Dagbani vowel phonology: competition between constraint hierarchies

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Abstract

This chapter provides a formal analysis of Dagbani vowel phonology, arguing that the surface forms of vowels emerge from: (i) faithfulness and markedness constraint hierarchies based on sonority, [ATR] and height features; (ii) prosodic conditioning and (iii) [+ATR] harmony. In non-final positions, mid vowels become [a] because they are marked in height specification. The preference for more sonorous vowels as syllable nuclei produces a hierarchy in which faithfulness to non-high vowels outranks faithfulness to high vowels. Prosodically-sensitive markedness constraints produce [i, ɨ, a, ʊ] in minimally bimoraic words. In sub-minimal words, an [ATR] markedness constraint hierarchy ensures that [i, e, o, u] are the only non-low [+ATR] surface forms. Rules of [+ATR] harmony produce [+ATR] variants of /a, ɛ, ɔ/ in non-final positions. The analyses demonstrate that in spite of the inherent differences between markedness and faithfulness-based approaches, analyses of harmonic patterns may require an eclectic approach.

1. Introduction

This chapter provides a formal analysis of Dagbani vowel phonology within Optimality Theory (OT) (Prince and Smolensky 1993/2004), demonstrating that a combination of markedness and faithfulness constraint hierarchies are required, each complementing the other, to derive surface vowel patterns. Descriptively, the phonology of Dagbani vowels is fairly well understood. From studies such as Wilson and Bendor-Samuel (1969), Dakubu (1997), Olawsky (1999), Hudu (2010, 2013), we know that vowel surface forms are shaped by various forms of neutralisation resulting from [ATR] harmony, vowel raising and lowering. This chapter builds on the descriptive details provided in these studies, arguing that the surface forms of Dagbani vowels emerge from the interaction of three forces: (i) faithfulness and markedness constraint hierarchies based on sonority considerations, [ATR] and height features; (ii) prosodic conditioning and (iii) [+ATR] harmony. In a non-final position, mid vowels neutralise to [a] because they have a marked height specification. The preference for more sonorous vowels as syllable nuclei produces a hierarchy in which faithfulness to non-high vowels outrank faithfulness to high vowels. This hierarchy explains why mid vowels neutralise with [a] through vowel lowering, and why the default epenthetic vowel in Dagbani is [+high]. Prosodically-sensitive markedness constraints produce [i, ɨ, a, ʊ] in minimally bimoraic words. In sub-minimal words, a markedness constraint hierarchy based on [ATR] ensures that the only non-low vowels that surface are [i, e, o, u]. [ATR] harmony produces a [+ATR] variant of [a] and the mid vowels [e, o] in non-final positions.

Assumptions regarding features are based largely on models of Feature Geometry recognising the identity of vocalic and consonantal place features (Clements and Hume, 1995, etc.) while maintaining the traditional features [high], [low] and [ATR] (e.g. Sagey 1986; Odden 1991 etc.). The major features are shown in Table (1).

Table 1. Dagbani vowel features

	i	ɨ	e	ɛ	a	ə	ɔ	o	ʊ	u
[high]	+	+	-	-	-	-	-	-	+	+
[low]	-	-	-	-	+	+	-	-	-	-
[ATR]	+	-	+	-	-	+	-	+	-	+
[LAB]							√	√	√	√
[COR]	√		√	√						
[DOR]						√	√	√	√	

The data are based on my intuitions as a native speaker, and several years of research involving native speakers of the Western and Eastern dialects. The data have also been used in Hudu (2010). Tone marking (only high, low and falling) and any dialectal differences in lexicon or transcription that may be observed likely reflect my native Eastern Dialect.

In the next section, the basic tenets of OT are introduced. Section 3 argues that the surface [ATR] value of vowels is determined by markedness considerations while Section 4 focuses on the distribution of mid vowels, which is determined by both markedness and faithfulness forces. A combination of [-ATR] markedness and the marked status of the mid vowels account for the loss of the height specification of [ɛ, ɔ]. However, the lowering of these vowels is driven by faithfulness constraints. Section 5 accounts for the restriction of [-ATR] vowels to minimally bimoraic domains. Section 6 concludes the chapter.

2. Optimality Theory

In OT, phonological surface forms result from constraints which make demands on what the output form of an input should be. Different constraints typically make conflicting demands, which means deriving the optimal form necessarily involves violating some constraints and satisfying others in a process determined by the relative importance or ranking of constraints. The higher a constraint is ranked, the greater the need to satisfy its demands and the worse the consequence of violating it. Unlike rule-based approaches such as autosegmental phonology and linear phonology, OT includes a component of the grammar called the Generator, which generates, for every input, many possible output forms that are evaluated by the set of ranked, violable constraints. The optimal output is the one with the least or no violation of highly ranked constraints. Thus the grammar has three main components: the CONSTRAINTS (CON), the GENERATOR (GEN) and the EVALUATOR (EVAL).

Constraints are of several categories, two of which are faithfulness and markedness constraints. Faithfulness constraints demand some resemblance of the output to the input while markedness constraints require that the output surfaces with unmarked or less marked structures. Current understanding of faithfulness constraints in OT is largely influenced by the theory of correspondence (McCarthy and Prince 1995). There is a faithfulness constraint called MAXIMALITY (clipped as MAX[1]), which demands that every segment or feature in the input has a correspondent (match) in the output. This constraint blocks the deletion of input segments or features. Outputs that lack segments or features present in the input violate MAX. For instance, imagine an input form with a coda cluster, *task.* One of the outputs GEN may supply for evaluation is *tak,* which deletes [s] to surface as a less marked, clusterless syllable. This deletion incurs one violation of MAX. While the input segments [t], [a], [k] each has an output correspondent, input [s] lacks a correspondent. Another faithfulness constraint called DEPENDANCY (DEP) demands that every segment in the output has a correspondent in the input. It millitates against insertion in the output, segments that are not in the input. An output form such as *tasik,* which would also be motivated by the need to avoid a coda cluster, violates DEP because [i] lacks a correspondent in the input *task.*

