Chapter - IV

Acoustic Base of The Phonology of Modern Standard Hindi
CHAPTER-IV

ACOUSTIC BASE OF THE PHONOLOGY OF
MODERN STANDARD HINDI

Acoustic medium is one of the five orienting principles for phonological analysis in the theoretical framework of Columbia School theory of phonology. Whereas the phonological units of Modern Standard Hindi, as of any other language or dialect, are established as the elemental units in terms of communication, the substantive “phonetic” characteristics of these units are jointly determined by physiology and acoustic. We selectively identify the substantive characteristics of some of the phonological units in terms of acoustics, and assess as to how the substantive acoustic makeup of the phonological units contribute to the justification of the phonological grid, and look into its manifestations in the syntagmatic organization of the syllable and the word. It must, however, be noted that we have mainly dealt with the physiological characteristics of the phonological units in support to our analysis in this work. For, any experimental acoustic study is beyond the scope of the present study.

In this chapter, the impact of acoustic medium is presented in four sections. In section A, we deal with the acoustic base of the phonological grid, clearly audible versus less clearly audible
apertures\textsuperscript{a}. In section B, we describe the formation of two resonant cavities within the supraglottal cavity, and examine the role of the two cavities in the production of vowels. In section C, we deal with the acoustic rationale for the lip rounding of the back dorsal vowels. In section D, summary and conclusions are presented.

Section A: Acoustic Base of the Phonological Grid: Clearly Audible versus Less Clearly Audible Units

Audibility of the sound is necessary for the purpose of communication.

On the basis of acoustic medium the speech sounds are divided into two types namely; clearly audible versus less clearly audible. For the production of clearly audible speech sounds:

1. The shaping of the supraglottal cavities, front and back, is done by the supraglottal articulators. The front cavity is shaped by the medium-dorsum mass and labia as articulators.

2. The excitation for voicing is provided by the glottis.

3. There should be no impediment in the air flow in the oral cavity. These factors are responsible for the production of clearly speech sounds which can be produced only at aperture 4 and above, these sounds are known as vowels.

Less clearly audible sounds are produced as a result of impediment of the air flow in the oral cavity by supraglottal
articulators. These impediments are possible only at aperture 0 through 3, thus, the speech sounds produced at these apertures which are termed as stops, fricatives, nasal and liquids are technically known as less clearly audible speech sounds, these sounds are traditionally known as consonants.

The speech sounds known as clearly audible and less clearly audible are very significant for the syntagmatic usage in the formation of morphemes and or lexemes. The clearly audible units, known as vowels are termed as keystones and less clearly units are termed as flanking units by Prof. William Diver.

This distinction is clearly shown in the makeup of the phonological grid of Modern Standard Hindi, Diagram I-1. It is in terms of the classification of apertures into clearly audible versus less clearly audible, that the 61 phonological units of Modern Standard Hindi are classified into 20 (vocalic) clearly audible units and 41 (consonantal) less clearly audible units.

Finally, the classification of the phonological units in terms of audibility can also be shown when these units are arranged in the formation of the syllables. We, therefore, have theoretical basis to divide the lexical units into the monosyllabic, the bisyllabic or the longer words in Modern Standard Hindi. It may be noted that the other languages may have different organization of the syllables in
terms of the number of syllables for the lexicon and the makeup of each syllable with respect to the number of flanking members on each side of the keystone.

Section B: Formation of Resonant Cavities in the Production of Vowels

Acoustic explanation of medium-dorsum mass as most preferred articulator for the production of vowels.

In the production of clearly audible speech sounds, the supraglottal resonant cavity is formed. This supraglottal cavity extends from the glottis to the lips and the size of this cavity is determined by the medium-dorsum mass as the articulator. The medium-dorsum mass determines the size of the two cavaties and the size of the opening of the back cavity because it divides the cavity into two-front and back cavaties, whereas the positioning of the lips determined the size of the opening of the front cavity. The resonant frequency of each cavity is determined by the shape of the opening and its size. Therefore, the resonant frequency of the front cavity $F_2$ is determined by the size of the front cavity and its opening, and the resonant frequency $F_1$ of the back cavity is controlled by the opening and size of the back cavity. That is by medium-dorsum mass, each of the clearly audible units, i.e. vowels have their unique combination of two resonant frequencies, namely $F_1$ and $F_2$. Thus, the inventory of the basic units is developed by the
varying combinations of these formant frequencies, and the voicing is produced by the excitation at the glottis.

