# ESTABLISHMENT OF A DISTINCTIVE FEATURE SYSTEM FOR CONSONANTS IN GUJARATHI

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Complex objects and events have sub-units or recognizable properties. These properties are termed as features. The features that help us distinguish between two entities are called distinctive features.

Earlier it was believed that phoneme was the smallest unit of language and it could not be divided any further. (Hocket, 1958), Jakobson *et al.* (1952), contradicted this concept and proposed that phonemes can be broken into smaller units. These smaller units are termed as features and the units that bring about, disinction between two phonemes are called 'distinctive features'. The distinctive features of the speech sounds may be defined as follows. ' The distinctive features are the ultimate distinctive entities of language. The distinctive features combine into one simultaneous or concurrent bundle to form a phoneme (Jakobson, Fant and Halle, 1952).

The framework of distinctive features is a promising tool to Speech Pathologists and Audiologists in handling various speech and hearing problems. This approach has been found to be useful in description of articulatory behaviour (McReynolds and Huston, 1974, Castello, 1970), in diagnosis, prognosis and treatment of articulatory deviation (Weber, 1970, Kamara and Kamara, 1974, Singh, 1970), in testing speech sound perception (Danhaner and Singh, 1975, Danhaner *etal.* 1978), in studying language acquisition and phonological acquisition (Menyuk, 1968), and in studying hemispheric specialization, (Studdert-Kennedy and Shankveiler, 1970).

Several attempts have been made to describe various languages of the world using distinctive features. Different systems of distinctive features have been proposed. (Jakobson *et al.* '1952; Chomsky and Halle, 1968; Singh and Becker, 1972), based on different methods of extracting features. These methods are,

1. The acoustic method (Jakobson, Fant and Halle, 1952);
2. The articularoty method (Chomsky and Halle, 1968) and
3. The perceptual method (Singh and Becker, 1972).

An attempt has been made to describe Hindi language using distinctive features. Ahmed and Agrawal (1969), Somasundaran (1973), has attempted to compare phonology of four languages, Tamil, Telugu, Kannada and Malayalam

using a feature system as proposed by jakobson, Fant and Halle (1952). Mowever, this is not an experimental study. Thus systematic establishment of distinctive feature system is done for Hindi language only.

To facilitate finer analysis of language and its disorder, an attempt has been made to establish a distinctive feature system for consonants in Gujarati language.

The purpose of the study was (1) To establish a distinctive feature system for consonants in Gujarati language, (2) To identify acoustic correlates of the proposed feature system, (3) To find out the information carried by each feature in perception of speech sounds, (4) To compare perception of speech sound by native and non-native listeners in order to test feature universality (Menyuk, 1968),

## Method

A distinctive feature system for consonants in Gujarati has been proposed based on a distinctive feature system for Hindi language, Ahmed and Agrawal, (1969) and phonetic description of consonants in Gujarati (Nair, 1979). The proposed distinctive feature system consists of following features: (1) Voicing, (2) Nasality, (3) Labial, (4) Alveolar, (5) Dental, (6) Retroflex, (7) Velar, (8) Aspiration, (9) Affrication, (10) Semi-vowel, (11) Lateral, (12) Flap, (13) Frication. All the features have binary specification. The presence of the feature is indicated by and absence of the feature is indicated by—.

Two experiments were carried out in order to find acoustic and perceptual correlates of the proposed feature system. They are: (1) Acoustic analysis, and (2) Perceptual analysis.

### 1, *Acoustic Analysis*

(A) *Stimuli:* 65 minimal word pairs were constructed consisting of 32 consonants of Gujarati language (Nair, 1979). The minimal pair words have been taken from Gujarati Vyakarana (Vyas, 1977). The minimal pairs were devised according to classification of consonants with respect to manner and place of articulation. The minimal pairs permitted comparison of features as they differed from each other at least by one feature.

(B) *Equipment:* Speech Spectrograph (VIC MK 700)

(C) *Procedure:* The 65 minimal word pairs were recorded using the internal tape recorder of the speech spectrograph on a professional tape by the experimenter. A gap of less than one second was given between the words and 'more than three seconds between the word pairs. The recording was done on a quiet condition and intensity was monitored using the Vu meter. A satisfactory recording, to ensure no variations between words and word pairs in terms of intensity, pause and intonation, was obtained after four trials as judged by the experimenter and a Speech Pathologist.