While both *tak* and *tasik* violate MAX and DEP, they satisfy a markedness constraint banning a consonant cluster (*CLUSTER) eventhough the input has a cluster. Similarly, an output form such as *ta* (for input *task*) satisfies a markedness constraint against a syllable with a coda (*CODA) while incurring two violations of MAX. Thus in order for an output to

1 As a convention, constraint names are in small capitals.

satisfy constraints of one category, strategies that typically lead to violations of constraints of the other category are either adopted or avoided. The difference between the grammars of two languages emerges out of constraint ranking. For a language like English that permits codas and clusters, MAX and DEP rank higher than *CODA and *CLUSTER; for a language that forbids them, the opposite ranking holds. Thus while the constraints are language-universal, their relative ranking is language-specific. In effect, in the OT framework, the grammar of a language is the language-specific ranking of language-universal constraints. The constraint types are illustrated in the sections below.[2]

3. ATR Markedness

Markedness broadly relates to the relative preference of features, structures, units or constituents in language. Among other diagnostics, marked units or structures are often avoided, dispreferred, less common, complex, or acquired late by children compared with unmarked or less marked ones. In the grammar of languages, the presence of marked structures or units often implies that of unmarked units, but not vice versa. Within phonology, markedness is useful in explaining asymmetric patterns observed between two or more units or values of a unit. Whereas a marked value is often deleted or lost through neutralisation, an unmarked value is often inserted or maintained. Indeed, structural neutralisation between two values as a markedness diagnostic has been noted in studies as early as Troubetzkoy (1939). The generalisation in (1) is how De Lacy (2006) expresses it.

(1) Neutralisation output as markedness diagnostic (de Lacy 2006: 28)

If /α/ and /β/ undergo structurally conditioned neutralisation to output [α], then there is some markedness hierarchy in which [β] is more marked than [α].

When applied to one of the patterns of neutralisation in Dagbani, the results suggest [+ATR] as the unmarked value. Bakovic (2000) even argues for [+ATR] as the universally unmarked value of [ATR]. For Dagbani, non-low vowels neutralise to their [+ATR] variants in unsuffixed CV lexical roots, producing only [e, o, i, u]. This is shown in (2). In words longer than CV, other patterns of neutralisation, discussed in Section 4, take place. This markedness

2 The introductory notes about OT are meant to cover only some of the basic tenets of the theory to allow readers not familiar with the theory to follow the discussion and analysis presented in this chapter. A more detailed understanding of the theory requires further reading. Kager (1999) offers a very useful introduction.

relation translates into two OT markedness constraints, defined in (3).

(2) Root-final position for [i, u, e, o, a]

[i]	bì 'be cooked'	tì 'give'	ʤí 'short'	mí 'rain'
[u]	bú 'beat'	tú 'insult'	gù 'block'	lù 'fall'
[e]	bè 'be alive'	tè 'filter'	ʤé 'dislike'	mè 'build'
[o]	bò 'seek'	tò 'pound'	gò 'travel'	ló 'tie'
[a]	bá 'ride'	tà 'smear'	ŋmá 'break'	là 'laugh'

(3) ATR markedness constraints

a. *[+ATR]: A [+ATR] vowel is banned

b. *[-ATR]: A [-ATR] vowel is banned

*[+ATR] militates against an output with a [+ATR] vowel. To satisfy this constraint, output forms must contain only [-ATR] vowels. Any output form with [i], [u], [e], or [u] violates it. *[-ATR] makes the opposite demand: only a [+ATR] vowel is permitted in outputs. *[-ATR] ranks above *[+ATR] to derive the neutralisation in (2). This is shown in the tableau in (4).

(4) A high vowel with surface [+ATR] feature (/tɨ̀/ → [tì] 'give')

/tɨ̀/	*[-ATR]	*[+ATR]
a. ☞ tì		*
b. tɨ̀	*!	

In (4), as in every OT tableau, the form in "/ /" is the input while the forms appearing under it in the same column are the possible output forms. Only one of the output forms, determined by constraint hierarchy, is optimal. The first (highest ranked) constraint, in this case *[-ATR], begins evaluating the output forms. If an output form violates its demand, the violation is marked with a star; if no output violates it, or if there are two or more outputs that satisfy it, the evaluation moves on to the next constraint. A star that is followed by "!" indicates a fatal violation, one that rules out the output as the attested form in the language. A constraint violation is fatal when there is at least one output form (other than the one violating the constraint) that satisfies the constraint as well as higher-ranked constraints, if any. The evaluation continues until only one output remains without a fatal violation. Such a remaining output is the optimal form, marked with "☞".

The violation mark of the output form in (4b) is fatal because (4a) satisfies the demands of *[-ATR], which is what (4b) violates, and also because there is no higher-ranked constraint (4a) violates which (4b) satisfies. The ranking of *[-ATR] over *[+ATR] means that violating *[+ATR] is not as bad as violating *[-ATR]. It also means that there is no harm in the optimal form violating *[+ATR] because the competing output form violates higher-ranked *[-ATR]. Thus (4a) is rightly predicted to be optimal.

There is a fundamental question that the above analysis has not answered: what forces Dagbani vowels to bear the [ATR] feature? If the tableau in (4) were to include an output form such as [tI], with [I] representing a high, non-back vowel not specified for [ATR], such an output form would surface as the optimal candidate given that it would satisfy both constraints. The fact that [tI] does not surface in Dagbani means that there is a constraint that blocks such output forms. Following similar proposals in the literature (e.g. Padgett 2002; Kim and Pulleyblank 2009), I propose the SPECIFY constraint in (5).

(5) Constraint on output specification for [ATR]
SPECIFY[ATR]: Every vowel is [+ATR] or [-ATR].

SPECIFY[ATR] outranks *[+ATR], which the optimal output form violates, to derive [+ATR] as the default value. Without any prosodic domain conditioning (see Section 5), all non-low vowels in Dagbani surface as [+ATR], as the tableaux in (6) and (7) show.

