# ESTABLISHMENT OF DISTINCTIVE FEATURE SYSTEM FOR CONSONANTS IN GUJARATI

*Falguni Pathak*

A DISSERTATION SUBMITTED IN PART FULFILMENT

FOR THE DEGREE OF MASTER OF SCIENCE

( SPEECH AND HEARING )

UNIVERSITY OF MYSORE

1982

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To

Ba, Ṭhakorji,

Ma and Appa,

- for inspiration and reassurance

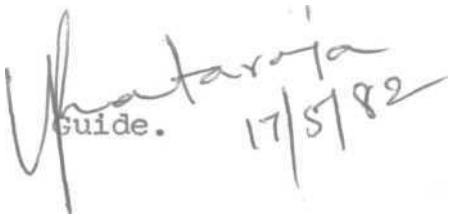
## C E R T I F I C A T E

This is to certify that the dissertation entitled "Establishment of Distinctive Feature System for Consonants in Gujarati" is the bonafide work in part fulfilment for M.Sc., Speech and Hearing, carrying 100 marks of the student with Register No: 2

Director,
All India Institute
of Speech & Hearing
Mysore.

## C E R T I F I C A T E

This is to certify that this dissertation entitled "Establishment of Distinctive Feature System for Consonants in Gujarati" has been prepared under my supervision and guidance



## D E C L A R A T I O N

This dissertation is the result of my own study undertaken under the guidance of Sri.N.P.Nataraja, Lecturer in Speech Pathology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other diploma or Degree.

Mysore: Reg. No.2

Date:

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# C O N T E N T S



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# CHAPTER I

## INTRODUCTION

"As humans we have the ability to detect and categorize features, without these skills, we could not observe consistencies among events that might otherwise appear unrelated. The early cognitive growth of young children heavily depends on decisions that involve features. Those feature that become important are regarded as distinctive . . . . . " (Singh, 1976).

"The sound pattern of a given language is fundamental to its structure (Danioloff et al, 1980). The segments of a sound pattern i.e., speech sounds take part in building different words and morphemes with the help of inherent distinctions. These speech sounds have got several parameters. These parameters are called Features. The G features which provided inherent distinction between speech sounds are called Distinctive Features".

"The 'Distinctive Features' of an individual phoneme would be tnose aspects of the process of articulation and their acoustic consequences that serve to contrast one phoneme with others (Berko and Brown, 1960).

A Distinctive feature system is an organized system of the phonemes in a language, each feature having two mutually

exclusive values. A complete feature system is the one which distinguishes all the phonemes of the language from each other.

Various approaches to establish feature system in a language have been reported. The major methods are: (1) Acoustic Method, (2) Articulatory method, and (3) Perceptual method.

In Acoustic method, various parameters of speech sounds are studied using speech Spectrograph. The Distinguishing characteristics of the sounds are extracted by inspecting the Spectrograms obtained for speech sounds. The important acoustic cues reported in the literature include (i) Voice Onset Time, (ii) Formant transitions, (iii) Duration, location and concentration of energy. This method was employed by Jakobson, Fant and Halle (1952) in order to establish a set of features to distinguish English consonants.

Articulatory method utilizes the phonetic descriptions of the sounds to define the distinguishing qualities of speech sounds. (Chomsky and Halle, 1968).

Perceptual method of establishing a feature system involves studying perceptual responses to sounds by the listeners. The analysis of errors made by the listeners in

various conditions of quiet, with noise and with filtering, helps to obtain a set of distinctive features utilized by the listeners in the perception of speech sounds. (Miller and Nicely, 1955; Singh and Black, 1960; Singh and Becker, 1972; Jeter and Singh, 1972).

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

Aposteriori method involves analysis of plethora of sample and then by various analysis techniques like fine analysis of spectrograms or multi-dimensional scaling analysis of perceptual data, tne features are tceged out. (Jeter and Singh, 1972).

The Apriori method lacks flexibility but it is comparatively less time consuming and simpler.

The distinctive features are considered to be the basic units of speech-sound production and speech sound perception. They provide guidelines to speech pathologists and Audiologists for the management of individuals having Speech and Hearing problems.

Recently the distinctive feature approach has been

used extensively and successfully in the management of deviant articulation behaviour.(Hans, 1963; Weber, 197O; Compton, 1970; McReynolds and Huston, 1971; Pollack and Rees, 1972; McReynolds and Bennett, 1972; Singh and Frank, 1972; Oiler, 1973; Kamara, Kamara and Singh, 1974; McReynolds et al, 1975; Costello and Onstine, 1976; etc).

The speech clinicians agree about the application of distinctive features in assessing, predicting and managing deviant articulatory behaviour (Ferris, 1978; Kim, 1978; Weiner and Bernthal, 1978; Metz et al, 1980; Ruder and Bunce, 1981). They report that distinctive feature system of analyzing articulatory behaviour is economical and efficient. Economical because the correction of one feature leads to correction of many phonemes, efficient, because it provides systematic path to evaluate and correct articulation deviation and to measure progress. Compton (1970) aptly says "The distinctive feature analysis itself is not a recipe for therapy, rather it is more like a map to aid us in choosing the best route to reach a destination".

Distinctive features have been employed to study the articulation acquisition in children. It provides a finer method to trace phonological acquisition and it explains many equivocal findings reported in the literature of phonological acquisition. It also provides basis to build

up phonological models.

The application of distinctive features in the studies of Speech perception open up new vistas in the study of perception of speech sounds. The feature approach helps us to find dimensions that are more important for perception of speech sounds. The feature analysis, as opposed to speech sound analysis provides multi-dimensional information about speech sound perception. The workers in the field of Speech perception have employed feature frame work to study speech perception in deaf individuals and have described perceptual strategies employed by the deaf individuals (Binnie, Montgomery and Jackson, 1974; Danhauer et al, 1978; Danhauer and Singh, 1975; Singh, Lawson and Singh, 1974; Walden and Montgomery, 1975; Blood, Blood and Danhauer, 1978; Doyle et al, 1981).

Hemispheric specialization for features has been explored. It has been found that highly encoded features are processed in left hemisphere for right handed individuals, which has got a special linguistic device. (Studdert Kennedy and Shankweiler, 1970; Day and Vigorito, 1972; Blumstein et al, 1973; Blumstein et al, 1977; Hayden et al, 1979).

There have been some crical reviews on distinctive features questioning its conceptual reality and theoretical

basis. (La Riviere et al, 1974; Ritterman and Freeman, 1974; Parker, l976). Some have even questioned the clinical applicability of these features due to contamination by various factors such as co-articulation, prosody, dialect, etc. (Walsh, 1974; Leonard, 1974; Lund and Duchan, 1978). The critical reports emphasize the need for physical representation of these abstract linguistic features.

Inspite of the limitations, distinctive feature approach is promising tool to speech pathologists and audiologists in handling various speech and hearing problems.

Thus it is useful to establish feature system in a particular language in order to study the speech sounds of. a language in detail. The detailed study of the speech sounds helps the Speech and Hearing specialist.

An attempt has been made to establish a distinctive feature system for consonants in Gujarati language. A set of distinctive features has been proposed. Two experiments have been carried out in order to identify acoustic correlates of the proposed feature system and to find out the information carried out by each feature in perception of speech.

A cross-linguistic study has been carried out in order to test universality of the proposed feature system. The

perceptual responses of Gujarati and non-Gujarati speakers have been compared and relative importance of the proposed features has been obtained for both the groups and has been compared.

**STATEMENT OF THE PROBLEM:-**

This study is carried out to explore the possible existence of distinctive feature system for consonants in Gujarati and to establish acoustic distinctive characteristics for this features system.

**HYPOTHESES:-**

(1) Gujarati language has a distinctive feature system.

(2) It is possible to propose a distinctive feature system based on the description of Gujarati consonants. (Nair, 1979).

(3) Consonants in Gujarati language are made up of following distinctive features : (i) Voicing, (ii) Nasality, (iii) Labi-al, (iv) Alveolar, (v) Dental, (vi) Retroflex, (vii) Velar, (viii) Aspiration, (ix) Affrication, (x) Semivowel, (xi) Lateral, (xii) Flap and (xiii) Fricative.

(4) The information content carried by each of these distinctive features vary.

(5) Each distinctive feature presents distinctive acoustic characteristics.

(6) No significant difference will be found in the listening performance of Gujarati and Non-Gujarati speakers when words with minimal differences are presented in a quiet situation.

**LIMITATIONS OF THE STUDY:-**

(1) Apriori analysis has been used.

(2) The group of Non-Gujarati listeners were small.

(3) In the present investigation, the distinctive feature system was developed for consonants only since the problems in articulation, discrimination and language acquisition are mainly of consonants.

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# CHAPTER II

# REVIEW OF LITERATURE

## 2.1 Distinctive Features - An Introduction:-

"Language is primarily (most efficiently, easily and directly) encoded as Speech,"(Daniloff etal 1980). "Speech has been for thousands of years the universal medium of communication; it still is"(Gray and Wise 1959). A language is a system of systems. This system can be broken down into five principal sub-systems - grammatical system, phonological system, morphophonemic system, semantic system and phonetic system(Hocket, 1958). These levels are hierarchical and the lowest string in this hierarchy is phonemics - the study of phonemes. The study of phonemes is very important to understand a language system.

Earlier it was believed, that a phoneme is the smallest unit of language and that it cannot be further divided. (Bloomfield 1933). The introduction of the distinctive feature concept by Jakobsen, Fant and Halle (1952) has rejected the concept that phoneme is the smallest unit of language.

The parameters of the phoneme are called "Features". The parameters which distinguish two phonemes of a language are called distinctive features. That is; according to Jakobsen, Fant & 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".

2.1.2

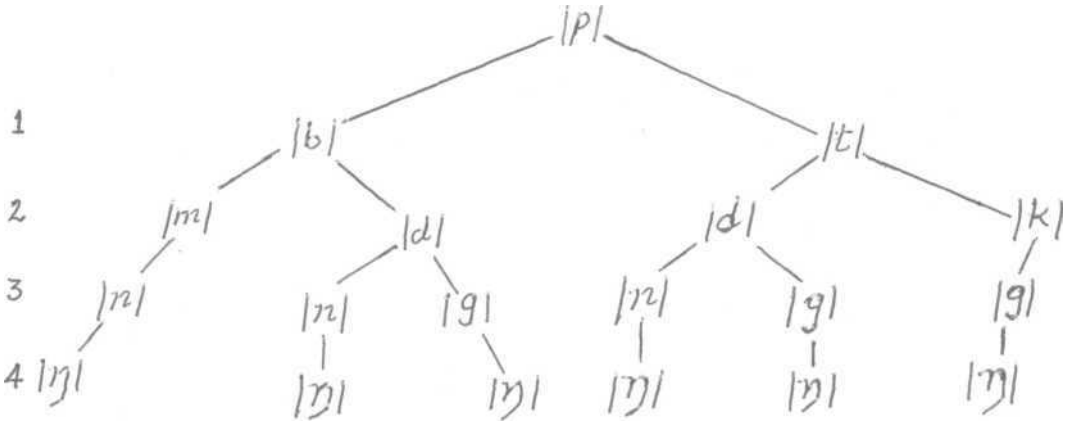
Attempts have been made to describe the distinctive features in terms of their acoustic articulatory and perceptual correlates.

Singh(1975) defines distinctive features in a following way; "Distinctive features are the physical(articulatory or acoustic) and psychological (perceptual) realities of the phonemes. In other words each phoneme can be described and differentiated in terms of 1) Articulatory features, namely the place of articulation and the manner of articulation 2) Acoustic features, namely frequency, intensity and duration of speech sounds, and 3) The perceptual features which are the result of the auditory discrimination between the phonemes"

The distinctive feature concept is based on principles of a) Binary scale b) Economy i.e. The binary principle basically considers the presence or absence of a particular feature. This, for example has been indicated by use of + & - for presence and absence of a feature by Jakobsen etal(1952-). Chomsky and Halle(1968) have used 1 and o to indicate the presence and absence of a feature. The use of binary scale has been found to be very useful. Some experiments have shown that the analysis of any event by human beings is based on binary principles. Further the use of binary scale would be very useful in the present days of computers for the analysis of data. The principle of economy is used to minimize the redundancy that is seen in the language, thus simplifying the process of describing the language.

The distinctive features perform various functions. They are:

1. Description of phonemes
2. Description of the interrelationships between the different phonemes of a language and also allophonic variations.
3. Quantification of these interrelationships.
4. Classification of the phonemes depending on the distinction, i.e., if a group of phonemes share a large number of features then they form a natural class and if a group of phonemes share a few commonalities they belong to an unnatural class.
5. Finding out the distances between phonemes.




A Tree Diagram illustrating the Hierarchical Interrelationships Between Nine Phonemes. (Singh S. "Distinctive Features: Theory and Validation" Baltimore University Park Press, 1976 Pp. 12)

The distinctive feature systems have been proposed by several people. The most frequently used systems are those proposed by 1.) Jakobsen etal (1952) 2) Chomsky & Halle(1968). Jakobsen etal (1952) have used phonemic theory to derive distinctive feature system and the distinctive feature system proposed by Chomsky and Halle(1968) is based on generative theory.

According to phonemic theory 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 the qualities contained in the speech signal itself that are necessary for the speaker-hearer to identify the phonemes of his language. Some of the implications that phonemic theory has for distinctive features are at least unnecessary, if not absolutely untenable. 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 tenets of phonemic theory are based are not valid; namely that there is a direct correspondence between phonemes and what speakers actually produces and hear in speech, (Packer,F. 1976).

In generative theory there is no one to one correspondence between distinctive features and speech signals. The aim of generative theory is to capture what the speaker knows about his language. The distinctive features are based on a theory of universal phonetics. Chomsky and Halle (1968, p.p.294 - 295) state that such features are "identical with the set of phonetic properties that can in principle be controlled in speech; they represent the phonetic capabilities of man and.... therefore are the same for all languages." Generative theory has several advantages over phonemic theory. It posits two levels of phonological structure (the classificatory matrix and phonetic matrix) rather than one (the phonemic level) which account for phonological alterations and the insertion and deletion of segments, (Parker, 1976).

Parker (1976) points to a limitation in generative theory. He says "Distinctive features as they are described in generative phonology are not components of speech production.....". He suggests a production matrix below the phonetic matrix in which distinctive features are translated into parameters of speech production.

Various feature systems have been proposed to describe sounds of English language. The main difference lies in the method of - extracting the features. The methods are acoustic method (Jakobsen etal 1952) articulatory method (Chomsky & Halle; 1968) and perceptual method (Miller & Nicely; 1955).

Different feature systems have been used to describe consonants and vowels by various investigators as they consider that production and perception of consonants and vowels have different basis. There are some feature systems which describe the consonants and vowels using the same features.

There are disagreements in describing consonant feature system. This is due to methodological variables and difficulty in finding one-to-one relation between the articulatory, acoustic and perceptual features, where as, in describing the vowels, using distinctive features, the controversy seems to be less. Different investigators (Bricker, 1967; Hanson, 1967; Pols, Van Der Camp and Plomp, 1969; Anglin, 1971; Singh and Woods, 1971) have agreed on the perceptual features of vowels and these features correlate with acoustic and articulatory features.

Different feature systems are given in Appendix 1.

The acoustic method, the articulatory method and the perceptual methods are used to arrive at features.

**ACOUSTIC METHOD**

Acoustic method has been used by Jakobsen, Fant and Halle (1952) - pioneers in the field of distinctive features. They proposed 12 binary, universal features using acoustic terms based on the spectrographic analysis. They demonstrated clear acoustic distinction between consonants and vowels. They beleived that in no language all these features are used. Based on 'Received Pronunciation' of English they specified 8 features to describe the English language.

Investigators at Haskin's laboratory have tried to find distinctive characteristics with the use of speech synthesizers. They have found that the Voice Onset Time, inharmonic noise duration, Format frequencies and Formant transitions are some of the acoustic cues which help to discriminate the speech sounds. (Liberman, Cooper, Delattre, 1952; Lisker and Abramson,

Massaro and Oden (1980) studied identification of synthetic stop consonants as either /bæe/, /Pæe/, /dæe/ and /tæe/ in two experiments in which the stimuli varied independently on Voice Onset Time(VOT) and Format transition($F_2$, $F_3$). And in experiment two, the intensity of the aspirated noise during the VOT was varied. The result indicated that there is interaction in the evaluation of acoustic features and the listeners need more extreme values of acoustic features for some speech sounds than for that of other sounds.

Soli (1979) investigated the utility of phonetic features versus acoustic properties for describing perceptual relations among speech sounds. The statistical analysis was done by INDSCAL program. The results indicated that acoustic properties of speech may give a better account of observed perceptual relation among speech sounds. These acoustic properties are 1) Temporal relation between periodicity and burst onset 2) Shape of voiced 1st formant transition 3) The shape of voiced 2nd formant transition 4) Amount of spectral dispersion. Thus he stressed on acoustic properties of speech signal for distinctions.

**The Articulatory Method.**

The articulatory method was used by Chomsky and Halle(1968) A universal set of phonological features was developed based on the phonological theory of generative grammer.

They described the articulatory features of universal sounds. The features are binary and are defined by antonymus adjectives. The vocal mechanism was considered in terms of source, areas of vocal tract involved, position of the tongue in relation to different areas and also oral and nasal cavity differences in terms of volume, eg., coronal/non coronal-coronal feature is present in sounds which are produced by the blade of the tongue raised from neutral position. Chomsky and Halle(1968) believe that the features extracted by this articulatory method provide a representation of an utterance which can be interpreted as a set of instructions to the physical articulatory system.

Recently Weiner & Bernthal (1976) proposed a set of phonetic features. The features are 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.

**The Perceptual Method**

The 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 for decoding auditory stimuli. The distinctive features play a great role in perception of speech stimuli.

In this method the features are retrieved from various speech perception experiments and various statistical analyses.

Perceptual method has been used by Miller and Nicely(1955), Singh & Black(1969), Singh(1968), Wickelgren(1966) for consonants and by shepard(1972), Singh & Woods(1971), Terbeek & Harshman (1971) for vowels.

Singh (1975) describes these perceptual methods as
1) Designation of apriori features to predict perceptual responses.
2) Extraction of aposteriori features from these responses.

1) Apriori designation of a feature system to predict perceptual responses:- This method of retrieval is called apriori because the experimenter determines how and based on

how many dimensions the data will be analyzed 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 strength of a feature system as a whole and also the relative importance of each feature in given feature system is determined based on perceptual responses.

The importance of distinctive features in a language is determined by presenting the distinctive features in question in following:

i) Conditions of acoustic distortion-Noise and Filtering of the stimuli; (Miller & Nicely; (1955)

ii) Cross linguistic settings. (Singh & Black (1966)).

iii) Recall in short terms memory (STM). (wickelgren(1966), Klatt (1966)).

iv) The utilization of choice reaction time as a measure of distinctive feature differences between the phonemes.(Cole & Scott (1972), Weiner & Singh (1974)).

v) The judgement of pairs and triads of speech stimuli utilizing various psychological methods for eliciting perceptual responses. (Singh (1970b), Singh (1971), Singh and Becker(1972), Wang & Bilger (1973)).

The experiments conducted using the above methods have been presented in a tabular form; Table 1.

Table 2 depicts comparisons of different feature systems for a constant set of perceptual data.

