log_2 \frac{P_{i} . P_{j}}{P_{ij}}$$

where,

$T_{(X,Y)}$ = Information transmission from input variable 'X' to output variable Y bits/stimulus.

Pi = ni/N

Pj = nj/H

Pij = nij/N

ni = Frequency of stimulus i

nj = Frequency of response j

nij = Frequency of joint occurence of stimulus i, and response j in a sample of N observations

N= Total number of observations: In table(l) cell entries are 'nij'; row seems are'ni'; column sums are nj and N is 24120.

To calculate $T_{(x,y)}$:

For example:

Response

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

Where $N = a+b+c+d$

$$T_{(x,y)} = \frac{a}{N} \log_2 \frac{\frac{a+c}{N} \times \frac{a+b}{N}}{a/N} + \frac{b}{N} \log_2 \frac{\frac{a+b}{N} \times \frac{b+d}{N}}{b/N}$$

$$= C/N \log_2 \frac{\frac{a+c}{N} \times \frac{c+d}{N}}{C/N} + \frac{d}{N} \log_2 \frac{\frac{b+d}{N} \times \frac{c+d}{N}}{d/N}$$

The information value carried by each feature was calculated using the above formula (See table 2 & 4).

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.

$$H = \sum_{n=1}^{8} P_x \log P_x$$

Px refers to the probability of occurence of a particular feature. For eg: the probability of occurence of 'voicing' (PI) is 18 out of 31 (i.e. out of 31 consonants 18 consonants are voiced), and for coronal (P2) - it was 20/31 and so on. The values P1 to p8 were substituted in the above formula.

$$\text{i.e. } H = \sum_{n=1}^{8} p_1 \log_2 P_1 + P_2 \log_2 P_2 + \text{-----} P_8 \log_2 P_8$$

and the composite channel information transmission was found to be 3.058 bits/stimulus.

DISCUSSIONS:

The percentage of correct responses to 860 words by 30 Telugu listeners was found to be 87.88 percent. By observing the pattern of error responses scattered around the diagnal line, (See table-1), it can be inferred that when two sounds differ in more number of features, the confusions are less; and when two sounds differ in less number of feature, then the confusions ace more for eg. more confusions between /k/ and /g/ and less confusions between /k/ and /p/ were observed.

The results indicate that several features play an important role in speech sound perceptions. These features work independent of each other in the perception of speech sounds. However, the features are not completely independent. This is supported by the finding that composite phoneme channel transmits 3.058 bits/stimulus information, whereas the total information transmission by eight features, is 5.2838 bits/stimulus whish is obviously greater than that for a composite phoneme channel. This difference is due to 'cross talk' or overlap between component channels and is attributed to redundancy of the language.

From table-2, it is clear that, all distinctive features do not have equal importance in speech sound perception. Some distinctive features transmit more information than few other distinctive features, thus supporting the hypothesis, 'The information content carried by each of these distinctive features vary'.

The ranking of the features according to the amount of information transmitted indicates that the feature 'voicing' is the strongest feature and the feature lateral the weakest. Venkatesh (1983) found similar ranking of features in Kannada language. Miller and Mcely (1955) found 'Voicing' to be the strongest feature in English.

Part-II

Analysis:-

The responses of 30 non-Telugu listeners to 860 words were analysed using a confusion matrix as described in Part-I (See table-3 for the confusion Matrix).

Results and Discussions:-

The percentage of correct responses for 24,120 observations by 30 non-Telugu listeners was found to be 86.57%. The percentage of correct responses is almost the same in both the groups. (Telugu listeners 87.88%). Further the pattern of error was found to be similar in both the groups. This makes clear that non-Telugu listeners(who had either one of dravidian languages other than Telugu as their mother tongue) use the same set of distinctive features as the Telugu listeners to identify speech sounds. This finds support in Somasunda (1972) study who found that nine of distinctive features namely; vocalic, consonantal, nasal, continuous, tense, grave, compact, flat and diffuse were common in all the four major Dravidian languages and the features sharp to be significant in Tamil and Malayalam and strident to be significant only in Malayalam.

Information transmission was calculated in bits/stimulus for composite channel and individual features, and the total channel transmission was also obtained. (See table-4). The obvious discrepancy between the total channel transmission and the composite channel transmission is attributed to 'cross talk' or overlap between component channels. This makes it clear that the features are not completely independent.

From table 4, it is clear that some distinctive features carry more information then certain other features ase found among the Telugu listeners. This supports the hypothesis 'the information content carrried by each of these features vary'.

The ranking of features according to the amount of information transmitted showed the feature 'coronal' the hold the highest rank and the feature 'lateral' to hold the lowest rank. See table(4). A comparison of the ranking of features between Telugu and non-Telugu listeners shows the ranking to be similar except that 'voicing' is ranked 1st among the Telugu listeners and it is ranked second among the non-Telugu listeners (see table-5). This difference in ranking may be attributed to heterogenous group among the non-Telugu listeners. (15 were Kannada speakers, 8 Tamil speakers and 7 Malayalam speakers - all belonging to the dravidian language group).

The similarity in performance of the Telugu and non-Telugu subjects 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 and Halle, 1968; Menyuk, 1968). However, this speculation must be viewd critically as the sample of non-Telugu listeners is small and also, this group comprised only of Dravidian languages (Tamil, Kannada, Malayalam). Other language groups such Aryan language groups, have not been considered. This would provide an interesting topic for research.

The similarity in performance of the Telugu and non-Telugu listeners supports the hypothesis that 'no significant differences will be found in the listening performance of Telugu add non-Telugu subjects when word with mimmal/few differences are presented in quiet situation.

An interesting observation was that, most of the listeners substituted /ś/ for /ṣ/. That is the percentage of correct response was 5.28% among Telugu listeners and 1.78% among non-Telugu listeners. Out of 625 observations for /ṣ/, This may be attributed to minimal difference between /ś/ and /ṣ/ and the infrequent usage of /ṣ/ in Telugu and also in other dravidian languages.