(6) A high vowel with surface [+ATR] feature (/tɨ̀/ → [tì] 'give')

/tɨ̀/	SPECIFY[ATR]	*[-ATR]	*[+ATR]
a. ☞ tì			*
b. tÌ	*!		
c. tɨ̀		*!	

(7) A mid vowel with surface [+ATR] feature (/tɛ̀/ → [tè] 'filter'

/tɛ̀/	SPECIFY[ATR]	*[-ATR]	*[+ATR]
a. ☞ tè			*
b. tÈ	*!		
c. tɛ̀		*!	

The output forms in (6b) and (7b) incur violations of SPECIFY[ATR] because they are neither [+ATR] nor [-ATR]. Candidates (6c) and (7c) also violate *[-ATR], while (6a) and (7a) violate *[+ATR]. The violations incurred by (6a) and (7a) have no effect because by the time we get to this constraint, the other two candidates in each tableau are ruled out for incurring a fatal violation of one of the two higher ranked constraints.

While all non-low vowels surface as [+ATR] /a/ surfaces in this context as [a]. This is due to the force of another constraint whose demand results in low vowels being an exception to the neutralisation under discussion. In similar observations in the literature, the failure of low vowels to surface as [+ATR] is attributed to the natural connection between a non-advanced or retracted state of the tongue root and a low gesture of the tongue body. In other words, tongue root non-advancement is grounded in a low tongue body, making it difficulty to achieve an advanced tongue root while maintaining a low tongue body gesture. Archangeli and Pulleyblank (1994) capture the relation between the two gestures using the grounded condition Low/ATR, defined in (8).

(8) [-ATR] grounded in [low] (Archangeli and Pulleyblank 1994: 174)
LO/ATR: If [+low] then [-ATR]

Within OT, this is a markedness constraint forbidding a low vowel from bearing a [+ATR] specification. Thus regardless of what the [ATR] specification of the low vowel is, LO/ATR requires that the output form is [-ATR]. When it ranks higher that *[-ATR], a surface [+ATR] feature for an input low vowel is blocked, as shown in (9). Note that the [+ATR] variant of the low vowel [ə] is phonologically [+low].

(9) Low vowel surfacing as [-ATR] (/tà/ → *[tə̀] 'smear'

/tà/	SPECIFY[ATR]	LO/ATR	*[-ATR]	*[+ATR]
a. ☞ tà			*	
b. tÀ	*!	*		
c. tə̀		*!		*

In (9), *[-ATR], which would have ruled out [tà], is not crucial in determining the optimal form because it is outranked by LO/ATR. The results in (6), (7), and (9) are the surface forms in unsuffixed CV roots. [+ATR] vowels occur mainly in unsuffixed root and final positions of phrases and utterances. In other positions, surface forms are determined by interaction of markedness and faithfulness constraints, and [ATR] harmony. Section 4 discusses this.

4. Markedness, faithfulness and [ATR] harmony

While the general distributional pattern shown in the preceding section is common to all vowels, the actual surface realisations of mid vowels are driven by markedness and faithfulness constraints based on vowel height and sonority, position-sensitive faithfulness constraints and [+ATR] harmony rules. These are discussed in sections 4.1 – 4.3.

4.1 Markedness vs. faithfulness hierarchies

The discussion in the preceding section makes use of the markedness-based harmony scale [+ATR] ≺ [-ATR] in analysing the [ATR]-based neutralisation. "≺" indicates that the preceding unit is more harmonic than the following one (cf. Prince and Smolensky 1993/2004 for more on harmony scales). This harmony scale indicates that a Dagbani vowel would more likely surface as [+ATR] than as [-ATR]. Within the markedness approach, this harmonic scale translates into the markedness constraint hierarchy *[-ATR] » *[-ATR], already discussed ("»" indicates that the constraint to the left ranks higher than the one to the right). According to this approach, the surface realisation of both [+ATR] and [-ATR] incur violations of constraints. However, the [+ATR] value, being more grammatically harmonic, incurs less severe violations than the [-ATR] value.

An alternative approach to analysis of grammatical harmony scales is the use of faithfulness constraints (Kiparsky 1994, Howe and Pulleyblank 2004). According to the faithfulness account, there are two possible ways of expressing relative harmony scales. Using the two values of [ATR], the scale FAITH[-ATR] » FAITH[+ATR] produces a result in which faithfulness to the less harmonic [-ATR] may rank higher than faithfulness to the more harmonic [+ATR], such that surface [-ATR] forms will be less subject to grammatical change than surface [+ATR] forms. Alternatively, the ranking FAITH[+ATR] » FAITH[-ATR] produces results in which faithfulness to [+ATR] may be more highly valued than faithfulness to [-ATR]. When mapping from input to output forms, this ranking provides surface forms with [+ATR] greater stability or immunity from processes such as deletion and neutralisation than those with [-ATR]. Howe and Pulleyblank (2004) argue that the faithfulness-based approach provides a better account of several phonological patterns. This section uses analysis of a pattern of neutralisation affecting mid vowels to evaluate both approaches.

In Dagbani, mid vowels surface as [a] in non-final position, where the only cue to the phonemic contrast between /a/ and the mid vowels in such words as the minimal pairs in (10) and (11) is the secondary articulation on the onset of mid vowels. Dagbani consonants are palatalised before front vowels and labialised before back vowels.