It may also be pointed out that the resonant cavity amplifies the distinction within the units. For, the production of back or medial vowels, a large resonance cavity of the back is formed which is characterized within the sufficient space for the medium of the tongue as an articulator to maneuver in this triangular cavity.

The large back cavity can very smoothly produce medial vowels as well as clearly maintain their distinct perceptions. On the other hand, for the back vowels (back-dorsal units), a very small cavity at the back from the glottis to the back-dorsal is formed. It is to be pointed out that due to the vertex of the angle of the jaw, the width of this back cavity is greatly reduced. As a result the vowels produced at the back-dorsum require greater precision of control in their production and an added effort in their perception. Thus, to solve this problem, a big/large front cavity is required to facilitate the smooth production of the back-dorsal vowels and provide amplification in order to get clear perception. This is done through the rounding of the lips. Thus, we can justify the rounding of the lips for the production of back-dorsal vowels as it becomes necessary for maintaining acoustic distinction in the production and helps in amplification of the distinction for the back-dorsal vowels.
It is noteworthy that on the other hand, unlike back vowels, front vowels are produced with larger cavity, with sufficient space to provide excitation as well as amplification for the front vowels.

**Section C: Acoustic Explanation of Lip-Rounding of Back Dorsal Vowels**

As discussed above in section B, the back-dorsal vowels are generally produced with rounded lips. There is a definite physiologico-acoustic explanation for the use of labium as an additional articulator for the rounding of the lips. It maybe noted that asymmetry of the vocal tract caused by the angle of the jaws is responsible for production of a smaller cavity at the back, the production of back-dorsal vowels requires an extra effort on the part of speaker to maintain distinction. The angle of the jaws is neutralized by the utilization of the labia as an additional articulator for producing labio-dorsal (“back rounded”) vowels. The vowels thus produced are characterized with acoustic distinction. That is why it becomes acoustically natural for ‘back rounded” vowels to have parity with the “front unrounded” vowels.

It may be pointed out that the acoustic explanation of back-dorsal vowels provided above can also be explained with the help of formant frequencies obtained through spectrographic analysis. As given in section B, vowels are characterized by various combinations of the formant frequencies of two resonant cavities.
The formant frequencies have been named as $F_1$ and $F_2$, where $F_1$ rears to first formant frequencies and $F_2$ reefers to the second one. We have developed the basic inventory of distinct units by changing $F_1$ and $F_2$ and combining the variants in different ways. Hence, the vocalic units can be identified in terms of $F_1$ and $F_2$ and subsequently analyzed acoustically. Hence, we will concentrate only on $F_1$ and $F_2$ because they are in near relation to the shape and size of vocal tract as the medium-dorsum mass moves to articulate the vocal units of speech.

In this section, an attempt has been made to systematically present the vowel system of Modern Standard Hindi as spoken in Allahabad in an acoustic perspective. However, it should be noted down that the formant frequencies for long and short vowels given in Table IV-1 and VI-2, do not depend on the experimental studies conducted by the researcher. Rather, they have been taken from Fatihi and Ali (2002: 34), where the authors have established the formant frequencies for Urdu vowels in their study. But as we know that colloquial forms of Urdu and Hindi are not far apart so the same could be taken for spoken Hindi as well.
Table IV-1

Formant Frequencies of Long Vowels

<table>
<thead>
<tr>
<th>Vowels</th>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>i:</td>
<td>500</td>
<td>2000</td>
</tr>
<tr>
<td>e:</td>
<td>700</td>
<td>2000</td>
</tr>
<tr>
<td>a:</td>
<td>800</td>
<td>1300</td>
</tr>
<tr>
<td>u:</td>
<td>500</td>
<td>800</td>
</tr>
<tr>
<td>o:</td>
<td>600</td>
<td>1000</td>
</tr>
</tbody>
</table>

Comments on Table IV-I

Comment-1: As is clearly evident from the Table above, the first formant (F₁) frequencies of front unrounded vowel i: and back rounded vowel u: are the same (500 Hz) so it is difficult to distinguish between them. Thus, the acoustic features for F₁ are
less helpful to distinguish the "front" vowel (i:) and from "back" vowel (u:)

**Comment-2:** When we look at the second formant frequencies (F2) in the Table, we find a gradual decrease in the F2 frequency from i: (2000) and u: (800). That is, it is easier to make perceptual distinction between rounded back vowels and unrounded front vowels in terms of acoustic cues of second formant frequency (F2). The acoustic distinction between rounded and unrounded vowels is obtained by bringing down F2 frequency of back rounded vowels. As a result, lip rounding becomes an essential device for making acoustic distinction between rounded and unrounded vowels

### Table IV-2

**Formant Frequencies of Short Vowels**

<table>
<thead>
<tr>
<th>Vowels</th>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>550</td>
<td>1800</td>
</tr>
<tr>
<td>A</td>
<td>750</td>
<td>1400</td>
</tr>
<tr>
<td>U</td>
<td>550</td>
<td>800</td>
</tr>
</tbody>
</table>
Comments on Table IV-2

Comment-1: As seen in the first formant (F1) frequencies, in the Table above, the front short vowels I and the back short vowel U have the same F1 frequency (550 Hz). Thus, again F1 has no significance in distinguishing front unrounded vowels and back rounded vowels.

