Implications of Hindi Prosodic Structure

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1 Introduction

In this paper, we present the results of an investigation of prosodic structure in middle class Delhi Hindi (one of the western Hindi dialects). We combine evidence about four phenomena: stress, final vowel lengthening, gemination, and [v]-[w] allophony. Data from these sources come together to provide a picture of Hindi syllable structure and word structure. From a typological point of view, the most notable features are that the language permits syllables of up to three morae; that it minimizes onsets to a single consonant while maximizing codas; and that it permits degenerate syllables at the right edge of the word. We then present three alternative approaches to formalizing the prosodic system. One is based on the Generalized Alignment Theory of McCarthy and Prince (1993), as extended by Itô and Mester (in press). The second builds most directly on Bird's (1995) treatment of branching constraints. The third builds on context-free parsing and on findings in the cognitive psychology literature.

These three approaches have been selected because they present points of close comparison despite emanating from different frameworks. All are constraint-based approaches which treat licensing in terms of positive statements about how prosodic nodes are related to phonemes or features. The approaches differ in several inter-related respects: the basic predicate on which licensing is built (whether alignment or domination); the entities available in formulating constraints (whether edges of prosodic categories, whole prosodic categories, or arbitrary partial descriptions); and the overt or implicit use of disjunction to delineate the class of forms to which a constraint pertains. In the GA based approach, a simple edge-oriented constraint schema in combination with a limited use of disjunction engenders many constraint violations, which must be adjudicated by the overall architecture for combining constraints (adopted from Optimality Theory). The second approach can eliminate constraint violations by using quantification over sets of prosodic nodes, something which is not available in GA. Under the third approach, highly bundled constraints in combination with free use of disjunction give rise to an excess of violation-free analyses of individual forms. The challenge is to prioritize the various good analyses. Thus the comparison of the three approaches reveals the intimate connection between the formulation of constraints and the method for combining them. Indeed, establishing this connection was one of the major scientific contributions of the suite of theorems in formal language theory known as the Chomsky hierarchy (see Harrison 1978, Chomsky 1963). Any attempt to argue for a particular method of combining constraints without simultaneously formalizing the constraints is technically incoherent.

The paper is organized as follows. Section 2 provides a synopsis of the Hindi stress system, and the conditions for gemination and final vowel lengthening. Section 3 describes experimental findings on [v]-[w] allophony. Although several authors have previously noted that [v] and [w] appear to be allophones of a single phoneme (which we will represent using the Devanagari grapheme व), none have succeeded in developing a predictive rule. By gathering a comprehensive data set and by applying the moraic theory of the syllable, we have found that the distribution can be predicted. Section 4 discusses the interaction of [v]-[w] allophony with gemination and its consequences for the prosodic representations. Section 5 then proceeds to develop and compare the three theoretical analyses.

2 Stress, Final Lengthening, and Gemination

2.1 Weight and stress

The previous literature on Hindi syllable structure is agreed that Hindi syllables exhibit contrastive weight. Weight is related both to the vowel length and the occurrence of postvocalic consonants: Short vowels (/ə/, /ʊ/, /ɪ/) have one mora each. Long vowels (/a/, /e/, /i/, /u/, /o/) and diphthongs with their allophones (/əɪ/, /əʊ/; [æ], [ɔ]) have two moras each. Because we are adopting a constraint based approach, there is no implication about the direction of the dependence between length and quality of vowels. Postvocalic consonants within the syllable have one mora each. The maximum number of moras is three, with the result that the following patterns are possible:

(1) C µ	L(Light)	kə.la 'art', prə.veʃ 'entry'
C µ µ	H(Heavy)	ka.la 'black', kʊr.ta 'shirt'
C µ µ µ	S(Superheavy)	kaɳ.ʈa 'thorn' (restricted occurrence)

As shown in Hayes (1991), the three-way weight distinction is reflected in the stress patterns. Of the dialects that he discusses, the one with the closest stress patterns to those found in Delhi Hindi is that of Kelkar (1968). This dialect exhibits a competition between weight and position in the assignment of word stress.

We studied all the cases of stress in Delhi Hindi. In several cases, Delhi Hindi had initial stress where Kelkar's Hindi had it elsewhere. These differences can be explained by differences in foot structure which are not crucial here. Assuming this result, word stress in Delhi Hindi can then be assigned by (2), a minimal modification of Hayes' (1991) analysis of the Kelkar dialect:

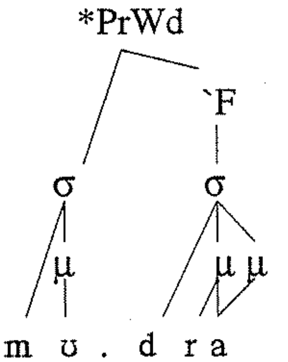
(2) Stress falls on the heaviest available FOOT, and in the event of a tie, the rightmost non-final candidate wins.

The foot in Hindi is trochaic, with a minimum of two (and a maximum of three) moras comprising it. Thus, for example, LL and H feet are both bimoraic while S, LLL and HL feet are all trimoraic.

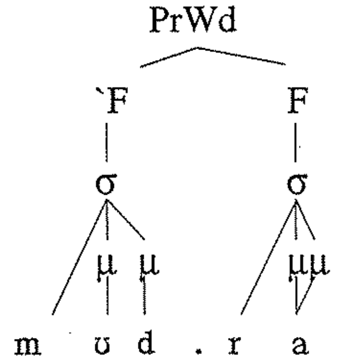
(3) L ˋH	/kə.ˋla/ 'art', /gə.ˋɳɪt/ 'mathematics'
ˋH H	/ˋka.la/ 'black', /ˋpəŋ.kədʒ/ 'lotus'
H ˋS	/ta.ˋlab/ 'pond', /məs.ˋtɪʃk/ 'brain'
ˋS H	/ˋʃan.ti/ 'silence', /ˋkʰod.na/ 'to dig'
ˋH L H	/ˋma.rʊ.ti/ 'make of a car', /ˋɪn.dɪ.ra/ 'a name'
ˋL L H	/ˋkə.vɪ.ta/ 'poem', /ˋsə.mɪ.ti/ 'committee'

Two consequences of the stress system will be critical to the subsequent discussion. First, Hindi syllables can have three moras; hence, the third mora can be used to parse segments in particular examples. Second, stress provides a test for how medial consonantal clusters are syllabified. For example, for the word [mʊdra] 'position', two syllabification alternatives [mʊ.dra] and [mʊd.ra] would give rise to the foot and word structures shown in (4):

(4) (a)



(b)



(In (4a), the parsing of /r/ under the first mora will be discussed in Section 4.)

The word actually has initial stress, indicating that it is parsed as HH rather than LH. Further examples of this type include:

(5) [`pək.ʃi] 'bird', [`tʃək.la] 'pastryboard', [`pʊt.ri] 'daughter'.

In all cases, medial clusters are divided so as to minimize the onset of the second syllable by parsing the first consonant as the final mora of the preceding syllable. This is the case even for clusters of rising sonority which many other languages would parse into the second syllable by a maximum onset principle.

2.2 Final Vowel Lengthening

Whitney (1889) and Pandey (1989) report that lax word-final vowels in colloquial speech are lengthened in word-final position. As a result, underlying lax vowels are neutralized with tense vowels, as illustrated in (6)-(7).

(6) Short vowel alternating with long vowel:

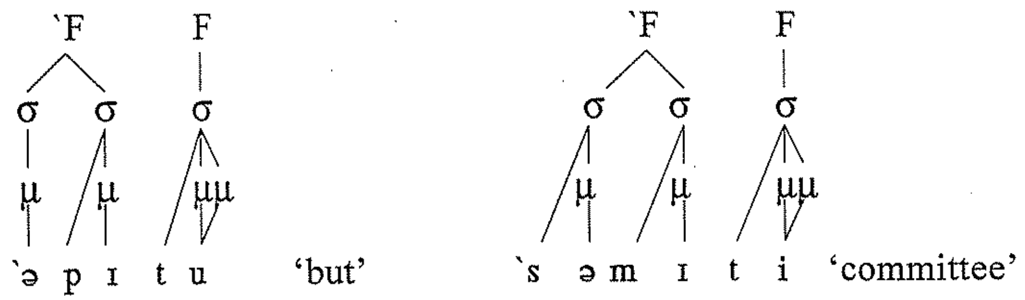
[rɪʃi]	'hermit'	[rɪʃɪkeʃ]	'name of a holy town'
[kəvi]	'poet'	[kəvɪta]	'poem'
[məd^{h}u]	'honey'	[məd^{h}ʊbən]	'name of a place'

(7) Invariant long vowel:

[gaɽi]	'vehicle'	[gaɽivan]	'coachman'
[tʃɔki]	'post'	[tʃɔkidar]	'watchman'
[abru]	'honor'	[abrudar]	'honorable'

We carried out a pilot experiment on the durations of underlyingly short and long vowels. In nonfinal position, the vowels exhibit a clear durational difference, whereas in final position no difference was observed. The lengthening appears to be obligatory in Delhi Hindi (in contrast to some other dialects). It is also the clear that the lengthening is phonological, because it feeds into the stress system. Words such as [rɪʃi] have final stress, reflecting the heaviness of the last syllable. Words transcribed by Kelkar as L`L L are pronounced in Delhi Hindi as `L L H. The final long vowel constitutes a foot in its own right, and the stress is on the first (L L) foot, as shown in (8).