Table - 1

Apriori studies

| Name of experimenter and year | Stimuli | Subjects | Conditions | Features | Analysis Technique | Results |
|---|---|---|---|---|---|---|
| 1. | 2. | 3. | 4. | 5. | 6. | 7. |
| Miller & Nicely (1955) | 16 English consonants in the context of vowel /a/ | 5 Female North-American Speaker and listeners. | 5 SN ratio conditions, 11 frequency band conditions and 1 normal condition. - | Voicing, duration affrication. placet (Ternary) nasality | Information transfer for both the phonemes and features was found by subdividing 17 confusion matrices into the voice communication network of 5 component channels. | 1) Different features held different ranks in speech perception as follows:- DNasality ii)Voicing iii)duration iv)affrication v)place.<br>2) Under noise conditions features nasality and voicing showed greater strengths than the features duration, Frication and place of articulation.<br>3) High information transfer for nasality, voicing and frication under low pass condition and for duration and place of articulation under high pass condition. |

| 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|
| Singh and Black (1366) cross linguistic study | 26 Consonants in the context of 12 vowels 21 from english & 5 from 3 other languages | Speakers & listeners of English, Hindi, Arabic & Japanese | Cross linguistic condition where speakers speaking Foreign language made more production errors and listeners listening to the Foriegn language made more perception errors. | Voicing, nasality Frication. Place of articulation (Quaternary), duration liquid. | Information transfer in % was found out for different language groups for different Features. | A single rank order of features across 4 languages was found - Nasality, Place, Liquid, Voicing, Duration, Frication aspiration. Results supported universality of features. |
| Singh (1966) | 6 Plosives in each language making it 12 | Hindi & English Speaking subjects 10 from each language | Acoustic and linguistic distortion condition. Temporal trunkation at 20, 40,60,80,100, 120 msec. Passed through band pass filters 106-425, 425-850,850-1700,1700-3400 3400-6800 & 850-1700, 1700 - 3400, 3400 - 6800. | Place, Voicing & Aspiration. | Information transfer in all conditions & both languages | For Hindi Speakers place seemed to do better than voicing and for English speakers vice versa. In Hindi voicing is weakened since voicing and aspiration have divided strength but in English voicing entails both voicing and aspiration cues. Bilabial place carried more information in both the languages. Between the Frequency bands 850 to 1700 place of articulation was stronger than voicing in both the languages. |
| Singh (1968) | Multiple intelligibility word list. Black(1957) | | Re analysis of Miller & Nicely (1955), Singh & Black(1966) & Kile(1966) data. | — | The graph of distinctive feature difference Vs % of errors was drawn. | Degree of errors and mean number of distinctive feature difference correlated negatively. Highest correlation in Singh and Black(1966) data. |

| 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|
| Singh (1970a) | 22 English Consonants pre-vocalically | 32 English & 32 Hindi speaking listeners. one Hindi & English Speaker (M) | The initial & longer portion of syllable (transition of consonant to the vowel) was truncated at the threshold of perception. | Affrication. Plosive, Voiced, Voiceless, Nasality Frication. | Time/intelligibility ratio was computed by dividing critical time factor for a feature by a number of correct responses. | The graph showing features on abscissa and time/intelligibility ratio on ordinate was drawn. Smaller the ratio stronger the feature. For both languages affrication was the strongest and frication and nasality were weaker. |
| Ahmed & Agrawal (1969) | 29Hindi Consonants in initial. 31 in final position of nonsense CVC with 10 vowels. | 1 Speaker & 1 listener of Hindi. | | Voicing, Nasality Frication, Place of articulation (Quaternary), duration liquid. | Information transmission. | Initial and final vowel transition play different role in recognition. Nasality and aspiration faired well in initial but weak at final. Place of articulation was poorer in initial but relatively sronger in final. |
| Gupta, Ahmed and Agrawal (1969) | | | Infinite peak clipping. | | | Largest clipping effect for place in initial & least for affrication. Order from most susceptible to least was place. nasality, liquid, continuant, aspiration, voicing, frication. affrication; Largest clipping effect in final position for nasality & least for affrication. The rank order was Nasality, Frication, Place, Liquid, Voicing, aspiration. Continuant. Greater effect of clipping on final than initial part of CVC. |

| 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|
| Singh (1971) | Minimally distinct pairs of CV Syllables. | 3 groups of 33 subjects. | 6 experimental conditions with noise and filtering. Similarity judgement by triadic comparison, The experimental conditions were 1) No Noise or fitter. 2)OdBSN ratio 3)Band pass filter 200-400 Hz and 2400-4800HZ 4)Same bands with OdBSN ratio 5)Bands 300-600HZ & 3000-6000 Hz. 6) Same bands with pdB SN ratio. | Singh and Black (1966) | Distance between 2 phonemes(i & j) was found by following measure<br>where<br>dij = Distance<br>Fi/j = Frequency with which j is identified as i.<br>Fj/i = Frequency with which i is identified as j.<br>Ni = Total occurance of i.<br>nj = Total occurance of j. | 1)Distinguishing characteristics of voicing improved in noise and deteriorated in quiet.<br>2)Frication improved in quiet and deteriorated in noise.<br>3)Nasality had maximal distinction in all conditions.<br>4)Nasality, liquid & glides were least affected by the filtering and noise. |
| Gelfand and Silmen (1979) | Lists A-E of modified rhyme test. Each list having 25 words initial & 25 word final sub-test. | 20 normal hearing subjects. | Reverberation .85 seconds. | Miller & Nicely's features Place, Stop, Frication, Voicing, Nasalization, semivowel, sibilance and duration. | Information transfer. | Poorest for place,stop and frication, Sibilance duration, and semivowel were barely affected. This indicates that small room reverberation affects phoneme recognition same as speech shaped masker. |

**Table – 2**

Apriori studies

Studies comparing different feature systems for a constant set of perceptual data.

| Name of experimenter/s and year | Psychological Method | | | Feature systems | Analysis | Results |
|---|---|---|---|---|---|---|
| | Stimuli | Subjects | Conditions | | | |
| 1. | 2. | 3. | 4. | 5. | 6. | 7. |
| Wickelgren (1966) | 16 consonants used by Miller and Nicely(1953) and other 23 consonants occuring in CV Syllables with vowel /a/. | | Short term memory recall(STMR) | Miller & Nicely(1955) Halle(1964) Wickelgren (1966) | Chi square | 1)Wickelgren's system was the best predictor. 2)The results indicated that intrusion errors in STMR have distinctive features in common with the presented consonants. Some features are recalled and some are not. Recall means, a recall of a set of features defining that consonant in memory, and each feature is recalled semi-independently. |
| Singh (1970b) | English Consonants in a CV Syllable | Speakers and listeners of English & Hindi | Judged similarity of english consonants with 5 S/N ratio & 4 signal level condition in initial and final position in triadic comparison. | Singh & Black(1966) Halle(1964) Wickelgren (1966) | Rank order correlation | 1) Most significant correlation in Singh & Black(1966), next Halle(1964) and last Wickelgren (1966) 2) Better correlation in listening mode than in speaking indicating that prediction was better in auditory response. |



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| 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|
| Singh & Becker (1972) | | | l)Seven point Scaling 2)Magnitude estimation(ME) & 3)Triadic comparison | 1)Miller & Nicely(1955) 2)singh & Black(1966) 3)Chomsky & Halle (1968) | 1)Multiple regression analysis 2)Multidimen-sional Scaling | The data was best predicted by Chomsky and Halle(1968) System,But none of the systems did well in all conditions, in-consistency suggested that people either do not use features of these systems in the same way from one task to another or that analysis technique may not be suitable. |
| Wang and Bilger (1973) | 24 initial & 19 Final consonants with 3 vowels (i,a,u).Four Syllable sets were construc-ted each having 16 syllables. They were $CV_1$, $VC_1$, $CV_2$, $VC_2$ | 6 lis-teners | 6 SN ratio conditions -10 to 15dBSN ratio and 4 Signal level conditions-50 dB, 65dB, 80dB and 95 dB. | 19 Features 1)Vocalic 2)Con-sonantal 3)High 4)Low 5)Back 6)Coronal & 7)Anterior 8)Voi-cing 9)Nasality l0)Continuancy 11)Stridency 12)Round 13)Fri-cation 14)Dura-tion 15)Place (Miller & Nicely l6)Place (Singh & Black 17)Place (wickelgren 18)Sibiluncy 19) openness. | Information transmission and Sequential analysis. | 1) Nasality,Voicing and round were important for all syllable sets.<br>2)Stridency and low were never found important in any set<br>3) Remaining Features were all sometimes important. |

| 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|
| | | | | Five feature systems<br>1) Miller and Nicely(1955)<br>2) Singh and Black (1966)<br>3) Wickelgren (1966)<br>4) Chomsky and Halle (1968)<br>5) Singh, Woods and Becker (1972) | | 4) Perceptual importance varied across the contexts indicating that the variance of features. This meant that the features did not form natural perceptual categories. |

Singh(1976) summarised the results of the studies done under apriori framework; "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 apriori systems:-

1) It leaves us 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 feature.

**2) Extraction of a posteriori features from perceptual responses:**

Aposteriori studies overcome the disadvantage of apriori system. Here the features are retrieved with the help of various statistical measures from the perceptual data collected. The features are teased out from the data and then the feature system is established.

The various methods of collecting perceptual data are 1) similarity judgements by triadic comparison 2)Confusion matrices. 3)Magnitude estimation by 7 point scaling 4) Choice reaction time 5) Same/different judgements.

The data collected by these various perceptual method can be subjected to different statistical analysis methods. They are 1) Factor analysis 2) Contingency tables, 3) Multidimensional scaling analysis 4) Individual scaling analysis.

**10 Factor Analysis:-** Black (1970) used this to group English consonants. He gave 24 consonants paired with 5 vowels to listeners and obtained similarity ratings in the manner of magnitude estimation. He derived 12 factors. 1) Nasality(m,n) 2) Slit fricative (ʊ, ð, f, v) 3) long duration fricative (s, z, ʒ). All remaining a factors isolated one consonant per factor; which may not be considered an elegant assignment of the factor to the phoneme. (Singh, 1975).

**2) Contingency tables:-** This was used by Klatt(1968) to reinterpret Wickelgren; short term memory errors. He found in his interpretation that long, frication, continuant, sonorant, sibilant and voiced were strong features where as consonantal, nasal, coronal, anterior and strident were weak features.

**3) Multidimensional scaling analysis:-** This measure has been successfully utilized by several investigators to uncover perceptual strategies used in making proximity judgements. The method helps to find dimensional spaces in which phonemes are perceived. Table 3 gives a summary of the studies done using multidimensional technique.

**4) Individual Scaling Analysis:-** This method is considered to be uniquely suitable for providing a spatial representation of the speech stimuli in a number of dimensionalities. (Singh, 1975). Table 4 gives an account of studies done using this method.

Table - 3

A posteriori features of consonant perception-Multidimensional scaling technique

| Study 1. | Condition 2. | Subject 3. | Response 4. | Context 5. | Stimulus 6. | Analysis 7. | Features[a] Na. 8. | Vo. 9. | Sib. 10. | Cont. 11. | Pla. 12. | Son 13. | Other[c] 14. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wilson (1963) | 1)Noise 2)Low pass 3)Highpass | 5adults | Open choice | CV | $2^4$ | MDS SW.C Wilson own adaptation of Shepard's | X | X | X[b] | X[b] | | Na | Reanalysis of Miller & Nicely's (1955)data. |
| Johnson (1967) | 1)Noise 2)Lowpass 3)Highpass | 5 adults | Open choice | CV | $2^4$ | HCS (J) Hierarchical clustering Scheme | X | X | X[b] | | | Na | |
| Shepard (1972) | 1)Noise 2)Lowpass 3)Highpass | 5 adults | Open choice | CV | $2^4$ | MDS (S) | X | X | | X | | Na | Reanalysis of Miller and Nicely's (1955 ) data |
| Peters (1963) | Quiet | 12 adults | 7 point scaling | CV | $2^4$ | MDS (Torgerson) | X[b] | X | X[b] | X[b] | | Na | |
| Shepard (1972) | Quiet | 12 adults | 7 point scaling | CV | $2^4$ | MDS (Shepard) | X | X | X | | | Na | Reanalysis of Peter's(1963) data. |
| Graham and House (1971) | Quiet | 4.5 year olds | Same/different | Word | $2^4$ | MDS (Shepard-Krushal) | X | | | X | | X | |

| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Singh, Woods & Tishman (1972) | Quiet | 4.5 year olds | Same/different | Word | $2^4$ | MDS (Shepard-Krushal | X | | X | X | | X | |
| Jeter & Singh (1972) | 1)visual 2)Auditory | 1)30 adults 2)30 adults | ABX | CV | $2^3$ | MDS (Shepard-Krushal) | Na | X | X | X | X | Na | The graphemes which were found important were vertical rounded,vertical crossed, angular overlap of place and stop/continuant |

2.1.21

Adopted from Singh (1975)

[a]Na; Nasality, Vo; Voicing, Sib; Sibilancy, Cont, Continuancy, Play Place & Son. Sonorancy. The presence of a feature is indicated by X, Na, not applicable [6]Singh (1975) interpretation from original sources.

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Table - 4

A Posteriori Features of consonant perception - Individual scaling Analysis Technique

| Study | Condition | Subject | Response | Context | Stimulus | Analysis | Features | | | | | | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Na. | Vo. | Sib. | Cont. | Pla. | Son. | |
| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13 | 14. |
| Wish (1970) | 1)Noise 2)Low-pass 3)High-pass | 5 adults | Open Choice | CV | $2^4$ | INDSCAL | X | X | X | X | 2No. Formant Transition | NA | He reanalyzed Miller & Necely's (1955)data and obtained higher and more elaborate structure. |
| Pruzansky (1970) | Quiet | | Similarity judgement | CV | $2^4$ | INDSCAL | X | | X | X | X | NA | |
| Singh, Woods & Becker (1972) | Quiet | 1)1,001 adults 2) 44 adults 3) 18 adults | L) AEX 2)Scaling 3)ME | CV Initial consonants | $2^{4.3125}$ 22 | INDSCAL | X | X | X | X | X | X | Response modes similar weightage to all the features. Method 1 gave importance to place and sibilancy more than nasality. |
| Singh & Singh (1972) | 1)Noise 2)0uiet 3)Peak-clipping | 10 adults (Hindi) | Open choice | CV VC | -4.25 | INDSCAL | X | X | X | Aspiration | | X | Noise level was varied to obtain SN ratio of OdB, 6dB,3dB,-3dB, -6dB. |

| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mitchel and Singh (1374) | l)Noise 2)Quiet | 5 adults | ABX | CV in a sentence | $2^4$ | INDSCAL | X | X | X | X | X | NA | 4 dimensional space was found for extreme noise condition and 5 dimensional space for less noisy condition. The results verified that the features present in isolated utterance are also there in declarative sentence. |
| Wiener & Singh (1974) | Quiet | 20 adults | CRT for diads. | CV 9 consonants | 2 | 3.125 INDSCAL | NA | X | | X | NA | X | MA | Choice reaction time decreases with increase in the distance between features. It is a good measure when extraneous factors are minimised. |
| Danhauer & Appel | 1)Visual 2)Tactile 3)Visualt Tactile | 24 adults | open choice | CV | $2^4$ | 4.3125 INDSCAL | | X | X | X | X | labial | | |

Adapted from Singh (1975)

[a]Na; Nasality, Vo; Voicing, Sib; Sibilancy, Cont; Continuancy, Pla; Place & Son; sonorancy. The presence of a feature is indicated by X; NA, not applicable.

[b]Singh(1975) interpretation.

[c]From original source.

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

2.2.1

## Distinctive Features - Articulation behavior.

As it is evident from the review, distinctive features are the underlying basis of phoneme production and phoneme perception. The problems associated with phoneme production and phoneme perception may be due to the misuse of distinctive features.

When the distinctive feature is misused in terms of phoneme production it would lead to articulation deviation.

Earlier speech clinicians have employed phonemic analysis to describe articulation problems. They classify the errors into substitution, distortion,omission and additions.

Now attempts have been made to apply distinctive feature systems to articulatory behaviour of the normal and abnormal speakers. This has helped in arriving at a more detailed and precise description of the articulatory behaviour. Further it has been found that this system is useful in diagnosis, planning therapy and in predicting the prognosis.

Haas (1963) studied the articulatory performance of a six and a half year old boy with dyslexia. He studied misarticulations on the basis of features plosives, sibilant, nasal, liquid and place of articulation. He found that, these features accounted for the misarticulations and he concluded that, the important element in teaching sounds

of speech is the discrimination of those features that the child fails to produce.

While studying transfer of training for consonants /S/, /Z/ and /r/, Elbert etal(1967) found that transfer was present when the two phonemes shared more features. If the phonemes were fqr apart in terms of features the transfer did not take place.

Weber(197O) studied articulatory behaviour of 18 subjects with articulation problem. He used the features place of articulation, manner of articulation and voicing. He found that deviant articulation behaviour is governed by a set of rules which are not normal. He identified approximately six sets of rules as being used by these cases with deviant articulatory behaviour.

He also established therapeutic strategy aiming at features rather than individual consonants. The treatment was based on two principles. 1) To teach either the entire pattern or a category. 2) To teach the child to contrast correct feature with incorrect feature throughout all the stages of therapy.

Compton(1970) analyzed substitutions in the articulatory behaviour of two children and emphasized the role of distinctive features in articulatory deviation. He further demonstrated that patterns underlying misarticulation stem from small

number of underlying phonological principles. These principles are the core of deviant articulation and therapy should be directed towards modifying these underlying rules.

MC Reynolds and Huston (1971) analyzed misarticulations of 10 subjects ranging in age from 4 years 4 months to 6 years 5 months using 13 features as proposed by Jakobson, Fant and Halle (1951) and chomsky and Halle(1968). They provided an index to quantify feature errors. This indix was computed by dividing the number of correct usage of feature by number of occurence of feature in the test situation. They said that application of distinctive features for diagnosis and therapy in articulation disorders is both economical and efficient- Economical, because teaching one feature corrects all the phonemes containing that feature; Efficient, because distinctive features are vehicles for phonological analysis and these provide basic elemental unit to train rather than training many phonemes. Moreover, feature approach fetches precision in articulation training program by dividing the errors into two groups, a)Errors due to omission of features b)Errors due to inappropriate usage of features. Thus MC Reynolds and Huston (1971) strongly recommended the application of distinctive features in articulation therapy.

"Distinctive feature analysis leads to a more intelligent clinical management."(Pollack & Rees; 1972). Pollack and Rees(1972) did phonological analysis of a child's speech with

defective articulation at 3 intervals of age; 5.2 years, 5.8 years and 6.3 years. Analysis at each age was compared with adult model to reveal the rules of the child's phonological competance. The results indicated the way in which the system changed, maintaining an internal orderliness, but gradually approximating that of the adult model. They indicated that distinctive features offer a base for measuring the severity of a child's articulation problem, measuring progress in articulatory skill, accounting for varying degrees of intelligibility among speakers with defective articulation, recommending therapy and planning and implementing the therapy program. They said that distinctive features can be used to predict intelligibility of speech. The intelligibility of speech depends upon 1) The importance of the feature used and misused in carrying information in a particular language 2)The number of features used and misused. They pointed out that distinctive feature approach may be initially time consuming but it brings about better understanding of the problem.

MC Reynolds and Bennett (1972) discussed generalization of features across phonemes. Three children were taken for feature training in the context of nonsense words, first at initial and then at final position. The training was given in programmed steps. The steps contained learning of a + or - aspect of a features, then contrasting + and - of a feature and lastly contrasting + and - aspect in varying

contexts. Tne programme was complete when 90% accuracy was achieved. Feature generalization across phonemes was found. The method was described as highly economical and elegant because the goal was to rectify the system rather than individual sounds. Feature is a component of several sounds, if the feature is established in the context of one sound, all other sounds bearing that feature are automatically corrected.

Feature generalization across phonemes during articulation training was found by Griffiths and Craighead (1972).

Singh and Frank (1972) investigated consonant articulation problems in 90 children with mean age of 72.4 months, in the light of a distinctive feature model. Following conclusions were derived.

1) Most recently acquired phonemes are replaced most often.
2) Phonemes used as substitutes are most often the ones learned earliest.
3) Stop feature is the most frequent replacement for other manner features.
4) A place feature is substituted by feature which is the closest and more frontal in place and same in the manner of production.
5) Stability and interphonemic similarity are the main principles governing substitutions.

Oller(1973) investigated application of generative phonology to speech sound substitution of five children with delayed articulation. Chomsky and Halle(li968) feature system was used for analysis. The results indicated that the use of distinctive feature system can help in searching for regularity and systematicity in seemingly irregular phonological system.

Oiler & Kelly(1973) studied substitution in a 6 year old hard of hearing child using distinctive feature frame. He observed that the child's substitutions were similar to that of younger normal children.

Leonard(1973) described two patterns of articulation deviation. 1) Phonological immaturity 2) Deviant articulation where in the children do not follow the normal process. He further stated that the first group may grow out of the problem with time but the second group needs immediate clinical intervention.

Kamara, Kamara & Singh (1974) analyzed substitution errors of 77 children with Kamara-Kamara-Singh articulation test of distinctive feature competence. Singh & Polen(1972) feature system was used to obtain feature gram profiles. Feature-gram is a graph which plots subjects discrimination/ articulation scores on ordinate and distinctive features on abscissa.

Further they grouped the subjects depending on feature-gram profiles as follows:-

| Groups | Characteristic Feature-gram |
|---|---|
| 1) Pathology,lesion,organic | Steady loss at all 7 features.(Less than 50%. |
| 2) Retarded | Dip at voicing |
| 3) Cleft palate | More than 70% for all features except front/back place&sonorancy |
| 4) Functional | Poor scores for place. Better for sonorancy & Nasality. |
| 5) Specific learning disability | Significant dip at the features front /back place & labiality. |

They stated that this information is useful for diagnosis and therapy the classification with the help of feature—gram profile is a break through in the literature of distinctive features, and further studies are required.

Kelly etal (1973) studied the articulation problems of 60 children ranging in age from 8-10 years consisting of 30 normals and 30 children with misarticulations. They gave them Templin-Darley test of articulation and also subjected them to distinctive feature analysis. Correlation between distinctive-feature analysis and Templin-Darley test was found. While comparing both the measures of articulatory efficiency they found that the Templin-Darley test is a unitary measure of the patients articulatory performance where as the distinctive feature test is a measure of

differential skill on a number of parameters reflecting the patient's underlying competence. The latter thus gives the precise and efficient description of the problem.

MC Reynolds, Kohn & Williams(1975) compared discrimination and articulation of 7 normal and 7 children with misarticulation with the help of same/different discrimination test and MC Donald's deep test of articulation. The minimal pairs for same/ different task were made up using Chomsky and Halle(1968) Features-voicing, nasality, stridency, continuancy, anterior and coronal.

Results indicated that normal children performed equally well on production and discrimination. The children with misarticulation performed poorly on production but as well as normals on discrimination measure. The children with misarticulation had scores which were slightly lower on discrimination task. Moreover children with misarticulation had discrimination of their correct phoneme as slightly better than incorrect ones. The inference can be made from this that feature discrimination training should precede feature production training.

Costello (1975) described a procedure of application of distinctive features in diagnosis and therapy. She suggested the following procedure for diagnosis and therapy.

**Pretreatment measurement of articulation**

a) Administer general articulation test to isolate phoneme errors b) Deep testing c) Distinctive feature analysis. (Singh & Polen; 1972) f) Select appropriate feature for training and select appropriate phoneme as a vehicle for instructions of this features.

**Instructions**

a) Teach 3-4 phonemes together b) Teach the correct phoneme in connected speech.

**Post treatment Measurement of articulation**

a) Assess the progress with the tests given before.

MC Callum (1975) studied 50 children with articulation problems to see whether phonological analysis will help differential diagnosis and thus aid prognosis. She used MC Reynold and Huston's(1971) technique of distinctive feature analysis. The features used were consontal,back,nasal, coronal,continuant, rounded and voiced. She did subjective analysis and found various patterns as related to each etiology. She admitted that these patterns are not standard and due to lack of statistical treatment, validity is limited. She concluded that distinctive feature patterning along with other data can prove to be a useful tool in differential diagnosis.

Martin(1975) advocated the use of teaching plus minus aspects of feature with all relevant phonemes instead of

teaching only one aspect of only one phoneme.