(10) Underlying low /a/ Underlying mid /ɛ/

a. làbɨ̀ 'return' /lɛ̀bɨ̀/ [lʲàbɨ̀] 'change/become'

b. pâm 'plait' /pɛ̂m/ [pʲâm] 'arrow'

c. dàm 'shake' /dɛ̀m/ [dʲàm] 'play'

(11) Underlying low /a/ Underlying mid /ɔ/

a. tám 'stand on' /tɔ́m/ [tʷám] 'bitterness'

b. gáb[ɨ] 'mix' /gɔ́bɨ́/ [gʷáb[ɨ]] 'wrap around'

c. láʔ[ɨ] 'woo' /lɔ́ʔɨ́/ [lʷáʔ[ɨ]] 'circumvent'

It is worth noting that mid vowels are the only vowels that lose their height specification when neutralisation between vowels takes place in Dagbani. This can be explained from a markedness point of view. Mid vowels combine features of low and high vowels, making them more complex, and thus more marked than other vowels (Flemming 2002). Mid vowels are also dispreferred from the point of view of dispersion (Flemming 2002), as reflected in surveys of vowel inventory structure (Crothers 1978). The surveys show that the presence of mid vowels in an inventory implies that of high and low vowels, but not vice versa. The relatively marked status of mid vowels is further demonstrated by their rarity as default or epenthetic vowels across languages, unlike low vowels (e.g. Axininca Campa (Payne 1981); Makkan Arabic (Abu-Mansur 1987)) and high vowels (e.g. Yoruba (Pulleyblank 1988), Alabama (Montler and Hardy 1991) and Dagbani (Hudu 2010)). These crosslinguistic patterns can be captured in the universal harmony scale in (12).

(12) Height-based harmony scale: [+high], [+low] ≺ [-high, -low]

In (12), [+high] is not projected to be more harmonic than [+low], so they are separated by a comma. Both features are more harmonic than mid vowels, which are [-high, -low]. The scale in (12) produces the three markedness constraints in (13) and translates into a height-based constraint hierarchy in which markedness constraints against mid vowels rank higher than those banning high and low vowels, shown in (14).

(13) Height-based markedness constraints:

a. *[-Hɪ -Lᴏ]: A [-high, -low] vowel is banned

b. *[+Lᴏ]: A [+low] vowel is banned

c. *[+Hɪ]: A [+high] vowel is banned

(14) Height-based vowel markedness hierarchy

*[-HI -LO] » *[+LO], *[+HI]

As in (12), the *[+LO] and *[+HI] constraints in (14) are separated by a comma, indicating no crucial ranking between them. In order words, both *[+LO] » *[+HI] and *[+HI] » *[+LO] produce the same result. Mid vowels do not surface as long as *[-HI -LO] ranks higher than *[-ATR] and *[+ATR]. This is illustrated in (15).

(15) No mid vowels in non-final position (/bʲɛ̀hɨ̀m/ → [bʲàhɨ̀m] 'doubt')

/bɛ̀hɨ̀m/	*[-HI -LO]	*[-ATR]	*[+ATR]
a. bʲɛ̀hɨ̀m	*!	**	
b. bʲèhɨ̀m	*!		**
c. ☞ bʲàhɨ̀m		**	
d. 👎 bʲìhɨ̀m		*	*

When the height specification of a mid vowel changes, the result is either vowel lowering, as in (15c), or raising, as in (15d). With two violations of *[-ATR], *bʲàhɨ̀m,* the optimal output form, loses to *bʲìhɨ̀m,* which has only one violation of this constraint. (15d) is projected as the optimal output. This incorrect result is further predicted by the fact that it is congruous with [ɨ] being the epenthetic vowel in Dagbani (Hudu 2010). Under approaches to vowel epenthesis based on markedness, various constraints characterising high vowels as less marked than mid and low vowels have been proposed (e.g. Kirchner 1997, Kager 1999). Given the dis-preference for surface mid vowels in Dagbani, underlying mid vowels would be expected to surface as high under such approaches, contrary to the attested pattern. The result in (15) shows that the markedness approach cannot account for Dagbani mid vowel lowering in non-final positions.

Arguing for the faithfulness approach, Howe and Pulleyblank (2004) reject the inherent claim of the markedness approach that high vowels are intrinsically unmarked. They cite evidence from vowel inventories and the typology of syllabic segments to show that high vowels are relatively marked based on independently established vowel markedness hierarchy. The faithfulness approach they propose for analysis of processes such as vowel deletion and insertion is based on vowel sonority. Unlike a markedness account, the sonority-based faithfulness hierarchy FAITHLOW » FAITHMID » FAITHHI consistently recognises non-high vowels as more harmonic than high vowels, and successfully accounts for high vowels being targets of both insertion and deletion even within one language.

The faithfulness account explains why high vowels are the epenthetic vowels in Dagbani. A faithfulness constraint to non-low specification also explains why mid vowels surface as [+low] and not [+high], as will be shown below. However, an approach based solely on faithfulness does not explain the pattern of height neutralisation affecting mid but not high vowels. To account for this, markedness considerations are essential, as in other grammatical patterns including vowel epenthesis, a point noted by Howe and Pulleyblank. Thus what is ultimately required for Dagbani is a faithfulness approach that appeals to the preservation of the height features [+high] and [+low]. Such an approach leaves mid vowels the most susceptible to deletion or loss due to neutralisation since they are [-high, -low]. With an input mid vowel, any change in output height specification is a change from a [-high] specification to [+high], or [-low] to [+low]. Within the theory of correspondence, the former violates of DEP[+HI] while the latter violates DEP[+LO], defined in (16) and (17).

(16) DEP[+HI]: An output [+high] has an input correspondent [+high]

(17) DEP[+LO]: An output [+low] has an input correspondent [+low]

With DEP[+HI], any change from input /ɛ, ɔ/ to output [i, u] is blocked, as it involves an insertion of a [+high] feature that is lacking in the input. Similarly, DEP[+LO] blocks a change from /ɛ, ɔ/ to [a], as that implies an insertion of a [+low] feature. Given that the avoidance of surface mid vowels (as driven by the constraint *[-HI -LO]) is achieved through vowel lowering in Dagbani, violation of DEP[+LO] is tolerated in the language, which means it ranks below DEP[+HI] in a hierarchy DEP[+HI] » DEP[+LO]. However, this ranking also predicts [a] as the epenthetic vowel in Dagbani, not the attested [ɨ]. The opposite ranking of the two DEP constraints (DEP[+LO] » DEP[+HI]) rightly predicts a high vowel as epenthetic, essentially the proposal of Howe and Pulleyblank, but forces mid vowel raising instead of lowering. This ranking paradox is resolved by a faithfulness constraint to the non-high specification of input vowels (MAX[-HI]) along with the ranking DEP[+LO] » DEP[+HI].