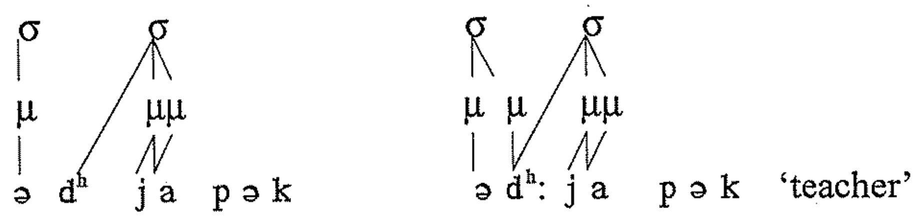
(8)



2.3 Gemination

This regularity (also reported by Pandey 1989) states that when the second consonant in a consonant cluster is a sonorant, the consonant preceding it (i.e. the first consonant) is subject to gemination. The alternation is exemplified in (9) using moraic notation:

(9)



(/j/ above is consonantal in the sense that it is not a vowel.)

Pandey does not explore the circumstances under which gemination is obligatory or optional. Our own exploration of this issue yields the following observations.

Gemination is impossible word-initially because initial consonants are not in a mora bearing position.

(10) [njaj] ⟶ *[n:jaj] 'justice'
[mrɪg] ⟶ *[m:rɪg] 'deer'

Gemination does not apply before vowels. Before vowels, the lexical contrast between underlying geminates and non-geminates is maintained. As an illustration, compare (11) and (12):

(11) [pəta] 'address' vs. [pət:a] 'leaf'
(12) [pəka] 'cook, imp.' vs. [pək:a] 'strong'

Gemination is variable for presonorant consonants in word-medial clusters, as in:

(13) [ədrək] ~ [əd:rək] 'ginger'
[kənja] ~ [kən:ja] 'daughter'

It is also optional when the triggering consonant is right at the word edge.

(14) [pətr] ~ [pət:r] 'letter'
[ənj] ~ [ən:j] 'other'

The status of this type of word termination will be very important for the analysis of [v]-[w] allophony. Regularities that we have already presented can be applied to show that words such as (14) end in degenerate syllables. In general, non-final Hindi syllables have a vocalic nucleus; sonorant consonants cannot stand as nuclei anywhere before the end of the word. However, the final consonants in (14) cannot be treated as vowels because they may trigger gemination of the preceding consonant; for vowels, as shown in (11) and (12), facultative gemination is impossible. Further support for the same point may be adduced from the failure of these final segments to undergo Final Lengthening. Although /j/ shares the high front articulation of /i/, it is not lengthened at the end of the word as /i/ would be.

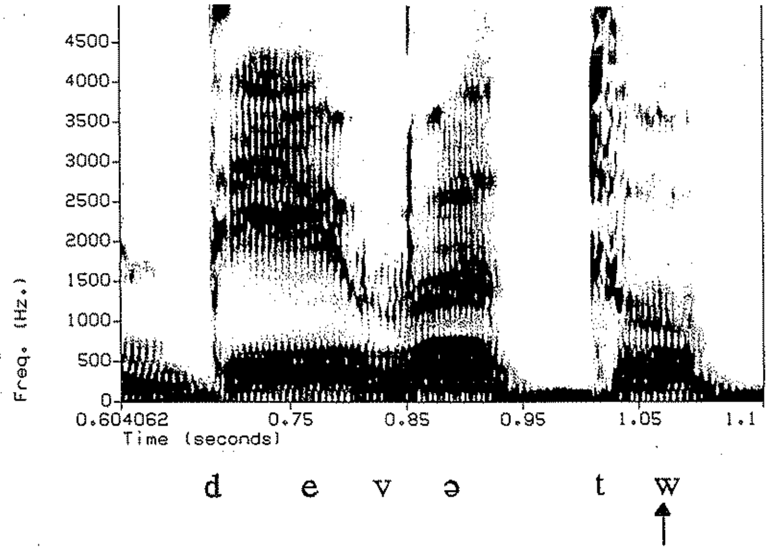
(15) /ənj/ → *[əni] 'other'
/cəkr/ → *[cəkr:] 'circle, wheel'

As shown in (16), the same is true for /व/.

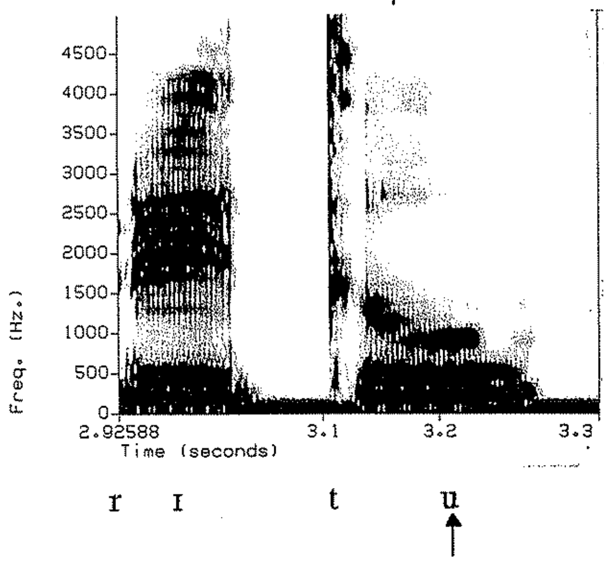
(16) /g^hənətव/ → [g^hənətw] 'density'
→ *[g^hənətu] 'density'

Despite being treated as consonants in these two respects, the final segments in (14) are sonority peaks. In spectrogram 1(a), representing the word /devətw/, the sonority of the final [w] is evident from the periodicity and formant structure. For comparison, 1(b) shows a spectrogram of /rɪtu/, which has a final /u/.

Fig.1 (a)

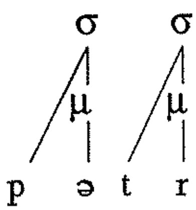


(b)

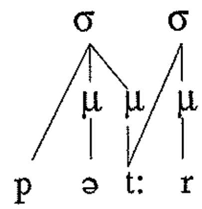


Because of their relative sonority, the final glides in (14)-(16) would, by general principles, project a mora. It is convenient to suppose that they project an entire syllable, since this assumption permits a standard representation of the geminate as dually affiliated to the last mora of one syllable and the onset of the next:

(17)(a)



(b)



3 [v]-[w] Allophony

Variation between [v] and [w] in Hindi has long been noticed; the Devanagari alphabet has a single grapheme for these two phones, /व/. However, none of the authors who take note of the alternation (Kelkar 1968, Kostic *et al.* 1975, Ohala 1983) have formulated a predictive rule, in part because all have been working with a segmentally oriented descriptive framework. The closest finding to ours is Mehrotra (1970). However, he does not study all the cases and does not bring syllable structure to bear.

We conducted a phonetic study to find the true nature of the [v]-[w] allophony. With the help of a dictionary search we tried to find all the possible prosodic positions for /व/. The quality of the adjacent vowels was also varied. Outcomes for 154 different words were determined.

Three native speakers of Delhi Hindi participated in the study. We made high quality recordings of their speech as they read sentences (written in Devanagari script) containing tokens of /व/. The sentences were sufficiently complex that the speakers did not realize what aspect of their speech was under investigation. Therefore, the data we obtained was real speech and not speakers' judgments about their own speech. We then analyzed the recordings with the help of a speech waveform editor and spectrograms. We also noted down lip-movement for cases that were not clear from the acoustic analysis. Rounding and protrusion of the lips indicates a rendition as [w], while the retraction of the lower lip indicates the rendition as [v]. Although the degree of closure varied gradiently, with many [v]'s showing only incomplete approximation of the lower lip to the upper teeth, there appeared to be a categorical difference between lip retraction for [v] versus protrusion for [w].