The wide band and narrow band spectrogram were obtained for each Word pair using. The speech spectrograph (VIC MK 700).

2. *Perceptual Analysis:* This experiment was conducted in two parts.

*Part-I*

(A) *Stimuli:* 130 words were derived from 65 minimal word pairs. Each word was recorded individually in a random order using a cassette tape recorder. (Sony TC 1000) on a Sony cassette by the experimenter. A gap of approximately 5 seconds was introduced between two words.

(B) *Subjects:* The subjects were 60 college students (30 males and 30 females) having Gujarati as their mother tongue and native language, langing 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 recorded words (130) were played to listeners in a quiet room situation. The subjects were instructed to listen to the words and write down what they heard on a sheet of paper given to them. The subjects were instructed to read out what they had written after listening to all words. Spoken responses were also obtained using a tape recorder.

*Scoring:* The responses were scored as correct or incorrect. The incorrect responses were further analyzed to find the pattern of errors.

*Part-II* (A) *Stimuli:* Same as Part I.

(B) *Subjects:* 10 graduate and post-graduate students (5 males and 5 females) ranging in age from 19-25 years, who were not having Gujarati as their mother tongue and/or native language were chosen as subjects. They had no history of speech and hearing problems.

(C) *Procedure:* The listening performance to 130 words was observed as described in Part-I. Only the spoken responses were collected.

(D) *Scoring:* The spoken responses were scored as in Part-I to obtain correct and incorrect responses.

## Results and Discussion

**1.** *Acoustic Analysis:* The close inspection of wide band and narrow band spectrograms for 65 minimal word pairs was carried out to identify distinct acoustic correlates for each feature proposed.

The distinct acoustic correlates for each feature proposed has been summarised in Table-1 as follows.

'TABLE 1

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

| Si. No. | Feature( ) | Acoustic Characteristics |
|---|---|---|
| 1. | Voicing | 1. Regular vertical striations in low frequency region occurring simultaneously with the burst.<br>2. Decreased burst intensity when compared to its voiceless counter* part. |
| 2. | Nasality | 1. Low frequency formant.<br>2. Tail like appearance. |
| 3. | Labial | 1. Downward transition"<br>2. Low frequency peak. |
| 4. | Alveolar | 1. Shortened transition upwards or downwards.<br>2. High frequency peak. |
| 5. | Dental | 1. Upward shift.<br>2. Higher peak when compared to labial. |
| 6. | Retroflex | 1. Upward shift.<br>2. Low frequency peak. |
| 7. | Velar | 1. Upward shift.<br>2. Mid-frequency peak. |
| 8. | Aspiration | 1. Extra energy concentration in aperiodic portion of the consonants at high frequency. |
| 9. | Affrication | 1. A small gap followed by a burst which has a long duration due to friction noise added to it. |
| 10. | Semi-vowel | 1. Dark and clear resonance bars.<br>2. Transitional curve. |
| 11. | Lateral | 1. Continuous periodic portions.<br>2. Small gaps. |
| 12. | Flap | 1. Several series of resonance bars.<br>2. Gaps. |
| 13. | Frication | 1. High frequency aperiodic portion of a long duration. |

The findings of the present experiment are similar to that of acoustic characteristics of distinctive features described for other languages (Like in English by Fry, 1979, Potter *et al.* 1969, etc.)

This supports the view that distinctive features are universal. It can be stated that the phonemes used in different languages have similar acoustic characteristics, which points out the fact that the speech mechanism and production in human beings is same throughout the world.

## *2. Perceptual Analysis*

### *Part-I*

The responses of 60 Gujarati listeners to 130 words have been analyzed using a confusion matrix as in Table-2.

Table 2. Table showing confusion matrix for 32 Gujarati consonants heard by 130 Gujara ti listeners