Costello and Onstine (1976) evaluated the effectiveness of remediation procedures based on distinctive feature theory through the administration of an articulation programme. Two preschool children with multiple phoneme errors were the subjects. They substituted stop phonemes for continuants. The results indicated that the treatment was adequate. When two target phonemes were corrected five other phonemes were produced correctly. Thus they found cross phoneme generalization and concluded that distinctive feature theory could produce cross phoneme generalization.

Ferris (1978) analyzed articulation errors using chomsky and Halle (1968) distinctive features for 14 children ranging in age from 4.6 to 6.9 years. It was found that all children had difficulty with strident and high features. There was a difference between young and old subjects indicating that defective speakers progress through the same stages as normals but at a slower rate.

Kim(1978) published the application of his segmental feature system. He gave analysis procedure for deviant articulation using features. He suggested the following steps. 1) Administration of deep articulation test 2) Segmental feature analysis in which a) Analysis of test phonemes b) Findingout sum of total number of phonemes tested.

c) Finding out frequency of correct responses, d) Analysis of incorrect responses, e) Counting frequency of incorrect responsing f) Finding out number of correct usage i) Finding out the sum of feature difference between correct and incorrect responses.

In conclusion Kim(1975) advocated feature analysis as a tool for articulation testing but he contra indicated complete feature analysis when few errors are made.

Weiner and Bernthal (1978) proposed a test of articulation based on distinctive features. This test has two levels, i.e. 1) To screen children's speech for pattern of feature errors, in which 21 consonants are elicited once in prevocalic and once in postvocalic position. If the errors made are beyond criterion on either + or - aspect of any one feature then second level test is given. 2) In level-2 a particular feature is selected. All the sounds in that language consisting of the test feature are presented to note the frequency of correct or incorrect usage of that particular feature.

Based on their clinical experience they suggested several criteria for selection of a feature for training. Tnese criteria are: l)Redunduncy:- The presence of a feature indicates the presence of other feature's. Hence there is no need to consider the feature which would occur in the presence of the other one.

**2.) Number of Features in error:** They suggested that a feature which is correctly produced for less number of times(lowest %) on the level 2 test must be considered first for therapy/ correction in children with errors on only few features and a feature which is correctly produced more number of times (highest %) on the level 2 test must be considered first for therapy/correction in children with errors on more features.

**3) Ease of instruction:-** They suggested that the features which are easy for demonstration should be taken up first eg Manner features are considered to be easier to learn than place features hence manner feature should be corrected first.

**4) Acoustic contrast:-** The features in which the plus and minus aspects are acoustically distinctive are easier to learn.

**5) Visibility:-** More visible features are easier to learn.

**6) Frequency of usage:-** The features which are more frequent in a language should be taught first.

7**) Physiological constraints:-** If feature learning is difficult due to physiological constraints then those features should be avoided in the beginning.

Blache(1980) gave a linguistic approach to distinctive feature training. This training paradigm stressed the importance of learning the linguistic function of feature. The

method given contains four steps. 1) First the child must understand that the two contrasting words (minimal pairs) differ in their meaning 2) The child should discriminate the two words 3) The child should produce the minimal pairs which are taught in response to a picture stimuli 4) Generalization.

Metz etal (1980) used distinctive feature approach to the remediation of voicing errors produced by hearing impaired adults. They used feature-usage rule training programme described by Costello & Onstine (1976). The results showed a lack of generalization from one phoneme to another. They concluded that there is a need for the development of sensitive, easily used phonological analyses procedures to describe the nature of articulation errors in hearing impaired subject. At present the clinical application of distinctive feature theory does not appear to fulfill this need.

Ruder and Bunce (1981) employed distinctive feature training for articulation correction for 2 children having severe articulatory problem. Both the children had phonetic disorder ie they had adult phonological competence but were not able to demonstrate this knowledge due to some organic involvement. The therapeutic outcome showed generalization across phonemes. This occured eventhough the sounds which should have been acquired earlier to these sounds in the

process of normal development had not been acquired. This showed that maturation is not the only factor in acquisition of articulation.

Distinctive features have been utilized to analyze phonological behaviour of apraxic and developmental Dysprakic individuals.

Yoss and Darley(1974) gave a battery of tests for speech production, auditory perception and sequential volitional movements to 30 children with articulation disorders. The children had normal intelligence, normal hearing and normal language abilities with no organic involvement.

The findings indicated impaired performance on test battery and the findings proved that the oral developmental Dyspraxia did exist in children who appeared normal. The distinctive feature analysis of defective articulation Showed 2-3 feature errors. One place error and omission were found to be significant characteristics of Dyspraxia.

Klich, etal (1980) analyzed using distinctive features, 825 consonants produced by 9 apraxics. The results indicated that substitution patterns were systematic. More substitution errors were made in initial word position and in stops. The retention and usage of the features in the substitution were closely related to the phonological markedness of the features. The marked was substituted by unmarked.

These findings supported the contention that errors are due to phonological deviation which are manifested in peripheral articulation changes. The consonant production is made simpler and the patterns resemble acquisition of articulation in children which supported Jakobson's regression hypothesis.

Investigators have explored phonological behaviour of aphasics with distinctive feature analysis.

Martin and Regrosky (1974) described the phonemic substitution errors made by a group of 15 aphasics in semantic and nonsemantic stimuli using distinctive feature system. The findings showed that the errors were not random and were highly similar to correct patterns.

Keller(1978) investigated vowel substitutions in 5 Brocas aphasics using distinctive feature system and markedness analysis. Marhedness theory had no predictive value in this sample. The tendency to use low vowels for high vowels was observed. This may be attributed to more simplicity in low vowel production.

Literature reports an additional application of distinctive features in the concept of 'Markedness'.

The theory of 'markedness' had its origin in the early prague school of linguistics. This theory says that all

features composing a phoneme may be assigned a 'marked' or 'unmarked' value. A marking system indicates relative complexity attributable to articulatory, and perceptual factors. When a feature is 'marked' in a phoneme, it indicates that in that phoneme that feature may require more articulatory/perceptual effort than in a phoneme in which it is 'unmarked'. Whether a feature assumes a'marked' or 'unmarked' value depends upon the other features present in a phoneme. Tne complexity of phonemes is equal to the sum of its marked features.

Cairns and Charles (1369) prepared a table for 'markedness' in which marked' and 'unmarked' value of features in the context of different phonemes is presented.

Cairns and Williams(1972) analyzed misarticulations of consonants in 384 children from 1st through 12th grade using Cnomsky and Halle(1968) feature system. They showed a typical pattern of substitution of features from more 'marked' to less marked'. The change was from + coronal to - coronal and from - anterior to + anterior. The direction of change from more difficult to easy features could be explained using 'markedness' theory.

MC Reynolds, Engmann & Dimmit (1974) studied articulation errors of 19 children within the 'markedness' theory framework. The unit for'mearkedness' analysis was distinctive feature.

The children did not substitute phonemes requiring less effort than the target phoneme consistently. The reverse ie from 'unmarked' to marked features was also true. The results only partially supported'markedness' theory.

Smith and Ruder(1975) questioned MC Reynolds etal(1974) stating that the sample used in the study was of severe misarticulation cases, moreover the effect of position and context was not considered and so the results were contaminated.

MC Reynolds (1975) in reply to Smith and Ruder(1975) stated that she accepts the comment that results might have been contaminated as the samples were only of severe misarticulation cases. Further she said that context sensitivity may be ruled out as consistent substitutions have been observed. She denied that she had not questioned the potentials of 'markedness' theory.

Weiner and Bernthal(1976) did not find support for 'markedness' theory in their investigation of normal feature acquisition in children.

Marquardt, Reinhart & Peterson(1979) did 'markedness' analysis of phonemic substitution errors in apraxia of speech. The results showed higher error rate in phonemes with high 'markedness'. The directional changes in substitution were from 'marked' to 'unmarked'. These findings indicated that an 'Apractic' tries to reduce the complexity of articulatory gestures for phoneme production.

## 2.3. Distinctive Features - Speech sound Perception

The role of distinctive features in perception of phonemes has been considered as vital(singh; 1976). It has been found that the distinctive features invoke the listener in perceiving speech sounds. The features are the underlying attributes of perceptual processing and thus speech sound perception and speech sound discrimination can be measured and quantified based on distinctive features. The efficiency and precision of evaluating speech sound perception increases with the application of distinctive features.

The studies on speech sound perception within distinctive feature framework can be discussed under following headings.

1. Speech sound perception in normal hearing individuals.
2. Speech sound perception in hearing impaired individuals.
3. Acquisition of speech sound perception.
4. Relationship between speech sound perception and speech sound production.
5. Dichotic speech sound perception.

### 1) Speech sound perception in normal hearing individuals:-

Singh(1968) studied the errors in multiple choice intelligibility test.(Black; 1957) by distinctive feature system. The results showed linear correlation between the number of errors and distinctive feature differences.

Tannahill and Mc Reynolds(1972) investigated same/different

discrimination task in 30 normal hearing subjects. The discrimination task was made more difficult by passing the stimuli (consonant pairs) via low pass filter. The 45 consonants were embedded in CV Syllables and they differed ,by 0, 1, 2 features. The features used were voicing, nasality, affrication, duration and place of articulation(Miller and Nicely(1955). The findings indicated that greater confusions occured when contrast was o or 1 feature. The conclusion reached was that discrimination of consonant pairs was differentially affected by the number of opposing features contained in each pair. Thus features provide acoustic cues to discriminate speech sounds.

Singh and Blackman(1974) analyzed errors on Modified Rhyme Test (House, 1965) with distinctive features for 25 normal college students. Various signal to noise ratio conditions were presented. The results indicated perfect correlation between the number of feature differences and percentage of errors made. The % of errors decreased with the increase in the number of feature differences.

Binnie, Montgomery and Jackson (1974) studied perceptual confusions of 16 english consonants presented to normally nearing subjects under auditory, visual and combined condition in varying signal to noise ratio condition. The information transmission analysis and % correct intelligibility was found out for an articuiatory feature class system.

The results indicated that in auditory condition the features nasality and voicing were least affected by noise and place of articulation was most affected. In visual mode subjects categorized pnonemes into discrete homophenous groups. In the combined mode tHe visual channel reduced place errors in various signal to noise ratio conditions.

Danhauer etal (1978) studied short term memory recall for 18 for 18 consonants with vowel /a/ in varying signal to noise ratio conditions - 1) 0 dB SN ratio 2) -5 dBSN ratio 3) -10 dBSN ratio 4) No noise. The subjects were 3 normal listeners. Tne results were analyzed by individual scaling method and the analysis indicated that the errors were few in quiet condition and increased with signal to noise ratio conditions. The results also showed that voicing and nasality features were resistant to noise but place was not. (Miller & Nicely; 1955 system).

**2) <u>Speech sound perception in hard of hearing individuals:-</u>**

Several investigators have advocated the use of distinctive features in assessment of perceptual processing in hard of hearing population. Fry(1960), Fry(1966), Danhauer and Singh(1975) and Singh etal (1974) have criticised the traditional methods of finding out processing of speech sounds. The pure tone audiometry should not be used to predict speech processing because speech is a complex signal. The speech audiometry including speech reception threshold

and speech discrimination scores do not provide sufficient insight into the interaction of the ear with critical properties of the speech sounds. Speech audiometry tests done with phonemic analysis give unidimensional information which is inadequate for assessment of multidimensional nature of the ear's response.

Singh, Lawson and Singh (1974) analyzed the responses of 30 hearing impaired individuals to modified Rhyme test (House) 1965) with the help of 7 distinctive features. The confusion matrices were obtained. The correlation and cluster analysis showed that the distinctive feature errors of 'Modified Rhyme Test' can be grouped into five significantly different diagnostic categories. This grouping provided insight into the processing of speech sounds by different groups of hard of hearing population.

Danhauer and Singh(1975) examined speaking and listening performance of 36 severely hearing impaired individuals belonging to 3 different language groups. Seven binary features were utilized for analysis. The features were 1) Front/back place 2) labial place 3) Sonorancy 4)Nasality 5) Continuancy 6) Sibilancy 7) Voicing. The subjects were 8.77 years of age on average and the severity of hearing loss was different in different language groups.

| Language | | Hearing loss |
|---|---|---|
| 1) English | | > 68 dB |
| 2) Yugoslavian | > | 58 dB |
| 3) French | | > 69 |

Feature gram profiles were obtained. Information transmission in % for all distinctive features in each language group was plotted and ranked from highest to lowest weighted features.

The results showed similar ranking in all language groups and supported language universality concept, Sonorancy, Nasality & Voicing obtained greater scores than place of articulation and labiality. The highest scores in nasality, voicing and sonorancy can be attributed to low frequency residual hearing and dominance of low frequency components in the features voicing, nasality and sonorancy.

The authers concluded that 'Feature-gram' reflects the nature of the speech perception and production. This information can help us in planning our therapy.

Danhauer and Singh(1975) studied perceptual processing of speech sounds in deaf subjects. The stimuli were CVCV syllables. They analyzed the responses and 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 to their long duration. Moreover they recognize 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.

Walden and Montgomery (1975) conducted a study on 3 groups of subjects-Normals, 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 groups formed by this analysis correlated with different hearing loss groups. For high frequency loss cases, the feature sonorant was dominantly used. This may be due to low frequency formant in sonorant feature. For flat hearing loss the feature sibilance was the dominant dimension, where as normals used both these equally. The inference that can be made is that the data on feature usage by listeners may help us to predict perceptual strategies employed by 'hard of hearing' population.

Bilger and Wang(1976) derived consonant confusion

matrices from 22 listeners with sensory-neural loss for four sets of CV and VC nonsense syllables. The nonsense syllables were used to maximize the contribution of acoustic factors and minimize the contribution of linguistic factors. The stimuli were presented monaurally at speech reception threshold. +40 dB Multidimensional scaling was used to find whether the patients grouped themselves in a systematic way. Three groups were found. 1) Normal Hearing 2) Flat or rising audiogram 3) High frequency loss.

The groupings depicted significant correlation between a audiometcic configuration and consonant confusions.

Blood, Blodd & Danhauer (1978) studied deaf children ranging in age from 8-14 years to find out the distinative features they used in their spontaneous production of consonants. All the subjects had left corner audiogram (Profound hearing loss). The stimuli used were 54 pictures to elicit 18 consonants in 3 vocalic positions. The consonants were /P,b,t,d,k,g,f, v,m,n,s,z,tʃ,dʒ,j,θ,ð/. The responses were phonetically transcribed. The substitution errors were analyzed by individual scaling analysis. The features were mainly related to place of articulation and indicated that current rehabilitation techniques focus primarily on those features while not exploiting others available in the speech signal.

Doyle, Danhauer and Edgerton (1981) analyzed errors on nonsense syllable test (A) and (B) for 10 normals and 8

patients with sensory-neural hearing loss. Individual scaling method was used for analysis. 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 suggested that both groups use similar perceptual strategy but the patients with hearing loss make more errors. Tnis study pointed to the stimulus variable as an important variable in extraction of features.

The studies on hearing impaired population points to an inference that hearing impaired individuals use same features as normals in speech sound perception but they weigh these features differently.

3) Acquisition of speech sound perception:-

The phonological development includes the development in speech sound production and speech sound perception.

Graham and House (1971) studied the relationship between the development of a phonological system and auditory perception The discrimination errors of children were analyzed with non metric multidimensional scaling. Chomsky and Halle(1968) feature system was used. The study concluded that this feature system failed to yield a decision process capable of identi-fying the various speech sounds. This suggested that features may not have psychological reality. They failed to show a definite patterning of features in the development in their sample.

Zlatin and Koenigsknecht (1975) investigated perceptual development of the voicing contrast in 2 year old children, 6 year old children and adults. The subjects were required to identify prevocalic stop consonants from synthetic speech. The stimuli differed with respect to acoustic cue voice onset time. Identification functions for labial, apical and velar stops were plotted. The results indicated that the magnitude of voice onset time difference required to distinguish between prevocalic stop cognates decreases as a function of age. Developmental differences were most consistently revealed for velar cognates.

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

Thus, to derive a complete description of language acquisition process, it is essential to have information about both the production and perception development. At the moment data is available on production development and more research is required in the area of perception development. (Graham & House, 1972).

**4) <u>Relationship between speech sound perception and speech:-</u>**

Williams and MC Reynolds (1975) investigated the effects of production and discrimination training on 4 subjects.

Results indicated that production training was effective in treating both production and discrimination where as discrimination training changed only discrimination.

Kumadavalli(l973) studied the relationship between articulatory performance and discrimination. A test of discrimination in kannada using distinctive features was developed. The test consisted of minimal pairs having one or two distinctive feature difference. The picture pointing responses were obtained. Using the same pictures articulation was tested. The discrimination and articulation of each item were then compared the subjects were school going children. The results indicated that production always preceded perception.

**5) Dichotic speech sound perception:-**

The literature in speech perception indicates that perception of vowels and consonant depends on different cues. Vowels are perceived based on acoustic/auditory cues available. Consonants are perceived based on extraction of linguistic features or acoustic restructuring of auditory parameters into so called 'encoded' phonetic parameters. Thus different perceptual strategies are employed to decode vowels and consonants and are also localized in right and left hemispheres respectively.

Studdert-Kennedy and Shankweiler(1970) investigated the role of dominant hemisphere in the perception of both vowels and consonants (voiced and Voiceless). They presented spoken

CVC stimuli dichotically in pairs which contrasted in only one phone. The results indicated significant right ear advantage for initial and final stops and non significant ear advantage for vowels. The significant ear advantage for articulatory features place and voicing proved that specialization of the dominant hemisphere in speech perception is due to its possession of a linguistic device. It is reported that both the hemispheres have capacity for auditory analysis. Ability of the dominant hemisphere to perceive consonants is considered as due to its ability to extract linguisitc features.

Studdert-Kennedy and Shahkweiler(1970) findings were contradicted by some experimenters. Fusisaki and Kawashima (1969) found that vowel perception has same processing mechanism as consonants when their acoustic characteristics are changed eg. Reducing the duration.

Crystal and House also expressed similar view saying that major difference between the vowels and consonants is their inherent intensities. They found minimal difference in ear preference when the intensities were equalized.

Day and Vigorito (1972) dichoticaily presented synthetic syllables containing plosive, liquid and vowel categories for temporal order judgements. Stop sounds had right ear advantage, liquid showed no ear advantage and vowels had left ear advantage.

Blumstein, Tartter and Michael (1973) studied perceptual reality of manner features in dichotic listening. The manner features were presented in CV context. The results indicated clear cut right ear advantage for consonants. The findings showed that right ear advantage was more for fricatives and stops than nasality.

Blumstein etal (1977) investigated the perception of vowels when presented dichotically. Twenty normal, right handed individuals were selected as subjects. The stimuli were CV syllables. The found that perception of vowels was not lateralized.

However they stated that "Vowel perception is based on processing mechanisms similar to those of consonant. In particular there was strong evidence for the use of phonetic features by the subjects at the level of response organization. . . . . The dichotic perception of vowels of normal duration does not seem to reflect the extraction of phonetic features. Rather, because of the accessibility of the acoustic information in auditory memory, the subject may be able to by pass phonetic categorization and, consequently, operate on the auditory parameters of the signal. In contrast at the level of response organization the stimuli need to be categorized for labeling and thus, the subject avails himself of phonetic features".

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

In conclusion it may be stated that "Those speech sounds which are highly encoded are dependent on perceptual decoding by specialized left hemisphere processors" (Libermann, Cooper, Shankweiler and Studdert Kennedy; 1967).

2.4.1

## Distinctive Features - Phonological Acquisition

Distinctive features have been used to explain phonological development.Hodson(1978) aptly states that "Although existing distinctive feature systems have certain limitations, they have opened new vista, in the study of child phonology".

In literature various models have been putforth and several studies have been conducted on development of phonology based on distinctive feature framework. Some investigators have even analyzed earlier phoneme acquisition data in the light of distinctive features.

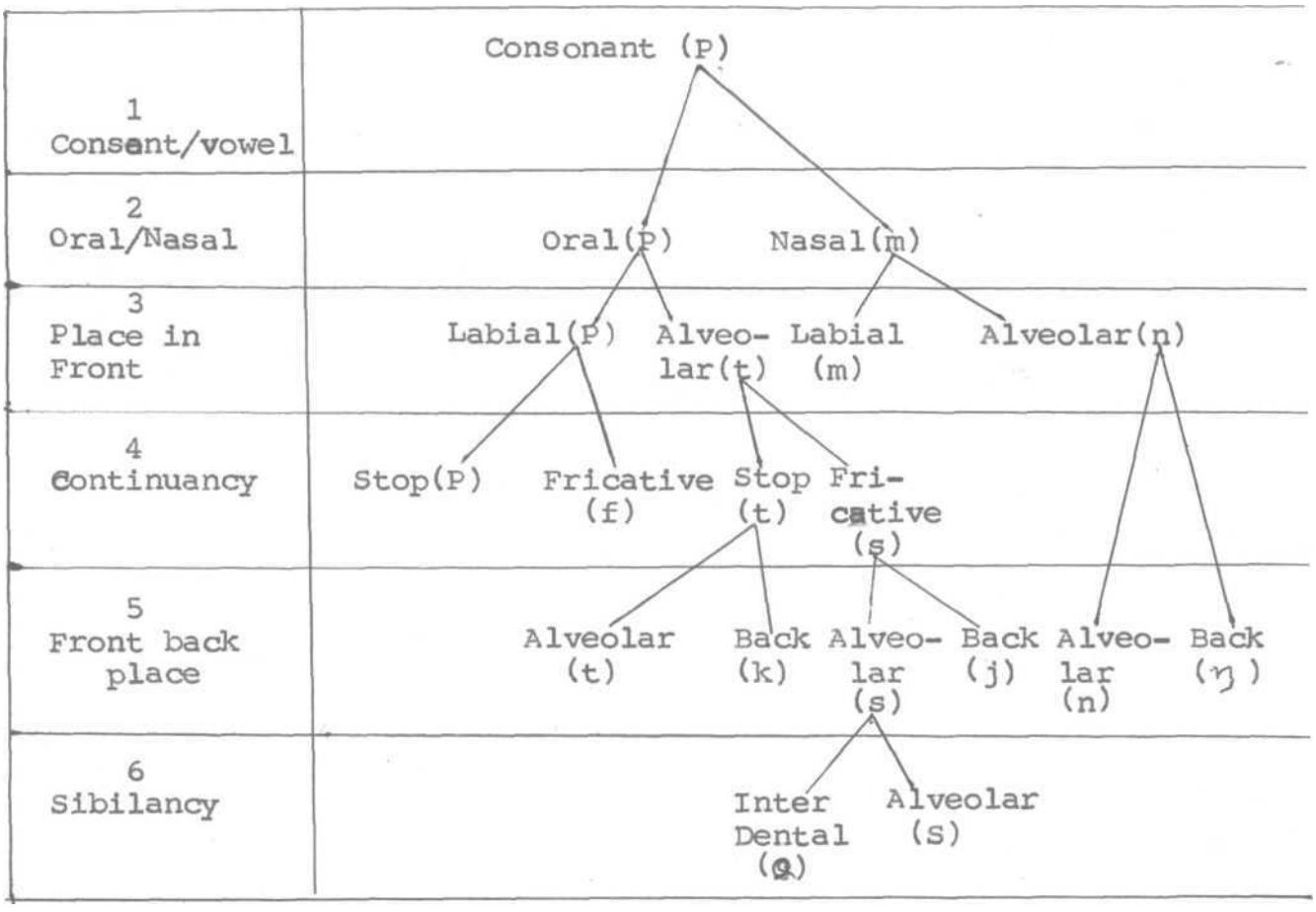
Jackobsen (1940-1968) putforth a model explaining the process of acquisition of phonology in children. The hypothesis states that "phonological binary contrasts govern the phonological development in childhood. The contrasting components are distinctive features". West(1973) agreed with this view.

