Chapter: Seven

Aspiration, h-deletion and gemination: strength asymmetry

7.0 Introduction:

Segmental strength can be interpreted not only in phonetic parameters but also in terms of phonological theorising. From a survey of recent work revolving round the theme of lenition, Backley and others (2002) have identified a general tendency in phonological behaviour—sound changes resulting from this kind of effect are faithful to a fixed scale of segmental strength. Whereas in phonetic parameters strength can be correlated with the notion of articulatory openness (Lass and Anderson 1975), phonological explanations seek to draw the resolution that the strength pertaining to a segment is reflected in its role within the sound system of a language (Foley 1977). According to Harris (1997) segmental strength is best captured through representational terms. Backley (2002) claims that the strength of a segment may be equated with its complexity, such that a relatively strong segment is endowed with a greater number of melodic components than a weaker one. Thus a further generalization can be drawn: a segment that undergoes a lenition or weakening process suffers the loss of melodic material from its phonological representation. To what extent this process of weakening or lenition correlates with the prosodic position is a topic of inquiry. Headship in melodic strength drives home the point that the constituents of prosodic structure are indicated by the presence of strong prosodic positions; in other words, the positions which are generally considered to be strong are the ones which carry the responsibility for demarcating the edges of prosodic domain.

This chapter is designed to address the issue of phonological strength in the backdrop of some phonological processes such as aspiration and gemination which are generally considered to be processes of fortition. In addition h-deletion in certain varieties of Hindi are taken in to consideration in order to explore the issue of onset coda asymmetry and thereby encompass the idea of phonological strength in an explicit way. The theoretical models which I am going to employ in this chapter for the illustration of my hypotheses will be based on Element theory, which makes an important distinction between headed and non headed melodic expressions.

In the next section I am going to give a rough outline of Element theory and its implications in the process of aspiration.
7.1 Element theory and strength relations:

Backley and Kuniya (2006) claim that the correlation existing between prosodic and melodic strength can be better represented in the framework of Element theory approach to melodic representation (Harris and Lindsay 1995; Backly and Nasukawa 2006). Headship distinction intends to reflect on differences in prosodic strength: strong prosodic positions signified by the acoustic cues contain segments represented by headed melodic expressions whereas weak positions contain segments represented by non-headed expression. Headship in Element theory tries to claim that melodic headship is one of the strategies that languages adopt to indicate prosodic strength. In Element theory segments are represented by means of certain limited features or elements /A I U H N ?/. Elements are unary and stand for a universal property which is instrumental in displaying active phonological behaviour that is mapped on to an information bearing pattern in the speech signal. In this set of six members the first three members /A I U/ constitute the resonating groups which are mostly involved in the description of vowel contrasts. The other members /H N ?/ constitute the laryngeal source and describe the laryngeal and manner properties of consonants. An unequal combination creates a head dependent relation between the elements concerned and in this regard it bears close affinity with that of Dependency phonology and Particle phonology. It is the head dependence asymmetry which plays a pivotal role in the formation of melodic strength. The headship in melodic theory performs two functions: it increases the number of possible melodic expressions and the number of contrasts and secondly it allows a situation in which one element (the head) dominates all others (the dependents), thereby displaying greater acoustic cues pertaining to the dominant element and thus predominate in the interpretation of the resulting melodic expression. A I U are regularly active in dynamic processes such as coalescence and diphthongization which strengthens the view that these properties have primitive status. It is to be mentioned in this context that although /A I U/ are mostly used for the description of vowel properties they also contribute to place of articulation properties in consonantal representations thereby implying the notion that a single element may have more than one interpretation relying on the context which allows cross category groupings. Elements may have different phonetic interpretations across different consonant categories. In Element theory the motivation for recognizing the elements /H/ and /N/ derives in part from the arguments which relate to voice onset timing (Backley and Nasukawa 2006). However both these categories /H/ and /N/ are brought to the purview of modification in order to accommodate the specific characteristics pertaining to aspiration languages and
voicing languages. Element theory incorporates in its melodic representations some form of head dependency relation holding between elements in the same expression and this headship is assigned two major functions: it increases the number of possible melodic expressions and thus the number of contrasts and secondly it allows a situation in which one element is performing the role of head and the other the dependent. Thus the dominant element is further characterized by stronger set of acoustic cues, which predominate in the physical interpretation of the resulting melodic expression. This head dependent asymmetry is supposed to play a pivotal role in the formulation of melodic expression. For convenience, mention can be made of compound vowels which comprise two or more elements either in symmetric or asymmetric fashion. The vowel element /I/ has high value of F2 in any expression wherever it is present and in articulatory parameter it corresponds to vowel frontness. In the same way the element /A/ is associated with high F1 value which implies an open articulation and manifested as a low vowel such as [a]. The fusion of two elements /I/ and /A/ combine in the same expression results in a blend with the properties of high F2 and high F1. It is to be noted that although symmetric fusion is possible it is common for elements to combine asymmetrically and in such cases one element is designated as the head of the expression and the other the dependent. If /I/ predominate as the head of a compound /I A/ combination the resulting compound vowel will be high front vowel that is lowered to [e] due to the influence of the dependent element /A/. On the other hand if /A/ acts as the head of the compound /I A/ the relating segment will be a low vowel [æ] with high F1 on which vowel fronting from /I/ has been superimposed. This headship of melodic segments can be used in the representation of consonantal segments. As, for instance, three laryngeal source elements are instrumental in displaying the headed versus headless distinction of consonants. /N/ implies the class of fully voiced stops; /H/ implies aspirated stops and /ʔ/ signifies the category of ejective stops. It is a topic of inquiry whether the headed status of aspirated, ejective and fully voiced stops provides an explanation for why these obstruent categories exhibit natural affinities for strong prosodic position.