Figure 2 shows a spectrogram for a clear example of [w]. Note the low second formant and the complete lack of frication. Figure 3 shows a clear example of [v], with substantial high-frequency components due to turbulence created where the lower lip met the upper teeth. Figure 4 provides a spectrogram for an ambiguous case. There is no frication, but the second formant is not very low either. This case was resolved by listening to the signal and by noting the configuration of the lips.

Fig.2 Case of a clear [w]

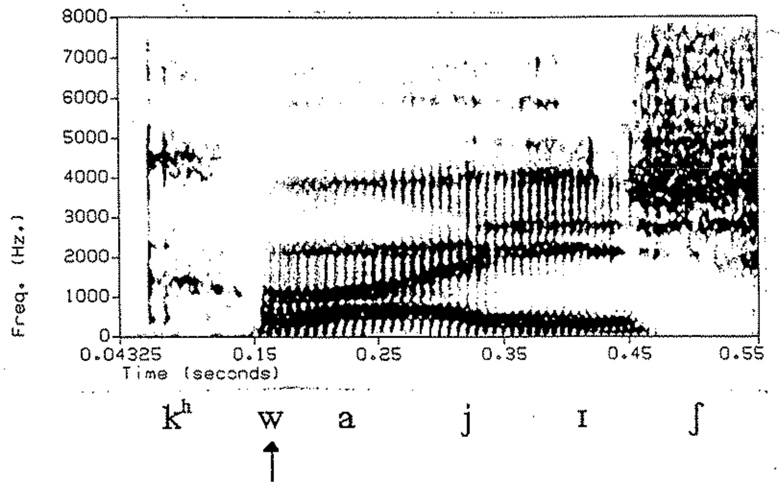


Fig.3 Case of a clear [v]

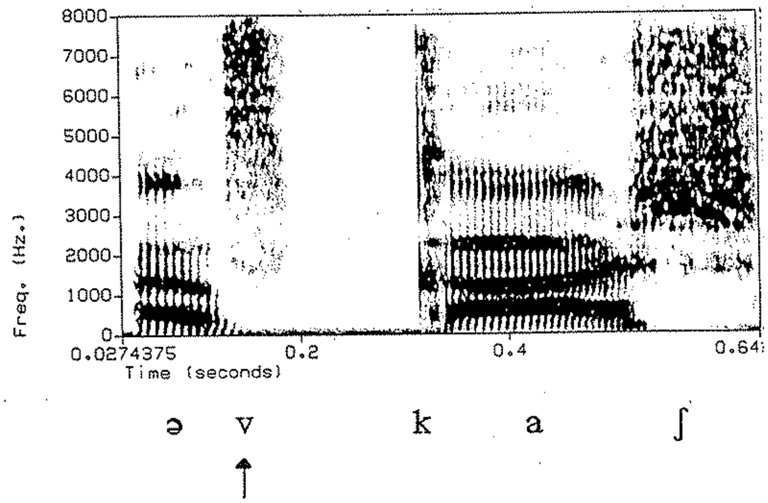
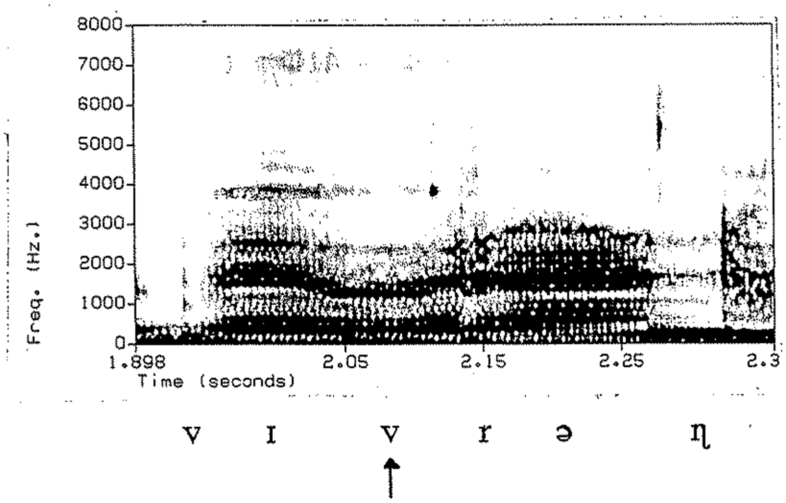


Fig.4 Case of an ambiguous [v]



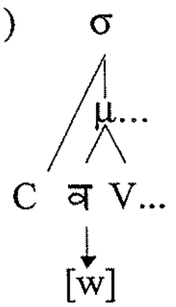
The data showed extremely regular patterns. As is not uncommon in a study of subphonemic detail, the objective data patterned more cleanly than intuitive judgments. No effect of vowel quality was observed, contra Kelkar (1968). Hence, we summarize our results according to prosodic position only. There are seven different relevant prosodic positions: Table I provides illustrative outcomes for each one.

Prosodic Position	/व/ rendered as	Examples
a. #__(C)V (no mora)	[v]	[vərdi], [vjət̪it]
b. #C__V	[w]	[swat̪ɪ], [dwip]
c. medial C__	[v] or [w]	[ədvæt], [ədwæt]
d. medial Gem__	[w]	[pək:wan] [əd:wæt]
e. 2ND OR 3RD μ	[v]	[əvtar], [gərv]
f. EXTRASYLLABIC	[v]	[purv]
g . C__# (C < sonorant than व)	[w]	[gʰənətw], [dwəndw] [gʰənət:w]

[Table I. *The result of the experiment according to the prosodic position*]

Our interpretation of these results is that [w] occurs when /व/ is in onglide position, under the first mora of the syllable (as in (18)),

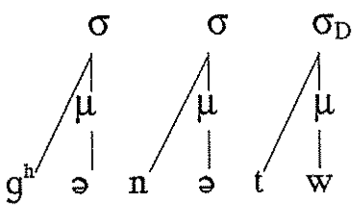
(18)



/v/ occurs otherwise. Note that the more sonorant allophone is posited when the segment is under the nuclear mora, and the less sonorant allophone, when the segment in other (MARGINAL) positions. For the significance of the nuclear (onglide) position versus the onset position for sonorants in other languages see Davis and Hammond (1995) and Hubbard (1995). Whitney (1889) reports a similar rule for Hindi (/व/ is rendered as [w] when it is preceded by a consonant in the same syllable, else it is rendered as /v/). However, he deals with the allophony rule only at the level of the syllable, and does not take the moraic structure into consideration. Secondly, his rule falsely predicts that /व/ under the third mora would be rendered as [w] as in /gərव/. Although pronunciation may have changed since 1889, we suspect that Whitney's observation was erroneous.

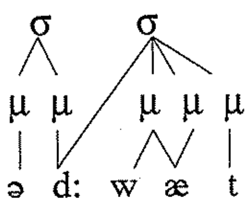
The onglides arise in three different ways. When /व/ is a sonority peak at the end of the word, it projects a degenerate syllable just as the other sonorants discussed in (14)-(17) do. (19) exemplifies another case of word-final degenerate syllable:

(19)



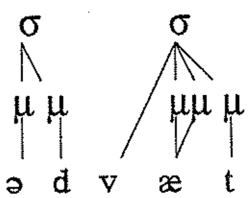
Medial gemination also puts /व/ into the onglide position, since the geminated consonant takes up the single available onset position in the second syllable, as portrayed in (20):

(20)



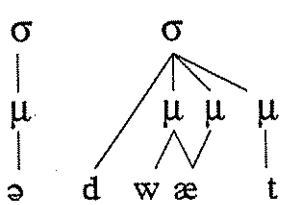
In contrast, in medial Cव clusters, general principles of Hindi syllable structure (disfavoring complex onsets) place /व/ in the onset and C in the last mora of the preceding syllable, as shown in (21).

(21)



Pronunciation with a singleton consonant and an onglide [ẇ] is also possible; that is, the form can be parsed with a non-moraic /d/ and a /व/ in onglide position, as in (22).

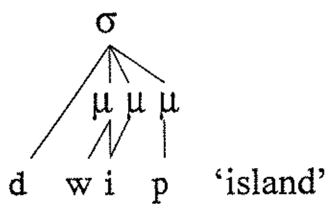
(22)



Variability in the prosodic parse, as in (20) versus (21) and (22) explains why some tokens of words such as [pʊlɪsवala] and [jʰagवala] were read with a [v] and some with a [w].

When a cluster is word-initial, dividing it between two syllables is not a possibility. Hence, just as for geminates, the /व/ is found in onglide position.

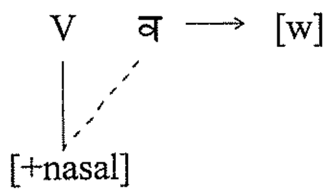
(23)



In all other prosodic positions listed, /व/ is not in onglide position. It is either a syllable onset ([vərdi] 'uniform' and [vjətit] 'past'), under the second or third mora rather than the first ([əvtar] 'incarnation' and [gərv] 'pride') or stray at the end of the word ([purv] 'before').