Another point to be noted is the high percentage of substitution of the unaspirated sound for the aspirated one. Though aspiration is distinctive in Telugu (eg. 50āli) name of a goddess and ఖాళీ (khāli) empty) most of the Telugu listeners were found to substitute the unaspirated sound for the aspirated one for eg. out of 729 observations for(K^{ha}) 105 were ½ ka/ substitutions. A similar trend was observed even among the non-Telugu listeners. Mallikarjuna (1974) found that the native speakers of Kannada who are not exposed to Sanskrit language are not able to make out the differences between aspirated and unaspirated sounds.

A comparison of the distinctive features of Telugu, Kannada, Malayalam (the Dravidian language group) and Gujarati is shown in Table-6+

The comparison reveals that many of the features are common to all the four languages thus supporting the existence of universal distinctive features. Further few features are distinct in one language and not in other. For eg. Arqti (1983) found that Malayalam speakers perceive nasal sounds better than the non-Malayalam speakers.

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

Acoustic Analysis:

Wide band spectrograms for 30 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 are as follows:-

1. Voicing:- The essential acoustic characteristics for voicing distinctions which can be seen in a spectrogram are:

1. Presence of low frequency energy termed as 'buzz' (Jacobson, Faut and Halle, 1952) in voiced sound and absence of this in a voiceless sound. The presence of this characteristic is marked by voice bars along the base of the spectrogram which are identifiable as vertical striations occuring at regular interval.

2. Voice onset time is identified as voice lead in voiced sounds and as voicelag in voicelss sounds.

3. The energy concentration in the noise components of the spectrum either in stop or fricative sound is greater in voice-less than in voice sounds.

The following acoustic characteristics were observed in the consonants of Telugu which were analysed spectrographically

1. Regular vertical striations in low frequency region which occur simultaneously with the burst (stop or frication) indicating voice lead.

2. Decreased intensity of burst when compared to its voiceless counterpart.

Nasality:

Acoustic characteristics of nasal feature are described as having a characteristic nasal formant at low frequency (200 Hz) and at very high frequency (2500 Hz) and a tail like appearance. It has also been reported that there is very little high frequency. (Daniloff et al, 1980; Jacobson, Fanet and Halle, 1969; Fry, 1979; Potter et al 1966). The above mentioned characteristics that is (l) presence of low frequency formant and (2) tail like appearance were present in the nasal consonants studied.

Aspiration:

The acoustic cue for this feature is extra-energy concentration in aperiodic portion. That is at high frequencies mimicing the friction noise in stops, fricatives and affricates. A comparison of spectrograms of the words containing aspirated and unaspirated, showed the above feature to be present in Telugu,

eg: /K/ different from/K^h/
/P/ different from /P^h/

Stridency:

This feature is characterised by high frequency turbulence of longer duration and greater intensity. These acoustics cues were present in the Telugu words examined spectrographically.

Continuent:

The acoustic characteristics seen in this feature are: a gradual onset of vibration, which is continued for a considerable length of time as can be seen in the production of consonants like /s/, /r/, /l/. The non-consonants present a sudden burst of vibration for a very short duration as can be seen in /p/, /b/, /t/, /d/. Examination of words containing continuents showed the following features to be present (l) gradual onset (increase in intensity with time) and (2) Longer duration of vibration.

Lateral:

Lateral sounds are associated with vowel like and consonant like characteristics (Jacobson, Faut and Halle, 1952). The continuous bars in them are representative of vowels and the gaps are characteristic of consonant parts.

Examination of words containing lateral sounds showed the presence of the small gaps.

Anterior:

Chomsky and Halle (1968) define that all labial, labiodental, dental and alveolar sounds as anterior and palatal, retroflex, velar, and glotal sounds as nonanterior. Based on this places of articulation it is possible to give acoustic characteristics.

Labial:

Characterised by downward transition, low frequency peak and very less VOT.

Dental:

Characterised by upward shift, higher frequency peak when compared to labial sounds, less VOT.

Alveolar:

Shortened transition upwards or downwards* high frequency peak, greater VOT when compared with labial and dental sounds.

Eg: /t/ /d/

Retroflex:

Upward shift and low frequency peak

Eg: /t/ /d/

Velar:

Upward shift of transition, mid frequency peak, greater VOT when compared with other sounds.

Eg: /k/ /g/

Coronal:

Coronal consonants are characterised by gradual upward movement of F1 and gradual downward movement of F2 and coronal consonants are characterised by sudden downward movement of F1 and sudden upward movement of F2.

Eg:- /t/ + coronal
/p/ - coronal.

Thus the acoustic analysis of word pairs in Telugu reveal distinct acoustic characteristics for each of the proposed feature. This supports the hypothesis that each of the distinctive feature proposed presents distinct acoustic characteristics.

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

Thus the existing distinctive feature system in Telugu has eight features which has been proposed based on the phonetic description of Telugu consonants. This supports the hypothesis 'It is possible to propose a distinctive feature system in Telugu based on phonetic description'.

For Speech and Language Pathologists the distinctive feature systems as described by others (Jacobson, Faut and Halle, 1952; Chomsky and Halle, 1968), seems to be a very useful tool in describing the developmental aspects of articulatory behavior, in planning therapy and in assessing prognosis in cases having misarticulation. The results of the present study has relevance to the above mentioned facts.

.V.