In the next section, I will show that the headed status of aspirated stops is mostly attached with the word initial and foot initial position which are considered to be prosodically strong positions, thereby strengthening the argument that melodic strength and prosodic strength cannot be dissociated from each other; both are complementary to each other. Prosodic strength or the positional strength stimulates the emergence of the melodic strength of a segment. The
data which I am citing here for illustration of the hypotheses are drawn both from secondary 
and primary sources.

7.1.1 Aspiration, Headedness and prosodic positions:

In this section, I am trying to address the issue as how headedness in aspirated stops in 
languages can be correlated with prosodically strong positions in a phonological domain.

The /H/ element appears in ‘aspiration’ languages like English, German and Korean. The 
distribution of aspiration in these languages correspond to features such as [asp] (Lombardi 
1994), [spread glottis] (Iverson and Salmons 1995) and [+tense] (Jessen 1998). In common 
parlance /H/ is used for voicelessness, but it is also used as aspiration on plosives and vowel 
shortening before fortis consonants. Backley and Kuniya (2006) have shown that the element 
/H/ performs a contrastive property in English, as evident from the following examples:

(7/1) The contrastive function of /H/

Fortis [pʰ] post, appear….. /? U H/

Lenis [b] brief, about…… /? U/

In English, the lenis stop [b] is produced without voicing. Moreover, lenis stops are 
phonologically neutral in the sense that they have no active laryngeal/voicing properties. So 
the above components have no /N/ element or other property referring to voicing (Backley 
and Nasukawa 2006). But the simple presence or absence of /H/ element is not sufficient to 
account for all laryngeal patterns attested in English. As for example, in order to capture the 
distinction between aspirated and unaspirated stops a distinction in terms of melodic structure 
is not sufficient. This is not a question of the presence or absence of an element. Both [p] and 
[pʰ] are voiceless and both should contain the element [H]. Rather the issue revolves around 
the theme of the relative prominence of /H/ in the overall expression. Consider the laryngeal 
contrasts in English: (data taken from Backley and Kuniya 2006)

(7/2) Laryngeal contrasts in English:

Aspirated voiced context examples

[pʰ] yes no foot initial pass, appear
In the above tableau it is seen that the aspiration is attested in the archetypal strong environment of foot initial position, but loses its aspiration in the weaker positions such as in the foot internal position. Nasukawa and Kuniya (2006) expressed the laryngeal categories in English in phonetic terms in the following manner:

(7/3) Representation of laryngeal categories in English:

<table>
<thead>
<tr>
<th>Category</th>
<th>Laryngeal Property</th>
<th>Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>[p^\text{h}] (aspirated)</td>
<td>long voicing lag</td>
<td>/H/ prominent (\rightarrow) /H/</td>
</tr>
<tr>
<td>[p] (unaspirated)</td>
<td>short/no voicing lag</td>
<td>/H/ present (\rightarrow) /H/</td>
</tr>
<tr>
<td>[b] (neutral)</td>
<td>short/no voicing lag</td>
<td>/H/ present (\rightarrow) /H/</td>
</tr>
<tr>
<td>[b] (voiced)</td>
<td>spontaneous voicing</td>
<td>laryngeal inactive (\rightarrow) / /</td>
</tr>
</tbody>
</table>

In the above representation table it is seen that the voicing lag or voicelessness associated with /H/ is perceptually more salient in aspirated than unaspirated stops and this heightened salience is indicated by the presence of the element /H/ in its stronger guise—namely as headed /H/. It is also a held assumption that the acoustic properties of a head are expected to be stronger and more prominent than when same element is a dependent. This dominance is reinforced on the basis of the head dependent asymmetries which have already been established. In fact the prosody headship and melody headship are very robust. In prosody it is seen that the head dependency relation between the two nuclei constituting a binary feet, it is typical for the head nucleus to be perceptually stronger than the dependent nucleus and acoustically more prominent (strong versus weak units in stress system). In melody too head dependency relation has phonetic implications. Hence as we have seen in the above illustration of the aspirated stops, the defining voicing lag is reinforced through melodic headship.
In this section I am trying to propose the argument that melodic strength and prosodic strength are interconnected. It is melodic strength which reflects prosodic strength and melodic strength is achieved through headship and prosodically strong positions are those which help language processing by indicating the location of various prosodic domains. If we apply these insights into the English laryngeal contrasts as stated above it is evident that the relevant prosodic domain is the foot, as aspirated stops, which are headed expressions are distributed in a way that marks the left edge of the foot domain. The prosodic word domain also seems to be significant in English, as aspiration is regularly interpreted word initially even when this position is not word initial. In English it is reported in literature that stress can also help listeners in the identification of foot domains, since the distribution of stressed syllables is linked directly to foot structure. Most of the works on psycholinguistic literature (Cutler and Noris 1988; Echols et al. 1997; Jusczyk et al. 1993) reflect on the notion that users of stressed timed languages rely on stress patterns in order to segment continuous speech into words which is needed before lexical retrieval can occur.

Strong or headed expressions can only be realized in prosodically strong positions (Backley and Nasukawa 2006, Vaux and Samuels 2005). In previous literature it has been discovered that strong positions are those which are rich in linguistic/prosodic information because they mark out the left edge of a prosodic domain. In case the prosodic requirement is not met, the result is a weaker or lenited analysis of the same segment. Lenition may result in the loss of some defining properties: stops may lose the place of articulation, fricatives can lose their audible friction and the peripheral qualities attributed to vowels may be lost. It is an assumption that if headedness is associated with strong prosodic positions it is likely to be found that lenition occurring in weak positions may result in the loss of headedness associated with an expression. For illustration, consider the data from Swedish in which /H/ is active as a laryngeal property as in English. The data is taken from Ringen and Helgason (2004) and Petrova et al. (2006). In Swedish too the aspiration is conditioned by prosody. Aspiration is attested only in the beginning of the word domain whereas the headed status of the expressions is lost in intervocalic and final position.