| | k | g | kh | gh | c | j | ch | jh | ɲ | h | sh | y | ṭ | ḍ | ṭh | ḍh | ṇ | l | t | d | th | dh | n | s | l | r | p | b | ph | th | m | w | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| k | 234 | 2 | 1 | 1 | 1 | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | 240 |
| g | 6 | 339 | | 4 | 1 | 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | 360 |
| kh | | 1 | 179 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 180 |
| gh | 9 | 23 | 13 | 130 | | | | | | 1 | | | | | | | | | 1 | | | 2 | | | | | | | | | | | 180 |
| c | 1 | | | | 283 | 14 | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | 300 |
| j | | | | | 13 | 339 | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | 360 |
| ch | | | | | 2 | 2 | 229 | 4 | | | | | | | | | | | | | 1 | | | 1 | | | | | | | | | 240 |
| jh | | | | | 2 | 76 | 43 | 117 | | | | | | | | | | | | | | | | 2 | | | | | | | | | 240 |
| ɲ | | 2 | | | | | | | 55 | | | | | | | | 4 | | | | | | 26 | | 1 | | 17 | | | | 131 | | 240 |
| h | | 1 | | | | | | | | 179 | | | | | | | | | | | | | | | | | | | | | | | 190 |
| sh | | | | | | | | | | | 110 | | | | | | | | | | | | | 9 | | | | | | | | | 120 |
| y | | | | | | | | | | | | 120 | | | | | | | | | | | | | | | | | | | | | 120 |
| ṭ | | | | | | | | | | | | | 299 | | | | | | 1 | | | | | | | 6 | | | | | | | 300 |
| ḍ | | | | | | | | | | | | | | 361 | | 20 | 3 | 24 | | 9 | | | | | 1 | 1 | | | | | | | 420 |
| th | 6 | | | 1 | | | | | | 1 | | | 9 | | 246 | 21 | | | 1 | | 12 | 1 | | | | | | | 2 | | | | 300 |
| dh | | 1 | | 5 | | | | | | | | | 23 | 7 | 8 | 179 | | | 1 | 8 | | 4 | | | | | | | | 2 | | | 240 |
| ṇ | | | | | | | | | | | | | | 10 | | | 266 | 7 | | | | | 13 | 1 | 2 | | | | | 2 | | | 300 |
| l | | | | | | | | | | | | | | 24 | 1 | | | 152 | | | | | 1 | 1 | 1 | 1 | | | | | | | 180 |
| t | | | | | | | | | | | | | 16 | | | | | | 210 | | 14 | | | | | | | | | | | | 240 |
| d | | 2 | | 1 | | | | | | | | | 2 | 25 | | 1 | | | 4 | 319 | 1 | 2 | 1 | | | | | | | | | | 360 |
| th | | | | | | | | | | | | | | | 6 | | | | 56 | 1 | 233 | 2 | | | | | | | | | | | 300 |
| dh | | | | | 7 | 1 | | | | | | | | | 2 | 3 | | | 4 | 3 | 15 | 202 | | | | | | | | | | | 240 |
| n | | | | | | | | | | | | | | | | | 8 | | | 1 | | | 288 | | | | | | | 5 | | | 300 |
| s | | | | | | | | | | | 1 | | | | | | | | | | | | | 233 | | | | | | | | | 240 |
| l | | | | | | 1 | | | | | | | | | | | | | | | | | | | 179 | | | | | | | | 180 |
| r | | | | | | | | | | | | | | | | | | | | 4 | | | | | 37 | 78 | | | | | | | 120 |
| p | 5 | 1 | 5 | | | | | | | | | | 2 | | | | | | 9 | | 2 | | | | | | 152 | | 1 | 1 | | 1 | 180 |
| b | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | 290 | | 1 | | | 300 |
| ph | 1 | 1 | | | | | | | | 1 | | | | | | | | | | | 1 | | | | | | 43 | | 97 | | | | | 240 |
| th | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 21 | 99 | | | 120 |
| m | | | | | 1 | | | | | | | | | | | | | | | | | | 2 | | | | 1 | | | | 296 | | 300 |
| w | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | 179 | 180 |
| | 262 | 373 | 198 | 142 | 311 | 442 | 272 | 130 | 55 | 182 | 117 | 120 | 351 | 427 | 265 | 224 | 281 | 183 | 298 | 345 | 279 | 214 | 332 | 245 | 221 | 80 | 213 | 299 | 210 | 106 | 429 | 180 | |

The vertical axis represent stimuli and the horizontal axic represent responses. •JEach cell of the matrix represents the joint occurrence of a corresponding stimulus and response. The total number of observations pooled in this matrix were 7800.

Further this matrix for 32 consonants in Gujarati has been subdivided into voice communication network of 13 component binary channels of linguistic features based on 13 features proposed. Again four fold confusion matrices were formed for each of the features.

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

A measure of co-variance based en infoirraticn theory (Shancn and Weaver, 1963) was employed to calculate information transmission for a composite phoneme channel and for 13 linguistic features.