(18) MAX[-HI]: Every input [-high] feature has an output correspondent [-high].

MAX[-HI] is violated when input mid and low vowels, both of which are [-high], surface as [+high]. When MAX[-HI] outranks DEP[+LO], underlying mid vowels cannot be raised to satisfy *[-HI -LO]. Surface [+high] feature is only possible where there is an input correspondent [+high] or no input correspondent. Where there is no input correspondent, insertion of a high vowel does not violate MAX[-HI]. This paves the way for a high vowel as the default epenthetic vowel in the language. The tableau in (19) illustrates how high vowel insertion and mid vowel lowering are both achieved. The tableau assumes that faithfulness constraints ensuring that input [+high] and [+low] are never changed can not be violated in the language. Due to space limitation, these constraints and output forms that violate them are left out of the tableau. *[-HI -LO] is also represented as *[MID] to save space.

(19) No [ɛ, ɔ] in non-final position (/bɛ̀hm/ → [bʲàhɨ̀m] 'doubt')

/bɛ̀hm/	*MID	MAX[-HI]	DEP [+LO]	DEP[+HI]	*[-ATR]	*[+ATR]
a. bʲɛ̀hɨ̀m	*!			*	**	
b. bʲèhɨ̀m	*!			*		**
c. bʲìhɨ̀m		*!		**	*	*
d. ☞bʲàhɨ̀m			*	*	**	
e. bʲàhàm			**!		**	

The input form in (19) has only one syllable, with a coda cluster. The most highly ranked *[MID] constraint rules out *bʲɛ̀hɨ̀m* and *bʲèhɨ̀m* for maintaining a mid vowel. This leaves behind output forms with high or low vowels. Replacing the input mid vowel with a high vowel to produce *bʲìhɨ̀m* violates MAX[-HI] fatally. The optimal output form *bʲàhɨ̀m* changes the input mid vowel into [+low], at the cost of a DEP [+LO] violation. While that violation is tolerated, insertion of a [a] in *bʲàhàm* is not, as it incurs an extra DEP [+LO] violation. This proves fatal, compared with the single violation incurred by *bʲàhɨ̀m*. With this ranking, both mid vowel lowering and high vowel insertion are achieved.

4.2 Markedness and faithfulness with sensitivity to features and positions

The constraint hierarchy so far presented blocks mid vowels anywhere in Dagbani phonology. To the contrary, [e, o] surface in final positions of words and other domains. They also surface in non-final position within a [+ATR] harmonic domain. When surfacing in non-final position, the trigger of the [+ATR] harmony is another [e] or [o] in final position. The data in (20) demonstrate surface [e, o] in both final and non-final positions.

(20) ROOTS	Root [-ATR] vowels		[+ATR] harmony	
a. /dɔɾ-/	[dʷáɾ-tɨ́]	'diseases'	[dʷóɾʷ-ó]	'disease-sg.'

b. /dɛm/	[dʲàm-á]	‘a play’	[dʲèm ó]	‘play with him/her’
c. /ʧɔɾ-/	[ʧʷàɾ-tɨ̂]	‘blow-pl.’	[ʧʷòɾʲ-ê]	‘blow-sg.’
d. /bɛ-/	[bʲá-hɨ̀]	‘shin-pl.’	[bʲé-é]	‘shin-sg.’

To derive [e, o] in final positions, two further measures are required. First, the markedness constraint *MID needs to be sensitive to the different values of [ATR] by specifying details about the positions from which mid vowels are banned. The second measure is a faithfulness constraint to the input [low] specification of vowels that is sensitive to domain-final position. Vowel height markedness interacts with [ATR] to ban only the [-ATR] mid vowels [ɛ, ɔ], not all mid vowels. Since [+ATR] vowels are more harmonic than [-ATR] vowels, as evidenced from the ranking *[-ATR] » [*+ATR], a markedness constraint blocking [ɛ, ɔ] needs to be ranked higher than one that blocks [e, o]. The *[Mid] constraint is thus split into the two constraints in (21). An abbreviated version of each is shown in parenthesis.

(21) Markedness constraints combining height with [ATR] feature values

a. *[-HI, -LO, -ATR]: A vowel is not specified for [-high, -low, -ATR] (*MID[-ATR])

b. *[-HI, -LO, +ATR]: A vowel is not specified for [-high, -low, +ATR] (*MID[+ATR])

The need for a position-sensitive faithfulness constraint is based on two assumptions. One is the principle of preservation of the marked, (22).

(22) Preservation of the marked (de Lacy 2006: 1)

There is a grammatical pressure to preserve marked elements. If x is more marked than y, x can be unaffected by a process while y is forced to undergo it.

In spite of being more marked than high vowels, underlying mid vowels are preserved in word-final position, where all high vowels have some restriction. Only the [+ATR] high vowels [i, u] occur in a word-final CV syllable. In words longer than one syllable, only [ʊ, ɨ] are found as discussed in Section 5. The mid vowels are not subject to these restrictions.

The second assumption regards the nature of the word-final position. In a study of positional neutralisation phenomena, Barnes (2006) notes the final position as a domain of ambiguity with respect to the phonological processes observed there. On the one hand, patterns of lengthening and gestural enhancement make this position phonetically and psycholinguistically prominent. It licenses vocalic and tonal contrasts, and resists some patterns of assimilation and reduction. On the other hand, drops in F0 and intensity and laryngeal processes such as devoicing decrease the prominence of final positions. These observations explain the behaviour of the Dagbani mid vowels in final position. The final positions takes 7 vowels, [i, ɨ, u, ʊ, e, o, a] licensing more contrast than the non-final position, which takes only 4 vowels [i, ɨ, ʊ, a] in non-harmonic contexts. On the other hand, mid vowels neither surface as [-ATR] nor become [a] in final position as they do in non-final position. Additionally, as already shown in Section 3, [ɨ, ʊ] do not occur in CV words. The restriction of [+ATR] vowels to final position indicates a drop in F1, indicating its weakness.