Our main generalization covers 148 out of 154 cases, which amounts to 96.1% of the forms studied. A small group of exceptions involving a preceding adjacent nasalized vowel suggests that /व/ may be rendered as [w] even in nonnuclear position if nasalization has spread from a preceding vowel.

(24)

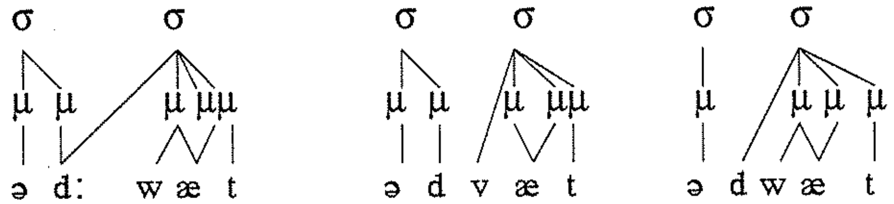


The minor rule (24) is probably related to the fact that nasal fricatives are aerodynamically difficult or impossible, because escape of air through the nose interferes with the buildup of pressure at an oral constriction. With this rule, the coverage of our data set increases to 99.4%.

4 Interaction of Gemination with [v]/[w] Allophony

An interaction of [v]-[w] allophony with gemination arises through the mediation of the Hindi syllabic template. In medial position, the optionality of gemination is associated with optionality in the pronunciation of /व/:

(25)(a) (b) (c)



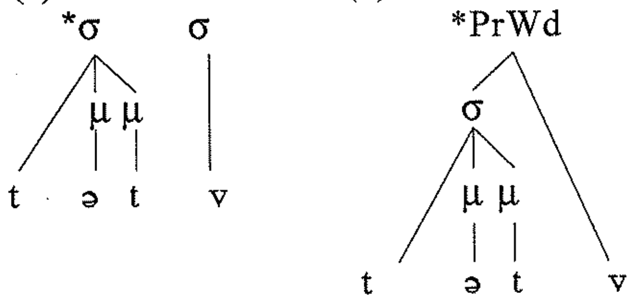
In case of gemination /व/ is always rendered as [w], otherwise it can be rendered either as [w] or as [v].

For similar combinations in final position, there are two outcomes, containing a consonant plus a [w].

(26) (a) (b)

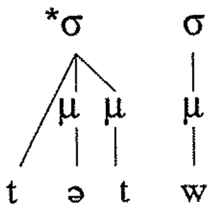
[tətv] is not found; it would correspond to the parses in (27).

(27) (a) (b)



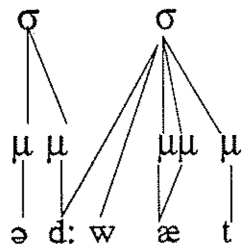
We also presume that (28) is ill-formed, because the last syllable does not have an onset even through a prenuclear consonant was available.

(28)



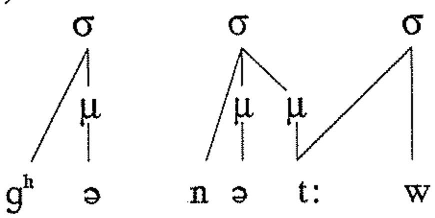
Having noted this interaction, we are now in a position to explain why we have rejected an obvious alternative to our formulation of the [v]/[w] allophony rule. The alternative formulation would hold that when pronounced as [w], the phoneme has been parsed as an (optional) second consonant in the onset, rather than as an onglide. [v] again figures as the default. (29) provides an illustrative parse for this formulation using moraic theory, in which two onset consonants are parsed as direct dependents of the syllable.

(29)



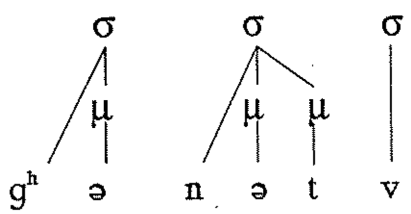
Either (29) or any of its close relatives would have the consequence that word-final [C:w] combinations are parsed with a bare onset and no material in the rhyme.

(30)



Under this account, it is extremely difficult to explain why the alternative parse in (31) is impossible, with /व/ appearing as a bare onset.

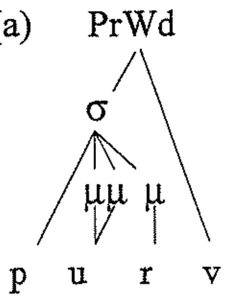
(31)



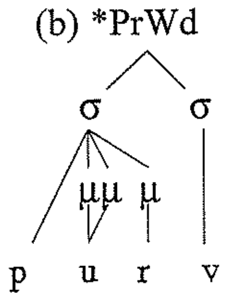
Note (by comparing (31) to (5b)) that Hindi in general permits a more sonorant onset to follow a less sonorant coda. Under our account, the differential acceptability between (30) and (31) follows from the fact that the final /व/ is a sonority peak and hence must project a head mora; this account relies on the claim that [w] is dominated by a mora.

On similar grounds, we propose (32a) over (32b):

(32) (a)

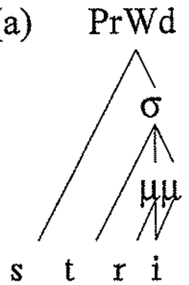


(b)

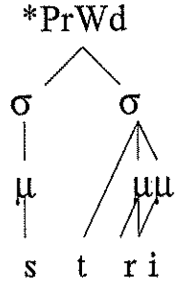


That is, when the /व/ is not a sonority peak, it is a direct dependent of PrWd (as proposed in Rubach and Booij 1990 for Polish). If (32b) were admitted, it would again be problematic to rule out (31). PrWd also parses an "extra" /s/ or /k/ at the beginning of the word; (33a) is correct, not the technically conceivable (33b).

(33) (a)



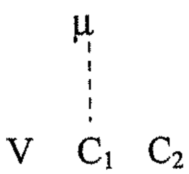
(b)



Two key observations about the prosodic grammar of Hindi are needed to describe the pattern of interaction just sketched. In order to lay groundwork for the comparison of theoretical models which follows, we state these observations in partially formalized fashion now; however, their reappearance in some approaches will be in a completely different guise. One observation, already mentioned in passing, is that every sonority peak projects a head mora and hence a syllable. Equally, every syllable has a sonority peak. There are no syllables containing only a coda consonant or only a bare onset. Insofar as syllables with a bare onset are justified in the description of other languages (such as French, see Dell 1995), a dimension of parametric variation amongst languages must be presumed.

The second observation is that Hindi optionally projects a mora for any post-vocalic consonant which precedes another consonant, as shown in (34):

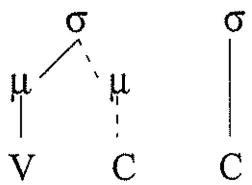
(34)



Inspired by Hayes (1989), we call (34) "Turbo Weight-by-Position". (34) may apply even when the V is bimoraic and even if C_1 is independently parsed as an onset. (34) is necessary to provide an account of why [əd:wæt] in (25a) is possible, similarly [tət:w], as in (26b).

(34) should be compared to Hayes' original formulation of Weight-by-Position, which projects a mora over a single post-vocalic consonant when that consonant is not independently syllabified as an onset. For the sake of comparison, Hayes' Weight-by-Position may be summarized as follows:

(35)



Weight-by-Position operates as a default, projecting a mora only over a consonant that is not in an onset; Turbo-Weight-by-Position is always applicable. Weight-by-Position, as per Hayes' discussion, can ordinarily create a second mora in its syllable but not a third mora; Turbo-Weight-by-Position can create either a second or a third mora.

5 Three theoretical approaches

5.1 Generalized Alignment

Having developed a semi-formal description of Hindi syllable structure as it relates to stress and allophony, we are now in a position to explore the consequences for current theoretical models of licensing and parsing. We compare three approaches. One approach uses Generalized Alignment constraints as proposed by McCarthy and Prince (1993) and extended in Itô and Mester (in press). The second relies most heavily on branching degree constraints, as formalized in Bird (1995). The last follows Bird in treating licensing through dominance, but uses a verbose context-free grammar to tie together parsing preferences.

Generalized Alignment may be viewed as an all-autosegmental approach to licensing and parsing. For one, superordinate and subordinate phonological categories are treated absolutely on a par. Second, the predicate which determines well-formedness is relative alignment (rather than dominance). An important feature of the approach is that constraints refer only to edges (though Pierrehumbert 1994 also argues for an extension to permit reference to heads). This means that no single constraint will refer to the entire extent of a prosodic node. For example, no single constraint could deal with the left edge, the right edge, and the head of a metrical foot all at once.