Comment-2: Similarly, front short vowel I and the back short vowel U can be distinguished from each other in terms of their second formant frequencies (F2) as F2 for front short vowel I, is 1800 Hz and back short vowel U is 800 Hz.
This drastic decrease in the F2 frequency of back-dorsal vowel (U) is caused by the rounding of the lips. This is why the rounding of the back vowels and the converse unroundedness of the front vowels is so naturally widespread in the languages of the world.

**Section D: Summary and Conclusions**

In this section, we summarize our findings as a whole for this chapter.

In section A, we have dealt with the acoustic base of the clearly audible versus less clearly audible distinctions of apertures. It was noted that the clearly audible phonological units (“vowels”) are formed on clearly audible apertures (aperture 4 and above) when three conditions are obtained.

1. The shaping of the supraglottal cavity, front and back, is done by supraglottal articulators. The front cavity is shaped by the medium-dorsum mass and labio as the articulators.

2. The excitation for voicing is provided by the glottis.

3. There should not be an impediment in the airflow in the oral cavity.

Less clearly audible units “(consonant)”, formed on the less clearly apertures (0 through 3) are produced as a result of
impediment of the airflow in the oral cavity by supraglottal articulators.

On the basis of the clearly audible versus less clearly audible distinctions, that the 61 phonological units of Modern Standard Hindi, are classified into 20 (vocalic) and 41 (consonantal) units.

It is to be pointed out that the classification on of the phonological units into clearly audible versus less clearly audible unit has an impact on the combination of the phonological units in the formation of the syllable. We, therefore, construct a theoretical basis to divide the lexical units into the monosyllabic or the longer words in Modern Standard Hindi, on the basis of the combination of the keystone and flanking units.

In section B, we have defined acoustic explanation of medium-dorsum mass as the most preferred for the production of the vowels.

The medium-dorsum mass determines the size of the two resonant cavities which ultimately determine the quality of the vowels.

In section C, we deal with the acoustic explanation of lip rounding of back-dorsal vowels.
This justification of the rounding of the back-dorsal ‘back’ vowels and converse unroundness of the medial ‘front’ vowels is shown by the formant frequencies $F_1$ and $F_2$ obtained through spectrographic analysis. Here, we have argued that due to the angle of the jaws, the back vowels are characterized with lesser space for maneuver as compared to the front vowels. As a result, back vowels requires more precision of control in their production. This problem is solved by increasing the size of the front cavity through the rounding of the lips. This front cavity amplifies the distinction between the front and the back vowels. Lip-rounding not only creates an additional chamber, but also brings down the second formant $F_2$ of the back-dorsal vowels to fulfill the acoustic need for amplification and keep distinctions apart between the ‘front’ and ‘back’ vowels.

**Conclusions:**

1. There are 61 phonological units of Modern Standard Hindi which are classified into 20 vocalic units, 41 consonantal units on the basis of clearly audible versus less clearly audible.

2. On the basis of the combination of keystone and flanking units, it is to provide a theoretical basis for the classification of the lexical units, into the monosyllabic, the bisyllabic and the longer word in Modern Standard Hindi.
3. The excitation for voicing is provided by the glottis, and they are different from one another by the varying characteristics of the two resonant cavities ‘back and front’ formed by the medium-dorsum mass as the articulator.

4. In the production of medial vowels, a large resonance cavity is formed at the back, extending from the glottis to the medium, which is sufficient enough to provide acoustic distinction to the medial vowels. On the contrary, a much smaller back cavity, from the glottis to the back-dorsum, is formed which has less vertical place to provide acoustic distinction to the back-dorsal vowels.