S \ R	k	kʰ	g	gʰ	c	cʰ	j	jʰ	ṭ	ṭʰ	ḍ	ḍʰ	ṇ	t	d	dʰ	n	p	pʰ	b	bʰ	m	y	r	l	v	ś	ṣ	s	h	ḷ	a	tʰ	O	
k	876	1	1				1		2					16	1			1			1														900
kʰ	105	574	11	19	3	5									1	1			5		1														729
g	2		884	6							6				1					1										3			1		900
gʰ	5	5	100	499		1																													625
c	2				913	1	6							1	3	6					2			1		2		1							961
cʰ	9	19			101	375	19	21		1				27				3																	576
j			7		2		885	2	4					24													2	1	6						900
jʰ	1		1	1	5	18	75	279	1		5	3		1	4	6											6		1						400
ṭ									800		2			31	4																				841
ṭʰ	5								50	559	11	22	1	36	3	22		4																	784
ḍ			1						5		980	10			23			14	25	5	5			2						4			20		1024
ḍʰ		1					1		2	5	75	296			7	12															4	1			400
ṇ											1		553		1		64	1																	625
t					1				13	1	1			874	5			4		1				1	2						2				900
d			3		1		2		4		45			5	723																				784
dʰ	2	1	4	10			1			1	6	4		9	88	768		2	2	2	6			1											900
n													14		1		806					17			3								1		841
p	4				1				12					20	1			785	1		15														841
pʰ														2				43	463	12	38	1								2					625
b	1		19												1			2	1	792	5					20	3	3	10	47		3			841
bʰ												1			1			1	1	100	622					2					37				729
m																	22					801				4				1					841
y																							721											14	729
r																	15							807	16									8	841
l															1										802	1					37			3	841
v	1																			19					1	877	1			1					900
ś					20	1								1													660	10	150						841
ṣ						1																					571	33	17	2		1			625
s					10																						29	44	847						900
h			1		1						2							1	3				1				2			883		6			900
ḷ			1								10														103						462				576
	1013	601	1033	535	1058	400	990	302	893	547	1144	336	568	1047	861	816	907	862	501	932	695	819	722	812	927	906	1274	62	1031	943	505	11	22	25	24120

Table 1. Confusion matrix showing the responses to stimuli for Telugu group.

TABLE-2

Table showing information transmission in bits/stimulus for eight linguistic features and the ranking of these features according to the amount of information transferred,in Telugu speakers.

Sl. No.	Features	Ranking	Information transmitted in bits/stimulus
1	Voicing	I	0.8772
2	Coronal	II	0.8379
3	Continuent	III	0.8005
4	Anterior	IV	0.7495
5	Strident	V	0.7405
6	Aspirated	VI	0.5352
7	Nasal	VII	0.4354
8	Lateral	VIII	0.3076

Total transmission in bits/stimulus = 5.2838

composite phoneme channel transmission = 3.058

S \ R	k	kh	g	gh	c	ch	j	jh	ṭ	ṭh	ḍ	ḍh	ṇ	t	d	dh	n	p	ph	b	bh	m	y	r	l	v	ś	ṣ	s	h	ḻ	a	th	o	
k	869	5	15											10				1																	900
kh	203	468	28	12	4	3		1						1		1					1					1				3		1	2		729
g	20	1	863	2			1				2			1	3															7					900
gh	8	5	124	460			1								2	21	1							1	1					1					625
c	19				874		3		2					17				1	1								11	2	31						961
ch	8	15			130	372	10	10						8							1						13	2	3				3		576
j	4		19		20		830		2		1			2	8												2		11			1			900
jh	3	1	3	2	22	15	80	251						3	6	6			1								5	2							400
ṭ	1				1				744		28			53	5			7											2						841
ṭh	7	4			1				48	481	26	3		47	11	8		17	40		5								5				81		784
ḍ			2				1		15		954	6		1	27	1				4		1		1	1	2					4			4	1024
ḍh			2					1	11		85	257			26	28		1		2	2		1			1			2					1	400
ṇ											1		603				20							1											625
t	5	1			2				32		1			833	11			11	1										2			1			900
d			3	1	2				1	1	29			5	739	1				1							1								784
dh	1	1		9	2			1	3		4			8	109	751				3	4					2				1		1			900
n													8				813					14	1		4							1			841
p									2					22	1			782		29									3	1		1			841
ph	1													5				13	484	44	23					2	1		11	39		2			625
b			10												1			15		781	2	1		1		30									841
bh			1									1			3			5	1	112	601	1								1		3			729
m			1																			830				6								4	841
y																							726											3	729
r																		1						838	2										841
l							1										1								820	2					17				841
v	1																			8		1	3	2	2	873								9	900
ś	1		1		3	4												1									764	15	50						841
ṣ																											608	12	5						625
s	3				2									3				1								4	53		835	2		1			900
h	1		6															4	2	1	1		2	1			1		3	851		23			900
ḻ																	1								53						522				576
	1154	501	1079	486	1069	391	327	264	869	482	1131	267	611	1019	942	817	837	860	530	985	640	848	733	845	883	923	1489	33	963	906	543	35	86	21	24120

Table 3. Confusion matrix showing the responses to stimuli for non-telugu group.

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-Talugu listeners.

Sl.No.	Ranking	Features	Information transmitted in bits/stimulus
1	I	Coronal	0.8375
2	II	Voicing	0.8260
3	III	Continuent	0.7894
4	IV	Anterior	0.7730
5	V	Strident	0.7385
6	VI	Hspiration	0.4938
7	VII	Nasal	0.4430
8	VIII	Lateral	013149

Total transmission in bits/stimulus = 5.2161

Composite phoneme channel transmission = 3.058

TABLE-5

Table showing the comparison of ranking between Telugu and Non-Telugu listeners

Sl.No.	Ranking	Features Telugu listeners	Features non-Telugu listeners
1	I	Voicing	Coronal
2	II	Coronal	Voicing
3	III	Continuent	Continuent
4	IV	Anterior	Anterior
5	V	Strident	Strident
6	VI	Aspirated	Aspirated
7	VII	Nasal	Nasal
8	VIII	Lateral	Lateral

TABLE - 6

Table showing the distinctive features of Telugu, Kannada, Malayalam and Gujarati ranked according to the Information transmission.