(7/4) Laryngeal properties in Swedish

[pʰ]acka ‘pack’ /? U H/ word initial
Ko[p]la ‘buy’ /? U H/ word medial
Ko[p]-te ‘bought’ /? U H/ obstruent cluster

Hence from the above observation it is seen that word initial is the only prosodically strong position in Swedish which is marked with aspiration and headed /H/ can be interpreted. In other positions the fortis remain fortis which is shown by the presence of /H/ but loses aspiration and thereby the headed expression. Backley and Kuniya (2009) also show that in Korean too the laryngeal properties are conditioned by prosodic factors.

(7/5) The Korean data:

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>[p]</td>
<td>lenis light aspiration</td>
<td>/? U H/ [paŋ] ‘room’</td>
</tr>
<tr>
<td>[p’]</td>
<td>fortis glottal reinforcement</td>
<td>/? U H/ [p’aŋ] ‘bread’</td>
</tr>
<tr>
<td>[pʰ]</td>
<td>aspirated heavy aspiration</td>
<td>/? U H/ [pʰaŋ] ‘bang’</td>
</tr>
</tbody>
</table>

In the data shown on Korean it is evident that word initial position behaves as prosodically strong position which is rich in information and perception as manifested in the three way laryngeal contrasts. In addition to aspiration, we can talk about the ejective in Korean which is also attested in word initial position. Crosslinguistically ejectives display a limited distribution: they function as contrastive sounds in syllable onset position and are mostly excluded from syllable codas which are considered to be weak positions in phonological domain. This is true of a number of American languages such as Klamath, Cuzco Quechua, Maidu, Navajo and Dakota (Rimrott 2003). Parker (1997) and Rimrott (2003) also claim that the appearance of aspirated and ejective stops is confined to syllable onset position, and in syllable codas all laryngeal distinctions are neutralised and only the voiceless stops can appear. Even morphological concatenations involve head dependency asymmetry and thereby highlighting the notion that the headed melodic structures are naturally drawn to strong prosodic units. In Quechua aspirated and glottalised stops can appear only in roots but never in suffixes.
7.1.2. Melodic strength: Evidence from Indian Languages

Now I am going to investigate the issue of prosodic versus melodic strength in the light of the data collected from Indian languages such as Hindi, Bangla and Assamese. The stop system of these Indo Aryan languages is unique in typological sense on the ground that it supports a four way laryngeal source distinction in stops.

(7/6) Laryngeal distinctions in Hindi:

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>[p]</td>
<td>voiceless unaspirated</td>
<td>/p UH/ [pɔndɪt] ‘wise man’</td>
</tr>
<tr>
<td>[pʰ]</td>
<td>voiceless aspirated</td>
<td>/pʰ UUl/ [pʰul] ‘flower’</td>
</tr>
<tr>
<td>[b]</td>
<td>voiceless unaspirated</td>
<td>/b UH/ [bəndər] ‘monkey’</td>
</tr>
<tr>
<td>[bʰ]</td>
<td>breathy voiced</td>
<td>/bʰ UH/ [bʰalu] ‘beer’</td>
</tr>
<tr>
<td>[t]</td>
<td>voiceless unaspirated</td>
<td>/t UH/ [tərikʰ] ‘date’</td>
</tr>
<tr>
<td>[tʰ]</td>
<td>voiceless aspirated</td>
<td>/tʰ UH/ [tʰɔɾa] ‘lille’</td>
</tr>
<tr>
<td>[d]</td>
<td>voiceless unaspirated</td>
<td>/d UH/ [dulha] ‘bride groom’</td>
</tr>
<tr>
<td>[dʰ]</td>
<td>breathy voiced</td>
<td>/dʰ UH/ [dʰəɾja] ‘patience’</td>
</tr>
<tr>
<td>[k]</td>
<td>voiceless unaspirated</td>
<td>/k UH/ [kam] ‘work’</td>
</tr>
<tr>
<td>[kʰ]</td>
<td>voiceless aspirated</td>
<td>/kʰ UH/ [kʰu:n] ‘blood’</td>
</tr>
<tr>
<td>[g]</td>
<td>voiceless unaspirated</td>
<td>/g UH/ [gaɾjək] ‘singer’</td>
</tr>
<tr>
<td>[gʰ]</td>
<td>breathy voiced</td>
<td>/gʰ UH/ [gʰəɾ] ‘house’</td>
</tr>
</tbody>
</table>

The examples of Hindi stated above are indicative of the fact that the full set of laryngeal contrasts is supported in the inherently strong word initial position. This is true for the stop
system as a whole, including labial, dental, velar series. In the interpretation of \([b^h]\) we have seen that the headed elements /H/ and /N/ are present in the same consonantal representation. Thus it can be shown that these sort of segments combines the full properties of /N/ and the aspiration properties /H/ within a single melodic expression. So in the above data \([b^h]\), \([d^h]\) and \([g^h]\) are characterized by two headed elements and such double headedness tends to give such expressions a relatively marked status in consonant inventories. In Element theory it is noted that headedness enhances a segment’s melodic strength and it should be correlated with prosodically strong positions. Even it is seen that the process of lenition targets the very source of the expression’s melodic strength, namely its headed elements. For convenience, consider the data on Hindi morphological concatenations:

(7/7) Effects on morphological concatenations in Hindi:

\([sath]\) ‘in the company of someone’ + \([dek^b\text{a}]\) ‘seeing’ \rightarrow sad-dek\text{a}

\([pa:c]\) ‘five’ + \([\text{guna}]\) ‘times’ \rightarrow pa:j-\text{guna}

\([\text{Jub}^h]\) ‘pious’ + \([\text{kam}]\) ‘deed’ \rightarrow \text{Jub}-\text{kam}

\([sa:t]\) ‘seven’ + \([b^b\text{ai}]\) ‘brother’ \rightarrow sa:d-b^b\text{ai}

\([b\text{b}^h]\) ‘greed’ + \([t^b\text{ra}]\) ‘less’ \rightarrow bb-t^b\text{ra}

\([\text{band}]\) ‘closed’ + \([k^b\text{irki}]\) ‘window’ \rightarrow band-k^b\text{irki}

In the above data the morphologically complex forms contain medial CC sequences in which the second consonant position justifies full laryngeal properties whereas the first one is prone to alternation. This asymmetry as exhibited between the two consonantal segments can be explained with reference to the unequal prosodic status of two respective positions. Since the second consonant occupies the strong prosodic position- that is the domain initial position so it resists change and exhibits the laryngeal contrast in a full fashion. Hence the consonant in that position allows any headed expressions (containing /N/ or /H/ or both) to be interpreted in full. In contrast the first consonant in the CC sequence occupies the prosodically weak
position, that is the domain final position where we have observed that the headed /H/ loses its headedness and just neutralizes to /H/. Thus the above set of data on Hindi morphological concatenation bears ample testimony to the fact that there lies a one to one correspondence between headed/nonheaded melodic expressions and weak/strong prosodic strength.