Following levels were demonstrated by Jakobsen starting from general differentiation of major phonemic classes to phonemic level of adult phonology. For each level of contrast physiological and acoustic correlates were included.

| Stage | Feature Contrast | Examples of sounds |
|---|---|---|
| 1 | Consonantal/Vocalic | p/a |
| 2 | Nasal / non-nasal | m/p |
| 3 | Grave / acute | p/t |
| 4 | Compact / diffuse(vowels) | - |
| 5 | Grave / acute (vowels) | - |
| 6 | Compact / diffuse | k/p |
| 7 | Flat / Plain | - |
| 8 | Continued / interrupted | s/t |
| 9 | Tense / lax | p/b |
| 10 | Strident / mellow | S/Q |

2.4.3

**Order of sound development dependent on binary contrast as given by Jakobsen (1940-1968)**




Crocker (1969) gave a linguistic model of children's articulation competance. He stated that children learn the rules of combining distinctive features in a particular developmental sequency. This model showed progression from a more general and all inclusive linguistic sounds usage to more specified and differentiated sounds.,

According to this model children develop phonology by applying the three following rules to combine phonological features.

Rule - 1) Combine a primary feature with a base feature set.

Rule - 2) Combine a secondary feature with a base feature set.

Rule - 3) Combine a secondary feature with a secondary feature.

Here prime features are the one which are required to establish a class of sounds. Base feature set is a set from which further sets develop. Secondary features are secondary to primary features.

Blache(1978) Criticises Jakobson's model by stating that "In all the theory's strength its abstruct and comprehensive nature-is its weakness. A lack of specificity for experimental purposes" (Blacke, 1978).

Blache (1978) revised this model and gave a model which could be imperically tested. The feature system utilized was Miller & Nicely's system. The experimental support was taken from various studies done with advanced statistical methods. The steps represented the most probable order of acquisition that most children follow.

Studies done on acquisition in the light of distinctive features are of two types:

1) The studies reported very early in literature have been reanalyzed by current investigators. The phonemic data

is converted into feature data. The limitations of these studies are that.

a) The age levels are above 3 years when most of the phonological development has already taken place.

b) It is difficult to determine feature acquisition from phonemic data not originally for feature analysis. Acquisition of correct phoneme production criterion does not account for the acquisition of individual features.

2) The studies in which distinctive feature analysis is used to trace development of phonology in children.

These two types of studies are summarised in table (4) and (5).

Table - 4

Studies depicting Re analysis of earlier investigations

| No. | Name of experimenter & year | Current investigator & year | Criterion used | Age | Phonemes | Features | Conclusions |
|---|---|---|---|---|---|---|---|
| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
| 1. | Wellman etal 1931 | Singh;S. 1975 | 75% | 3 | /m,n,f,h,w,b/ | Nasality,labiality. Voicing,continuancy, Sonorancy | Features nasality, labiality Sonorancy, Voicing and continuancy are acquired earlier than features Front/back place and sibilancy.. |
| | | | | 4 | /p,j,k,g,d/ | Voicing | |
| | | | | 5 | /d,r,s,ts,s,v, t,z/ | Front/back place, Sibilancy | |
| | | | | 6 | /dz / | | |
| 2. | Poole (1934) | Singh,S. 1975 | | 3.5 | /m,p,h,w,b/ | Nasality,Voicing, labiality,Sonorancy. | |
| | | | | 4.5 | /n,ŋ,s,k,d, g,t/ | Front/back place | |
| | | | | 5.5 | F | Continuancy | |
| | | | | 6.5 | /j,v,l,θ,ʒ/ | Sibilancy | |
| | | | | 7.5 | /r,s,θ,z,M/ | | |

| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
|---|---|---|---|---|---|---|---|
| 3. | Templin 1957 | Sing,S 1975 | 75% | 3 Yrs. | /m,n,ŋ,p,f,h,w | Nasality,Sonorancy labiality,Voicing, continuancy | Marked features are acquired last. |
| | | | | 3.5 " | /j/ | | |
| | | | | 4 " | /k,b,d,g,r/ | Front/back place | |
| | | | | 4.5 " | /s, ʃ ,tʃ/ | Sibilancy Voiceless | |
| | | | | 6 " | /t,θ,v,l/ | - | |
| | | | | 7 " | /ð ,z,ʒ,dʒ ,M/ | Sibilancy voice | |
| 4. | Nakazima (1962) | Sing,S. (1975) | | 2 to 5 months | Front vowels labial consonants | labiality | Found similar findings in Japanese and American children |
| | | | | 7 months | labial,alveolar, palatal consonants | Voicing,nasality, aspiration | |
| | | | | 9 to L m. yr. | (ʃ) (l) | Sibilancy, Sonorancy | |
| | | | | 1 year | | Voicing,nasality, place,sonorancy, continuancy. | |
| 5. | Snow (1963) | Singh 1975 | | 7 year 2 months | | 95% correction in all other manner features except voiced fricatives voiced 8% fricatives. | Continuancy, Front/ back place and sibilancy produced most errors. |

*****

Table - 5

Studies depicting investigations using distinctive feature analysis

| No. | Name of experimenter & year | Age | Stimuli | Procedure | Analysis | Features | Conclusion |
|---|---|---|---|---|---|---|---|
| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
| 1. | Bricker (1967) | 3 to 3.9 Ys. 4 to 4.9 " 5 to 5.9 Ys. | | Imitation behavior analysis | | Place, manner and voicing | Maximum precision in all the 3 groups for voicing and minimum precision for place was found. |
| 2. | Messer (1967) | 3 Ys. 7 months | Word pairs of English and non-English words. | Judgement of english sounding words in a pair | Substitution errors were analyzed | Jakobsen, Fant & Halle system(1952) | Large majority of errors were made by changing of only one distinctive feature. |
| 3. | Menyuk (1968) | Japanese children from 1 to 3 Ys. American children from 2 to 5 years. | Syllables | Repetition task | % of correct usage of the features in different age groups was found and rank ordered. | gravity, diffuseness stridency, nasality. continuancy and voicing. | Rank order of correct usage of features was same in both American and Japanese groups. The rank order was Nasality, gravity,voicing, diffuseness, continuancy and stridency. This order of acquisition was parallel with Jakobson's model. |

| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
|---|---|---|---|---|---|---|---|
| 4. | Prather, Hedrick & Kern(1975) | 24 to 48 months. | Photo-articulation test | | Plotted correct production of distinctive features as a function of age. | Nasality, Voicing, gravity, diffusedness,continuancy, stridency. | The children acquired features earlier than Menyuks study ages. The rank order was nasal. grave,diffuse,voicing, continuancy & stridency. They also found that +&- specification of features have different rank order in development. |
| 5. | Weiner & Bernthal | 2 to 6 years old | Pictures were stimuli for 23 consonants | Targets were evaluated with templetes having a list of features for each phoneme. | Proportion of errors for each feature was computed. | Modification of Chomsky & Halle(1968) system was used. Features were 1)Anterior 2)coronal 3)High 4)Back 5)low 6)Distributed 7)Nasal 8)lateral 9)Delayed release l0)continuant 11)voice. | l)There were few errors with -low +nasal,-lateral and - voice. 2)High proportion of errors for -anterior than + anterior. 3)The results of 4 features were predicted by Markedness theory 4)Findings suggested that tongue manipulations are difficult & so they are acquired later. |

| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
|---|---|---|---|---|---|---|---|
| 6. | Hodson (1375) | 4 years old | - | - | Fine phonetic transcription and feature analysis was done to find % correct scores | 1)Sonorant, 2)Anterior 3)aronal, 4) 5)Continuane 6) 7) voiced. | 1) Sonorant,strident, continuant & anterior were well established. 2) Inappropriate use of the features coronal strident and high was found. |



The studies on phonological acquisition demonstrate the role of distinctives features in developmental studes, The features offer a precise and fine tool for the evaluation of articulation development.

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2.5.1

## Distinctive Features - Limitations

Tnus the concept of distinctive features has been found to be useful in studying 1) Articulation Behavior 2) Speech sound perception and 3) Phonological acquisition.

However, some have considered that there are certain limitations in the use of these distinctive features.

Many have questioned the conceptual reality of features.

La Riviere etal (1974) assessed the conceptual reality by a sorting task as suggested by Winitz(1972). A series of sounds were presented several times in random order, and the subjects were asked to assign sounds to one of the two categories. The subjects were divided as control and experimental group. The subjects in the control group classified the sounds only with the help of paired association where as the experimental group could classify the sounds on the basis of distinctive features and paired association both. The features used were voice, nasal continuant, student and vocalic. The results indicated that there was difference between experimental and control group. This difference was considered as due to the use of features nasal, strident and vocalic by the experimental group. Voice and continuant features were considered to be not useful in sorting and were considered conceptually unreal.

Ritterman and Freeman (1974) studied the role of relevant and irrelevant stimulus dimension in discrimination for 32 subjects. The results showed no significant differences in performance as a function of number of the irrelevant dimension nor characteristics of relevant dimensions. The results indicated that no perceptual dimension (Feature) was more important than the other. The study supported La Riviere's view.

Walsh(1974) criticises the feature systems which give importance to structure of phonological contrasts and ignore the concrete manifestations. He questioned the applicability of feature systems put forth by the prague school of linguistics'. (Jakobson and others) to speech clinicians who deal with speech production.

Parker (1976) compared existing distinctive feature systems and has drawn our attention to the fact that all the feature systems are not the same. They have different theoritical back grounds. Some (Chomsky and Halle; 1968) have a strong theoritical support where as some (Jakobsen, Fant and Halle; 1955) do not have it. Parker also printed out to abstract representation of well found phonological feature system. (Chomsky and Halle; 1965) and advocated to add a production matrix to consider physiological phenomena and to relate them to abstract entities.

Leonard (1974) pointed out the limitations in clinical application of distinctive features. He stated that the distinctive features serve two functions - An abstract classificatory function and the phonetic function. At abstract level, the features assume two values + and -, at the phonetic level they are physically represented and they may indicate ranging degrees of plus or minus parameters. Now an instructor should use this phonetic level and just binary specifications should not be used.

Lund and Duchan (1978) presented their views on phonological analysis. They criticised phonemic view alone. They also criticised distinctive feature analysis. They stated that this approach does not detect within phoneme errors; and does not reveal consistency unrelated to features; and also does not explain omission where error- target matching is not possible. The authers advocated a multifaceted approach to overcome the limitations of various individual approaches. This multifaceted approach included phonemic analysis, feature analysis, context sensitive analysis, reduplication analysis, assimilation analysis and idio syncractic analysis. They found this approach to be useful.

Singh(1976) put several limitations to-gether for the distinctive features by saying that the features do not consider coarticulation and timing factors in speech production. Moreover they may vary with dialects and prosody of the speaker. Thus these limitations may limit their use.

2.5.4

Inspite of the limitations, the distinctive feature concept is still considered as a valid and useful tool in the studies in speech sciences and in the clinics of speech correction.

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# CHAPTER III

## METHODOLOGY

A feature system for Hindi consonants has been proposed by Ahmed and Agrawal (1969) using 9 features. As there is similarity between Gujarati and Hindi language in terms of phonemes also, it was decided to use, the same feature system with two modifications; that is l)Place of articulation feature has been represented by five features namely 1) Labial 2)Alveolar 3)Dental 4) Retroflex 5!velar; to make the distinction more clear within that feature and 2) Insead of using the term liquid, lateral has been used in this system.

The distinctive feature system proposed for describing the consonants in Gujarati language consists of following features. l) Voicing, 2)Nasality, 3)Labial, 4)Alveolar, 5)Dental, 6)Retroflex, 7)Velar, 8)Aspiration, 9)Affrication, 10)Semivowel, ll)Lateral, 12)Flap, 13)Frication. All the features have binary specifications.

The consonants considered here are based on the phonetic classification in terms of manner and place of articulation of consonants in Gujarati language. (Nair; U.;1979).

This study has been restricted to consonants only. No attempt has been made here to describe the vowels because of many constants.

The following experiments were conducted in order to find out the efficiency of the proposed feature system by 1) Acoustic analysis, 2)Perceptual analysis.

**1) Acoustic Analysis:-**

A) Stimuli:- 65 minimal pairs were constructed consisting of 32 consonants of Gujarati language.(Nair;U. 1979). The minimal pair words have been taken from'Gujarati Bhashanu Vyakaran'(Yogendra Vyas; 1977).

The pairs were developed according to the classification of consonants with respect to the manner of articulation and place of articulation. The minimal word pairs also permit comparison of features as the words differed from each other at least by one feature. This list of minimal pairs consisted of at least one word pair representing a particular feature. Thus the word list consisted of all the features proposed.

Table 6 indicates the number of minimal pairs representing presence and absence of a particular feature.

The list of minimal pairs as they are classified according to the proposed feature system is given in Appendix 3.

Table - 6

Table showing the Number of minimal pairs representing each Feature.

| Features | Number of minimal pairs |
|---|---|
| Voicing | 10 |
| Nasality | 3 |
| Labial | 3 |
| Alveolar | 2 |
| Dental | 2 |
| Retroflex | 9 |
| Velar | 3 |
| Aspiration | 14 |
| Affrication | 8 |
| semivowel | 3 |
| Lateral | 3 |
| Flap | 2 |
| Frication | 3 |

**B) Equipment :-** Speech Spectrograph (VIC MK 700) which has a provision for recording speech sample beyond 2.4 seconds continuously and to analyze speech sample of 2.4 seconds duration at a time.

**C) Procedure :-** The 65 minimal word pairs were recorded using the tape recorder of the Speech Spectrograph on a professional tape by the expermimenter. The VU meter of the tape recorder was used to monitor the intensity. A gap of less than one second was given between the words

and more than 3 seconds between the word pairs. This was done in a quiet condition. Further, a unidirectional microphone was used for recording.

A satisfactory recording was obtained after recording for four times as judged by the experimenter and a speech pathologist. This was done to make sure that there were no variations between the words and pairs in terms of intensity, pause and intonation.

Then wide band and narrow band spectro grams for each word pair were obtained using the speech spectrograph (VIC MK 700).

The spectrograms thus obtained were analyzed to inspect following characteristics, (i) Voice lag or voice lead (ii) Formant transition, (iii) Frequency at which concentration of energy is seen, (iv) Presence of periodic or aperiodic energy.

This analysis was done to find the acoustic correlates of the features proposed.

**2) Perceptual Analysis:-**

This experiment was divided into part I and Part II.

**Part I:-**

(a) Stimuli:- 130 words were derived from 65 minimal pairs. Each word was recorded individually in a random order. The

words were recorded using a cassette recorder(Sony TC 1000) on a Sony cassette by the experimenter. A gap of approximately 5 seconds was given between two words to give time for responses from the listeners.

**(b) Subjects:-** The subjects were 30 males and 30 females. They were college students having Gujarati as their mother tongue and native language. They ranged in age from 19 to 25 years. They had no history of speech and hearing problems and they could read and write Gujarati.

**(c) Procedure:-** The tape recorded words were played to each listener in a quiet room. The following instructions were given in Gujarati language:

"તમને કેટલાક ગુજરાતી શબ્દો સંભળાશે. જેવો એક શબ્દ સંભળાય કે તરત, તેને ઓળખીને, જે કાગળ તમને આપ્યો છે તેમાં લખી નાખજો. બધા શબ્દો સાંભળ્યા અને લખી નાખ્યા પછી, તમે, તમે પોતે જ જે લખ્યું છે, તે મોટેથી વાંચી જજો."

(You will hear several Gujarati words. As soon as you recognize the word you write it down in a sheet of paper which is given to you. After listening to all the words and writing them down, you have to speak all of them as you have written).

The same procedure was followed for all the 60 subjects.

**(d) Scoring:-** The responses of all the subjects were scored as correct or incorrect. A response was considered as correct if the written and spoken responses were the same as the stimulus presented. A response was considered incorrect if the written and spoken responses were different from the stimulus presented, ie when a sound in the stimulus word presented was substituted or distorted.

The incorrect responses were further analyzed to find out the sounds which were substituted and the sounds for which substitutions were made.

**Part II:-**

(A) Stimuli:- Same as in part I.

(B) Subjects:- Five males and five females who were not having Gujarati as their mother tongue and/or native language were chosen as subjects. They were graduate and post graduate students in speech and hearing. They ranged in age from 19-25 years. They had no history of speech and bearing problems.

**(c) Procedure:-** The tape recorded stimulus words were played to each listener in a quiet room. The following instructions were given to them in English.

"You will hear several words from an unknown language. You lesten to each word carefully and as soon as you listen you speak whatever you think you have heard".

The same procedure was followed for all 10 subjects.

(D) Scoring:- The spoken responses of all the 10 subjects were scored as in part I to obtain correct and incorrect responses.

*0*0*0*0*0*0*0*0*0*0*0*0*0*

# CHAPTER IV

## RESULTS; AND DISCUSSION

The findings of the two experiments conducted provide the acoustic correlate for the distinctive feature system proposed for the consonants in Gujarati and also the amount of information carried by each distinctive feature for the perception of the speech sounds.

As stated earlier the proposed distinctive feature system for consonants in Gujarati consists of 13 features 1)voicing, (2)Nasality, (3)Labial, (4)Alveolar, (5)Dental, (6)Retroflex, (7)Velar, (8)Aspiration, (9)Affrication, (lO)Semivowel, (11) Lateral, (12)Flap, (13)Frication.

**1) Acoustic Analysis:-** Wide band and narrow band spectrograms for 65 minimal pairs were classified based on the proposed distinctive feature system.

The close inspection of all the spectrograms cevealed distinct acoustic characteristics for each feature proposed.

The distinctive acoustic characteristics for the proposed distinctive features are as follows.

**1) Voicing:-** This feature is studied in great detail in earlier investigations. (Fry,1979, Potter,Kopp & Kopp;1966, Lisher and Abramson; 1964 ,Jakobson, Fant and Halle,1952)

The essential acoustic characteristics for voicing distinction as reported are; l)Presence of low frequency energy termed as 'buzz'(Jakobson, Fant and Halle?1969) in the voiced sound and absence of this in voiceless sound. The presence of this characteristics 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 voice lag in voiceless sounds. 3)The energy concentration in the noise component of the spectrum either in stop or Fricative sound is greater in voiceless than in voiced sounds.