Analysis of this asymmetry requires a positional faithfulness constraint (Beckman 1997) to the feature [low] in word-final position. The constraint blocking mid vowel lowering is simply a position-sensitive version of the DEP constraint in (17).

(23) Faithfulness to word-final [low]

DEP[+LO]]$_{wd}$: An output word-final [+low] has an input correspondent word-final [+low].

There is an effective conflict between the demands of DEP[+LO]]$_{wd}$ and the *MID[ATR] constraints. While DEP[+LO]]$_{wd}$ blocks mid vowel lowering, the *MID[ATR] constraints effectively ban mid vowels from all positions. The restriction of mid vowel lowering to non-final position implies a non crucial ranking between *MID[-ATR] and DEP[+LO]]$_{wd}$. The combined violations of *MID[-ATR], DEP[+LO]]$_{wd}$, and MAX[-HI] are needed to derive the right distribution of mid vowels. *MID[-ATR] rules out [-ATR] mid vowels anywhere in the word, DEP[+LO]]$_{wd}$ and MAX[-HI] ensure that word-final mid vowels are maintained as mid. Given the hierarchy *MID[-ATR] » *MID[+ATR] already established, it follows that DEP[+LO]]$_{wd}$ outranks *MID[+ATR] to derive word-final mid vowels. This is shown in (24).

(24) Final [+ATR] mid vowel (/sɨ̀m-ɔ́/ → [sɨ̀m^{w}-ó] 'a dear friend')

/sɨ̀m-ɔ́/	*MID [-ATR]	MAX [-HI]	DEP [+LO]]$_{wd}$	*MID [+ATR]	DEP [+LO]	DEP [+HI]
a. ☞ sɨ̀m^{w}-ó				*		
b. sɨ̀m^{w}-ɔ́	*!					
c. sɨ̀m^{w}-á			*!		*	
d. sɨ̀m^{w}-ʊ́		*!				*

High ranking *MID[-ATR] rules out (24b) with a final [ɔ]. There are only two ways to avoid violations of this constraint. One is to change the height of the mid vowel, as in (24c) and

(24d). However, that is blocked by the MAX and DEP constraints. The other is to change the [ATR] value of the mid vowel, as in (24a), which produces the optimal output.

While *MID[-ATR] correctly derives the output of a domain-final mid vowel preceded by a root high vowel, it is not sufficient to derive a mid vowel in non-final position. The tableau in (25) illustrates this limitation.

(25) Sequence of mid vowels with a final mid vowel (/dOɾ-ɔ/ → [dʷóɾʷ-ó] 'a disease')

/dɔ́ɾ-ɔ́/	*MID [-ATR]	MAX [-HI]	DEP [+LO]]$_{wd}$	*MID [+ATR]	DEP [+LO]	DEP [+HI]
a. ☞ dʷóɾʷ-ó				**!		
b. dʷóɾʷ-ɔ́	*!			*		
c. dʷáɾʷ-ɔ́	*!		*			
d. dʷáɾʷ-á			*!		**	
e. dʷáɾʷ-ʊ́		*!			*	*
f. 👎 dʷáɾʷ-ó				*	*	

In (25), *dʷóɾʷ-ó* and *dʷáɾʷ-ó* satisfy all the undominated constraints. The optimal *dʷóɾʷ-ó* is ruled out with two violations of *MID[+ATR], wrongly projecting *dʷáɾʷ-ó*, as optimal. Section 4.3 shows that *dʷáɾʷ-ó* is blocked by a constraint that derives [+ATR] harmony.

4.3 [+ATR] harmony and mid vowels

The data in (20) show mid vowels as triggers of regressive [+ATR] harmony with root non-high vowels as targets (for a detailed description of Dagbani [ATR], see Hudu (2010, 2013). For the purpose of the brief analysis here, McCarthy's (2004) Span Theory is used to derive [ATR] harmony. In this theory, every harmonic feature creates a span of that feature, and every segment in a harmonic domain belongs to only one span. A sequence of [+ATR] and [-ATR] within one harmonic domain implies two spans: one span of [+ATR], another span of [-ATR]. Vowel harmony is achieved with the constraint *A-SPAN[F], which bans two spans of one harmonic feature within one harmonic domain. This is defined in (26) using [ATR].

(26) No adjacent [ATR] spans (McCarthy 2004: 5)
*A-SPAN[ATR]: Assign one violation mark for every pair of adjacent spans of the feature [ATR]

The only way to satisfy this constraint is for all vowels in a harmonic domain to have one

[ATR] feature value: either all vowels are [+ATR] or they are [-ATR]. *A-SPAN[ATR] ranks higher than *MID[+ATR]. The tableau in (27) shows how [+ATR] vowels emerge in non-final position to achieve [+ATR] harmony. Parentheses mark span boundaries.

(27) Non-final [+ATR] mid vowel (/dɛm ɔ/ → [dʲèmʷ ó] 'play with him/her')

/dɛm ɔ/	*MID [-ATR]	DEP [+LO]]$_{wd}$	*A-SPAN [ATR]	*MID [+ATR]	*[+ATR]
a. ☞ dʲ(èmʷ ó)				**	**
b. dʲ(è)(mʷ ɔ́)	*!		*	*	*
c. dʲ(àmʷ ɔ́)	*!				
d. dʲ(àmʷ á)		*!			
e. dʲ(á)(mʷ ó)			*!	*	*
f. dʲ(ɛ̀mʷ ɔ́)	*!*				

The closest to the optimal output is (27e). It has two vowels, the first is [-ATR], the other is [+ATR]. Each vowel thus creates a different span of [ATR]. Given that the entire phrase constitutes one harmonic domain, having two spans of the same feature constitutes a violation of *A-SPAN[ATR]. The ranking *A-SPAN[ATR] » *MID[+ATR] makes the violation a fatal one; the opposite ranking would have produced (27e) as the optimal output. Regressive harmony produces a [+ATR] variant of [a], the only context in which a [+ATR] [a] occurs. Examples are shown in (28).