7.2 h-deletion in Hindi and the notion of phonological strength:

This section is an attempt to interpret the notion of phonological strength in the light of the asymmetric behavioural pattern that /h/ displays in Hindi, an Indo Aryan language. The phenomenon of h-deletion in coda position in certain varieties of Hindi is illustrated here in order to substantiate the argument of positional asymmetry in phonological patterning in human languages. This hypothesis is also explicated with acoustic data using PRAAT.

In Indian languages /h/ is known to play a significant role in inducing phonological change (cf. e.g. Chatterji 1960, Vajpeyi 1981). It is the only sound which gets its reference in Paninis Pratyaharas- in one of them it occurs alone. The loss of medial [h] and of aspiration in voiced sounds in Punjabi has given rise to substantial change in Punjabi phonology (Chatterji 1960: 113-14 and Hock 1986 with reference). In East Bengali /h/ has become a glottal stop, among other related changes (Chatterji 1960:112-13). Pandit (1957) claims that Gujrati has acquired murmered vowels under the influence of medial [h] (which is lost) and of voiced aspirates. In the same way in Chaddho, an American Indian language described in Chafe 1968, [h] is lost if followed by a sequence of two consonants, and a preceding vowel gets stressed. In the same way in Gitskan dialect of Tsmishian (Anderson 1974: 175-178), [h] is subject to deletion in the intervocalic position, leading to the lengthening of short vowel. Pandey (1992) claims that /h/ is about to be lost after /a/ word finally, before consonant, and before /a/, but not before other vowels in some varieties of Hindi. According to him, fronting of a preceding schwa can function as a way of leaving a trace of its loss in the language., just like murmer in Gujrati, tone in Punjabi, stress in Chaddho, and vowel lengthening in Gitskan Tsimshian. On the basis of the comparative evidence of other languages, Pandey (1992) the loss of /h/ after a fronted schwa, or rather after [c] < /a/, is a common feature in some varieties of western Hindi and of Rajasthani, giving rise to forms such as [pe:la:] for /pəhla/ ‘first’, [ke:na] for /kəhna/ ‘to say’, etc. The loss of Hindi takes place even in standard Hindi is already registered, as manifested in the example [ce] or [ce:] < /cəh/ ‘six’. 183
Consider the data showing optional loss of word final /h/ in the numeral forms of Shekhawati (Gusain Lokhan 2001):

(7/8)
gyaräh > gyara ‘eleven’
baräh > bara ‘twelve’
teräh > tera ‘thirteen’
cɔːdɔh > cɔwɔda ‘fourteen’
pɔndräh > pɔndra ‘fifteen’
sɔdɔh > sola ‘sixteen’
saträh > sattara ‘seventeen’
aʈʰaräh > aʈʰara ‘eighteen’

7.2.1 Acoustic properties of h in different prosodic contexts:

In this section I am going to discuss different acoustic properties of the segment ‘h’ in Hindi in different positions in a word such as word initial and word medial position. The debate concerning onset coda asymmetry in regards to phonological patterning of segments can be related with the acoustic properties as exhibited by ‘h’ in different prosodic contexts in Hindi.

This section also focuses on the assumption that there must be a correlation between specific articulatory states and gestures and specific acoustic cues thereby implying the notion that for a feature to get its phonetic manifestation its defining acoustic attribute must be present in the signal. Both acoustic and articulatory structures of speech are instrumental in the definition of phonological features. In this context mention can be made of Quantal theory of speech, developed by K.N.Stevens and his colleagues (e.g. Stevens 1989, 2002, 2003, 2005; Stevens and Keyser 2010). This theory gives equal status to acoustic, auditory and articulatory dimensions of spoken language. According to Quantal theory there are phonetic regions in
which the relationship between an articulatory configuration and its corresponding acoustic output is not linear. Stevens and Keyser (2010) claim that the defining acoustic attributes of a feature are a direct consequence of its articulatory definition. As, for instance, for a feature to be recovered from a speech event we have to consider not its articulatory condition but also acoustic definition which has to be satisfied.

The segments in different positions exhibit different articulatory gestures which can be further explicated and supported with the acoustic properties as displayed by the segments using PRAAT. Phonology in the recent decades tries to amalgamate articulation and acoustics. A segment can be said to bear a feature at the phonetic level only if it satisfies both its articulatory and acoustic definition. As, for instance, in literature it has been shown that an articulatory definition of the feature [+spread glottis] in terms of single common glottal configuration is inadequate to characterize the process of aspiration. In fact, different glottal sizes and different interarticulator timing of laryngeal and supralaryngeal gesture can result in aspiration. From this perspective aspirated segments can be characterized in terms of both acoustic and articulatory dimensions. Articulatory presence of a glottal noise source and acoustic presence of aspiration noise, that is aperiodic energy in the second and higher formants can attribute the feature [+spread glottis]. Ridouanne et al (2010) claim that timing relation is not an important parameter in specifying the process of aspiration. VOT is no longer an important correlate of aspiration. Aspiration is characterized by greater laryngeal noise which can be treated as greater opening in articular terms. In acoustic parameter aspiration is marked by the presence of formants such as $F_1$ and $F_2$.