Sl.No.	Telugu	Kannada	Mayalam *	Gujarati
1.	Voicing	Voicing	Consonantal/nonconsoe nantal	Retroflex
2.	Coronal	Coronal	Abstruent/nonabstruent	Velar
3.	Continuant	Stridency	Nasal/oral	Dental
4.	Anterior	Anterior	Continuent/nonconti-nuent	Labial
5.	Strident	Continuent	BacK/nonback	Alveolar
6.	Aspirated	Nasality	Coronal/noncoronal	Voicing
7.	Nasal	Aspiration	Retroflex/nonretroflex	Aspiration
8.	Lateral	Lateral	Palatal/nonpalatal	Afftication
9.			Retracted/nonretracted	Nasality
10.			Voiced/voiceless	Frication
11.			Aspirate/nonaspirate	Semivowel
12.				Lateral
13.				Flap

* Features not ranked according to information transmission)

CHAPTER - V

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

Distinctive features which are the smallest units of language are defined to be the "physical and psychological realities of a phoneme (Singh, S. 1976)". The present study aimed at establishing a distinctive feature system of Telugu consonants.

430 word pairs were prepared using 31 Telugu consonants. These word pairs were prepared such that there was atleast one feature difference between the two consonants of the word pair. Perceptual and Acoustical analysis were carried out to establish the features.

Perceptual analysis was carried out in two stages - Part-I the word pairs were presented to a group of 30 subjects (individual who were native speakers of Telugu. 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-Telugu speakers and their responses were recorded.

The perceptual data was analysed using confusion matrices and by calculating information content of each feature. 30 words were analysed spectrographically to observe the acoustic characteristics. The following conclusions were drawn from the study*-

1. It is possible to propose a distinctive feature system in Telugu based on phonetic descriptives of Telugu language.

2. Consonants in Telugu are made up of the following features: a) Voicing (b) Nasality (c) Contingent (d) Anterior (e) Coronal f) Stridency (g) Aspiration (h) Lateral.

3. Information carried by each feature differs.

4. Each feature has distinctive acoustic characteristics.

5. No significant differences were found between the listening performance of Telugu and Non-Telugu speakers when the word* pairs were presented in a quiet situation.

Implications:-

1. The distinctive feature system thus established given an indepth analysis into the phonology of Telugu.

2. This distinctive feature system can be used to study the phonological acquisition of Telugu in children, to assess articulatory disorders and in planning articulation therapy.

3. Distinctive feature discrimination tests can be developed for audiological testing.

4. An articulation drill book in Telugu can be prepared based on this.

5. It can be used to improve the telecommunication system for transmission in Telugu.

6. It can be used in the development of speech synthesizers.

Recommendations:-

1. The present distinctive feature system can be further validated using other methods of distinctive feature analysis.

2. Further study can be done on substitution analysis that is which of the features are substituted bythe other features.

3. Distinctive feature system can be developed for vowels in Telugu.

4. An articulation test in Telugu can be developed on the basis of the distinctive feature system.

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APPENDIX-1

Definition of Distinctive Features Proposed for Telugu consonants.

1. Voicing:- In the production of + voicing consonants the vocal folds vibrate; and in the production of -voicing consonants vocal folds do not vibrate.

   eg: + voicing:- /g/ /g^h/ / j / / j^h / /d/ /d^h/ /n/
   /d/ /d^h/ /n/ /b/ /b^h/ /m/ /y/ /r/
   /r/ /w/ /l/

   - voicing /k/ /k^h /c/ /c^h/ /t/ /t^h/ /t/
   /p/ /p*V /s/ /ʃ/ /h/

2. Coronal:- The + coronal sounds produced 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 / / j^h / /t/ /t^h/ /d/
   /d^h/ /n/ /t/ /d/ /d^h/ /n/
   /y/ /r/ / j / /ʃ/ /s/ /l/

   - coronal:- /k/ /k^h/ /g/ /g^h/ /p/ /p^h/ /b/ /b^h/
   /m/ /w/ /h/

3. Strident:- The + strident consonants are marked acoustically by greater noisiness.

   Eg:+Strident:- /s/ /ʃ/ /c/ /ch/ / j / / j^h / /h/

4. Anterior:- All the front sounds are known as: +anterior i.e. the bilabial, labio dental, dental, and alveolar sounds are + anterior sounds. The palatal, retroflex velar and glottal sounds are:-Anterior sounds'

Eg:-+Anterior: /t/ /d/ /d^h/ /n/ /p/ /p^h/

/m/ /r/ /l/ /w/ /s/

-Anterior: /k/ /K^h/ /g/ /g^h/ /c/ /c^h/ /j/

/j^h/ /t/ /t^h/ /d/ /d^h/ /n/ /y/

/ʃ/ /h/ /l/

5. Continuent:- The + continuent 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:- /y/ /r/ /l/ /w/ /s/ / / /h/ /l/

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

   Eg:- + nasal:/n/ /ṇ/ /m/

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

   Eg:-+Aspiration: /k^h/ /g^h/ /c^h/ /j^h/ /t^h/ /d^h/

   /d^h/ /p^h/ /b^h/

8. Lateral:- The + lateral consonants are produced by lowering the mid section of the tongue.

   Eg:- +lateral: /l/ and /ḷ/

PHONEMES OF TELUGU LANGUAGE

APPENDIX - 2

Manner of	Points of Articulation					
	Bilabial	Labio dental	Alveotar	Retroflex	Palatal	Velar glottal
Stops	P b		t d	t d	c j	k g
	p^h b^h		d^h	t^h d^h	C^h j^h	k^h g^h
Fricatives		(f)	s	S	S	h
Nasals	m		n	n		
Laterals			1	1		
Flap			r			
Continuants	W				y	

Appendix-3.

WORD-PAIRS.