5. The impact of the angle of jaws then is more than compensated by the rounding of the lips in the production of back-dorsal vowels.
Chapter - V

Role of Vision in the Phonology of Modern Standard Hindi
CHAPTER-V

ROLE OF VISION IN THE PHONOLOGY OF MODERN STANDARD HINDI

This chapter discusses the role of vision in the phonology of Modern Standard Hindi. As discussed in the introduction (cf. C2, e), vision plays a vital role in human communication. In other words, the advantage of the visibility factor of the labium definitely gives a boost to speaker-hearer roles in communication, for it helps in comprehension.

In chapter III, we have observed that the communicative load carried by the initial position of the word is greater than the medial and final positions of the word. Thus, we may expect more use of labium at the beginning of the word than at the end of the word. Labial consonants make the identification of a word easy, by reinforcing in speech act in another sense, vision. Many gaps of hearing are filled through vision. We often watch the lips of the speaker, and even see people saying ‘watch my lips’! Language used by deaf mutes, consist of the speaker symbols involving vision, through the action of speaker’s lips or their facial expressions. Therefore, we can say that the visibility of the labial articulator definitely boosts comprehension. It may be pointed out that in many cases, where speakers and hearers cannot see each
other visibility of the articulator does not aid in comprehension, but
the ordinary conversational situation has always allowed for visual
reinforcement of an acoustic perception.

In the present chapter, we make an attempt to compare the
occurrences of the labial and non-labial consonants in the initial and
final positions of the words in Modern Standard Hindi. In sections A
and section B, we discuss the role of vision in Modern Standard
Hindi phonology.

Section A: Labial versus Non-Labial Consonants in the Word
Initial and Final Positions.

We present the frequency of occurrence of the labial and non-
labial consonants in this section. We compare the labial occurrences
with that of the apical, dorsal, medial and post dorsal occurrences in
both the initial and final positions of the word in three subsections
below. In section A1, we compare the frequencies of the labial and
the non-labial stops in the initial and final positions of the words. In
section A2, the occurrences of the labial and non-labial fricatives in
the initial and final positions have been taken up, and in section A3,
we deal with the comparison of the occurrences of labial and non-
labial nasals in the initial and final positions of the words.
Section A1: CVC Stops in the Initial and Final Positions: Labial versus Non-Labial

We present the actual occurrences of the labial and non-labial stops as they appear in the initial and final positions of the monosyllabic words in Modern Standard Hindi in Table V-I below:

Table V-I
Labial versus Non-labial Stops in the Word Initial and Final Positions in the CVC Words.

<table>
<thead>
<tr>
<th></th>
<th>Apical</th>
<th>Labial</th>
<th>Dorsal</th>
<th>Medial</th>
<th>Post-dorsal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Initial</td>
<td>352</td>
<td>40.41</td>
<td>383</td>
<td>74.80</td>
<td>274</td>
<td>46.06</td>
</tr>
<tr>
<td></td>
<td>250</td>
<td>62.98</td>
<td>5</td>
<td>50</td>
<td>1264</td>
<td>52.99</td>
</tr>
<tr>
<td>Final</td>
<td>519</td>
<td>59.59</td>
<td>129</td>
<td>25.20</td>
<td>321</td>
<td>53.94</td>
</tr>
<tr>
<td></td>
<td>147</td>
<td>37.02</td>
<td>5</td>
<td>50</td>
<td>1121</td>
<td>47.00</td>
</tr>
<tr>
<td>Total</td>
<td>871</td>
<td>100</td>
<td>512</td>
<td>100</td>
<td>595</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>397</td>
<td>100</td>
<td>10</td>
<td>100</td>
<td>2385</td>
<td>100</td>
</tr>
</tbody>
</table>

Comments on Table V-I

Comment 1: As seen in this Table, of the 1070 occurrences of the stops in the initial position of all the monosyllabic words, the labials have 383 occurrences, followed by the apical 352 occurrences of the apicals 274 occurrences of the dorsals, 250 occurrences of the medials, only 5 occurrences of the post-dorsal stops. Here we observe that the labial stops in the initial and final positions of the words shown an edge over the other stop types. The preferential norm in favour of the labials and against the other stop types can
be well attributed to the visibility factor associated with the labium as an articulator.

**Comment 2:** A look at the figures of stops in the final position shows that the 129 labial stops are least preferred, while the apicals increase many times the occurrences of the labials. This sudden upsurge in the apicals can be attributed to the high adroitness of the apex. On the other hand, the low frequency of the labials are justified in terms of vision, for there is more visibility impact in the beginning of the word than at the end.