(28) Advanced low vowel before final mid vowel

a. /dà/	[dà lɨ́]	'buy it'	[də̀ ó]	'buy it (animate)'
b. /pal-/	[pál-lɨ́]	'new-sg.'	[pʲə́l-ó]	'new-sg. (animate)'
c. /bá/	[bà-já]	'ride-perf.'	[bə́ ó]	'ride it (animate)'
d. /gáɾ-/	[gáɾ-tɨ́/	'bed-pl.'	[gə́ɾ-ó]	'bed-sg.'
e. /kál-/	[kál-tɨ́]	'enamel ware-pl.'	[kə́l-ó]	'enamel ware-sg.'
f. /tàdáb-/	[tàdáb-tɨ̂]	'writing ink-pl.'	[tə̀də́b-ô]	'writing ink'

The same hierarchy used in the preceding tableau derives the right output, as (29) shows.

(29) Non-final [+ATR] low vowel (/gaɾ-ɔ/ → [gə́ɾʷ-ó] 'bed-sg.')

/dɔ́ɾ-ɔ́/	*MID [-ATR]	DEP [+LO]]$_{wd}$	*A-SPAN [ATR]	*MID [+ATR]	LOW [ATR]	*[-ATR]
a. ☞ g(ə́ɾʷ-ó)				*	*	
b. g(ə́)(ɾʷ-ɔ́)	*!		*		*	*
c. g(á-ɾʷ´ɔ)	*!					**
d. g(áɾʷ-á)		*!				**
e. g(á)(ɾʷ-ó)			*!	*		*

It is worth noting that as [+ATR] harmony triggers, final mid vowels only target low and mid vowels, as discussed extensively in Hudu (2010, 2013). This hierarchy accounts for the distribution of all non-high short vowels. Section 5 presents analyses of high vowels.

5. Prosodic Conditioning

There are four prosodic contexts, shown in Table (2), where any Dagbani vowel may occur.

Table 2 Distributional restrictions on [i, ɨ, a, u, ʊ] (in non-harmonic contexts)

	Restricted	**Permitted**
a. Free-standing CV (verb) root	*ɨ, *ʊ	a, i, u, o, e
b. Bound CV (nominal/adjectival) root	*ɨ, *u	a, i, ʊ
c. Free-standing CVN root	*u	a, i, ʊ, ɨ
d. More than one syllable	*u	a, i, ʊ, ɨ

Section 3 shows how [ɨ, ʊ] are restricted from CV words. In the remaining three prosodic positions, only [-ATR] vowels and [i] occur. The data in (30)–(32) show the distribution. Since no section in this chapter is dedicated to the distribution of [a], its distribution is included here to show that it has a similar distributional pattern to the [-ATR] high vowels.

(30) Bound CV (Nominal/adjectival) root

[ʊ]	[a]	[i]
a. nʊ́-hɨ̂ 'hand-pl.'	d. kpá-lɨ́ 'occiput-sg.'	g. tì-á 'tree-sg.'
b. bú-á 'goat-sg.'	e. dà-hɨ́ 'market-pl.'	h. bí-hí 'child-pl.'
c. pʊ́-lɨ̂ 'stomach-sg.'	f. já-ʔʊ́ 'bead-sg.'	i. pí-á 'ten-sg..'

(31) CVN words

[ɨ]	[ʊ]	[a]	[i]
a. dɨ̀m 'bite'	d. dʊ̂ŋ 'enmity'	g. tàm 'forget'	j. ʤìm 'belch'
b. tɨ̀m 'send'	e. tʊ̀m 'work'	h. bàŋ 'know'	k. ʒîm 'blood'
c. zɨ̂ŋ 'miss a target'	f. kʊ́ŋ 'empty'	i. mâm 'lover'	l. tìḿ 'medicine'

(32) Roots with more than one syllable.

[ɨ]	[ʊ]
a. bɨ̀l[ɨ̀]s[ɨ̀] 'fondle with'	g. bʊ̀ʔ[ɨ̀]s[ɨ̀] 'describe'
b. bɨ̀l[ɨ̀]m 'roll'	h. bʊ̀h[ɨ̀]m 'share'
c. bɨ̀ɾ[ɨ̀]m 'confuse'	i. kʊ́l[ɨ́] 'go home'

[a]	[i]
d. tábs[ɨ̂] 'touch'	j. ʧìʔ[ì]s[ɨ̀] 'jump'
e. tábg[ɨ̂] 'kick'	k. jíʔ[í]s[ɨ̂] 'get up'

f. záh[ɪ̂]m ‘measure’ l. jírg[ɪ̂] ‘get frightened’

5.1 Analysis of surface [ɨ], [ʊ]

Analysis of the distribution of [ɨ] and [ʊ] rests on two proposals. The first, discussed in detail and motivated in (Hudu 2010), is that, the mora exists as an active unit in Dagbani phonology. Recognising an active mora leads to the generalisation that the distribution of a [ɨ, ʊ] is prosodically conditioned. It occurs only in a constituent that is minimally bimoraic: a word with more than one syllable or one closed syllable. It is restricted from a CV verb, which is sub-minimal because it has only one mora. Back [ʊ] occurs in nominal and adjectival CV roots because these roots surface with a number suffix. The licenser of [-ATR] in a CV nominal or adjectival root is the entire word not the root. The central /ɨ/ does not occur in a bound CV root, an accidental gap in the distribution that has no effect on the overall generalisation that /ɨ, ʊ/ are restricted to minimally bimoraic domains. The second proposal is that, any domain that has more than one mora is a prosodic foot. The fact that this domain uniquely blocks surface [+ATR] vowels supports its position as an active phonological unit in Dagbani.

The universal hierarchy SPECIFY[ATR] » *[-ATR] » *[+ATR] motivated in Section 3 is not sufficient to account for surface [ɨ, ʊ]. SPECIFY[ATR] constraints that are sensitive to the prosodic foot are required to complement the analysis. These are defined in (33) and (34).