పక్క - నక్క
పోకు - షోకు
పట్టుం - ఘట్టుం
తాపం - శాపం
పాడి - దాడి
దాడి - గాడి
చరము - షరము
పాపి - పాణి
పరం - ఖరం
బగ్గు - వగ్గు
బండ - రండ
బలుపు - సలుపు
కోత - కోట
బలము - జలము
పని - రని
దక్కు - టుక్కు
పోరు - గోరు
పరి - ధరి
తాత - రాత
బుట్ట - గుట్ట
బక్క - నక్క
బావి - భావి

దారం - భారం
బెట్టు - చెట్టు
ఘోల - టోల
పాత - పాష
బేధం - ఖేధం
బోడి - కోడి
డక్క - వక్క
జనం - ధనం
పాటు - మాటు
జటు - ఛటు
దక్కు - రక్కు
తాటి - ధాటి
పాప - పాటు
ఫక్కి - మక్కి
కాచి - కాళి
బాటు - బాధ
టాకు - చాకు
దాగు - సాగు
తానం - యానం
ఛాపు - దాపు
పోను - ఫోను
బల్లు - ఘల్లు

తలము - ఫలము
పేలు - వేలు
బాకీ - టాకీ
పత్రము - ఛత్రము
పాకు - సాకు
మాటు - మాయ
చీమ - సీమ
బక్క - ఢక్క
పతి - యతి
కోన - సోన
తాకు - సాకు
తావి - భావి
బలము - ఫలము
తక్కు - ఢక్కు
కుట్టు - కుళ్ళు
షాపు - బాపు
దాటి - ధాటి
మరి - ధరి
బిచ్చం - బియ్యం
ఊబ - ఊళ
తాపం - ఛాపం
జరి - ఝరి

తారు - జా
బేధం - ఛే
చోలి - ఫ
గటి -
కాలు -
భక్తి -
పావు -
తాడు -
చెక్క - డె
ముబ్బు - డ
తోక - కో
డబ్బు - గ
ధాటి - లా
వోరు - హా
తారు - వా
దోంగ - కో
బడి - తడి
పాలు - చా
విషయం - వి
తాళి - ఖా
చయం - భయ
దబ్బు - డబ్బు
టుకు - కక

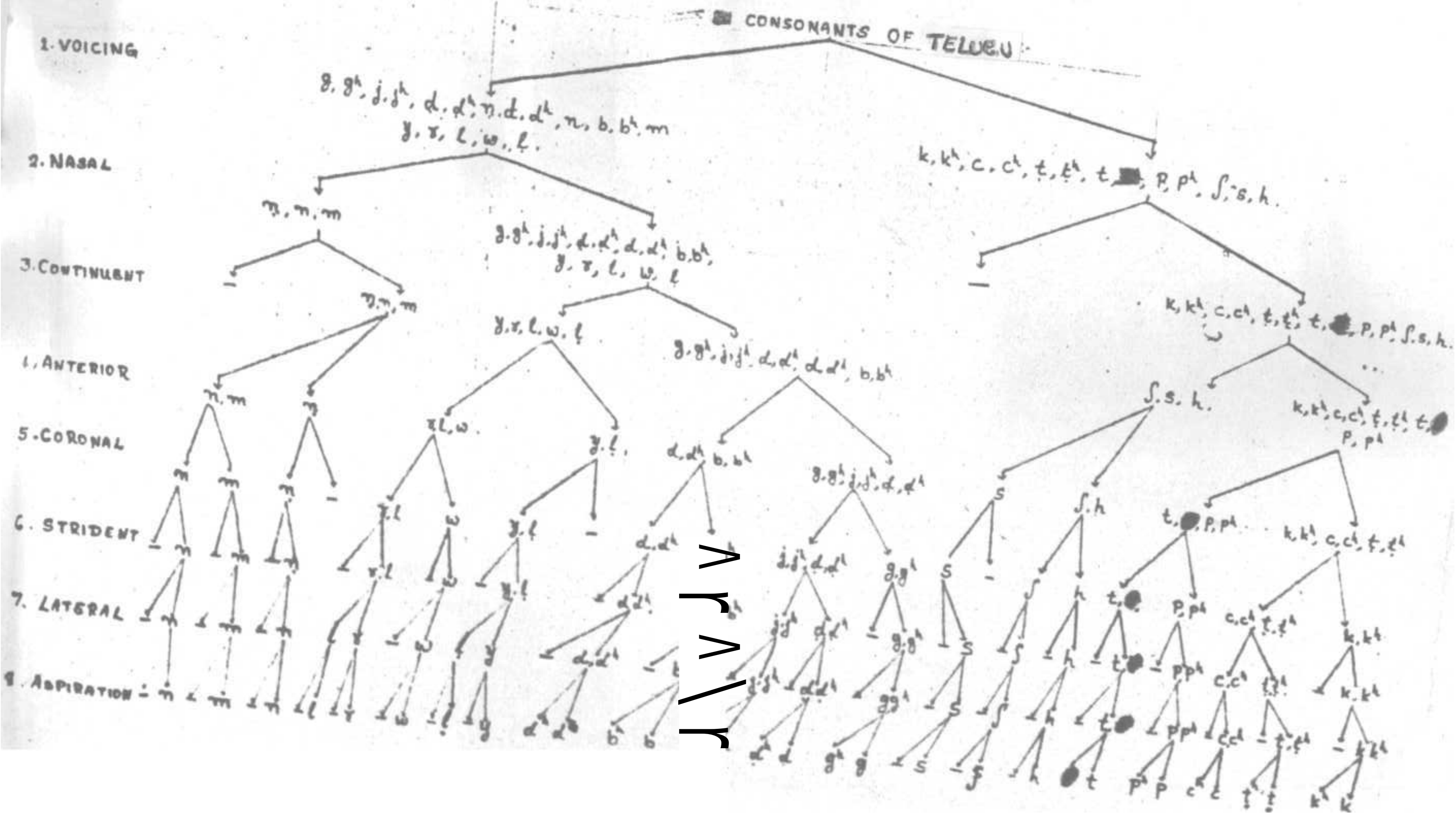
తొవ్వ - లావు	నగ - ధగ	జాగ - రాగ	ఊత - ఊళ
పొంగు - కొంగు	చాకు - వాకు	కటు - ధటు	నాడు - వాడు
దాచు - చాచు	డక్క - హక్క	చావు - తావు	పావు - లావు
రాణము - భాణము	గోల - సోల	ఫలకము - నలకము	బిడ్డ - బిళ్ళ
చరము - హరము	దయ - లయ	ఫలము - ఛలము	డక్క - కక్క
తప్పు - డప్పు	తడి - గడి	ఝరి - హరి	లట్టు - రట్టు
భరణం - మరణం	తలం - హలం	ఢిల్లి - ఝిల్లి	కటు - ఛటు
దానం - యానం	గతము - గణము	భయం - లయం	జాగ - లాగ
చలము - ఫలము	థాక - శాక	జావి - భావి	గాటు - ఘాటు
టాకు - నాకు	కలం - ఫలం	పక్క - డక్క	ఖంగు - రంగు
టక్కు - ధక్కు	టొక్క - భాక్క	బావ - యావ	తంటు - ఘంటు
సగ్గు - లగ్గు	చాకు - కాకు	హరి - జరి	డక్కి - ఫక్కి
టోకు - షోకు	మది - మణి	భేదనం - ఛేదనం	మేళ - మేత
డబ్బు - సబ్బు	శాటి - ఘాటి	కాటు - మాటు	ఫక్కి - రక్కి
డేగ - లేగ	కఫము - కరము	నప్పు - డప్పు	ఫలితం - లలితం
గట్టు - భట్టు	దండ - తండ	గాబు - గాణ	దాచు - వాచు
వేప - వెళ	తక్క - డక్క	తావు - రావు	జలము - ఖలము
విషయం - విరమం	కటు - ఫటు	పక్క - ధక్క	సద్దు - రద్దు
కోరు - నోరు	దాత - యాత్ర	పాటి - పాణి	బాబు - డాబు
చిత్ర - రిత్ర	తావు - రావు	డోకు - షోకు	థాకు - నాకు
డక్క - ధక్క	జనం - ఘనం	విషయం - విలయం	షోకు - దోకు
జాడ - కాడ	రాశి - రాణి	బార - థార	ధటు - ఛటు
దాళి - ఖాళి	బడి - తడి	దాకు - బాకు	గంటు - మంటు
గడ - వడ	ఖరము - మరము	ధక్క - లక్క	చేమ - నేమ