In this section the main aim lies in finding out the asymmetry of acoustic properties of segments in different positions, such as onset and coda. For illustration of this point the segment ‘h’ is taken in to consideration keeping in consonance the phonological change this segment induces in Indian languages. The loss of h in coda position is evident in some varieties of Hindi, as mentioned in the previous section. This observation in articulatory phonetics can be supported further with the help of acoustic correlates of the segments.

A study reported in Pandey, Dutta and Mahesh (in preparation) shows that ‘h’ in word initial and word medial position in Hindi display different acoustic properties. In the same fashion ‘h’ in onset position and ‘h’ in coda position in Hindi are characterized by asymmetric acoustic features. The fact that positional asymmetry is crucial in the patterning of segments
is supported by this observation. Here, the positions considered for investigating the acoustic properties are as follows:

(7/9)

a) h in word initial position, as in [hathi], [həvəi].

b) h in word medial position. In medial position the behaviour of h is observed in different contexts:
   i) when it is followed by low back vowel 'a', as in [suhana].
   ii) when it is followed by obstruents after schwa, as in [məhta].
   iii) when it is followed by sonorant nasal after schwa, as in [gəhna].

The study was based on six Hindi Native Speakers. All speakers were over the age of 22; all of them are native speakers of Hindi from Delhi. Hence it has become easy on our part to have uniformity in the data sample. The Data was recorded in advanced studio Lab in JNU, without any background noise. High quality Digital wav Voice Recorder Roland-09HR has been used for recording the data with sampling frequency 44.1kHz which helps in the accuracy of the data. The informants were given a story comprising of words with phoneme /h/ in different environments such as initial, middle and final etc. They were suggested to read the story as naturally they speak. The story is given in the Appendix I. Acoustic Analysis of the Data was completed using the Praat software designed by Paul Boersma and David Weenink (www.praat.org). Each word with /h/ phoneme has been separated for detailed analysis in different context. The following acoustic analysis has been done with detailed annotation as stated below:

a. Read the File

b. Annotate for phoneme tier and word tier

c. Edited the file

d. Accoustic Analysis

e. to measure the frequency

f. to display the spectrum

g. to measure the duration
The data were extracted from continuous speech. The informants are given a story in which the words containing ‘h’ in different contexts are incorporated. The acoustic properties of the data are investigated using PRAAT.

7.2.2 Result of the investigation:

It is clear from the observation that h in onset and coda position exhibit asymmetric acoustic properties. Word initial h in the words like ‘hathi’ and ‘havai’ exhibit distinct acoustic properties. Consider the following PRAAT pictures:

![Figure No 7/A: PRAAT analysis of Hindi word ‘hathi’](image)

![Figure No 7/B: PRAAT analysis of Hindi word ‘havai’](image)
Word initial and word medial ‘h’ followed by ‘a’ display same acoustic features. The reason for this symmetry may lie in the fact that in both the words (‘hathi’ and ‘suhana’) the segment ‘h’ assumes the onset position. Consider the PRAAT picture given below for convenience:

![PRAAT analysis of Hindi word 'suhana'](image)

Figure No 7/C: PRAAT analysis of Hindi word ‘suhana’

In these positions ‘h’ exhibit formants which are aperiodic in nature. ‘h’ in these positions is characterized by acoustic properties which can easily distinguish itself from surrounding vowels.

‘h’ in medial position followed by consonants after schwa display asymmetric acoustic properties depending upon the nature of the consonant such as sonorant or obstruent.

For convenience consider the word ‘mehta’ in PRAAT module:
From the PRAAT picture it is observed that 'h' has lost its formants which are present in word initial and onset position. In this position the acoustic properties pertaining to 'h' are lost. This position is characterized by less laryngeal noise. From this observation a generalization can be formulated that F1 and F2 are lost when 'h' is followed by obstruents.

What is interesting to observe that 'h' and following vowel get merged in intervocalic position when it is followed by sonorant nasals. In such words such as 'gehna' there is no separate time frame for h and the following vowel as the vocalicness continues.

Figure No 7/D: PRAAT analysis of Hindi word 'mehta'

Figure No 7/E: PRAAT analysis of Hindi word 'gehna'
From the above PRAAT representations some generalizations can be formulated:

The phonetic properties of ‘h’ are lost in certain contexts. It brings ample light upon the onset coda asymmetry in phonology. ‘h’ in the onset position exhibit aperiodic formants but these F1 and F2 are lost in the coda position.

Secondly the properties of ‘h’ are severely affected in the case of following consonants. So it can be argued that context plays a pivotal role in the strengthening or weakening process of segments. The following obstruent weakens ‘h’ by making it losing its formants. In contrast the sonorant nasal superimposes the formants of the vowel upon ‘h’.

7.2 Gemination and the notion of phonological strength:

In this section emphasis will be laid on the analysis of the phonological process of gemination from the perspective of segmental patterning and positional asymmetries. This section is divided in to various sub sections. The first sub section focuses on the process of gemination from the notion of phonological strength. A review of literature is attempted keeping in consonance the view of gemination as a process of fortition, especially in the framework of Head Driven Phonology. The next subsection takes in to consideration the debate of onset coda asymmetry in the light of Pali geminates which result as a process of assimilation from its Sanskrit counterpart. The third subsection is devoted to the analysis of the role played by liquids and glides in the process of gemination in Sanskrit thereby justifying the dictum that phonological patterning of segments has some bearings upon the segmental property.

7.3.1 Gemination as process of fortition:

The process of gemination can be considered as a process of fortition as geminate consonants are reported to resist lenition processes, even when occupying traditional lenition sites, where as single consonantal segment in the same locations readily undergo segmental weakening. Hayes (1986a) and Schein & Steriade (1986) have discussed about geminate inalterability thereby making a subdivision of a phonological representation into two parallel planes- a segmental layer that contains melodic specifications and a CV tier which typifies the prosodic status of the segment. Although the schemata of gemination as propounded by Hayes (1986a)
and schein & Steriade (1986) differ considerably, they share the common assumption that
geminates resist lenition as they contain a single melodic unit doubly linked to the timing tier.