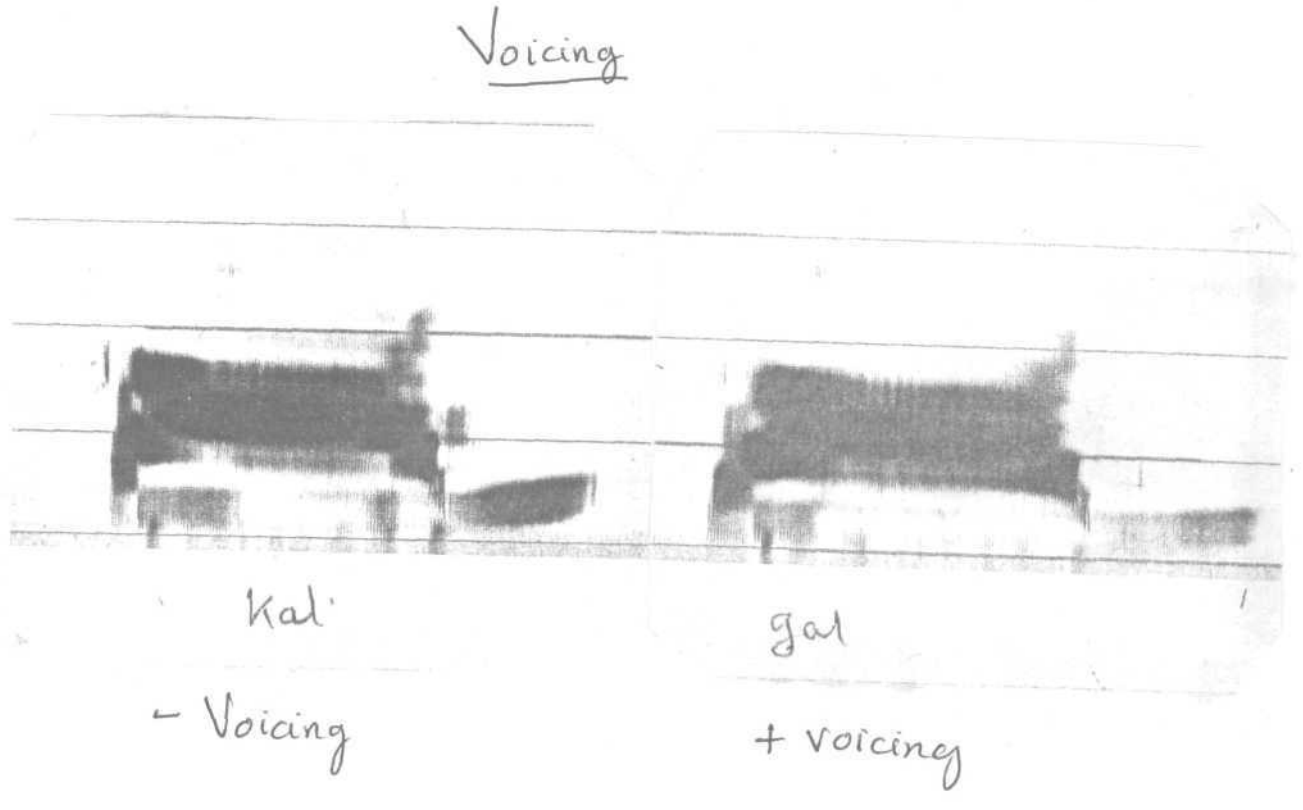
These characteristics were observed in the analysis of following word pairs which were used as representatives of voiced and voiceless consonants to identify the acoustic characteristics related to voicing feature.

**Word Pairs**

1) કાલ - ગાલ Kal-gal
2) છેટે - છેડે chete-chede
3) છરી - ઝરી Chari-jhari
4) ફરી - ભરી Phari-bhari
5) પાપ - બાપ Pap - bap
6) સાથી - સાધી Sathi - Sadhi
7) માતા - માલ Mata - mada
8) કાઠી - કાઢી Kathi - Kadhi
9) વચન - વજન Wacan - Wajan
10) આખો - આઘો a:kho - a:gho.

Therefore it can be concluded that presence of voicing

feature is acoustically represented by the presence of: 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 counter part, and this feature ia present in the language studied ie. Gujarati. The acoustic characteristics are shown in the spectrogram given below.



**2) <u>Nasality:-</u>** Acoustic characteristics of nasal feature are described as having a characteristic nasal formant at low frequency (200) and at aery high frequency(25OO), and a tail like appearance, it has also been reported that there is very little high frequency. (Danial off etal 1980,Jakobson, Fant and Halle; 1969, Fry; 1979, Potter et al; 1966).

Following word pairs were anlyzed which had nasal and nonnasal consonants in order to identify the acoustic characteristics related to nasality feature.

Word Pairs

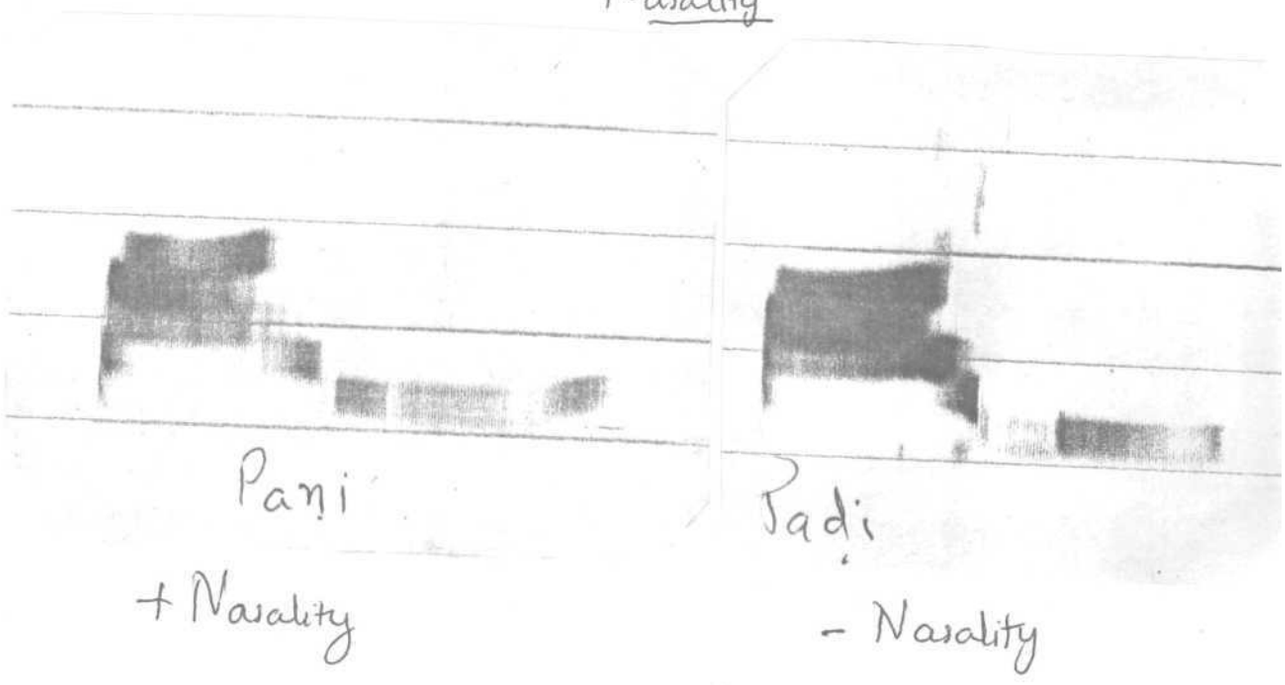
1) પાણી - પાડી 2) કાન - કાગ 3) માગ - બાગ

Pani - Padi Kan - Kag Mag - bag

It was observed that low frequency formant and tail like appearance ie. acoustic characteristics mentioned above, were present for all nasal consonants. The high frequency formant was not observable. This may be due to reduced energy concentration at high frequencies in nasal sounds.

Therefore it can be stated that nasality feature is present in Gujarati language and it can be identified by 1) The presence of low frequency formant, 2)Tail like appearance. The acoustic characteristics are shown in the spectrogram given below.

4.5 Nasality




The following five features labial, alveolar,dental, retroflex and velar have been termed as features indicating the place of articulation.

It is reported that changes in formant frequency(transition) and the changes in noise filtering are the major acoustic cues for place of articulation.

The earlier findings about acoustic characteristics of place of articulation feature may be summarised as follows. (Fry;1979, Potter et al; 1966, Jakobson et al; 1969, Blache, 1378).

| Feature | Transition | Noise Filtering |
|---|---|---|
| Labial | Downward transition | Low frequency peak. |
| Alveolar | Small transition Upwards or downwards | High frequency peak. |
| Dental | Upward shift | Higher peak than labial |
| Retroflex | - | - |
| velar | Upward shift | Mid frequency peak |

Following are the word pairs employed as representatives of the different places of articulation of consonants to identify the acoustic characteristics of the features labial, alveolar, dental, retroflex and velar.

**Labial**

1) વાદ - યાદ
Wad - Yad

2) કામ - કાન
Kam - Kan

**Alveolar**

1) સાપ - શાપ
Sap - Ŝap

2) હાથ - સાથ
hath - sath

**Dental**

1) સાથ - સાફ
Sath - Saph

2) આદુ - આબુ
a:du - a:bu

3) ળત - ળપ
lnt - lnp

**Retroflex**

1) કાળ - કાળ
Kaḷ - Kaḷ

2) કાણ - કાન
Kaṇ - Kaṇ

3) કાળ - કાં
Kaṇ - Kaṇ

4) સાઠ - સાથ
Saṭh - Saṭh

5) કાણ - કામ
Kaṇ - Kaṃ

6) ધોળો - ધોળો
dhoḷo - dhoḷo

7) માઠી - માછી
maṭhi-machi

8) ગાડી - ગાદી
gaḍi - gadi

9) વાટ - વાટ
Waṭ - Waṭ

Velar

1) હીરો - શીરો  2) કાં - કાળ  3) કાં - કામ

hiro - ~siro  Kaɲ - Kan  Kaɲ - Kam

The above mentioned characteristics were observed in all the word pairs for the features labial, alveolar, dental and velar.

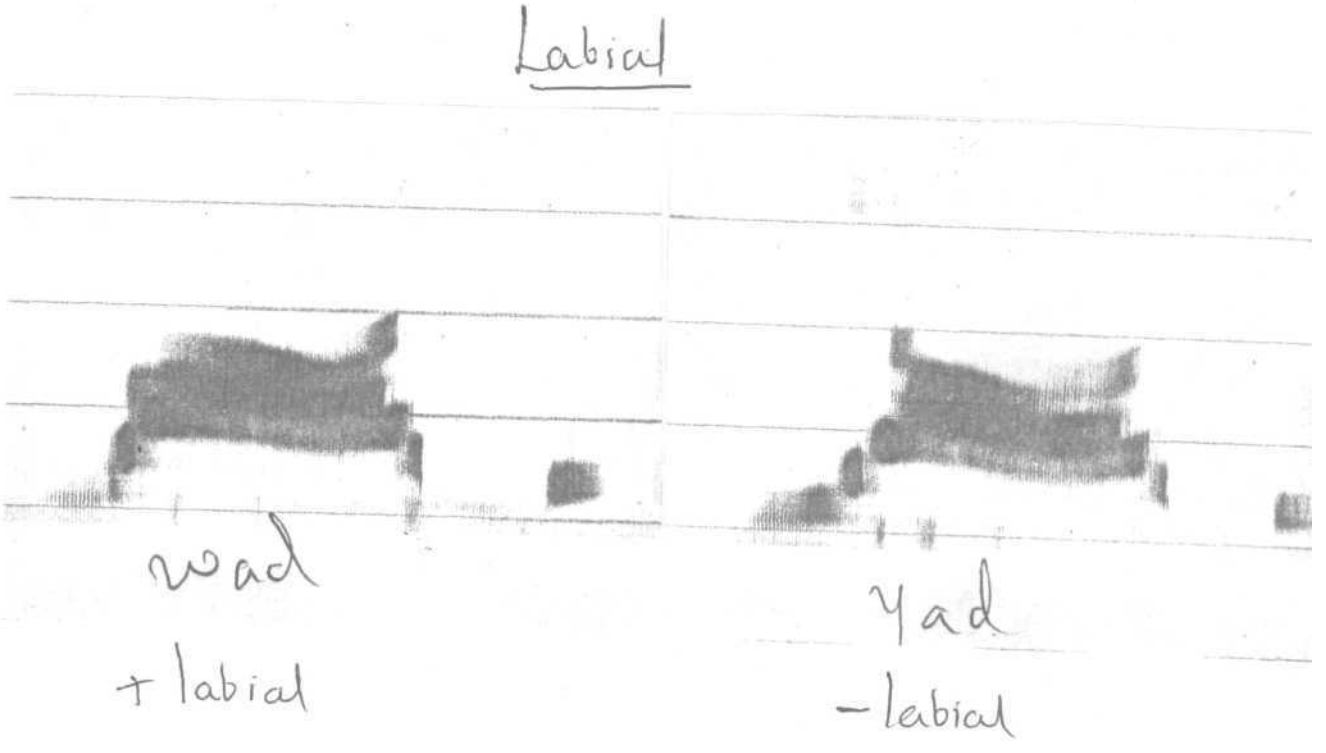
The information regarding the acoustic characteristics of retroflex feature is not available to present investigator. The spectrographic analysis of word pairs representing retroflex-non retroflex consonants revealed relatively low frequency energy concentration and upward transition as a characteristic of the feature retroflex. Thus it differs from other place of articulation features and it can be identified by considering these two acoustic characteristics.

Therefore it may be concluded that presence of labial, alveolar, dental, retroflex and velar features are acoustically represented by the presence of following acoustic characteristics.

| S.No. | Features | Transition | Noise Filtering |
|---|---|---|---|
| 3) | Labial | Downward shift | Low frequency peak |
| 4) | Alveolar | Small upward or downward shift | High frequency peak |

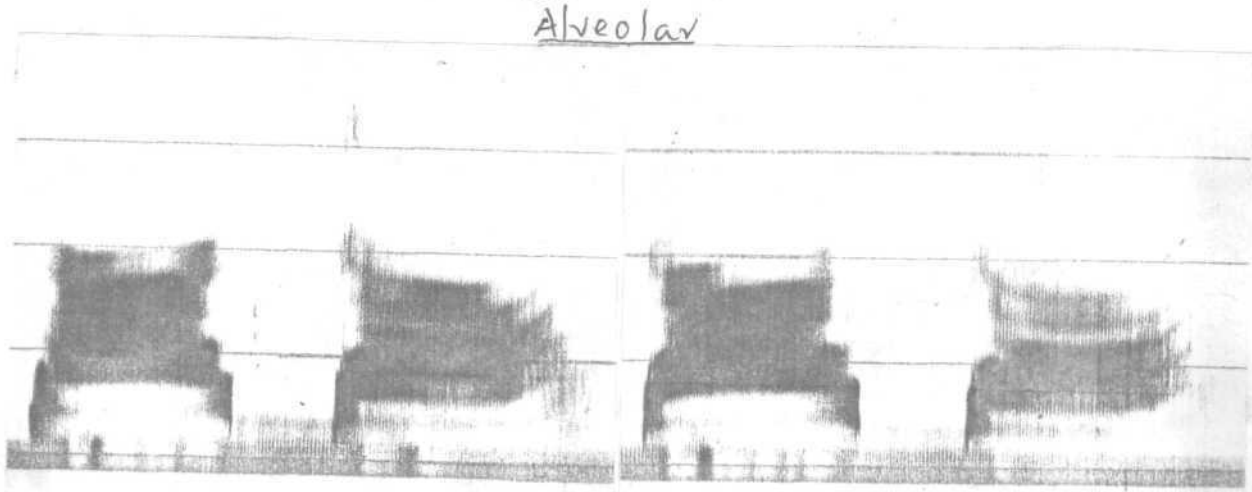
| S.No. | Features | Transition | Noise filtering |
|---|---|---|---|
| 5) | Dental | Upward transition | Higher than labial |
| 6) | Retroflex | Upward transition | Relatively low frequency peak |
| 7) | Eelar | Upward transition | Mid frequency peak. |

These features are present in Gujarati language and each of them have their own characteristic acoustic features which distinguish them from each other. The spectrograms for the features labial, alveolar, dental retroflex and velar are as follows.



4.9

Alveolar



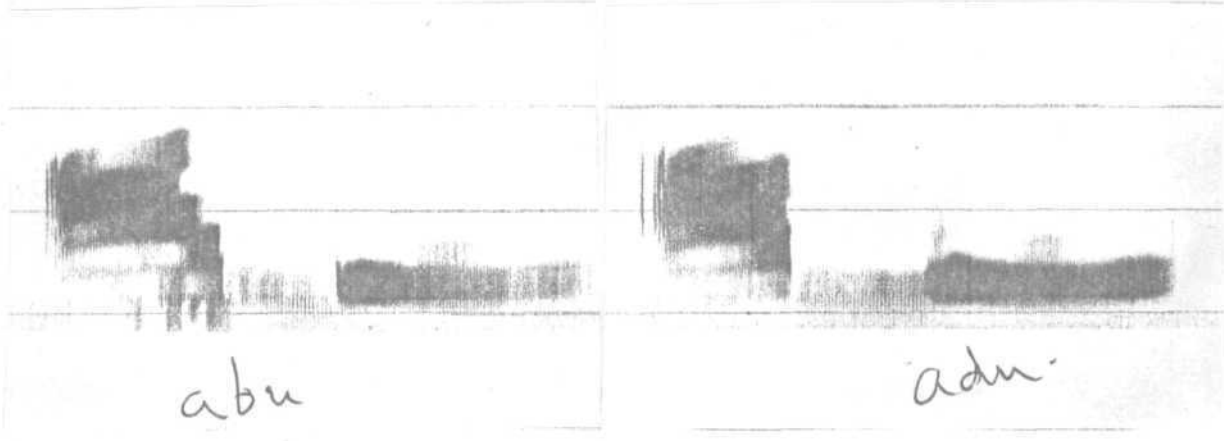
dada

-Alveolar

sada

+Alveolar

Dental



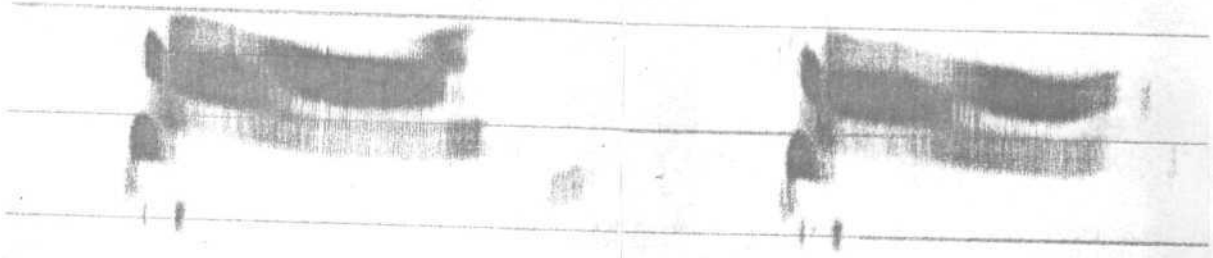
abu

-Dental

adu

+Dental

# Retroflex



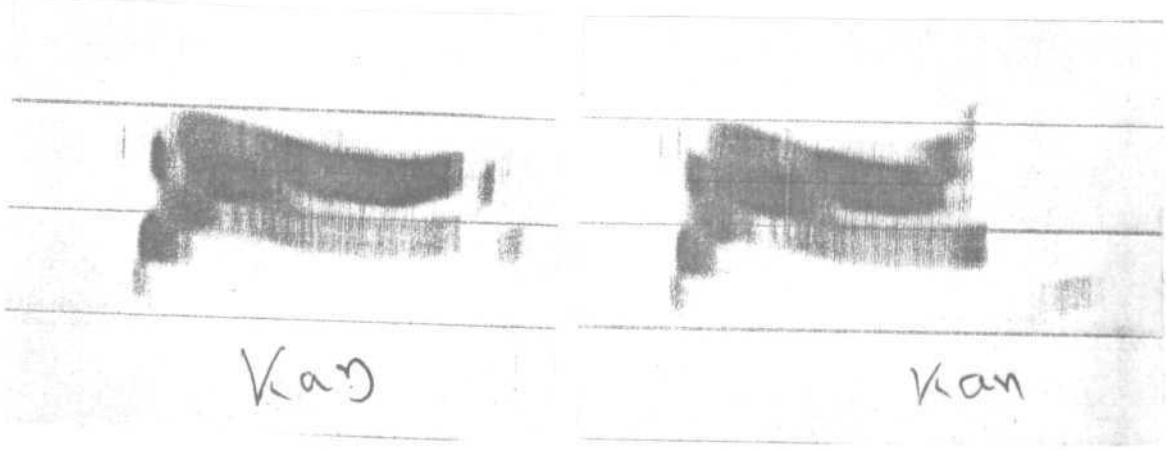
ɾan

+ Retroflex

kaɳ

– Retroflex

# Velar



Kaŋ

+ Velar

Kan

– Velar

^
*

**8) <u>Aspiration:-</u>** The feature aspiration is not distinctive in English, In some allophonic variations of stop sounds (Bilabial stops) aspiration is observed.(Singh;1970).

The feature aspiration is distinctive in Gujarati language in that it distinguishes two sounds of the language and therefore it has been considered as a separate feature. The minimal pairs representatives of aspirated and non-aspirated sounds are.