తాలం - దూలం	ఆటు - ఆశ	భయం - నయం	మేళం - మేష
ధనం - ఘనం	కాలు - రాలు	కలిక - కళిక	విషం - విధ
జీవి - తీవి	టక్కు - డక్కు	మాడు - నాడు	ఖరం - వర
కాణి - కాలి	ధాత - వాత	జాలి - గాలి	కూడు - గూ
మడ్డి - మళ్ళి	భరణము - ఘరణము	కవలు - యవలు	ఖిన్నము - భిన్న
ఘాతము - యతము	ధక్కు - భక్కు	హద్దు - సద్దు	జలము - ఫలము
చని - శని	దారం - ఘోరం	ఠక్కు - వక్కు	దాసి - దాశి
ధరము - ఝరము	ఆధారం ఆహారం	ధాత - యాత	టక్కు - వక్కు
ఫాలము - వాలము	డీలు - జీలు	కాయి - కాణి	పట్టు - భట్టు
చేదు - లేదు	భంగు - వంగు	రాణము - శాణము	లచ్చి - వచ్చి
మేథ - యేధ	బండ - మండ	కాళి - ఖాళి	జాతము - యాత
భరణం - హరణం	జాగు - వాగు	చలము - ఛలము	ఖండం - షండ
రాకు - షాకు	ఘాటు - రాటు	దారి - నారి	రాణి - వాణి
కఫము - కటము	పుట్టు - జుట్టు	రోమము - రోషము	కాళి - కాశి
చరము - ఝరము	జటు - నటు	పాషం - పాయం	భేదం - ఖేదం
ఝోకు - షోకు	ధూపం - రూపం	తోనం - తాళం	
దరి - ఝరి	తరి - ఝరి	కర్మ - శర్మ	సరం - వరం
టూపు - ఛాపు	కోరి - కోణి	కళ్ళ - కజ్జ	శకం - రకం
చంక - ధంక	దీవి - జీవి	కాగు - లాగు	త్రేగు - త్రేణు
గాటు - నాటు	ధరము - ఖరము	ఫలము - ఖలము	రాకు - వాకు
జారు - యారు	బరి - ఝరి	ఛర్ది - సర్ది	టక్కు - రక్కు
టక్కు - మక్కు	సతి - యతి	డాపు - ఛాపు	ఝరం - ఖరం
ఫలము - శలము	బాల - శాల	చారు - జారు	రోగం - రోషం