This one to many relation that applies to long vowels and geminates is represented below:

```
x  x
  \     \p
   \ ---
```

Figure No 7/F: Representation of one to many relation in geminate

This inalterability hypothesis is responsible for the fact that the spirantization in Tigrinya
intervocalic velar stops does apply to an underlying singleton but not to a geminate (Hayes
1986a) as shown in the following illustrations of the data from Trigrinya:

(7/10)

?iti xalbi  ‘the dog’ (cf. kəlbi ‘dog’)

fəkərə  ‘boasts’ (* fəxərə, * fəxrə)

According to Hayes (1986) the weakening rule typifies a single association between the velar
melody and the CV tier, whereas the geminate structure contains two association lines. If the
rule’s structural description fails to be met, the rule itself can not apply and no weakening
occurs.

This resistance to lenition as exhibited by geminates can be shown in the framework of OT
developed in Kirchner (2000). The phenomenon is represented as a conflict between an effort
minimization constraint termed as LAZY and a set of faithfulness constraints which prevent
segmental weakening to take place. It can be argued that whereas LAZY induces lenition by
favouring a reduction in articulatory effort (i.e. downward shift along the strength hierarchy,
input-to-output faithfulness preserves the underlying specifications of those features typically
targeted by lenition processes. As an instance of the latter Kirchner uses IDENT [cont] to
refer to the I-O correspondence of the feature [continuant] which changes its value under
spirantization, thereby violating IDENT constraint. Depending on the differing ranking of
the constraints in question, LAZY and IDENT[cont], different possibilities are formulated as
shown below:
LAZY > IDENT [cont] : /aka/ → [axa]

IDENT [cont] > LAZY: /aka/ → [aka]

From the above schematic representation of OT constraints, it is evident that spirantization occurs when LAZY emerges as the winner in the conflict and IDENT [cont] is sacrificed in order that more highly ranked constraint LAZY can be satisfied. It also shows that individual grammars differ by their differing constraint rankings. By extending the inalterability hypothesis of gemination in OT account of lenition Kirchner (2000:535) espouses the assumption that “more effort is required to produce a geminate continuant consonant than a geminate stop.” In other words, the process of spirantization on geminate continuants results in a surface form, that is sub optimal in two respects. First, it involves greater articulatory effort than the alternative geminate stops- which amounts violation of LAZY. Secondly, it dissociates from its input form with respect to the feature [cont], which means a violation of the faithfulness constraint IDENT [cont]. This OT account is appealing only from the perspective of simplicity. According to Backley (2002) this inference drawn by Kirchner is not so clearly established. By refering to Kirchner, Backley (2002) continues by implying that “it seems plausible, however, that additional effort cost is associated with the precision involved in maintaining a steady state partial constriction [in the articulation of a fricative] for a prolonged [geminate] interval, as compared to a geminate stop.” (Kirchner 2000:536).

The reader is referred to as Rennison (2000) and van der Hulst & Riter (2000) for representative arguments against an OT analysis on gemination. Backley (2002) claims that OT imposes no restriction on the nature or the formulation of the constraints being used, as an instance of which LAZY constraint, proposed by Kirchner (1998) can be cited, which implies a tendency on the part of the speakers to minimize the effort required in articulating speech sounds. According to Backley (2002) laziness with articulatory precision does not define anything belonging exclusively to the domain of phonological knowledge; but it can be acclaimed as a characteristic of human behaviour in general, of which verbal communication is one of the manifestations. Hence, it can be argued that Kirchner’s OT account of geminate inalterability is filled with limitations, some of which stem from assumptions concerning the measurement of articulatory effort involved in the production of certain sound categories, whereas some problems can be traced back to more general issues.
pertaining to OT formalism. So geminate behaviour resisting lenition can be better interpreted in the framework of head dependent asymmetries (HDAs, henceforth), which has some bearings upon DP and GP. In HAD framework one element functions as the head of the melodic expression and licenses another component within the same segment.

7.3.2 Geminate and HDP:

The notion of Head dependent asymmetry as popularised in Head driven phonology (henceforth HDP) can be traced back to Dependency phonology, Particle phonology and Government phonology. In HAD, the head position can license a dependent position to its right and thereby form a constituent (licensing) domain. This notion of HAD s can be better interpreted in Head Driven Phonology developed in Dresher & van der Hulst (1998) and van der Hulst & Ritter (1999b). HDAs claim that the distinction derive from the inherent differences which are assumed to exist between head units and dependent units regardless of which particular units or which level of structure may be involved. Backley (2001) claims that the geminate fails to be targeted by dependent processes such as the loss of elements as perceived in lenition, instead retaining its head like properties and giving the appearance of inalterability. But now the issue which needs consideration is an explanation as how single consonants in weak positions are treated as dependents that undergo lenition whereas complex geminate consonants occupying same positions are analysed as head which resist lenition. In response to this issue Backley (2001) shows that singletons behave like dependents, while geminates behave like heads. Geminates can be represented as single melodic structure which is interpreted as the duration of two syllabic positions. It can simply be represented in to the multiple association of one melodic expression to two prosodic units. Geminate is represented as coda onset sequence illustrated below as a suitable representation of a geminate consonanat.
In the above representation of the geminate /atte/ the first portion is assigned to the dependent position of a branching rhyme. By virtue of being in a weaker position within an intra constituent licensing domain, it is licensed by the head position to its left. The second portion of the geminate also assumes dependent status as it occurs in the slot of an onset. In accordance with the GP conventions of prosodic licensing, this position creates an interconstituent domain where the nucleus occurring in the right assumes the head status and licenses the dependent onsets to its left. Both slots of the geminates are licensed by their respective domain heads. In addition, another asymmetric licensing relation can be established with reference to ‘coda licensing condition’ (Kaye 1990), which implies that the weak position of a branching rhyme must also be licensed by a following onset head in order to maintain structural well-formedness. In geminates the left hand side is directly licensed by the right hand slot as the relation as exhibited here is of inter constituent one. In the case of geminates the domain of licensing shares melodic material between the two respective positions. Backley (2001) claims that in consonance with the GP principles and other autosegmental framework it can be assumed that in geminates it is the dominant position to the right that contains the lexically specified melodic material, which is then associated or doubly linked to the left hand dependent position.
7.3.3 Onset and coda asymmetry: evidence from the data of assimilation on Sanskrit Pali geminates