1) ભાલ - બાલ
bhal - bal

2) સાફ - સાપ
Saph - Sap

3) ધર - દર
dhar - dnr

4) ધામ - દામ
dham - dam

5) સાથ - સાત
Sath - Sat

6) ઠોક - ટોક
thok - tok

7) દાઢી - દાડી
dadhi - dadi

8) માઠી - માટી
maṭhi - maṭi

9) સાથ - સાત
Saṭh - sat

10) રાજ્ઞ - રાજ
raṣh - raj

11) ઘામ - ગામ
gham - gam

12) છાલ - કાલ
chal - kal

13) ખાનુ - કાનુ
Khanu - kanu

14) છાલ - ચાલ
chal - cal

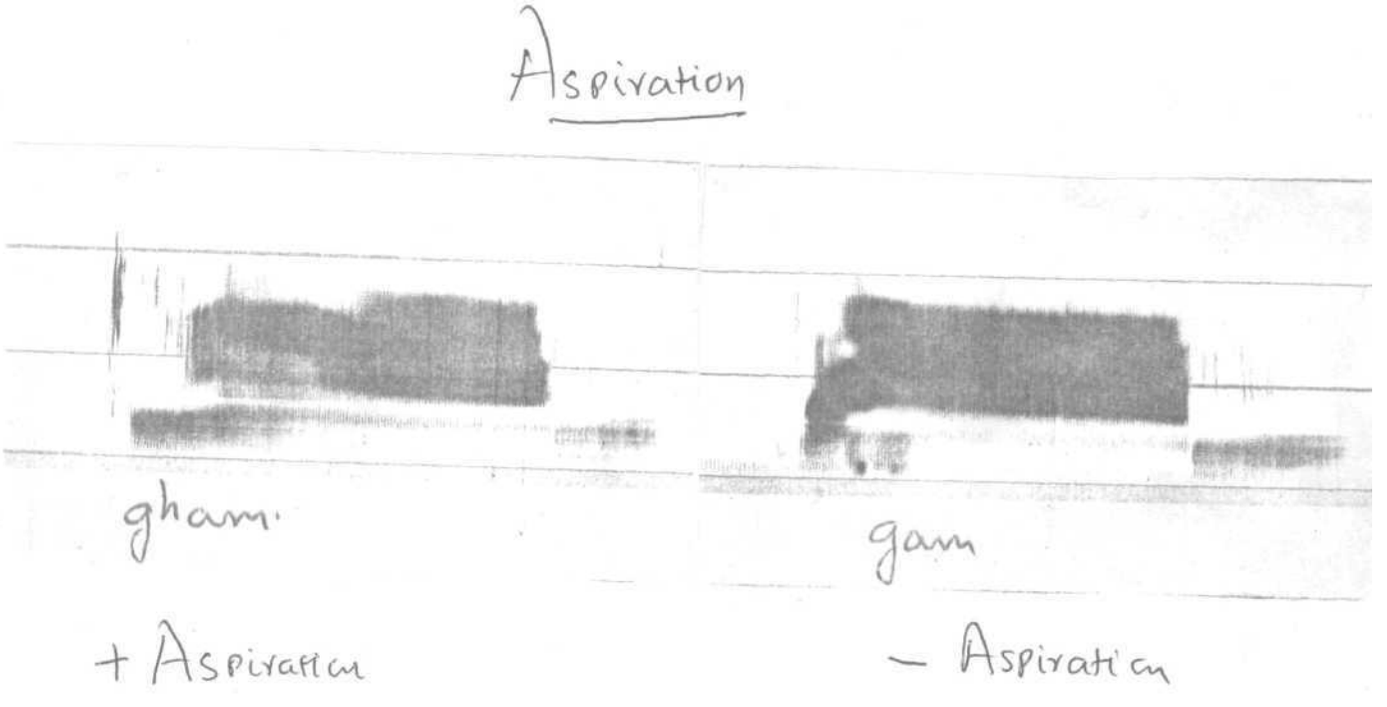
A comparison of the spectrograms of the words with aspirated and words with nonaspirated consonants revealed distinction in acoustic characteristics. The acoustic cue for this feature is extra energy concentration in aperiodic portion ie., at high frequencies mimicthing the friction noise in stops, fricatives and affricates.

Therefore it may be derived that the presence of the

feature aspiration, is marked by extra energy concentration in aperiodic portion of the consonants at high frequencies which is identifiable on spectrogram as dark patches in the upper portion.

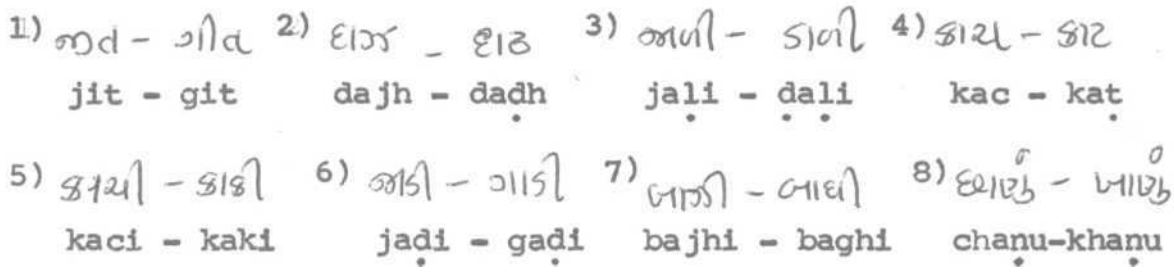
Thus the feature aspiration is present in Gujarati with its own acoustic characteristics.

A representative spectrogram is given below.



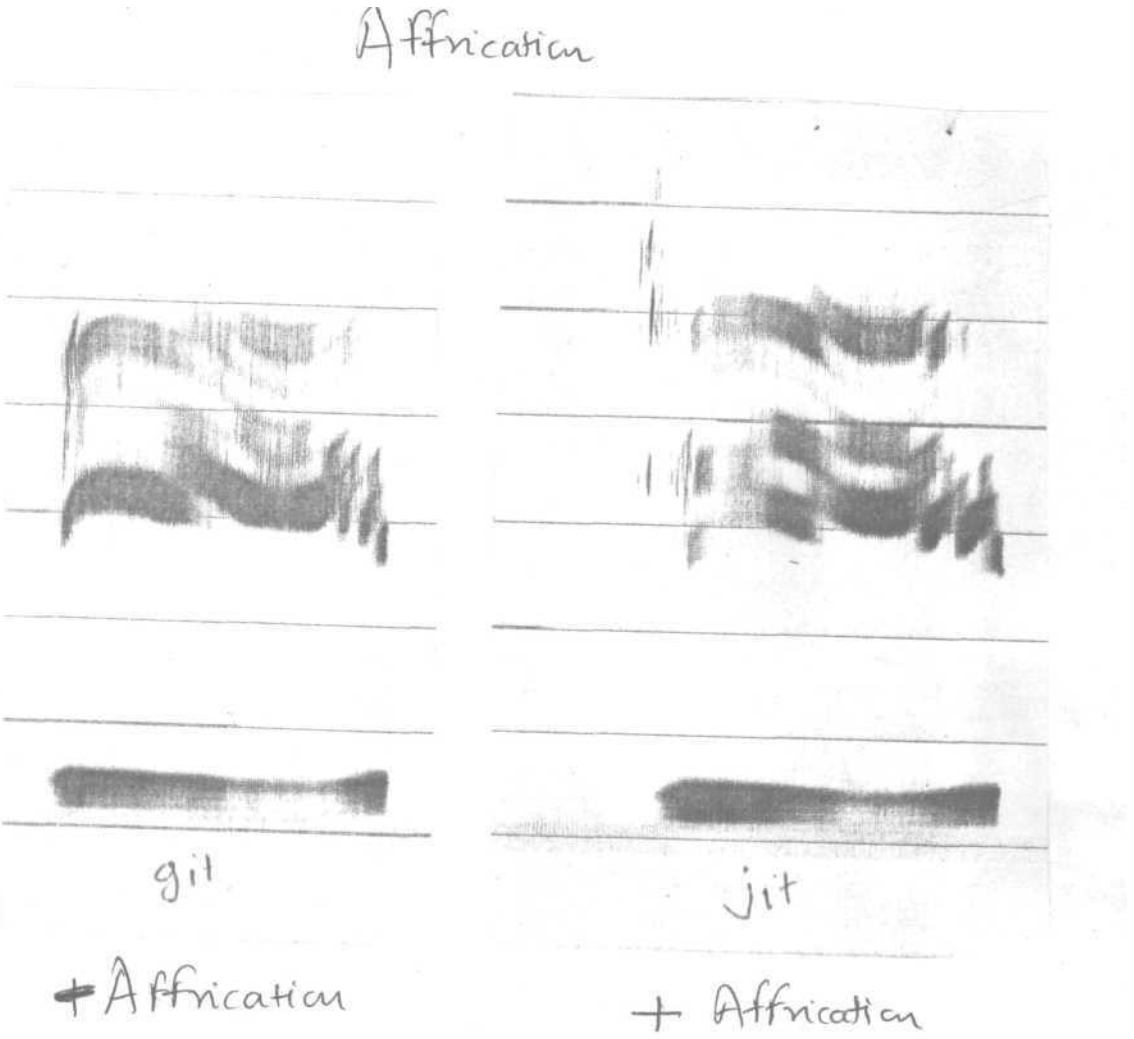
**9) <u>Affrication:-</u>** This feature has been described as +Fricative +stop manner feature (Danialaff; 1980). The acoustic characteristics related to this feature as reported in early investigations reveal a gap followed by sharp burst and friction noise. Due to addition of friction noise the aperiodic portion is comparatively longer than that for steps. (Fry; 1979)

These characteristics were observed in the analysis of following word pairs which were used as representatives of affricated and non affricated sounds;




It may be concluded that the presence of the feature affrication is acoustically marked by the presence of a small gap followed by a burst which continues into the friction noise with high frequcny concentration.

Therefore it can be derived that the feature affrication is present in Gujarati and it has distinct acoustic characteristics. The spectrographic display of the feature is given below.




**10)<u>Semi Vowel:-</u>** As reported by earlier investigation the feature semi-vowel is characterised by dark and clear resonance bars as that of vowels, and the transitional curve of the resonance bars due to combination of vowels. (Potter et al; 1966, Danialoff et al; 1980).

These acoustic characteristics were found to be present while inspecting the spectrograms of the minimal pairs which represented semivowel and non semi-vowel consonants to

:identify acoustic characteristics related to semivowel feature. The minimal word pairs are:

1) યાર - જાર Yar - jar

2) વાલ - બાલ Wal - bal

3) વન - મન Wnn - mnn

It can be concluded that the feature semivowel is present in Gujarati with its own acoustic characteristics. A representative spectrogram of the feature semivowel is given below.

**11) Lateral:-** The lateral sounds are associated with vowel like and consonant like acoustic characteristics. Vowel like; because they have continuous resonance bare and consonant like as they have gaps.(Jakobson,Fant & Halle;1969)

Following word pairs were examined spectrographically as they represented lateral and non-lateral consonants in order to identify acoustic characteristic related to the feature; lateral.

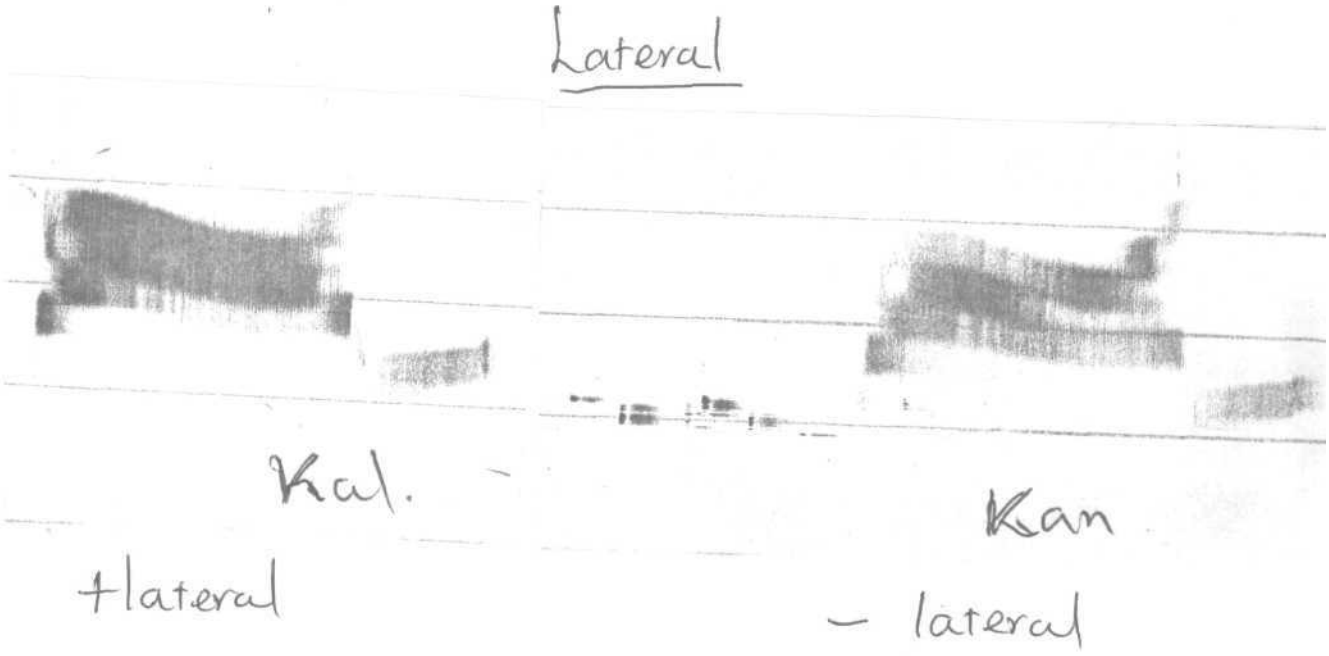
1) કાલ - કાન
Kal - kan

2) પાલ - પાડ
pal - pad

3) પાલી - પાની
pali - pani

The inspection of the spectrograms of these word pairs revealed a distinct continuous periodic portion and small gaps as shown in the spectrogram below.

Thus it may be inferred that the presence of the feature lateral is acoustically marked by the presence of continuous bars and small gaps. This feature is present in Gujarati language with its own distinct acoustic characteristics.




**12)<u>Flap:-</u>** The feature'flap'as described earlier is characterised by vowel and consonant like structure. It is said to have dark resonance bars and presence of gaps, Unlike lateral the resonance bars are interrupted in the Flap sounds. (Jakobson et al 1969).

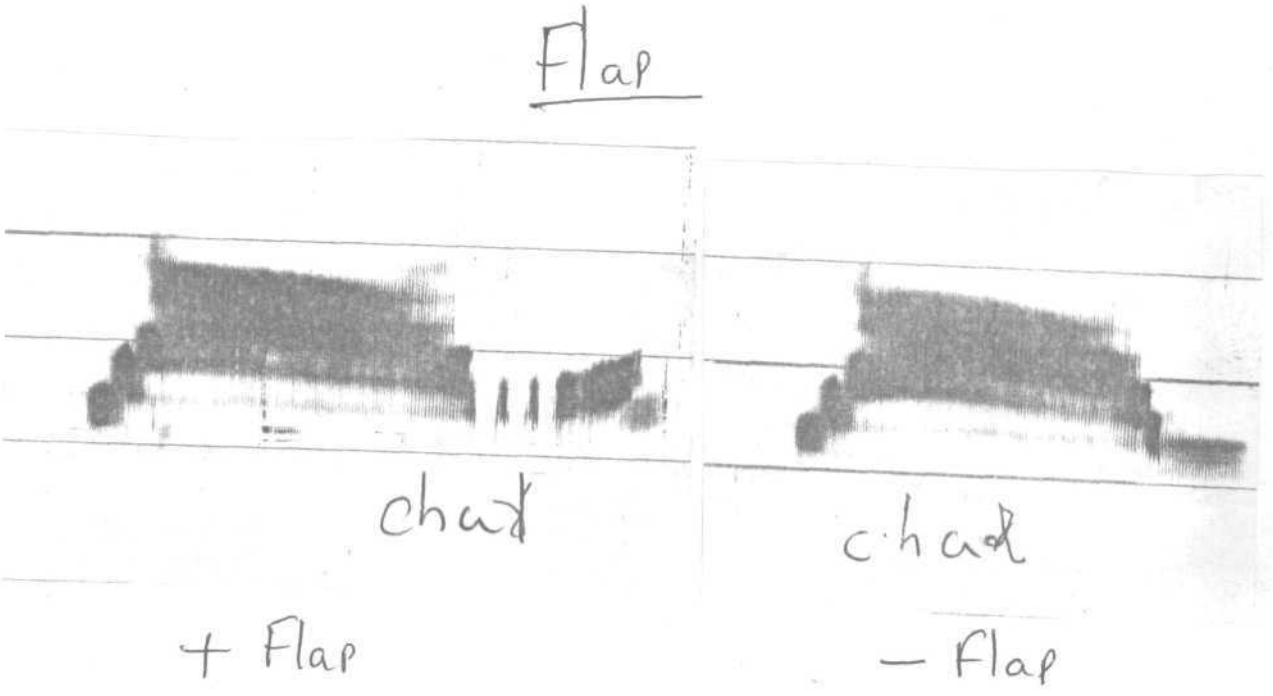
Following word pairs were used as representative of Flap and nonflap consonants to identify the acoustic characteristics related to 'Flap' feature.

1) કાર - કાલ
Car - cal

2) સારી - સાળી
Sari - Sali

The examination of spectrograms of these word pairs revealed a pattern on the spectrograms of flap sound having many resonance bars with little gap inbetween them. This corresponds to rapid multiple movements of the tongue towards the palate.

Therefore it can be concluded that the feature flap is present in Gujarati language and it has distinct acoustic characteristics as depicted in the spectrogram below.



**13) <u>Frication:-</u>** The earlier reports describe fricatives aa having high frequency turbulence of longer duration and greater intensity which is identifiable on the spectrograms as a dark, aperiodic portion of a great duration at the upper portion.

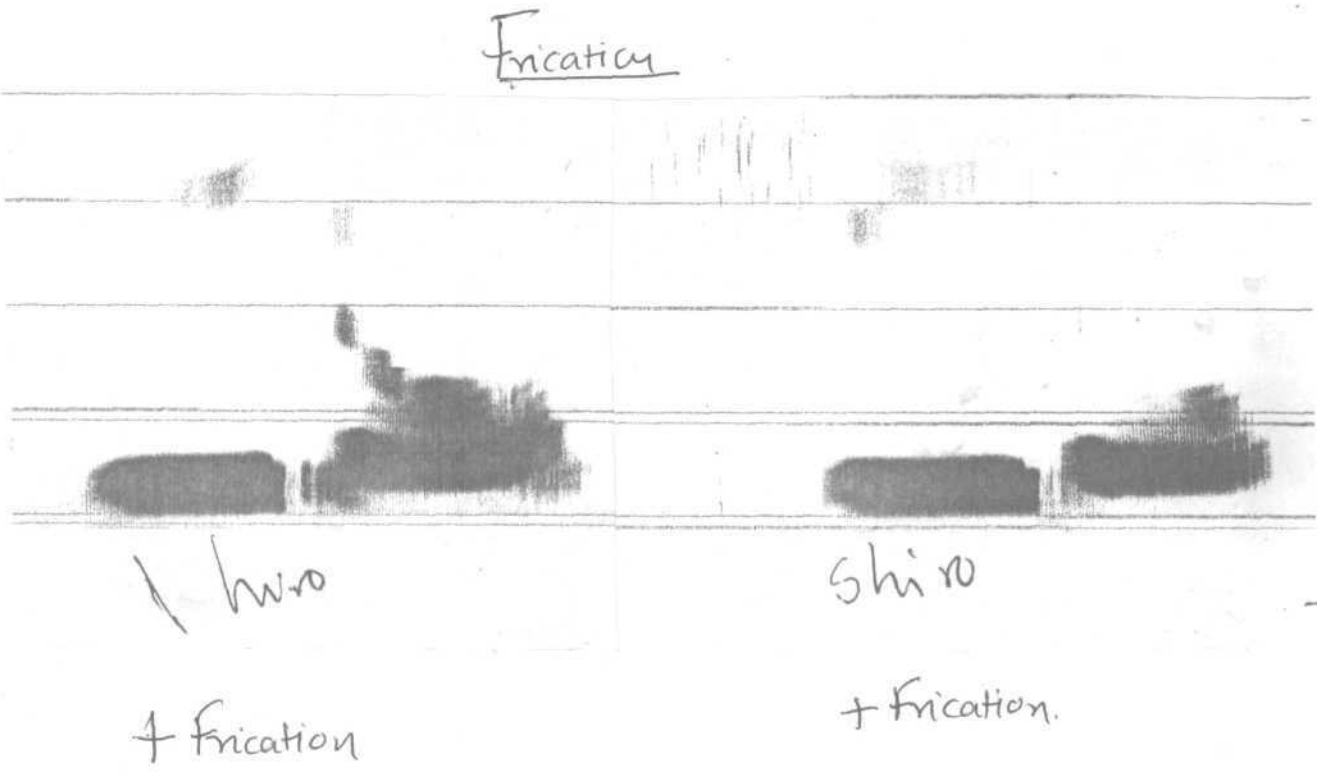
These acoustic characteristics were observed while studying the spectrograms of the word pairs which represented fricative and nonfricative consonants to identify the acoustic characteristics related to frication. The work pars are:

1) હોલો - ગોલો
holo - golo

2) સાદા - દાદા
Sada - dada

3) સાળી - ડાળી
Sali - dali

It may be therefore concluded that the feature 'Frication' is present in Gujarati and its presence is marked by high frequency concentration of noise componeyx for longer duration as shown in the spectrogram below.




The acoustic analysis of minimum pairs in Gujarati revealed distinct acoustic characteristics for each of the proposed feature, therefore hypothesis 5 stating that "Each of the distinctive feature proposed presents distinct acoustic characteristics", is accepted.

The distinct acoustic characteristics for each feature proposed have been summarised in the table 7.

Table - 7

Table showing the acoustic characteristics of each Feature(+) when it is present

| Sl.No. | Feature(+) | Acoustic characteristics |
|---|---|---|
| 1 | Voicing + | 1) Regular vertical striations in low frequency region occuring simultaneous with the burst. 2)Decreased burst intensity when compared to it* voiceless counterpart |
| 2 | Nasality + | 1) Low frequency Formant 2) Tail like appearance |
| 3 | Labial + | l)Downward transition 2) Low frequency peak. |
| 4 | Alveolar + | ^Shortened transition upwards or downwards, 2)High frequency peak. |
| 5 | Dental + | DUpward shift 2)Higher peak when compared to labial |
| 6 | Retroflex + | DUpward shift 2) low frequency peak. |
| 7 | velar + | 1) Upward shift 2) Mid frequency peak |
| 8 | Aspiration + | 1) Extra energy concentration in aperiodic portion of the consonants at high frequency. |
| 9 | Affrication + | L) A small gap followed by a burst which has a longer duration due to friction noise added to it. |
| 10 | Semivowel + | 1) Dark and clear respnanse bars 2) Transitional curve |
| 11 | Lateral + | 1) Continuous periodic portions 2) Small gape |
| 12 | Flap + | 1) Several series of resonance bars 2) gaps |
| 13 | Frication + | L) High frequency aperiodic portion of a long duration. |

Thus each feature presents the acoustic characteristics typical for that particular feature. This further supports the hypothesis 1 stating that ' Gujarati language has a distinctive feature system".

The findings of the present experiment are similar to that of acoustic characteristics of distinctive features described for other languages (Like in English by Potter etaly 1966, Fry; 1979, Danialoff; 1980).

This supports the view that the distinctive features are universal or in other words it can be stated that the phonemes used in different languages have similar acoustic characteristics; which points out the fact that the speech mechanism in human beings is same throughout the world.