గావు - రావు	ముగ్గు - సగ్గు	శయనం - నయనం	అరణ్యం - అర
తక్కు - హక్కు	పరి - ఝరి	గట్టు - రట్టు	కథయు - కణ
ఢాక - గాక	అవ - అష	మగ - వగ	లత్త - హత్త
శ్లోకం - లోకం	గాథ - గాఢ	శుక్తి - యుక్తి	చిర - గిర
హరి - నరి	ఘటన - వటన	జోరు - నోరు	ఛవి - రవి
రాయము - ఝాయము	రాచి - రాణి	కాలు - వాలు	రాము - ఝూ
కావు - రావు	ఝరి - మరి	భాసము - ఘూసము	ఛలయు - వల
చరము - ధరము	థక్కా - మక్కా	తక్కు - థక్కు	ఖంగు - హం
ధట - సట	కరా - షరా	తల్లి - నల్లి	భంగు - డం
హాలము - ఛలము	శుక్తి - యుక్తి	నల - నల	దాకా - దా
గూని - ఖూని.	టక్కు - నక్కు	తాకు - నాకు	కరి - ఝరి
త్రీట - త్రీగ	తేట - చేట	రణం - రవం	కాథ - కాయ
మావి - రావి.	భరణి - ధరణి	దక్క - థక్క	అవి - అ
ఝరి - సరి	తోల్లు - ఘోల్లు	పాగ - బాగ	థక్క - వక్క
బరి - హరి	థక్కు - హక్కు	గగ్గు - లగ్గు	గంప - ఝంప
దక్కు - రక్కు	కణుపు - కడుపు	ఖాతం - ఘాతం	బక్క - లక్క
రేతం - హాతం	టాపు - లాపు	జోలము - ఢోలము	రాజె - రాణి
గని - ధని	గవి - ఛవి	మేళం - మేహం	ధని - శని
మణి - మరి	భోగి - యోగి	టంగు - ఖంగు	రాకు - థాకు
ఛాగము - లాగము	మేక - లేక	ఘట - ఛట	ఘూటి - లాటి
కాఫి - కాళి	కాళి - కాయ	మరి - హరి	గోపము - గోప
దోస - దోష	మేఘం - మేళం	గణి - ఫణి.	డంబు - ఖంబ

వక్క - హాక్క	మనం - ఘనం	కళ - కవ
షహా - సహా	టక్క - హాక్క	నాతం - యాతం
ఘోల - రోల	ఝరి - వరి	రావి - రాశి
బోర - బోయ	రమంత - హాంత	ముక్తి - యుక్తి
చరం - ఖరం	ఖాతం - యాతం	గహి - గశి
ఛాగము - యాగము	నేడు - రేడు	కల - కళ
భారం - సారం	కారం - హారం	నక్క - హాక్క
గసి - గశి	కారం - భారం	వనం - ఘనం
చారు - మారు	రావు - లావు	ఘటు - సటు
రాయి - యాయి	ఘాలము - యాలము	రోమం - హోమం
దక్క - లక్క	తాకు - తాళు	ఘటము - హాటము
భంగు - రంగు	పేథ - పేళ	ఖడ్డి - లడ్డి
నిశ - నిష	ఖరము - శరము	నరము - ఖరము
గాలం - గాయం	డాలు - శాలు	ఖరము - నరము
బగ్గు - బళ్ళు	కళ్ళు - కర్రు	గానం - ఊనం
శరం - వరం	థక్క - నక్క	గని - రవి
ఝుంప - రంప	శేశి - శేయి	ఘలము - హాలము
డక్క - రక్క	రాయు - ఛాయు	థక్క - రక్క
యాయ - ఛాయ	నఘా - నభా	ఘలం నలం
		ఝరము - నరము
శలము - ఛలము	దట్టం - ఘట్టం	రాకు - మాకు
రావి - రాయి	జేతం - శేతం	ఛటు - ఝటు

APPENDIX-4: TREE DIAGRAM



APPENDIX - 5

Distinctive features of Telugu Consonants

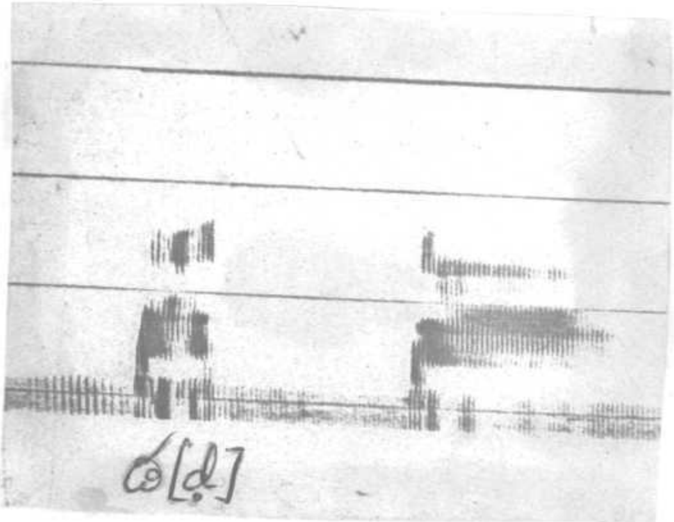
sounds	k	k^h	g	g^h	c	c^h	j	j^h	ṭ	$ṭ^h$	ḍ	$ḍ^h$	ṇ	t	d	d^h	n	p	p^h	b	b^h	m	y	r	l	w	ʃ	s	h	ḷ
voicing	−	−	+	+	−	−	+	+	−	−	+	+	+	−	+	+	+	−	−	+	+	+	+	+	+	+	−	−	−	+
nasal	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	+	−	−	−	−	+	−	−	−	−	−	−	−	−
continuent	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	+	+	+	+	+	+
anterior	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	+	+	+	+	+	+	+	−	+	+	+	−	+	−	−
coronal	−	−	−	−	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	−	+	+	+	−	+	+	−	+
strident	−	−	−	−	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	+	−
lateral	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	+
aspiration	−	+	−	+	−	+	−	+	−	+	−	+	−	−	−	+	−	−	+	−	+	−	−	−	−	−	−	−	−	−