**Section A2: Labial versus Non-Labial Fricatives in the Word Initial and Final Positions**

For the labial and non-labial fricatives, in the initial and final positions of the CVC words, the actual occurrences of the labial non-labial fricatives are presented in Table V-2 below:

**Table V-2**

**Labial versus Non-labial Fricatives in the Word Initial and Final Positions in the CVC Words.**

<table>
<thead>
<tr>
<th></th>
<th>Apical</th>
<th>Labial</th>
<th>Dorsal</th>
<th>Medial</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No %</td>
<td>No %</td>
<td>No %</td>
<td>No %</td>
<td>No %</td>
</tr>
<tr>
<td>Initial</td>
<td>177 61.89</td>
<td>55 62.5</td>
<td>18 72</td>
<td>67 58.27</td>
<td>317 61.68</td>
</tr>
<tr>
<td>Final</td>
<td>109 38.11</td>
<td>33 37.5</td>
<td>7 28</td>
<td>48 41.73</td>
<td>197 38.32</td>
</tr>
<tr>
<td>Total</td>
<td>286 100</td>
<td>88 100</td>
<td>25 100</td>
<td>115 100</td>
<td>511 100</td>
</tr>
</tbody>
</table>
Comments on Table V-2

Comment 1: As shown in the Table V-2, we find 317 occurrences of the fricatives in the initial position, the labials have 55 occurrences, the apicals have 177 occurrences, followed by 18 dorsals while 67 are medials. Here, the apical fricatives posses the highest frequency which is the result of the adroitness of the apex. The labials compete well in the initial position which is basically due to the visibility factor of the articulator and its contribution is reinforced comprehension.

Comment 2: Of a total of 197 occurrences of the fricatives in the final position, 33 are labials, 109 apicals, 7 dorsals and 48 are medials. Thus, we find that labial fricatives which are preferred in the initial position of the words are less preferred here and come down to only 33 occurrences in the word final position due to the decreased visibility impact in this position in the word.

Section A3: Nasals in the Initial and Final Positions: Labial versus Non-Labial

Here we will study the proportionate occurrences of the labial and non-labial nasals in the initial and final positions of the CVC words as presented in Table V-3 below.
Table V-3
Labial versus Non-labial Nasals in the Word Initial and Final Positions in the CVC Words

<table>
<thead>
<tr>
<th></th>
<th>Apical</th>
<th></th>
<th>Labial</th>
<th></th>
<th>Dorsal</th>
<th></th>
<th>Total</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>%</td>
<td>No</td>
<td>%</td>
<td>No</td>
<td>%</td>
<td>No</td>
<td>%</td>
</tr>
<tr>
<td>Initial</td>
<td>75</td>
<td>36.77</td>
<td>135</td>
<td>66.18</td>
<td>-</td>
<td>-</td>
<td>210</td>
<td>49.19</td>
</tr>
<tr>
<td>Final</td>
<td>129</td>
<td>63.23</td>
<td>69</td>
<td>33.82</td>
<td>19</td>
<td>100</td>
<td>217</td>
<td>50.81</td>
</tr>
<tr>
<td>Total</td>
<td>204</td>
<td>100</td>
<td>204</td>
<td>100</td>
<td>19</td>
<td>100</td>
<td>427</td>
<td>100</td>
</tr>
</tbody>
</table>

Comments on Table V-3

Comment 1: As seen in this Table, of a total of 210 occurrences of the nasals in the initial position of all the monosyllabic words in Modern Standard Hindi, 135 are labial labium and only 75 are apical nasals. This preference for the labial nasals in the initial position of the CVC words is explainable in terms of vision, which helps in communication by making additional information through sight and fills in many gaps as to what the word is.

Comment 2: We find a meager 69 occurrences of the labial nasals in the final position of all the monosyllabic words. This reduction in the figure from 210 in the initial to only 69 in the final, the position is due to low visibility impact in this position.
Section B: Summary and Conclusions

In this chapter, we have made an attempt to evaluate the impact of vision as an orienting principle on the phonology of Modern Standard Hindi. We have defined a motivated rationale in terms of vision for the phonological skewing observed in word initial and final positions, in favour or against the labial versus non-labial consonants as they appear in the monosyllabic words of Modern Standard Hindi.

In section A, we have made comparison between labial and non-labial consonants in the initial and final position of the words. It has been shown through the frequency counts for CVC words, in both positions of the CVC words, that there is marked preference for labial consonants in the initial position of the words. The preference for the labial consonants is geared up by the fact that they employ labium as an articulator, which is visible and thus leads to ease in identifying the words by reinforcing in speech another since that is vision.

Thus, it is vision which demonstrates the importance of communication by favoring visibility in the initial position of the words, just where most of the distinctiveness is at stake.