**2) Perceptual Analysis:-**

**PART I**

**Analysis:-** The responses of 60 Gujarati listeners to 130 words have been analyzed using a confusion matrix.(As shown in table-8)

A confusion matrix is a matrix in which the stimuli and responses are portrayed.

32 consonants presented to 60 listeners as they occured in 130 words are represented on vertical axis of the matrix as stimuli. The same 32 consonants as perceived by 60 listeners and written out/spoken out as responses are represented on the horizontal axis as response. The matrix is made up of 130 observation of 60 listeners making it 7800 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 sums give the total frequency of stimuli presented and column sums give the total frequency of responses which occured.

Table - 8

Table showing confusion

| | K | g | kh | gh | c | j | ch | jh | ɲ | h | sh | y | ṭ | ḍ | ṭh | ḍh |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K | 234 | 2 | 1 | 1 | 1 | | | | | | | | | | | |
| g | 6 | 339 | | 4 | 1 | 9 | | | | | | | | | | |
| kh | | 1 | 179 | | | | | | | | | | | | | |
| gh | 9 | 23 | 13 | 130 | | | | | | 1 | | | | | | |
| c | 1 | | | | 283 | 14 | | 1 | | | | | | | | |
| j | | | | | 13 | 339 | | 8 | | | | | | | | |
| ch | | | | | 2 | 2 | 229 | 4 | | | | | | | | |
| jh | | | | | 2 | 76 | 43 | 117 | | | | | | | | |
| ɲ | | 2 | | | | | | | 55 | | | | | | | |
| h | | 1 | | | | | | | | 179 | | | | | | |
| sh | | | | | 1 | | | | | | 110 | | | | | |
| y | | | | | | | | | | | | 120 | | | | |
| ṭ | | | | | | | | | | | | | 299 | | | |
| ḍ | | | | | | | | | | | | | | 361 | | 20 |
| ṭh | 6 | | | 1 | | | | | | 1 | | | 9 | | 246 | 21 |
| ḍh | | 1 | | 5 | | | | | | | | | 23 | 7 | 8 | 179 |
| ṇ | | | | | | | | | | | | | | 10 | | |
| ḷ | | | | | | | | | | | | | | 24 | 1 | |
| ṭ | | | | | | | | | | | | | 16 | | | |
| ḍ | | 2 | | 1 | | | | | | | | | 2 | 25 | | 1 |
| th | | | | | | | | | | | | | | | 8 | |
| dh | | | | | 7 | 1 | | | | | | | | | 2 | 3 |
| n | | | | | | | | | | | | | | | | |
| s | | | | | | | | | | | 7 | | | | | |
| l | | | | | | 1 | | | | | | | | | | |
| r | | | | | | | | | | | | | | | | |
| p | 5 | 1 | 5 | | | | | | | | | | 2 | | | |
| b | | | | | | | | | | | | | | | | |
| ph | 1 | 1 | | | | | | | | 1 | | | | | | |
| bh | | | | | | | | | | | | | | | | |
| m | | | | | 1 | | | | | | | | | | | |
| w | | | | | | | | | | | | | | | | |
| | 262 | 373 | 198 | 142 | 311 | 442 | 272 | 130 | 55 | 182 | 117 | 120 | 351 | 427 | 265 | 224 |

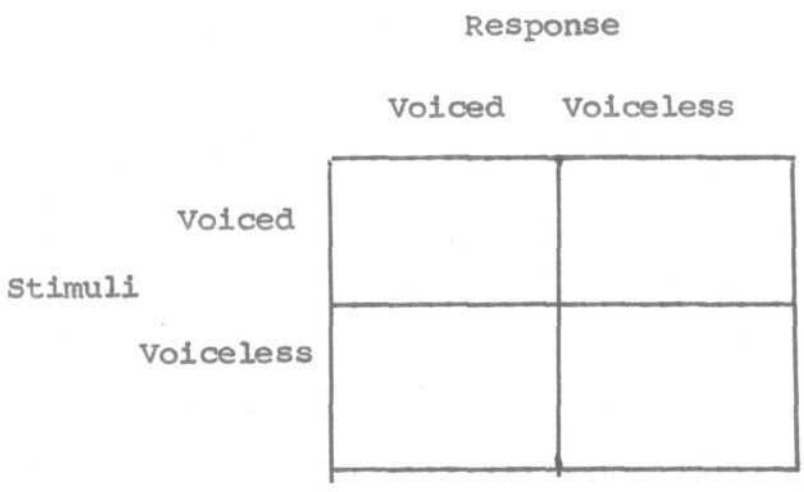
For 32 Gujarati consonants heard by 130 Gujarati listeners

| ṭ | d | th | dh | n | s | l | r | p | b | ph | bh | m | w | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | 240 |
| | | | | | | | | | | | | | | 360 |
| | | | | | | | | | | | | | | 180 |
| 1 | | | 2 | | | | | | | | | | | 180 |
| | | | | 1 | | | | | | | | | | 300 |
| | | | | | | | | | | | | | | 360 |
| | | 1 | | | 1 | | | | | | | | | 240 |
| | | | | | 2 | | | | | | | | | 240 |
| | | | | 26 | | 1 | | 17 | | | | 131 | | 240 |
| | | | | | | | | | | | | | | 180 |
| | | | | | 9 | | | | | | | | | 120 |
| | | | | | | | | | | | | | | 120 |
| 1 | | | | | | | | | | | | | | 300 |
| | 9 | | | | | 1 | 1 | | | | | | | 420 |
| 1 | | 12 | 1 | | | | | | | 2 | | | | 300 |
| 1 | 8 | | 4 | | | | | | | | 2 | | | 240 |
| | | | | 13 | | 2 | | | | | | 2 | | 300 |
| | | | | 1 | | 1 | 1 | | | | | | | 180 |
| 210 | | 14 | | | | | | | | | | | | 240 |
| 4 | 319 | 1 | 2 | 1 | | | | | | | | | | 360 |
| 56 | 1 | 233 | 2 | | | | | | | | | | | 300 |
| 4 | 3 | 15 | 202 | | | | | | | | | | | 240 |
| | 1 | | | 288 | | | | | | | 3 | | | 300 |
| | | | | | 233 | | | | | | | | | 240 |
| | | | | | | 179 | | | | | | | | 180 |
| | 4 | | | | | 37 | 78 | | | | | | | 120 |
| 9 | | 2 | | | | | | 152 | | 1 | 1 | | 1 | 180 |
| | | | 1 | | | | | | 298 | | 1 | | | 300 |
| | | 1 | | | | | | 43 | | 197 | | | | 240 |
| | | | | | | | | | | 21 | 99 | | | 120 |
| | | | | 2 | | | | 1 | | | | 296 | | 300 |
| | | | | | | | | | 1 | | | | 179 | 180 |
| 298 | 345 | 279 | 214 | 332 | 245 | 221 | 80 | 213 | 299 | 220 | 106 | 429 | 180 | |

Further, this confusion matrix for 32 consonants in Gujarati was subdivided into voice communication network of 13 component binary channels of linguistic features, based on 13 features proposed.

Again confusion matrices were formed for each of this linguistic feature. These matrices were four fold matrices,

For eg:-




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

A measure of covariance based on information theory (Shannon & Weaver; 1963) was employed to calculate information transmission for a composite phoneme channel and for 13 linguistic features.

The formula was

$$T(x,y) = - \sum_{ij} Pij \log \frac{Pi\ Pj}{Pij}$$

T(X,Y) = Information transmission from input variable x to output variable y bits/stimulus.

$n_i$ = Frequency of stimulus i

$n_j$ = Frequency of response j

$n_{ij}$ = Frequency of joint occurence of stimulus i and response j in a sample of n observations.

$P_i = n_{i/n}$
$P_j = n_{j/n}$
$P_j = n_{j/n}$
$P_{ij} = n_{ij/n}$

In table 8 cell entries are $n_{ij}$, row sums are $n_i$ , column sums are n. and n is 7800.

**Results and Discussion:-** The percentage of correct response to 130 words by 60 Gujarati listeners was calculated. This was found to be 86.92%. By observing the pattern of error responses scattered around the diagonal line it can be inferred that when the two sounds share more number of features the confusions are more and when the two sounds have very few features in common the confusions are less. For eg. More confusion for the phonemes /k/ and /g/ and less confusions for the sounds /k/ and /b/ were observed.

Table - 9

Table showing information transimission in bits/stimulus for 13 linguistic features and ranking of the features according to the amount of information transfer in Gujarati listeners.

| Sl.No. | Ranking | Feature | Information Transmission in bits/stimulus |
|---|---|---|---|
| | | Retroflex | .7039 |
| 2 | 1 | velar | .7027 |
| 3 | | Dental | .557 |
| 4 | | Labial | .546 |
| 5 | | Alveolar | .111 |
| 6 | 2 | Voicing | .787 |
| 7 | 3 | Aspiration | .6188 |
| 8 | 4 | Affrication | .5639 |
| 9 | 5 | Nasality | .535 |
| 10 | 6 | Frication | .33 |
| 11 | 7 | Semivowel | .228 |
| 12 | 8 | Lateral | .1628 |
| 13 | 9 | Flap | .0782 |

Total transmission in bits/stimulus = 5.3228

Composite phoneme channel transmission = 4.197

The results indicate that several features play an important role in speech sound perception. These features

work independent of each other in the perception of speech sounds. However the features are not completely independent. This is supported by the finding that composite phoneme channel transmits 4.197 bits/stimulus information, where as the total of the information transmission by 13 features yield information transmission of 5.42 bits/stimulus which is greater than that for a composite phoneme channel. This is due to 'cross talk' or 'overlap' between component channels. The difference is also known as redundancy.

The findings highlight the point that all proposed distinctive features do not have equal importance in speech sound perception. Some distinctive features transmit more information than the others. Therefore hypothesis 4 stating that "The information content carried by each of these distinctive features vary" is accepted.

The ranking of the features according to the amount of information transmitted indicates that the feature 'place' the strongest feature and the feature'Flap' is the weakest feature. The feature 'place' includes five individual features namely labial. Alveolar, Dental, Ketroflex and Velar. The results support Singh(1971)findings. He had found perceptual confusions for various conditions of noise and filtering. In quiet condition the feature place inclusive of various points of articulation was preserved

best. Among various features pertaining to place of articulation retroflex and velar hold first two ranks respectively.

The findings of this study are in agreement with other apriori studies 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"(singh;1976).

**Part II**

**Analysis:-** Analysis by generating confusion matrices was carried out as described in part I, for 130 words containing 32 Gujarati consonants presented to 10 non Gujarati listeners. (As shown in table 10).

**Results and Discussion:-** The percentage of correct response for 1300 observations by 10 listeners was calculated. This was found to be 78.38%. The percentage is lesser than that for Gujarati listeners. Although the number of errors is more for non-Gujarati listeners the pattern of errors for both the groups is similar. The sounds which share more features are confused more often than the sounds which share less features, eg. /g/ is more confused with /k/ than it is confused with /p/. This indicates that non Gujarati listeners employ the same set of distinctive features to identify speech sounds. The results might have been influenced by selection of subjects ie. most subjects had kannada as their mothertongue and native language and most of the consonants presented do occur in kannada.

Information transmission was calculated in bits/stimulars for composite phoneme channel and individual features. The features were ranked according to the amount of information transmitted from the highest to the lowest amount. The feature 'place' holding the highest rank and the feature 'Flap' being the lowest. The results of information transfer analysis are presented in table 11.

Table - 11

Table showing information transmission in bits/stimulus for 13 linguistic features and ranking of the features according to the amount of information transfer in non Gujarati listeners.

| Sl.No. | Ranking | Features | Information Transmi-ssion bits/Stimulus |
|---|---|---|---|
| 1 | 1 | Velar | .7285 |
| 2 | | Labial | .57 |
| 3 | | Retroflex | .4788 |
| 4 | | Dental | .417 |
| 5 | | Alveolar | .2997 |
| 6 | 2 | Affrication | .59 |
| 7 | 3 | Nasality | .5584 |
| 8 | 4 | Voicing | .5504 |
| 9 | 5 | Aspiration | .513 |
| 10 | 6 | Frication | .3596 |
| 11 | 7 | Semivowel | .2312 |
| 12 | 8 | Lateral | .163 |
| 13 | 9 | Flap | |

Total transmission in bits/stimulus = 5.542

Composite phoneme channel transmission = 4.950

4.31.

When the ranking was compared to that of the Gujarati listeners it was found that the ranking was more or less the same. There are some differences as shown in table 12.

**Table - 12**

Table showing comparison of ranking between Gujarati and non Gujarati listeners.

| Sl. No. | Ranking | Features Gujarati listeners | Features Non Gujarati listeners |
|---|---|---|---|
| 1 | 1 | Retroflex | velar |
| 2 | | Velar | Labial |
| 3 | | Dental | Retroflex |
| 4 | | Labial | Dental |
| 5 | | Alveolar | Alveolar |
| 6 | 2 | Voicing | Affrication |
| 7 | 3 | Aspiration | Nasality |
| 8 | 4 | Affrication | Voicing |
| 9 | 5 | Nasality | Aspiration |
| 10 | 6 | Frication | Frication |
| 11 | 7 | Semivowel | Semivowel |
| 12 | 8 | Lateral | Lateral |
| 13 | 9 | Flap | Flap |

The findings of this part of the experiment indicate that there has been similarity in the performance of Gujarati and non Gujarati subjects. This may be because of the use of almost the same set of distinctive features in the language of non-Gujarati subjects as in Gujarati language. Thus the findings indicate the possible existence of universal distinctive features. (Chomsky and Halle; 1968, Menyuk;1968). However this speculation must be Viewed critically as the sample of non Gujarati subjects in the present data is small. ,

Therefore the hypothesis 6 stating that "No significant difference will be found in the listening performance of Gujarati and non Gujarati subjects when words with minimal differences are presented in quiet situation" is accepted.

The results of perceptual analysis of the proposed distinctive feature system for consonants in Gujarati support the existence of these proposed features in speech sound perception with some amount of redundancy. The findings also point to the possibility of existence of universal distinctive features.

The present study shows the existence of a distinctive feature system in Gujarati language. This supports the hypothesis 1 stating that "Gujarati language has a distinctive feature system".

The existing distinctive feature system has 13 distinctive features; proposed based on phonetic description of Gujarati consonants available. This supports the hypothesis 2 stating that "It is possible to proposed distinctive features based on phonetic description of Gujarati consonants available".

These proposed distinctive features have been identified acoustically as distinctive.

Thus it is possible to analyze the consonants in Gujarati language using these 13 distinctive features. Therefore the hypothesis 3 stating that consonants in Gujarati language are made of the following distinctive features: 1)voicing, 2)Nasality, 3)Labial, 4) Alveolar, 5)Dental, 6)Retroflex, 7) velar, 8)Aspiration, 9)Affrications, lO)Semivowel, 11)Lateral, 12) Flap, 13) Frication" is accepted.

The method used in this study to validate the existence of particular set of distinctive features in a language seems to be simple and useful as the findings of the perceptual evaluations have been confirmed by the acoustic analysis. Therefore this method can be used to propose and evaluate the distinctive features that may be present in a particular language.

The present investigation has several applications and implications as follows:

The information carried by different features vary, in other words, some features play very important role in carrying information in a particular language, eg. In Gujarati the feature 'place' carries the maximum information. Therefore if an individual does not use place feature or misuses (substitutes 'place' feature by some other feature) the intelligibility would be affected to a greater extent when compared to an individual who does not use or misuses any other feature. Therefore the distinctive feature system presented here may be used to assess the severity of misarticulation in case of Gujarati speakers.

Further, this distinctive feature system can be used bo choose the sounds to be carrected in articulation therapy ie. give priority to the correction of feature, which carries more information when compared to other features.

Further, information provided by this study can also be used in designing telecommunication systems for the use of Gujarati speakers, gibing priority to see that the features that carry maximum information are not missed or distorted during transmission.

In light of the findings of the recent investigations

on distinctive features and the present study it may become necessary to consider the possibility of describing the ultimate units of a language in terms of distinctive features.

For speech clinicians/the distinctive feature systems as described by others(jakobson,Fant & Halle,1952,Chomsky and Halle; 1968), seems to be a very useful tool in describing the articulatory behaviour in various cases, in classifying the cases with misarticulation, in planning therapy and in assessing prognosis in cases having misarticulation.

It may be possible to develop a classificatory system to classify the cases of misarticulation based on distinctive features ie. considering the information value carried by the feature missing or misplaced and the distance between the feature to be produced and the feature that is being actually produced. (Difference in terms of distinctive features between two Rounds).

Attempts have already been made to study various languages using distinctive feature system of that particular language. A study to describe Gujarati language using the present distinctive features may be of use to linguist and speech clinician.

Thus the findings of the present study are useful in better understanding of Gujarati language.

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# CHAPTER V

## SUMMARY AND CONCLUSIONS

The events and objects are distinguished by the presence of certain features unique to each event and object. These features are termed as distinctive features. The speech sounds are distinguished from one another by the existence of such distinctive features in the speech sounds. Earlier, phoneme was considered as the smallest unit of language. (Bloomfield; 1936).Jakobson etal(1952) showed that it is possible to describe each phoneme making use of distinctive features, each having unique acoustic characteristics. Thus, these features became the ultimate units of a language.

Several attempts have been made to describe various languages of the world using these distinctive features. Different systems of distinctive features have been proposed (Jakobsen, Fant and Halle, 1952; Chamsky Halle, 1968; Singh & Becker, 1971). Various methodologies have been used to describe the languages using different distinctive feature systems.

The distinctive feature system has been found to be very useful-(l) To describe a language (2) To describe articulatory aspects of speech in a given language (3) To describe speech sound perception in normal individuals and hearing impaired individuals. 4) To study dichotic

speech sound perception and (5) To study articulatory acquisition.

To speech clinicians, distinctive feature systems have been a very useful tool in analyzing the language and articulation in nromals and pathological cases. Many have shown that therapy based on distinctive feature systems is useful and economical (McReynolds & Bennett,1973) (Pollack and Rees; 1972).

An attempt has been made to describe Hindi language using distinctive features(Ahmed and Agrawal, 1969). Somasundaran(1979) has attempted to compare phonology of four languages- Tamil, Kannada, Malayalum and Telugu using distinctive features as proposed by Jakobson, Fant and Halle(1952). However this is not an experimental study. Thus systematic establishment of distinctive feature system is done for Hindi language only. Therefore to make a beginning the present study has been attempted.

65 minimal word pairs were prepared using 32 consonants in Gujarati(Nair,U). The minimal pairs were taken from Gujarati Vyakarana(vyas,1977). The minimal pairs were such that there was at least one feature difference between two pairs of consonants.

These minimal word pairs were subjected to acoustic and perceptual analysis.

The acoustic analysis was carried out using speech spectrograph (VIC MK700) and narrow band and wide band spectrograms for each minimal pair were obtained.

The perceptual analysis was carried out in two parts. In the first part 130 words (obtained from 65 minimal pairs) were played to 60 Gujarati listeners- 30 males and 30 females, in a random order. The subjects had to listen to these words and write down/speak out what they heard.

In the second part the same stimuli were played to 10 non-Gujarati listeners. The spoken responses to 130 words were recorded.

The analysis of wide band and narrow band spectrograms was carried out to identify acoustic characteristics of the features proposed.

The perceptual data was analyzed using the confusion matrices and by calculating information transmitted by each of the features proposed.

The results of the acoustic and perceptual analysis led to following conclusions.

**Conclusions:-** 1) There is a distinctive feature system in Gujarati language.

2) Distinctive feature can be proposed based on phonetic description of Gujarati language.

3) There are distinct acoustic characteristics for each of the feature proposed.

4) All the features do not have equal importance in carrying information for speech perception. Some carry more information than the others.

5) Non Gujarati speakers show the same pattern of errors on listening performance as Gujarati speakers and they show similar ranking of features in carrying information for speech perception. This points to the possibility of the use of the same set of features by Gujarati and non Gujarati speakers. A speculation about the existence of universal feature system can be made from this and based on Acoustic analysis.

6) The features proposed are
(1) Voicing, (2)Nasality, (3)Labial, (4)Alveolar, (5)Dental, (6)Retroflex, (7)velar, (8)Aspiration, (9)Affrication, (lO)Semi-vowel, (ll)Lateral, (12)Flap, and (13)Fricative.

**Implications of the Study**

1.) The feature system developed can be used in describing the sounds of Gujarati language.

2) The feature system developed can be used in assessment and rehabilitation of individuals having problems with speech language and hearing.

3) The feature system may be helpful in classifying articulation disorders and in measuring severity in the cases of misarticulation. Further it can be useful in choosing sounds for articulation correction.

4) The distinctive feature system developed may help to develop a speech discrimination test in Gujarati.

5) The distinctive feature system described in the present study can be used in designing a telecommunication system for the Gujarati speakers.

6) Further research in Phonology, language acquisition and speech pathology may be facilitated by the development of distinctive feature system.

**Recommendations:-**

1) The feature system for vowels in Gujarati can be developed using the same method.

2) The distinctive feature systems may be developed in different languages using different methods. This will validate the method employed in the present study.

3) The perceptual experiment may be carried out in various conditions of noise and filtering.

4) The experiment using nonsense syllables instead of words may be carried out.

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## APPENDIX 1-A

## Distinctive feature system as proposed by Jakobson,Fant and Halle (1952)

1. Vocalic / Non-vocalic

Acoustically - Presence(versus absence) of a sharply defined formant structure.

Genetically - Primary or ordinary excitation of the glottis together with a free passage through the vocal tract.

2. Consonantal/Non consonantal:

Acoustically- Low(versus high) total energy.

Genetically - Presence (versus absence) of an obstruction in the vocal tract.