Bird's work on branching degree provides an all-metrical approach to licensing and parsing. The critical predicate is dominance, which is antisymmetric (though Bird also formalizes the concept of autosegmental association in other applications.) A constraint stated in terms of dominance is indifferent to where under the superordinate node the subordinate element appears; dominance constraints do not single out edges. (Other types of constraints do single out edges). Like GA, Bird's treatment inherits from the literature on constraint-based syntax the concept of a constraint as a partial logical description of a structure. Both approaches propose general logical schemata whose instantiations provide actual constraints operative in grammars.

The third approach, which directly applies context-free grammars, shares with Bird's the use of dominance as the central concept. However, instead of unbundling the dominance relations into logical schemata, it keeps them bundled up into entire templates. This bundling is used to reconstruct the concept of a dominant scansion level, which is active in parsing preferences. In Hindi, the dominant scansion level appears to be the syllable.

One technical theme running through this comparison is the degree of bundling of different information contributing to well-formedness. GA constraints are very atomistic; Bird's constraints are more bundled by virtue of quantifying over sets of nodes rather than single node types. The last proposal has the most bundling of all, providing templates which cover the entire extent of each node.

A related issue is that of overt or effective disjunction in the grammar. GA was developed within the framework of Optimality Theory, which has the appearance of an all-conjunctive control structure. That is, in general all constraints are met at every point in every form; Constraint 1 is true, and Constraint 2 is true, and Constraint 3 is true, etc. The conjunctive control structure is modified only by the prioritization needed to handle constraint conflicts. However, there are in effect two ways for a constraint (or partial description) to be met at a location in a form. A constraint such as "All features of type [+voice] are in onset position" is equivalent to the statement "If a feature is [+voice], then it is in onset position". Via the standard interpretation of the material conditional (see Quine 1972), this is in turn equivalent to "Either a feature is not [+voice], or it is in onset position". In /ba/ the constraint is met because both the antecedent and the consequent of the material conditional obtain, but in /sa/ the constraint is met because the antecedent fails. Because of its use of universal quantifiers, GA in effect brings in disjunction; indeed there is no known viable approach to linguistic description which completely lacks disjunction. An important issue, then, is whether the specific use of disjunction in GA is the correct one. Declarative Phonology, the framework in which Bird is working, makes different claims about the proper use of disjunction. Context-free parsing provides disjunction over templates in a fashion which is unavailable in GA.

5.2 Generalized Alignment

Optimality Theory, as described in Prince and Smolensky (forthcoming) posits a framework for combining constraints without making a strong commitment to the form of the constraints. A specific proposal about the form of a major class of constraints is found in McCarthy and Prince's (1993) paper "Generalized Alignment", which deals with the problem of aligning phonological categories (such as syllables, feet and prosodic words) both with each other, and with morphosyntactic categories. For present purposes, the key ingredients of this proposal are the following:

Alignment constraints have a fixed form:

(36) Align (Cat_1, $Edge_1$, Cat_2, $Edge_2$)

(36) is read as "For all instances of Cat_1, there exists a Cat_2 such that $Edge_1(Cat_1)$ and $Edge_2(Cat_2)$ coincide."

In (36), Cat_1 and Cat_2 are bona fide prosodic or grammatical categories, drawn from the (reasonably short) list provided by universal grammar. The quantifiers in (36) are of fixed types and in a fixed scope relationship. That is, the schema does not provide for constraints which would be read as "For all Cat_1 and for all Cat_2 ..." or "There exists a Cat_1 such that for all Cat_2 ..." Similarly, there is no provision for Boolean conditions inside the scope of the quantifiers. Hence, there are no constraints such as "For all Cat_1, there exists a Cat_2 or a Cat_3 such that ..."

Constraints in OT can be either positive or negative. An example of a positive constraint is the constraint ONSET, which is formalized in Generalized Alignment as (37). (In cases in which the two edge arguments are the same, we henceforth follow Itô and Mester's (in press) notation in which the edge argument is folded into the name of the function.)

(37) AlignLeft(σ, C)

"All syllables are left-aligned to a consonant". Examples of negative constraints are NO-CODA and *COMPLEX. NO-CODA is a constraint against syllables which have a consonant in the coda. Constraints of the *COMPLEX family disfavor nodes with branching.

The constraints proposed in Generalized Alignment are entirely positive. This is an attractive feature of the theory, because negative generalizations have a marginal cognitive status. As suggested in McCarthy and Prince (1993), the negative constraint NO-CODA can be formulated positively using the GA schema (38). This reformulation relies on the complementary status of vowels and consonants: "Don't end in a consonant" means the same thing as "End in a vowel".

(38) AlignRight (σ, V)

Turbo-Weight-by-Position (34 above) cannot be immediately cast into GA format in this way. For one, constraints in OT are supposed to be universal and there is at present no evidence that Turbo-Weight-by-Position is universal. More significantly, in Turbo-Weight-by-Position the triggering structure (VC_1C_2) is not a prosodic category; it bridges part of one syllable and the beginning of the next. GA makes no provision for a universal quantification of such a structure. Furthermore, the existentially quantified element (the mora above C_1) is not aligned with either edge (nor even the head) of the triggering structure.

As a result, the straight GA style analysis of Hindi which is attempted in this section must forego Turbo-Weight-by-Position as such, and achieve the same results through the interaction of other constraints. An avenue is suggested by Itô and Mester's (in press) reformulation of *COMPLEX, specifically of *COMPLEX (onset). What they propose is a mirror image of ONSET (37 above), namely (39).

(39) AlignLeft(C, σ)

Because (39) reverses the quantification of (37), (37) and (39) together state that all syllables begin with a consonant and all consonants begin syllables. The only strings which violate neither constraint are strings of CV syllables. On its own, (39) amounts to the (sole) licensing condition for consonants in a language with CV syllable structure.

(39) is stronger than the original version of *COMPLEX. *COMPLEX (onset), for example, intuitively disfavors branching onsets while saying nothing about other positions for consonants. (39), in contrast, has the consequence that C's are favored ONLY in onset position. In Hindi, more must be said because there are several other allowable positions for consonants: extra-syllabic at the beginning of the word; in onglide position under the first mora; as the second or third mora; extra-syllabic at the end

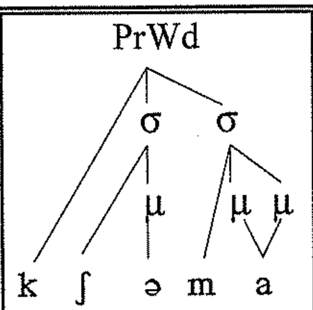
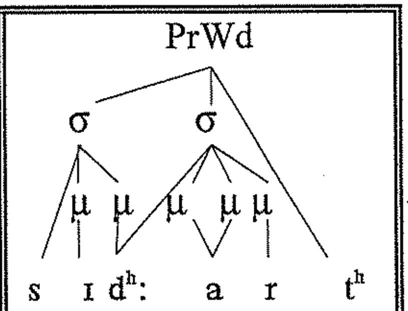
of the word. All of these are better than the truly bad positionings which would render a form unsyllabifiable. Extending Itô and Mester's (in press) proposal to accommodate these cases would lead to the following set of constraints, amounting to a summary of all the positions that license consonants.

(40) AlignLeft(C,σ)
AlignLeft(C, PrWd)
AlignLeft(C, μ)
AlignRight(C, PrWd)

(40) takes advantage of the fact that a C is leftmost in a mora if it is the only thing in a mora; hence, all moraic affiliations can be treated uniformly.

When the constraints in (40) are applied to parse ordinary words of Hindi, massive violations result because only a few consonants meet more than one licensing condition. For example, the following OT tableaux would be found for the words [kʃəma] 'forgiveness' and [sɪdʰ:artʰ] 'Buddha's pre-enlightenment name', whose prosodic structures are as shown in (41).