The formula was, $T(X,Y)= \Sigma P_{ij} \cdot \mathbf{Log} \frac{Pi\ Pj}{P_{ij}}$

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

$n_i$=Frequency of stimulus$_i$

$n_j$=Frequency of responses$_y$.

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

$P_i = N_{i/n}$

$P_j = n_{j/n}$

$P_{ij} = n_{ij/n}$

In the Table-2 all entries are $n_{ij}$, now sums are $n_i$, column sums are $n_j$ and n is 7800.

The percentage of correct responses for 130 words by 60 Gujarati listeners was found to be 86.92 per cent. The observation of pattern of error response revealed that when the two sounds share more number of features, the confusions are more and when the two sounds have very few number of features in common the confusions are less.

Table-3 gives information transmission for a composite phoneme channel and 13 component channels of linguistic features in bits/stimulus. The table also depicts the ranking of linguistic features according to the amount of information transmission from highest to the lowest, the feature place having the highest information transfer and the feature flap having the lowest value of information transfer. (See Table-3)

TABLE 3

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

| SI. No. | Ranking | Feature | Information Transmission in bits/stimulus |
|---|---|---|---|
| 1 | | Retroflex | .7039 |
| 2 | | Velar | .7027 |
| 3 | 1 | Dental | .357 |
| 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 | Semi-vowel | .228 |
| 12 | 8 | Lateral | .1628 |
| 13 | 9 | Flap | .0782 |

Total transmission in bits/stimulus=5.9228

Composite phoneme channel transmission=4.197

The results suggest the semi-independence of features in carrying information for the perception of speech sounds. Certain amount of redundancy was indicated by the difference between information transfer for composite phoneme channel and the sum of information transfer for linguistic features—the latter being more.

The findings also point to the fact that all the proposed distinctive features do not have equal importance in speech sound perception. Some features transmit more information than others. The ranking of the features was similar to that found in experiment carried out by Singh (1971). This suggests a possible existence of universal features.

*Part-II:* The responses of 10 non-Gujarathi listeners to 130 words were analyzed on a confusion matrix as described earlier.

The information transfer for a composite phoneme channel and for 13 linguistic features was calculated as described before.

The percentage of correct response by non-Gujarathi listeners was found to be 78.3890. Although the percentage of error response is more, the pattern of errors is more or less the same. The sounds which share more number of features are confused more often than the sounds which share less number of features.

Table-4 shows the amount of information transmission for a composite phoneme channel and 13 linguistic features. The table also depicts the ranking of features according to amount of information transmitted from highest to lowest; place having the highest information transfer and flap having the lowest.

The results of part II also indicate semi-independence of features and relative importance of features in speech sound perception.

TABLE 4

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

| SI. No. | Ranking | Feature | Information Transmission in bits/stimulus |
|---|---|---|---|
| 1 | | Velar | .7285 |
| 2 | 1 | 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 | Semi-vowel | .2312 |
| 12 | 8 | Lateral | .163 |
| 13 | 9 | Flap | .084 |

Total transmission in bits/stimulus=5.5436

Composite Phoneme channel transmission=4.959

The comparison of ranking for both the groups of listeners depict similarity.

This highlights the point that listeners of Gujarathi and non-Gujarathi must be using the same set of features for the perception of speech sounds. This supports the notion of universality of features" as proposed by Menyuk (1968).

Finally, the results of this study validate the proposed distinctive features by identifying acoustic and perceptual correlates. Further, an existence of universal feature system can be speculated based on perceptual and acoustic analysis.

The major conclusions drawn from the present investigation are as follows:

1. Distinctive feature system can be proposed based on phonetic descriptives of Gujarati language.
2. There are distinct acoustic characteristics for each of the feature proposed.
3. All the features do not have equal importance in carrying information for speech perception, some carry more information than the others.
4. Non-Gujarati subjects show the same pattern of errors on listening performance as 'Gujarathi subjects and they show similar ranking of features in carrying information for speech perception.

The findings of the present experiment may be helpful to speech clinicians who deal with speech, language and hearing disorders in individuals having Gujarathi as their mother tongue. It may aid in (1) Diagnosis, (2) Prognosis, (3) Judging severity, (4) Planning treatment, and (5) Measuring progress.

The development of feature system in Gujarati language provides opening to the finer study of language.

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