3. Compact/Diffuse:

Acoustically - Higher (versus lower) concentration of energy in a relatively narrow, central region of the spectrum, accompanied by an increase (versus decrease) of the total amount of energy and its spread in time:

Genetically - Forward-flanged (versus backward-flanged). The difference lies in the relation between the shape and volume of the resonance chamber in front of the narrowest stricture and behind this stricture. The resonator of the forward-flanged phonemes(wide vowels, and velar and palatal, including post alveolar, consonants) has a shape of a horn, whereas the backward-flanged phonemes(narrow vowels, and

labials and dentals, including alveolar, consonants) have a cavity that approximates a Helmholtz resonator.

**4. Grave / acute:-**

Acoustically:- Concentration of energy in the lower (versus upper) frequencies of the spectrum;

Genetically:- Peripheral (versus medial), peripheral phonemes (velar and labial) have an ample and less compartmented resonator than the corresponding medial phonemes (palatal and dental).

**5. Flat / plain:-**

**Acoustically:-** flat phonemes are opposed to the corresponding plain ones by a downward shift or weakening of some of their upper frequency components.

**Genetically:-** The former (narrowed slit) phonemes, in contradistinction to the latter (wider slit) phonemes, ace produced with a decreased back or front orifice of the mouth resonator, and concomitant valorization expanding the mouth resonator.

**6. Nasal / Oral:-** (Nasalized / non na&alized)

**Acoustically:-** Spreading the energy over wider (versus narrower) frequency regions by a reduction in the intensity of certain (primarily the first) formants and introduction of additional (nasal) formants.

**Genetically** - Mouth resonator supplemented by the nose cavity versus the exclusion of the nasal resonator.

**7. Tense/lax:**

Acoustically - more(versus less) sharply defined resonance regions in the spectrim, accompanied by an increase(versus decrease) of the total amount of energy and its spread in time.

**Genetically** - greater(versus smaller) deformation of the vocal tract away from its rest position. The role of muscular strain, affecting the tongue, the walls of the vocal tract and the glottis, requires further investigation.

**8. Interrupted/continuant**

**Acoustically -** silence(atleast in the frequency range above the vocal cord vibration) followed and/or preceded by a spread of energy over a wide frequency region(either as burst or as a rapid transition of vowel formants)(versus absence of abrupt transition between sound and "silence").

**Genetically** - rapid turning on and off of source either through a rapid closure and/or opening of the vocal tract that distinguishes plosives from constrictives or through one or more taps that differentiate the discontinuous liquids like a flap or Trill /r/ from continuant liquids the lateral /l/.

**9. Strident/mellow:**

**Acoustically -** Higher intensity noise versus lower intensity noise;

**Genetically** - rough-edged (versus smooth edged). Supplementary obstruction creating edge effects(...)at the point of articulation distinguishes the production of the rough-edged phonemes from the less complex impediment in their smooth-edged counterparts.

**10. Checked/unchecked:**

**Acoustically -** Abrupt decay is opposite of smooth one.

Genetically - The air stream is checked by the compression or closure of the glottis.

**11. Sharp/plain:**

**Acoustically -** Slight rise of the second formant and to some degree also of the higher formants.

**Genetically:-** oral cavity reduced by raising a part of the tongue against the palate. This is palatization.

(Adopted from Winitz; H, "Articulatory acquisition and behavior" N.Y., Appleton-Century-crofts, 1969,Pp 82-84 and Jakobson R, Fant G., & Halle M. preliminaries to speech analysis. The distinctive features and their correlates". Massachusetts, The MIT Press, 1969 .

## Appendix 1-B

## Distinctive feature system as proposed by Chomsky and Halle(1968)

There are five major categories in the universal phonetic features of the Chomsky and Halle feature system. They are l)Major class features, 2)Cavity features, 3)Manner of articulation features, 4) Source features, and 5)Prosodie features.

Major class Features:

**Consonantal/non consonantal:**

The consonantal sounds are produced with obstruction somewhere in the vocal tract, and the nonconsonantal sounds are produced without such obstruction. All English vowels, glides and the consonant /h/ are considered nonconsonantal.

**Vocalic/Nonvocalic:**

Vocalic sounds are produced only when the most radial constriction in the oral cavity does not exceed that in the vowels /i/ and /u/, and when the vocal cords are positioned to produce "spontaneous voicing". All English vowels and the liquid /l/ are vocalic sounds, and the remainder are nonvocalic sounds.

**Sonorant/Nonsonorant:**

Sonorants are produced with "spontaneous voicing". Sonorants include vowels, glides, nasals and liquids of English.

**Cavity features:**

**Coronal/Non coronal**

Chomsky and Halle described coronal sounds as produced with the blade of the tongue raised from its neutral position and noncoronal sounds as produced with the blade of the tongue in the neutral position.

The English consonants /r,l,t,d,θ,ð,n,s,z,tʃ,dʒ,ʃ,ʒ/ are considered as coronal and the remainder as non coronal.

Anterior/Non anterior:

All front sounds are called anterior and all back sounds are called nonanterior.

English consonants have the following distribution on this feature, all labials /p,b,f,v,m/, all linguadentals /θð/, and all alveolars /t,d,s,z,n,l/ are + anterior. All palatals /r,tʃ,dʒ,ʃ,ʒ,j/ and all velars /k,g,ŋ,h/ are nonanterior. Vowels are labelled as nonanterior.

**Tongue Body Features:**

The three features high, low, and back relate to the position of the body of the tongue. All these projections of the tongue are measured from its neutral position. The neutral position of the tongue has been defined as in the status of producing the vowel ( ʌ ) in English(bʌt).

**High/nonhigh:** High sounds are produced by raising the tongue body higher than its neutral position, the English consonants /tʃ, dʒ, ʃ, w, ʒ, k, g, ŋ/ are considered high and all other consonants as nonhigh.

**Low/noplow:** Low sounds are produced by positioning the tongue body lower than the neutral position, nonlow sounds are produced without such a lowering. The English consonant/h/ is considered low. All other consonants are nonlow.

Back/nonback: Back sounds are produced by moving the body of the tongue further back than the neutral position. The back consonants of English a /k, g, w, ŋ/. l l other consonants are nonback.

**Round:-**

Rounded sounds are produced with the rounding of lips to form oval or round variable shapes depending on the amount of rounding needed for the production of a given phoneme. Rounding is not a distinctive feature asked for English consonants.

**Distributed/nondistributed:**

Distributed/nondistributed is a place of articulation, feature not utilized in characterizing the sounds of the English language.

"Distributed consonants are produced with a constriction

That extends for a considerable distance along the direction of the airflow, nondistributed sounds are produced with constriction that extends only for a short distance in this direction".

**Covered/noncovered:**

The feature covered/noncovered is restricted only to vowels.

**Glottal constrictions:**

Glottally constricted sounds are produced by the constriction of the glottal area beyond the neutras narrowing position.

**Secondary Appertunes:**

There are two categories of secondary apertures nasal/ nonnasal and lateral/nonlateral.

**Nasal/non-nasal**: Nasals are produced with the lowered velum whereas non-nasals are produced with the velum raised. In English /m,n, / are nasal consonants and all other consonants are non-nasal(oral).

**Lateral/nonlateral:** Lateral consonants are produced by lowering the midsection of the tongue.

Manner of Articulation features:Continuant/noncontinuant(stop)

The continuant consonants are produced with the constriction in the vocal tract regulated in such a way that complete

closure or blocking of the air passage never occurs. The noncontinuants or the stop consonants, on the other hand, are produced with complete closure or constriction of the vocal tract so that the passage of air is blocked effectively. In english the continuant consonants, according to Chomsky and Halle, are /r,l,f,v,θ,ð,s,z,ʃ,ʒ,h/ and the noncontinuant or stop consonants are /p,b,m,t,d,n,tʃ,dʒ, k,g,ŋ/.

Release Features:

Two kinds of release features are described by Chomsky and Halle, and both apply to stop consonants only. While the plosine stops of English /p,b,t,d,k,g/ are considered as released instantaneously, the affricate stops /tʃ, dʒ/ are considered released with some delay.

**Tense/Nontense:**

The consonants that are voiceless /p,t,k,f,θ,s,ʃ,tʃ h/ are tense and those that are voiced are nontense or lax.

Source features:

**Voiced/Voiceless:**

In the production of the voiced consonants, the vocal folds vibrate, and in the production of the voiceless consonants they do not vibrate.

**Strident / nonstrident:**

Strident sounds are marked acoustically by greater noisiness than their nonstrident counterparts. In English, /f, v, s, z, ʧ, ʤ, ʃ, ʒ/ are strident consonants and the rest are nonstrident.

(Adopted from Singh; S. "Distinctive features: Theory and validation" Baltimore,University Park press, 1976, Pp 55-63)

## Appendix 1-C

## Linguistic Features for Hindi consonants as Proposed by Ahmed and Agrawal (1969)

**1) Affrication:-** Four sounds (tʃ , tʃʰ, dʒ, dʒʰ) are considered as affricates.

2) Friction:- Three sounds (s, ʃ , h) are considered as fricatives.

**3) Nasality:-** Three sounds (m,n,ɳ) are considered nasals.

**4) Aspiration:-** Twelve consonants (pʰ, tʰ, ʈʰ, kʰ, bʰ, dʰ, ɖʰ, gʰ, hˌ, tʃʰ, dʒʰ, ɽʰ) are classified as aspirated. The sound h is a fricative, but it shows an aspirated character and hence it is included in this category.

**5) Voicing:-** 19 consonants (b, d, ɖ, g, bʰ, dʰ, ɖʰ, gʰ, dʒ, m, ɳ, l, ɽ, ɽʰ, n, w, j) are treated as voiced sounds.

**6) Liquids:-** Two sounds l & r are placed in this category since these are lateral and rolled sounds.

7) Flapped liquids:- This is the name given to the three sounds (ɳ, ɽ, ɽʰ) that occur only in the final position.

8) Continuants:- Two sounds w and j are treated as continuants,

9) Place:- Since every sound has a place, each consonant is designated by a number according to the place in which it is grouped. Five places of articulation are defined in the following manner. a) Front sounds: Bilabial sounds have been included here. They are p, pʰ, b, bʰ, m, w)

**b) Middle Front:** Dental and alveolar sounds have been included here. They are (t, $t^h$, d, $d^h$, n, s, l), c) Middle Sounds: Retroflex sounds are placed in this category, namely (ṭ, $ṭ^h$, ḍ, $ḍ^h$, ṛ, $ṛ^h$, n, r) **d) Middle bach:** The sounds which are spoken with the help of soft palate and palate are included here. They are (ts, $ts^h$, dʒ, $dʒ^h$, ʃ, j) **e) Back sounds:** The soundo that velar and glottal are considered here. They are (k, $k^h$, g, $g^h$, h).

in order to describe place, the consonants are numbered serially 1,2,3,4,5 according to the categories described above.

(Adopted from Ahmes;R. and Agrawal; S.S. "Significant features in the perception of (Hindi) Consonants" Journal of acoustical society of America, Vol.45(3), 1969,Pp 758-763)

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## Appendix - 2

### Consonant Phonemes of Gujarati

| | Glottal | Velar | Palatal | Retroflex | Dental | Alveolar | Labial |
|---|---|---|---|---|---|---|---|
| **Stops** | | | | | | | |
| Unaspirated | | | | | | | |
| Voiceless | | k | | ṭ | t | | p |
| Voiced | | g | | ḍ | d | | b |
| Aspirated | | | | | | | |
| Voiceless | | kh | | ṭh | th | | ph |
| Voiced | | gh | | ḍh | dh | | bh |
| **Africates** | | | | | | | |
| Unaspirated | | | | | | | |
| Voiceless | | c | | | | | |
| Voiced | | j | | | | | |
| Aspirated | | | | | | | |
| Voiceless | | ch | | | | | |
| Voiced | | jh | | | | | |
| **Nasals** | | | | ṇ | n | | m |
| **Fricatives** | h | | ś | | | s | |
| **Laterals** | | | | ḷ | | l | |
| **Flaps** | | | | | | r | |
| **Semivowels** | | | y | | | | w |

(Adopted from Gujarati phonemic Reader)

Appendix 3- List of minimal pairs as they are classified according to the proposed feature system.

## I Voicing

1) કાલ - ગાલ
kal - gal

2) છરી - ઝરી
chari - Jhari

3) પાપ - બાપ
PaP - bap

4) માતા - માદા
mata - mada

5) વચન - વજન
wacan - wajan

6) chete - chede
છેટે - છેડે

7) ફરી - ભરી
Phari - bhari

8) સાથી - સાધી
Sathi - Sadhi

9) કાઠી - કાઢી
Kathi - Kadhi

10) ~~વાઘ~~ઘો - વાઘો
a:kho - a:gho

## II Nasality

1) પાણી - પાડી
Pani - Padi

2) કાન - કાગ
Kan - Kag

3) માગ - બાગ
mag - bag

## III Labial

1) વાદ - યાદ
wad - yad

2) કામ - કાન
Kam - Kan

## IV Alveolar

1) Sap - Jap

2) હાથ - સાથ
hath - sath

## V Dental

1) સાથ - સાફ
Sath - saph

2) દાદુ - દાબુ
a:du - a:bu

3) ઉત - ઉપ
ʌt - ʌp

## VI Retroflex

1) કાળ - કાલ
kaḷ - kal

2) kaṇ - kan
કાણા - કાન

3) કાણા - કાં
kaṇ - kaŋ

4) સાઠ - સાથ
saṭh - sath

5) કાણા - કામ
kaṇ - kama

6) ઢોળો - ધોળો
ḍholo - ધોળો

7) માઠી - માછી
maṭhi - machi

8) ગાડી - ગાદી
gaḍi - gadi

9) વાટ - વાત
waṭ - wat

## VII Velar

1) હીરો - ઝીરો
hiro - ʒiro

2) કાં - કાન
kaŋ - kan

3) કાં - કાગ
kaŋ - kag

## VIII Aspiration

1) ભાલ - બાલ
bhaḷ - baḷ

2) સાપ્ - સાપ
Saph - sap

3) ધર- દર
dhAr - dAr

4) ધામ - દામ
dham - dam

5) સાથ - સાત
sath - sat

6) ઠોક - ટોક
ṭhok - tok

7) દહી- દડી
dadhi - daḍi

8) માથી - માટી
maṭhi - maṭi

9) Sath - sat
સાથ - સાત

10) રાજ્ - રાજ
rajh - raj

11) ઘામ - ગામ
ghamu - gam

12) ઘલ - કાલ
chal - kal

13) ખાણુ - કાણુ
khaṇu - kaṇu

14) ઘલ - ચાલ
chal - cal

## IX Affrication

1) જીત - ગીત
jit - git

2) દાજ્ - દાઘ
dajh - dadh

3) જાળી- કાળી
jaḷi- ḍaḷi

4) કાચ - કટ
kac - kaṭ

5) કાચી - કાકી
kaci- kaki

6) જાડી- ગાડી
jaḍi- gaḍi

7) બાઝી - બાકી
bajhi - bagi

8) ચાવું - ખાવું
chaṇu - khaṇu

## X Semivowel

1) યાર- જાર
yar - jar

2) વાળ - બાળ
waḷ - baḷ

3) વન- મન
wʌn - mʌn

## XI Lateral

1) કાળ - કાળ
kal - kan

2) પાળ - પાડ
paḷ - paḍ

3) પાળી- પાણી
paḷi - paṇi

## XII Flap

1) કાર - કાળ
car - cal

2) સારી - સાળી
sari - saḷi

# XIII Frication

1) હોલો - ગોલો
holo - golo

2) sada - dada
સાદા - દાદા

3) સાળી - કાળી
Sali - dali

Appendix - 4 The Distinctive Features of 32 Gujarati consonants

| Features | Consonant Phonemes | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K | g | Kh | gh | c | j | ch | jh | ŋ | h | S | y | ṭ | ḍ | ṭh | ḍh | ṇ | ḷ | t | d | th | dh | n | s | l | r | p | b | ph | bh | m | w |
| Voicing | - | + | - | + | - | + | - | + | + | - | - | + | - | + | - | + | + | + | - | + | - | + | + | - | + | + | - | + | - | + | + | + |
| Nasality | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | + | - | - | - | - | - | + | - | - | - | - | - | - | - | + | - |
| Labial | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + | + | + |
| Alveolar | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | + | + | + | - | - | - | - | - | - |
| Dental | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + | + | - | - | - | - | - | - | - | - | - |
| Retroflex | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Velar | + | + | + | + | + | + | + | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Aspiration | - | - | + | + | - | - | + | + | - | - | - | - | - | - | + | + | - | - | - | - | + | + | - | - | - | - | - | - | + | + | - | - |
| Affrication | - | - | - | - | + | + | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Semi-Vowel | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + |
| Lateral | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | + | - | - | - | - | - | - | - |
| Flap | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - |
| Frication | - | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - |

Appendix 5 Units of Differences for

| | k | g | kh | gh | c | j | ch | jh | ɲ | h | y | ṭ | ḍ | ṭh | ḍh | ṇ | l | t | d | th | d |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| k | | | | | | | | | | | | | | | | | | | | | |
| g | 1 | - | | | | | | | | | | | | | | | | | | | |
| kh | 1 | 2 | - | | | | | | | | | | | | | | | | | | |
| gh | 2 | 1 | 1 | - | | | | | | | | | | | | | | | | | |
| c | 1 | 2 | 2 | 3 | - | | | | | | | | - | | | | | | | | |
| j | 2 | 1 | 3 | 2 | 1 | - | | | | | | | | | | | | | | | |
| ch | 2 | 3 | 1 | 2 | 1 | 2 | - | | | | | | | | | | | | | | |
| jh | 3 | 2 | 2 | 1 | 2 | 1 | 1 | - | | | | | | | | | | | | | |
| | 2 | 1 | 3 | 2 | 3 | 2 | 4 | 3 | - | | | | | | | | | | | | |
| h | 2 | 3 | 3 | 4 | 3 | 4 | 4 | 5 | 4 | - | | | | | | | | | | | |
| y | 3 | 2 | 4 | 3 | 4 | 3 | 5 | 4 | 3 | 3 | - | | | | | | | | | | |
| t | 2 | 3 | 3 | 4 | 3 | 4 | 4 | 5 | 4 | 2 | 3 | - | | | | | | | | | |
| d | 3 | 2 | 4 | 3 | 4 | 3 | 5 | 4 | 3 | 3 | 2 | 1 | - | | | | | | | | |
| th | 3 | 4 | 2 | 3 | 4 | 5 | 3 | 4 | 5 | 3 | 4 | 1 | 2 | - | | | | | | | |
| dh | 4 | 3 | 3 | 2 | 5 | 4 | 4 | 3 | 4 | 4 | 3 | 2 | 1 | 1 | - | | | | | | |
| n | 4 | 3 | 5 | 4 | 5 | 4 | 6 | 5 | 1 | 4 | 3 | 2 | 1 | 3 | 2 | - | | | | | |
| l | 4 | 3 | 4 | 3 | 5 | 4 | 6 | 5 | 4 | 3 | 2 | 2 | 1 | 3 | 2 | 2 | - | | | | |
| t | 2 | 3 | 3 | 4 | 2 | 3 | 4 | 5 | 4 | 2 | 3 | 2 | 3 | 3 | 4 | 5 | 4 | - | | | |
| d | 3 | 2 | 4 | 3 | 4 | 3 | 5 | 4 | 3 | 3 | 2 | 3 | 2 | 4 | 3 | 3 | 3 | 1 | - | | |
| th | 3 | 4 | 2 | 3 | 4 | 5 | 3 | 4 | 6 | 3 | 4 | 3 | 4 | 2 | 3 | 5 | 5 | 1 | 2 | - | |
| dh | 4 | 3 | 3 | 2 | 5 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 2 | 4 | 4 | 2 | 1 | 1 | - |
| n | 4 | 3 | 5 | 4 | 5 | 4 | 6 | 5 | 2 | 4 | 3 | 4 | 3 | 5 | 4 | 2 | 4 | 2 | 1 | 3 | 2 |
| s | 3 | 4 | 3 | 4 | 4 | 5 | 5 | 6 | 5 | 2 | 4 | 3 | 4 | 4 | 5 | 5 | 5 | 3 | 4 | 4 | 5 |
| l | 4 | 3 | 5 | 4 | 5 | 4 | 6 | 5 | 4 | 4 | 2 | 4 | 3 | 5 | 4 | 4 | 2 | 4 | 3 | 5 | 4 |
| r | 4 | 3 | 5 | 4 | 5 | 4 | 6 | 5 | 5 | 3 | 2 | 4 | 3 | 5 | 4 | 4 | 3 | 4 | 3 | 5 | 4 |
| p | 2 | 3 | 3 | 4 | 3 | 4 | 4 | 5 | 4 | 3 | 4 | 2 | 3 | 3 | 4 | 4 | 4 | 2 | 3 | 3 | 4 |
| b | 3 | 2 | 4 | 3 | 4 | 3 | 5 | 4 | 3 | 3 | 3 | 3 | 2 | 4 | 3 | 3 | 3 | 3 | 2 | 4 | 3 |
| ph | 3 | 4 | 2 | 3 | 4 | 5 | 3 | 4 | 5 | 3 | 5 | 3 | 4 | 2 | 3 | 5 | 5 | 3 | 4 | 3 | 3 |
| bh | 4 | 3 | 3 | 2 | 5 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 4 | 4 | 4 | 3 | 3 | 2 |
| m | 4 | 3 | 5 | 4 | 5 | 4 | 6 | 5 | 2 | 4 | 4 | 4 | 3 | 5 | 4 | 2 | 4 | 4 | 3 | 5 | 4 |
| w | 4 | 3 | 5 | 4 | 5 | 4 | 6 | 5 | 4 | 4 | 2 | 4 | 3 | 5 | 4 | 4 | 4 | 4 | 3 | 5 | 4 |
| s' | 2 | 3 | 3 | 4 | 3 | 4 | 4 | 5 | 4 | 1 | 4 | 2 | 3 | 3 | 4 | 4 | 4 | 2 | 3 | 3 | 4 |