Onset–Nucleus-Coda is considered as a sequential frame in Kiparsky (1979) has turned to be a unit of phonological representation that is assigned the status of minimum articulatory unit. However in literature evidence is found in favour of separating onsets from codas owing to the differences in their roles in phonetics and phonology (see McCawley 1968, Selkirk 1982, Browman and Goldstein 1989, 1991, Jun 1995 Lombardi 1995, Padget 1995). In the canonical syllable structure of the languages onsets are considered to be obligatory components whereas there is no language requiring an obligatory coda in its canonical syllable structure. Onsets must be released; codas, more often are unreleased. Onsets don’t bear any moraic weight, but codas may have moraic weight in quantity sensitive systems. The asymmetry between onset and coda lies in the fact that onsets allow more open classes of consonants than codas. The processes of strengthening such as aspiration and lengthening are assigned to the onset position whereas codas are subject to weakening processes such as devoicing. In the same fashion it is observed that the phonological phenomenon of deletion is more pronounced in the coda position where insertion is very rare. Consonants are inserted in the form of glides or glottal stops in many languages requiring obligatory onsets. The asymmetry evident in the behaviour of onsets and codas can be found in the uncontroversial observation that children acquire open syllables prior to closed syllables (see Locke 1993). Even in the babbling stage of language acquisition CV units are present; CVC units are found at the later stages. The Maximal Onset Principle in phonology which provides a favoured position to onsets as compared to codas in the world languages is implicated in the biological make up. Language change also bears ample testimony to the phenomenon of onset coda distribution in world languages. As, for instance, Bybee (2001) claims that CVC syllables are derived from CV syllables on account of a loss of vowels in CVCV sequence. The loss of schwa in the word final (see Srivastava 1968) and foot final positions (Pandey 1989) has given rise to CVC syllables from CVCV sequence. The ‘lost vowel’ hypothesis for the emergence of closed syllables can account for exceptional complex consonant clusters in certain languages. In this context mention must be made of Gondi (Andres 1977, Steever 1998) which shows asymmetry in the distribution of consonants at word edges and word internally. Gondi does not permit clusters at word edges and word internally, but medial clusters can comprise up to four consonants in the word medial position the reason for which can be attributed to the result of lost vowels in open syllables.
The onset coda debate can be analyses in relation to language evolution which stipulates the assumption that human linguistic ability originates in the emergence of human muscular control for articulation (see Liberman 2002). Even the proposal put forward by Carstais-McCarthy (1999) in relation to the special status of CV units can be subsumed under the rubric of human muscular control. It has been found that relatively more muscular control is feasible for consonants in the onset position than in the coda position thereby implying the notion that onsets have greater perceptual distinctness than codas. Pandey(2003) maintains that the preponderance of open syllables in world languages has its bearings upon the biological motivation of underscoring the increased resonance and greater muscular control over the production of syllables, a function which codas are not able to perform in an efficient fashion. Onsets are instrumental in achieving the targeted quality and resonance of the following vowels and thus they contribute as an intrinsic part of the minimal sequential unit of speech. Even the literature on psycho-neuro-linguistics studies on speech processing show that speakers of languages with both CV and CVC type syllables, show preference for the former. Orthography too plays a role in the processing. Derwing, Yoon and Cho (1993), in an word blend experiment found out that Korean speakers prefer CV type segmentation to VC type segmentation, although Korean has both types of syllables represented in their orthography, known as Hankul. The phonetic study conducted by Engestrand and Krull (2000) on Dutch spontaneous speech shows that inspite of the existence of VC syllables in Dutch, there is ample evidence of derived CV units which emerge as a result of phonetic processes, such as nasal deletion, vowel contraction, vowel epenthesis, cluster simplification etc.

Moreover, the tradition of akshara also drives home the supremacy of onsets over the codas. The line of demarcation between akshara and syllable is following a general distinction between the content and the frame units of speech (see e.g. Mac Neilage 1998). The chief motivation of both the akshara and the syllable lies in integrating the segments and are thus related to each other in terms of the general Elsewhere Condition, which is also known as Panini’s Theorem (e.g. McCarthy and Prince 1993). According to the interpretation of this theorem, the formation of more specific unit takes precedence over the formation of more general unit, the syllable. As the onset is the integral component of akshara so Panini’s theorem ensures the formation of maximal onsets prior to the formation of codas. From this it can be argued that the incorporation of akshara as an articulatory unit in phonology has an
advantage of explaining the asymmetry between onsets and codas and accounting for maximal onsets using Panini's theorem.

In this section I am going to consider some geminates from Pali and compare them to their Sanskrit counterparts. The data is extracted from Wilhelm (1955) A Grammar of the Sinhalese language.