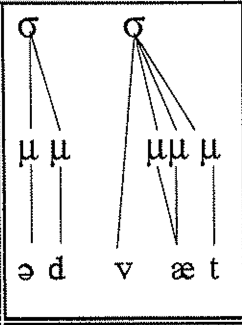
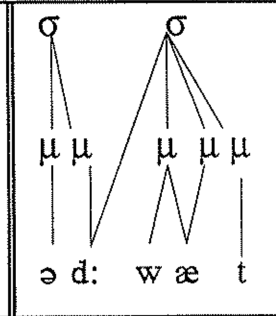
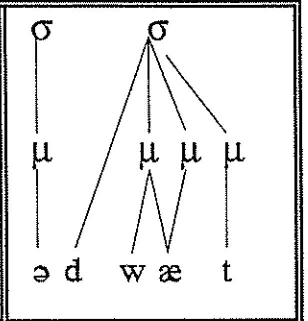
(41)

		
AlignLeft (C, σ)	*	* *
AlignLeft (C, μ)	* * *	* *
AlignLeft (C, PrWd)	* *	* * *
AlignRight (C, PrWd)	* * *	* * *

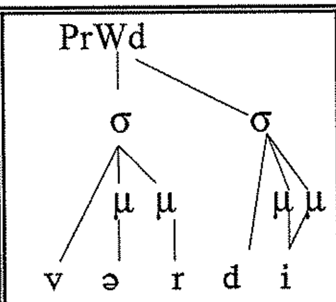
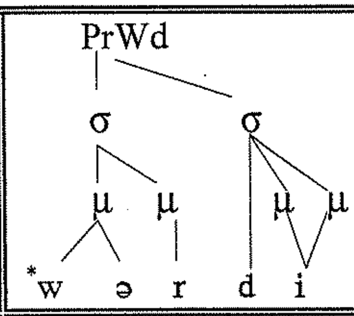
We believe that many of these constraint violations are spurious, in the sense that they arise from the interaction of the particular formulation of the constraints with a conjunctive control structure. However, OT is not concerned with constraint violations per se, but rather with relative constraint violations. The outcomes displayed in (41) are not problematic, provided that no better outcomes for the same forms are available. The proposal must be tested by comparing the various possible outcomes for key forms.

The critical comparisons appear to be those in (42) and (43). We consider these in turn, showing for each form the parses corresponding to its allophony. The third constraint in each tableau, "CrispEdge", is needed to make the analyses work out and will be discussed below.

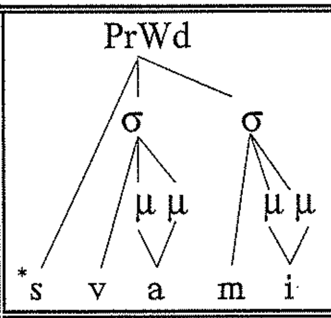
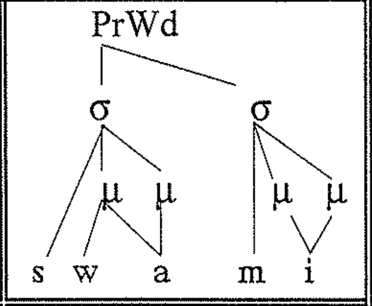
(42)

	(a)	(b)	(c)
			
AlignLeft (C, σ)	* *	* *	* *
AlignLeft (C, μ)	*		*
CrispEdge		*	

(43)(a)

		
AlignLeft(C, σ)	*	*
AlignLeft(C, μ)	* *	*
CrispEdge		

(43)(b)

		
AlignLeft(C, σ)	*	*
AlignLeft(C, μ)	* * *	* *
CrispEdge		

In both (42) and (43), violations of AlignLeft(C, PrWd) and AlignRight(C, PrWd) are omitted because they are identical for all forms. In evaluating whether alignment constraints are met, we have taken Cat_1 and Cat_2 to be Left-aligned if the leftmost element of the fringe of Cat_1 is identical to the leftmost element of the fringe of Cat_2 (and similarly for Right-alignment). The "fringe" (as defined in Pierrehumbert and Beckman, 1988) is the string of substantive elements directly or indirectly associated with a prosodic node. This definition of edge-alignment is also used by Itô and Mester (in press). As they point out, the different definition of edge-alignment provided in McCarthy and Prince (1993) cannot be coherently applied to forms in which single feature bundles are multiply attached.

For (42), (a), (b) and (c) are in free variation. This result cannot be obtained from the interaction of AlignLeft(C, σ) and AlignLeft(C, μ); (a) and (c) have identical violations for these two constraints, whereas (b) is better. Hence, the outcome should be (b). However, (b) contains a geminate which is lacking in (a) and (c). If, following Itô and Mester (in press), we place a penalty on non-crisp edges (or edges with doubly affiliated elements), then (b) will contain a violation which (a) and (c) lack. Under the assumption that this additional constraint, CrispEdge, is unranked with respect to AlignLeft(C, μ), the correct outcome for these forms is derived via the Cancellation Lemma (Prince and Smolensky to appear).

Turning now to (43), the preference for [swami] over [svami] emerges from the fact that [swami] contains more consonants left-aligned to moras. However, describing the preference for [vərdi] over [wərdi] would require yet another constraint; [wərdi] is better with respect to the constraints introduced so far. Note in particular that [wərdi] does not violate ONSET because the syllable is indeed left-aligned with a consonant. The link of [w] to the mora does not bear on the evaluation of the AlignLeft(C, σ); an important consequence of using alignment (rather than direct domination) as the core predicate is that it permits a single element to simultaneously meet constraints stated with respect to all superordinate nodes. In short, relative alignment is the autosegmental equivalent of direct or indirect domination; it corresponds to direct or recursively inherited autosegmental association.

One candidate for bolstering the candidacy of [vərdi] is a NonEdgemost constraint for moraic material, as outlined in McCarthy and Prince (1993). Specifically the constraint should penalize parses in which a mora is leftmost in PrWd. This constraint would need to be higher ranked than the constraints in tableau (43).

In the above sketch, we have attempted to use GA constraints as much as possible. However, three significant aspects of the analysis do not fit into the GA format. First, the NonEdgemost is treated as a negative constraint in McCarthy and Prince (1993) and we make no proposal about how to recast it in positive terms. Second, the sketch does not deal with the fact that the syllable template permits three moras, but no more. Sherer (1994) proposes to penalize longer syllables (in comparison to shorter ones) via a GA constraint which aligns all moras to the right edge of syllables. However, this proposal does not absolutely preclude mora counts greater than three. We believe it is not possible to formalize this limit in GA format, because the constraints on branching degree involve quantification over sets of nodes, as we will discuss in the next section. Lastly, Itô and Mester (in press) do not formalize CrispEdge in GA format and it does not appear possible to do so. Their formalization of CrispEdge is, in effect, an "upside down" constraint on branching degree, just as the standard autosegmental diagrams would suggest. Combining CrispEdge with GA style constraints gives a formally heterogeneous treatment of licensing. In Bird's approach, which we next examine, upward and downward looking branching constraints are formalized in a uniform fashion.

5.3 Bounded branching

A different approach to the relationship between licensing and parsing is taken in Bird (1995). Like the GA papers, Bird (1995) treats this relationship through related upward and downward looking constraints describing phonological structures. However, in contrast to the GA treatment, in which alignment is the workhorse predicate, Bird's treatment uses dominance as the workhorse.

A critical notion in Bird's treatment is that of a phonological sort. Sorts are predicates which pick out all and only the phonological entities of a given type. For example *mora(x)* is true if and only if entity x is a mora. The allowable sorts are organized into a lattice, which expresses the fact that some sorts are mutually incompatible, whereas others are not. For example, it is impossible for any single node in the representation to be both a mora and a syllable (though it could be a mora which was in turn parsed as a syllable); however, it could be simultaneously an example of an /e/ and an example of a segment. In the light of Bird's model, GA can be viewed as having a particularly simplistic view of sorts: the permissible variables in the GA schema are the various prosodic and morphological sorts. Sorts can also be viewed as boolean functions. Each function determines whether a particular entity does or does not belong to a given sort. For example *mora(x)* returns True if x is a mora, and False if it is not.

With these preliminaries, Bird defines the concept of licensing as follows:

(44) s_1 licenses s_2 if for all nodes of sort s_2 there is a node of sort s_1 (directly or indirectly) dominating s_2.

For this definition to approach with common understanding, it should probably be amended to state that s_1 is the lowest type of node meeting the condition. If s_2 = C, then s_1 is PrWd. For Hindi, all consonants are directly or indirectly dominated by PrWd. No lower node type will emerge as licenser under this approach because some consonants are not dominated by the syllable or by the mora. Like other Declarative Phonologists, Bird views constraints as inviolable.

(44) is only one side of licensing. This is the upward looking side which corresponding to alignment constraints such as (40) which universally quantify over the subordinate prosodic category. The downward looking side concerns how many instances of a given sort one prosodic node can support. To handle this issue -- that of branching degree -- Bird develops a family of constraints which place a maximum of count i on the number of instances of s_2 that a node of s_1 may dominate. In cases in which i=1, this reduces to:

(45) For all x, y, and z such that x dominates y and x dominates z and $s_1(x)$ and $s_2(y)$ and $s_2(z)$, then $y = z$.