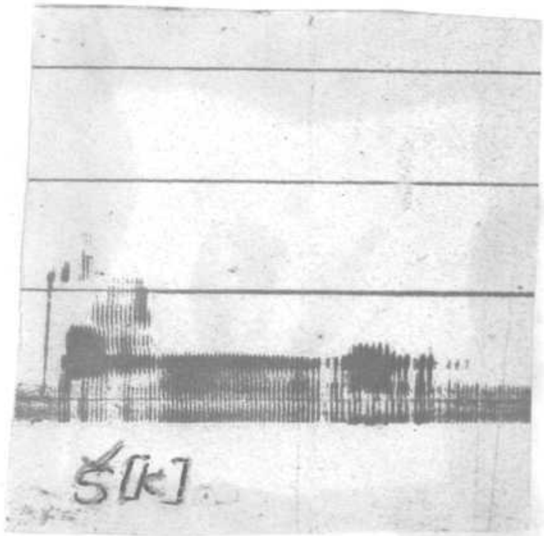
APPENDIX – 6 : Unit of Differences for 30 consonants based on Appendix-5.

	k	kʰ	g	gʰ	c	cʰ	j	jʰ	ṭ	ṭʰ	ḍ	ḍʰ	ṇ	t	d	dʰ	n	p	pʰ	b	bʰ	m	y	r	l	v	ś	s	h	ḷ
k	0																													
kʰ	1	0																												
g	1	2	0																											
gʰ	2	1	1	0																										
c	2	3	3	4	0																									
cʰ	3	2	4	3	1	0																								
j	3	4	2	3	1	2	0																							
jʰ	4	3	3	2	2	1	1	0																						
ṭ	1	2	2	3	1	2	2	3	0																					
ṭʰ	2	1	3	2	2	1	3	2	1	0																				
ḍ	2	3	1	2	2	3	1	2	1	2	0																			
ḍʰ	3	2	2	1	3	2	2	1	2	1	1	0																		
ṇ	3	4	2	3	3	4	2	3	2	3	1	2	0																	
t	2	3	3	4	2	3	3	4	1	2	2	3	3	0																
d	3	4	2	3	3	4	2	3	2	3	1	2	3	1	0															
dʰ	4	3	3	2	4	3	3	2	3	2	2	1	2	2	1	0														
n	4	5	3	4	4	5	3	4	3	4	2	3	1	2	1	2	0													
p	1	2	2	3	3	4	4	5	2	3	3	4	4	1	2	3	2	0												
pʰ	2	1	3	2	4	3	5	4	3	2	4	3	5	2	3	2	3	1	0											
b	2	3	1	2	4	5	3	4	3	4	2	3	3	2	1	2	2	1	2	0										
bʰ	3	2	2	1	5	4	4	3	4	3	3	2	4	3	2	1	3	2	1	1	0									
m	3	4	2	3	5	6	4	5	4	5	3	4	2	3	2	3	1	2	3	1	2	0								
y	3	4	2	3	3	4	2	3	2	3	1	2	2	3	2	3	3	4	5	3	4	4	0							
r	4	5	3	4	4	5	3	4	3	4	2	3	3	2	1	2	2	3	4	2	3	3	1	0						
l	5	6	4	5	5	6	4	5	4	5	3	4	4	3	2	3	3	4	5	3	4	4	2	1	0					
v	3	4	2	3	5	6	4	5	4	5	3	4	4	3	2	3	3	2	3	1	2	2	2	1	2	0				
ś	3	4	4	5	1	2	2	3	2	3	3	4	4	3	4	5	5	4	5	3	4	4	2	3	4	4	0			
s	4	5	5	6	2	3	3	4	3	4	4	5	5	2	3	4	4	3	4	2	3	3	3	2	3	3	1	0		
h	2	3	3	4	2	3	3	4	3	4	4	5	5	4	5	6	6	3	4	2	3	3	3	4	5	3	1	2	0	
ḷ	4	5	3	4	4	5	3	4	3	4	2	3	3	4	3	4	5	5	6	4	5	5	1	2	1	3	3	4	4	0

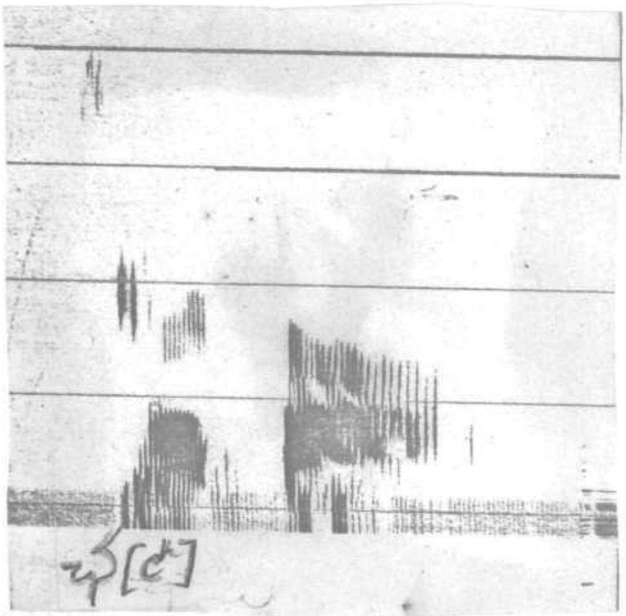
Appendix - 7

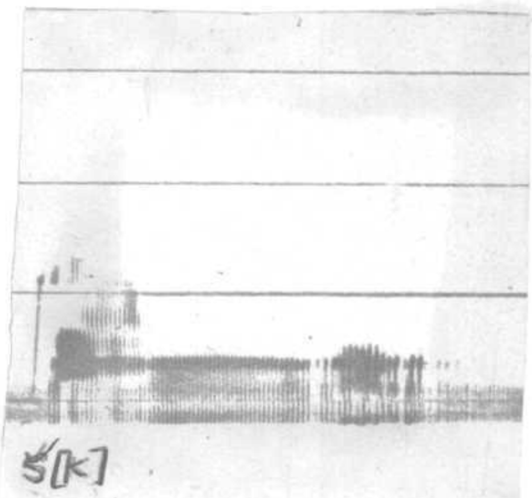
Few Representative Spectrograms.





VOICED | UNVOICED





STRIDENT | NON STRIDENT.