(7/12)

<table>
<thead>
<tr>
<th>Pali data on geminates as a process of assimilation</th>
<th>Sanskrit root words</th>
</tr>
</thead>
<tbody>
<tr>
<td>atta</td>
<td>atma (soul)</td>
</tr>
<tr>
<td>ṣoṣṭa</td>
<td>ṣabdā (sound)</td>
</tr>
<tr>
<td>sattā</td>
<td>saptā (seven)</td>
</tr>
<tr>
<td>suṭṭa</td>
<td>supṭa (asleep)</td>
</tr>
<tr>
<td>guṭṭa</td>
<td>gupta (secret)</td>
</tr>
<tr>
<td>muṭṭa</td>
<td>mukta (free)</td>
</tr>
<tr>
<td>uṇkkat</td>
<td>uakra (curved)</td>
</tr>
<tr>
<td>patṭa</td>
<td>patica (pot)</td>
</tr>
<tr>
<td>jukkat</td>
<td>jukla (light)</td>
</tr>
<tr>
<td>lāggat</td>
<td>lagna (moment)</td>
</tr>
<tr>
<td>sābbat</td>
<td>sarba (all)</td>
</tr>
<tr>
<td>utṭa</td>
<td>ukte (this)</td>
</tr>
<tr>
<td>ukkata</td>
<td>utoke (orissa)</td>
</tr>
<tr>
<td>pakkat</td>
<td>pakua (cooked)</td>
</tr>
</tbody>
</table>
This Pali data on gemination are instances of assimilation when they are derived from its root Sanskrit. The close investigation on the Pali geminates drives home the point that mostly the segment on the onset position is not subject to change whereas the segment on the coda position is prone to change. Indeed the segment in the coda position assimilates to the segment in the onset position. As, for instance consider the following instances:

(7/13)

saptə (seven) > səṭə
guptə (secret) > guṭə
puḍgələ (person) > puggələ
səṭpuruʃə (good person) > səppuruʃə
uktə (this) > utə
tukələ (orissa) > utələ

Hence from the data on Pali it is revealed that whenever there are two adjacent obstruent clusters, one in the coda position and another in the onset position, the segment in the coda position assimilates to the following consonant in the onset position and thereby establishes the claim of positional privilege and onset coda asymmetry in distribution. But, what is interesting to observe that whenever the segment in the onset position is either liquid or nasal being preceded by obstruent in the coda position of the previous syllable the onset segment assimilates to the preceding coda segment. For illustration consider the following examples:
This phenomenon can be explained with reference to sonority parameter. We have already seen that whenever there are two adjacent segments of same sonority value, mostly onstruents, coda segment assimilates to the following obstruent in the onset position. But when the adjacent segments are of asymmetric sonority value, that is, liquids or nasals on the onset position and obstruents in the coda position, the former assimilates to the latter and thereby violates the dictum of positional privilege. It can be argued in the framework of complexity condition within the purview of Government phonology. A more complex segment is a better candidate to be assimilated whereas the less complex segment is susceptible to alternation.

7.3.4 Gemination as a process triggered by liquids and semivowels:

In this section I am proposing a problem that in Sanskrit gemination of obstruents is triggered by the following liquids and glides such as ʝ,ɻ,ɭ,ɥ but not other segments such as nasals and obstruents. Only the liquids and semivowels have the potential to trigger gemination to the preceding obstruents. As, for instance, consider the following examples in Sanskrit:

(7/15)

jeṭra - jeṭtra (here)

jeṭra - jeṭtra (there)
The reason behind the motivation for the process of gemination triggered by glides and liquids can be supported with cross linguistic observation. For convenience, consider the internal representation of a word ‘sætja’ (truth):

(7/16)

This internal representation can be made in two ways:

a) If we consider word internal stop as a better candidate for the coda position the representation will be as follows
b) In contrast, stop and liquids form well formed consonant cluster cross linguistically. From this perspective, the following will be the representation:

Figure No 7/H: Representation of word internal stop in coda position

From the above representations it is clear that either coda condition or well formed onset cluster condition will be fulfilled. But from cross linguistic evidence it is seen that alveolar and velar stops function not only as better candidates for the coda position in a word but also form well formed consonant cluster with liquids and glides. The fulfilment of these two conditions lies in the process of gemination of the stops as shown in the following representation:

Figure No 7/I: Representation of word internal stop in the onset position forming a cluster with following liquid

Figure No 7/J: Representation of word internal stop both in the coda and the onset position
But, what is interesting to note in this context that other sounds apart from these liquids and semi vowels do not have the potential to trigger gemination to the previous obstruent. As, for illustration consider the following instances:

\[
\begin{align*}
\text{santi} & - *\text{san.nti} \\
\text{J\~b\~d\~} & - *\text{J\~b.b\~d\~} \\
\text{m\~n\~d\~} & - *\text{m\~n.n\~d\~} \\
\text{atma} & - *\text{at.tma}
\end{align*}
\]

The motivation hidden behind the non occurrence of the process of gemination of the obstruents followed by nasals and obstruents can be assigned to the fact that obstruent and nasals do not serve as well formed consonant cluster. Hence, it can be argued that glides and liquids have the special property of being appropriate coda as well as a member in the onset consonant cluster resulting in the process of gemination. In addition, another generalization can be observed from the above process of gemination that the asymmetry in phonological processes can be attributed to the segmental properties and cross linguistic well formedness conditions.

7.1 Conclusion:

This chapter bears ample evidence to the issue that phonological strength of a segment can be correlated with the prosodic positions. Here we have seen that aspiration is attested in the archetypal strong environment of foot initial position or word initial position, but aspiration is susceptible to loss in the weaker positions such as in the foot internal position or the word final position. It implies that melodic strength and prosodic strength are complementary to each other. Prosodic strength or the positional strength stimulates the emergence of the melodic strength of a segment. This positional privilege is further reinforced from the acoustic analysis of Hindi sound ‘h’ in the onset and the coda position. The same segment ‘h’ in different prosodic positions exhibit different acoustic properties. In addition, the Pali data on geminates resulting as a process of assimilation in the course of development from Sanskrit also show the preponderance of onset over coda. In most cases, the segment in the onset position is retained whereas the segment in the coda position is subject to alternation or change. Even in this chapter it becomes obvious that segmental properties inherent in a sound
and cross linguistic well formed conditions also play a significant role in the triggering of certain phonological processes. In Sanskrit only the liquids and semivowels have the potential to trigger gemination to the preceding obstruents, but nasals and obstruents fail to do so. From such segmental behaviour it can be generalized that glides and liquids have the special property of being appropriate coda as well as a member in the onset consonant cluster resulting in the process of gemination unlike obstruents and nasals which do not constitute well formed consonant cluster.