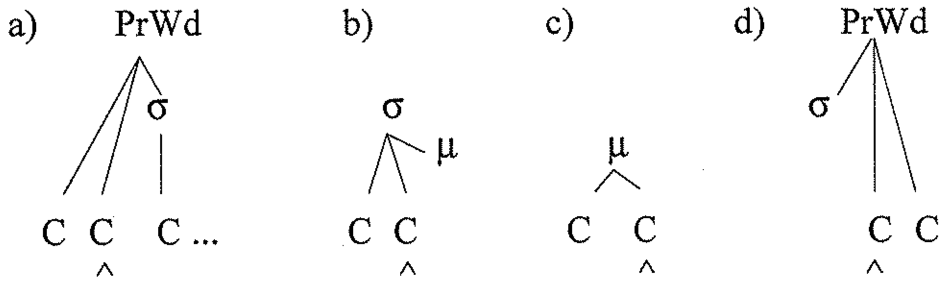
.(Intuitively: if x dominates y and z, and y and z are of the same sort s_2, then y and z are the same identical entity.) We will call constraints such as (45) "Unibranching constraints". Note that the critical variables in (45) are the prosodic sorts s_1 and s_2; hence it is possible to have a mnemonic shorthand of form (46).

(46) Unibranch(s_1, s_2)

Dibranching and tribranching constraints can be formalized in a similar fashion but somewhat more complicated fashion, as will be obvious from pp. 61 and facing of Bird (1995).

Returning now to Hindi, observe that a common feature of fatally misaligned consonants is that they entail too much branching on a single node.

(47)



Consonants in the tagged positions in (47) fail to meet any left-alignment or right-alignment constraint in (40) above. Equally, they provide one more token of sort *Consonant* than is permissible under each node. Hence, consider the possibility that Hindi has, in place of (40), a set of Unibranch constraints.[1]

(48) (a) Unibranch(PrWd,C)
(b) Unibranch(σ, C)
(c) Unibranch(μ, C)

[kʃəma] and [sɪd^h:art^h], discussed above, do not violate any of these constraints. The violations disappear in comparison to the GA approach because (in contrast to AlignLeft(C, Cat_2) and AlignRight (C, Cat_2)), Unibranch(Cat_2, C) does not pertain to C's which are dominated by nodes other than Cat_2. Similarly, the forms [ədvæt], [əd:wæt], [ədwæt], [swami] and [vərdi] meet all the Unibranching constraints. Branching of the first mora to an onglide and a vowel is acceptable because these are of different sorts (C and V).

The limit of three moras in a syllable is describable as Tribranch(σ, μ). Just like GA, Bird's approach provides no explanation of why natural languages in general permit syllable parsing to count up to three, but no further. The number three receives no special status under the widespread assumption that language "does not count", with apparent cases of counting held to reduce either to binary comparisons, or to recursion or embedding of binary comparisons. However, after this assumption entered linguistics, work in cognitive science greatly clarified the ability of infants to conceptualize numerosity. Even preverbal infants can effectively count up to three or four. Strauss and Curtis (1981) showed that 11-month infants detect the difference between two and three; females could detect the difference between three and four, but no infants at this age could detect the difference between four and five. A series of experiments by Starkey, Spelke and Gelman (1990) demonstrated that the difference between two and three is mode-independent for 7-month infants. That is, this difference is detectable for visual stimuli, for auditory stimuli, and also for the simultaneous or sequential comparison of unrelated visual and auditory stimuli. Thus, we would claim that linguistic theory as such need not provide any special status for the number three. Given that the concept of "three" is available to infants who are learning to talk, they can apply it in acquiring the grammars of particular languages. Their poor conceptualization of bigger numbers explains why these are unavailable during early acquisition.

In order to describe the plausibility of [əd:wæt] (as compared to [ədvæt] and [ədwæt]), this approach would adopt Turbo-Weight-by-Position exactly as stated in (34). There is no impediment to doing so, because the framework does not restrict itself to variables ranging over basic categories. Optionality of the constraint would be described via disjunction. The outstanding problems are therefore the preference for [vərdi] over [wərdi] and that for [swami] over [svami]. To achieve observational adequacy, without bringing in violable constraints, rather particular constraints encoding parsing preferences appear to be required. Obviously, it is also possible to imagine a hybrid approach using branching degree and violable constraints to describe parsing preferences.

5.4 Canonical form

Both of the previous sections offer ways to use logical descriptions to describe parsing and licensing. Both forego the *COMPLEX constraints of Prince and Smolensky (1993) in favor of positive statements. The GA style treatment uses a universal quantification over instances of phonological sorts (the Cat_1 of the GA schema) to describe licensing. Bird's approach uses universal quantification over sets of nodes which are related via domination. By quantifying over sets of nodes, instead of individual nodes, Bird's approach limits the range of application of each constraint. This has the effect of eliminating many constraint conflicts which follow in GA from applying every alignment constraint at so very many locations in each phonological form. Compared to GA, Bird's approach may be characterized as involving a heavier use of quiet disjunction. GA also uses quiet disjunction as discussed in the introduction to section 5, because each alignment constraint only pertains to tokens of the universally quantified sort in the Cat_1 position.

The specific use of quiet disjunction in Bird's approach is inherited from the standard interpretation of grammars in formal language theory. In this section, we explore a third description of the data which builds more transparently on formal grammar. The reason for presenting this third approach is to bring out a shared weakness of the GA and Unibranch treatments. Both unbundle the prosodic structure into many small constraints. Hence, they treat as unrelated several aspects of the prosodic structure which appear to be functioning together. Specifically: 1) a glide at the right edge of the word projects a syllable if it constitutes a sonority peak, 2) a word-initial glide is parsed as a canonical onset rather than as an onglide under the first mora, 3) a word-initial /s/ is parsed if possible as a canonical onset rather than as a direct dependent of PrWd. All of these observations suggest that the syllable is the dominant prosodic unit of Hindi, and that the preferred parsing pattern is one in which syllables are imposed back-to-back all the way to the edges of the word.

We have taken the concept of a dominant scansion level from experiments on the perception of prosody in various languages by Cutler *et al.* (1986). We now attempt to reconstruct it theoretically using context-free grammars.

A rule in a context-free grammar has a single symbol on the left which is expanded into a string of symbols on the right. For example, a generic prosodic hierarchy has U (the utterance) as a top-level node, and each U is expanded into one or more intonation phrases (see Pierrehumbert and Beckman 1988).

(49) $U \rightarrow IP+$ (Where Kleene + means "one or more")

Omitting intervening levels in the prosodic hierarchy, another fragment of a prosodic grammar is provided by (50) through (53).

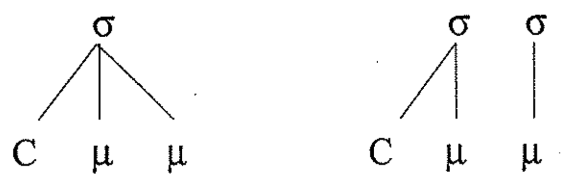
(50) $\sigma \rightarrow \mu$
(51) $\sigma \rightarrow \mu\ \mu$
(52) $\sigma \rightarrow C\ \mu$
(53) $\sigma \rightarrow C\ \mu\ \mu$

These particular rules provide for syllables with or without an onset, with either one or two moras.

Rules such as (50) through (53) are interconvertible with trees. The tree over any successfully parsed terminal string represents a record of the rules which were invoked in the course of the parse. That is, the "rules" in a context-free grammar are not derivational rules, but rather synopses of allowable node expansions. In a standard interpretation of the formalism, different expansions of the same node type represent alternatives in generation or parsing. A basic parser returns all possible analyses via any set of rule applications; in order to return only one parse for a terminal string which is in principle structurally ambiguous, it is necessary to complicate the picture with prioritization of some type.

For example, without further prioritization, Cμμ will receive both parses in (54) via rules (50-53).

(54)



Rules such as (50)-(53) can be converted into a set of logical statements about trees; see tutorial sections of Bird (1995). However, an arbitrary set of logical statements about trees cannot necessarily be converted into a context-free grammar. This is because the logical statements are descriptions of trees, not trees or pieces of trees. The descriptions could be incomplete or inconsistent with respect to any context-free grammar. As discussed in Shieber (1986), some formalizations of constraint-based theories of language make a clear separation between a context-free structural skeleton and further logical constraints which are imposed on the structures. Others treat the structural skeleton fairly homogeneously with the other constraints. The present proposal finds its clearest antecedents in work on syntax positing a context-free structural core, such as LFG and GPSG; see also Kaplan and Bresnan (1982), Kaplan (1987), Gazdar *et al.* (1985)

In developing a GA-style analysis of Hindi syllable structure, the challenge is to accommodate the cases of free variation within the overall OT control structure. In a theory with a context-free skeleton, different expansions of the same node in general lead to multiple parses of some forms. The challenge is to explain why not all parses are possible. The critical cases are: 1) word-initial /s/ is parsed by σ rather than by PrWd if possible, as in (43), 2) a word-initial consonant is parsed directly by σ even if it is a consonant which could stand as an onglide, as in (43), 3) a final sonority peak must be parsed as a nucleus rather than as an extrasyllabic consonant.

The type of difficulty raised by (54) is well-known and the literature contains some proposals about how to deal with it. However, these proposals do not cover the regularities of Hindi just summarized. The treatment of stress in Chomsky and Halle (1968) uses a rule in transformational format to achieve the effect of iterating a structural template across a form. Alternative templates are collapsed together using parenthesis notation, and Chomsky and Halle define the interpretation of the notation as requiring that the longest available rule expansion apply in any given case. This convention will not work for the present situation, since the longest possible expansion of the syllable is selected in (43b); but the longest expansion of the head mora is not selected in (43a). Not all of the correct parses of /ədvæt/ maximize the sizes of the syllables (see 42). Template maximizing adaptations of the same proposal in more current metrical theory fail for the same reason.

Another claim related to the theory of parsing preferences is Scobbie's (1993) proposal that the Elsewhere Condition provides the sole means of constraint adjudication available in phonology. The Elsewhere Condition, as developed in Kiparsky (1972) and originally deriving from work by Paṇiṇi, requires a specific constraint to take priority over a more general one. The words "specific" and "general" are to be understood in terms of logical subsumption. At first blush, it appears that this proposal, too, fails to cover the facts of Hindi prosodic scansion. As already noted, the syllable is the dominant sort in the prosodic scansion. However, the syllable does not stand in any subsumption relationship with any other sort of prosodic node. Since the syllable is neither at the top nor at the bottom of the prosodic hierarchy, it is similarly intermediate in terms of temporal extent, featural complexity, and so forth.

The dominance of the canonical syllable over other prosodic units in scansion can, however, be formulated in a way that falls under the Elsewhere Condition. Consider the set of acceptable prosodic forms and set of ideal prosodic forms. The ideal forms are a proper subset of the acceptable forms; this means that the universe of all forms properly subsumes the universe of ideal forms. One way to describe the ideal forms is through a subgrammar of the prosodic grammar needed for all forms. For example, although it is possible to have an extrasyllabic /s/ or /k/ at the beginning of the word, this is not ideal. The ideal expansion of PrWd is (55), whereas the full expansion is (56)

(55) PrWd $\rightarrow \sigma+$

(56) PrWd $\rightarrow \left\{ \begin{matrix} s \\ k \end{matrix} \right\} \sigma+ \text{ (C)}$

Similarly, the ideal syllable has an onset consonant directly dominated by the syllable node, whereas in less ideal syllables this consonant may be lacking:

(57) $\sigma \longrightarrow$ C μ (μ (μ))
(58) $\sigma \longrightarrow$ (C) μ (μ (μ))

Since the rule for the "ideal" expansion of each node is now a proper subcase of the rule for the general expansion, it will take priority in parsing via the Elsewhere Condition. For example, for display (43) above, (57) yields the parse /vərdi/, containing an onset consonant for the first syllable. The alternative parse /wərdi/ could arise only by invoking the expansion in the less specific rule (58), hence /vərdi/ takes priority over /wərdi/. Similarly /swami/ arises by the canonical expansion (55) of PrWd. It is preferred to /svami/, which would arise only through the more general expansion of PrWd in (56). 42(a) (/əd.væt/) and 42(c) (/ə.dwæt/) are both fine because no preference has been defined for expanding the syllable node with one versus two, or three moras. If (for the sake of illustration), the canonical syllable were defined as having two moras, then /əd.væt/ (with the first syllable dimoraic) would win over /ə.dwæt/. Alternative 42(b), /əd:wæt/, exceeds the descriptive range of a bare-bones context-free grammar because a single element (the /d/) is parsed twice. The reader is referred to Bird (1995) for some formally conservative approaches to gemination.

The reader will no doubt have noted that this solution to the problem is rather verbose. Such verbosity requires additional justification. A large body of experimental research on the privileged status of canonical members of categories suggests a line of justification. In general, canonical members of categories are shown to have various cognitive advantages over noncanonical members. Experimental findings specifically related to recall and production include the following: Mehler (1963) showed that kernel sentences, in the sense of Chomsky (1957), are easier to remember than nonkernel sentences; errors in recall of sentences disproportionately involve nonkernel sentences recalled in kernel format. Handel and Garner (1965) report a study in which subjects were asked to produce a dot matrix pattern which was similar, but not identical to, a stimulus dot matrix pattern. Productions were systematically concentrated on patterns which were independently rated as "good" patterns (in this study, the good patterns proved to be those with maximal symmetry). Mervin *et al.* (1976) report that good examples of categories are produced more readily. Heit

(1994) and Ross and Anderson (1982) discuss experiments demonstrating the perseveration of stereotypes in cognitive representations of people.

Other ways in which canonical members of categories display their privileged status include appearing more familiar than they really are, and being processed faster than noncanonical members; see reviews in Nosofsky (1991) and Estes (1988).

There are a number of major outstanding issues in the present understanding of such experimental results, and our intention here is to remain neutral on these issues. Although many studies have demonstrated a connection between canonicity and frequency, there are also other factors. As discussed in Rosch (1973), it is more typical for central members of a category to count as canonical than for peripheral ones to. In addition, facts of nature (including facts about sensory physiology) make some types of stimuli more perceptually salient or otherwise more important than others. Exactly these issues come up in the study of syllable structure and they deserve further investigation. It may be the case that the canonical prosodic structures of Hindi are independently the most frequent ones. However, some types of syllables are less marked universally than others; in particular the preference for a consonantal onset appears to be universal (see Itô 1988). Much of current experimental research seeks to explain such observations in terms of facts about language acquisition, motor control, speech acoustics, and auditory perception.

A further question is whether the privileged status of canonical stimuli is to be explained in terms of an explicit abstract cognitive prototype, or arises instead indirectly through the way that each new stimulus is compared to many remembered examples. (See Medin and Ross 1990, Nosofsky 1991, Heit 1993; and papers reviewed there.) In the present connection, this amounts to the issue of whether sub-grammar rules such as (55) and (57) are imputed to the minds of speakers as such, or whether these provide an external scientific synopsis of the types of examples which would be processed as canonical examples. The type of data examined here does not address this issue, which could only be addressed through detailed experiments on perception and processing. See also the reply by Pierrehumbert, Beckman, and Ladd (this vol.).

6 Conclusion

Hindi has prosodic structures which are fairly complex and unusual in some respects. Syllables may be as long as three moras. Onsets are minimized to a single consonant, even at the expense of creating a superheavy syllable or splitting a rising sonority contour. Optional gemination arises from optional projection of a mora over preconsonantal consonants. In addition to licensing consonants in onset and post-nuclear moraic position, Hindi allows a nuclear onglide and also an extra consonant at each word edge. Simple themes running through this complexity are the fact that no single node can directly dominate two adjacent consonants, and that preferred parses exhaustively syllabify the word out to the edges.

We have sketched three theoretical treatments of these phenomena. Both GA and Bird (1995) approach licensing through instantiations of logical schemata. These logical schemata quantify over prosodic sorts, and, like previous work on constraint-based theories of syntax, they view constraints as partial descriptions of forms. Differences arise because GA uses relative alignment as the foundation of the formal treatment, whereas Bird uses domination. Because Bird's branching restrictions are formalized using universal quantification over sets of variables rather than individual variables, it generates many fewer constraint violations than GA. Although the constraints are more complex, there is less of a burden on the control structure (or the method by which the constraints are combined).

Both the GA style sketch and the Bird style sketch use rather small constraints, which treat independently some parsing preferences which appear to be functioning together. In order to reconstruct the dominance of the canonical syllable in parsing, we have used a context-free grammar to bundle them up again. We also propose a connection between canonical parsing and the production and perception of canonical forms in general.

NOTES

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[1] A slightly subtle point arises from the fact that extrasyllabic material at the two edges of the word in Hindi does not in any way violate well-formedness: (i) is unproblematic.

(I) PrWd

C σ+ C

(i) does not represent any type of violation, evidently because the two C's directly dominated by PrWd are not adjacent to each other. Hence, our understanding of Unibranch must be augmented to pertain only to entities which are not separated by intervening material. This means that unibranching has a strong formal relationship to the OCP (see the discussion of "convexity" in Scobbie 1991 and Bird 1995).

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