(33) SPECIFY-FOOT-[+ATR]: In a phonological word that has a foot, every vowel is [+ATR] (= SPEC-FT-[+ATR]).

(34) SPECIFY-FOOT-[-ATR]: In a phonological word that has a foot, every vowel is [-ATR] (= SPEC-FT-[-ATR]).

SPEC-FT-[+ATR] requires a vowel in a word with two or more moras to be [+ATR] while SPEC-FT-[-ATR] requires that a vowel in such a domain be [-ATR]. In order to derive [ɨ, ʊ], the role of other constraints and appropriate ranking are assumed. These are (i) FOOT-BIN-μ (Prince and Smolensky 2004), a constraint demanding that all feet have two moras, (ii) DEP-μ (Kager 1999) a constraint that blocks the insertion of mora, and (iii) having both constraints outrank PROPERHEADEDNESS (Ọla 1995), a constraint requiring every prosodic word to dominate a foot. With this hierarchy the effects of SPEC-FT-[+ATR] and SPEC-FT-[-ATR] are restricted to output forms with more than one mora.

To analyse words with odd-numbered syllables, the notion of proper bracketing required in standard metrical theories (e.g. Liberman 1979) is discarded in favour of intersecting feet (Hyde 2002).[3] A three syllable CVCVCV would be parsed as (CV[CV)CV], with "( )" and "[ ]" marking different foot boundaries. In this approach, SPEC-FT-[-ATR] is satisfied in all domains with more than one mora, with the appropriate ranking of other constraints on foot structure and maintaining foot binarity. The ranking SPEC-FT-[-ATR] » SPEC-FT-[+ATR] is required for [ɨ] and [ʊ] to surface. Additionally, SPEC-FT-[-ATR] has to outrank *[-ATR] which has a conflicting demand. This is illustrated in (35) and (36). In all tableaux below which show the prosodic constraints, foot boundaries are marked with "[ ]".

(35) [-ATR] vowels in words with more than one mora (/tim/ → [tɨ̀m] 'send')

/tim/	SPEC-FT-[-ATR]	SPEC-FT-[+ATR]	*[-ATR]	*[+ATR]
a. ☞ [tɨ̀m]		*	*	
b. [tìm]	*!			*
c. [tÌm]	*!	*		

(36) [-ATR] vowels in words with more than one mora (/dʊʔ-ɾɨ/ → [dʊ́ʔ.-ɾɨ̂] 'pot-pl.')

/dʊʔ-ɾɨ/	SPEC-FT-[-ATR]	SPEC-FT-[+ATR]	*[-ATR]	[+ATR]
a. ☞ [dʊ́ʔ.]-ɾɨ̂		**	**	
b. [dúʔ.]-ɾî	*!*			**
c. [dúʔ.]-ɾɨ̂	*!	*	*	*
d. [dÚʔ.]-ɾÎ	*!*	**		

The candidates in (35b, c) and (36b, d) are ruled out by SPEC-FT- [-ATR] because the vowels are not specified as [-ATR]. (36b) incurs an extra violation of this constraint because the second vowel is [+ATR]. It does not matter whether the vowel is footed or not. As long as it is part of a phonological word that is minimally bimoraic, SPEC-FT-[-ATR] requires it to be [-ATR]. These violations leave (35a) and (36a) the optimal forms, in spite of their violations of SPEC-FT-[+ATR] and *[-ATR].

This ranking derives all vowels and their [ATR] variants in words of two or more

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3 Proper bracketing says that a syllable belongs to only one foot. It rules out intersecting feet, where one syllable may belong to two feet. Hyde (2002) argues to the contrary. Due to space limitations, these are not discussed in greater detail. For the same reason, FOOT-BIN-μ, DEP-μ, PROPERHEADEDNESS and constraints discussed in previous sections that are not crucial to the remaining analyses are left out of all tableaux below.

moras except /i/. It incorrectly prevents the surfacing of /i/, deriving all input high non-back vowels as [ɨ]. The tableau in (37) shows this effect. Section 5.2 discusses how surface [i] is derived in domains with more than one mora.

(37) No [+ATR] vowels in words with two or more mora (/tim-a/ → *[tìm-á] 'medicines')

/tim-á/	Spec-Ft-[-ATR]	Spec-Ft-[+ATR]	*[-ATR]	*[+ATR]
a. 👎 [tɨ̀m-á]		**	**	
b. ☞ [tìm-á]	*!	*	*	*

5.2 Contrastive /i/ in two or more moras

/i/ is the only contrastive [+ATR] vowel that is also [+high] and [COR]. The front vowels [ɛ, e] are [COR] but not [+high]; [ɨ, ʊ] are [+high] but not [COR]. In this regard it is worth noting that both [+high] and [COR] have been found cross-linguistically to enhance the feature [+ATR]. As discussed extensively by Archangeli and Pulleyblank (1994), fronting and raising the tongue, the two primary gestures involved in producing front and high vowels respectively are in sympathetic relations with tongue root advancement. Archangeli and Pulleyblank (1994) express these as the grounded path conditions HIgh/ATR and Back/ATR, defined in (38) and (39). In (39), the Back/ATR condition is reformulated as COR/ATR in conformity with the feature theory approache assumed here.

(38) High/ATR Condition: If [+high] then [+ATR] (Archangeli and Pulleyblank 1994:174)

(39) Coronal/ATR Condition: If Coronal then [+ATR]

The fact that [i] is the only contrastive [+ATR] vowel means that the emergence of surface [+ATR] is grounded on both [COR] and [+high] features. This is formulated in (40).

(40) HiCOR/ATR: If [+high] and [COR] then [+ATR].

Being undominated, HiCOR/ATR prohibits surface [ɪ] and accounts for why Dagbani lacks [ɪ] in its grammar. Max-COR, defined in (41), also ensures that [ɨ] is not the surface form as long as the input is [COR], as illustrated in (42).

(41) Max-[COR]: An input [COR] has an output correspondent [COR]

(42) Surface [i] with Max-[COR], HiCOR/ATR » Spec-Ft-[-ATR]

/tim-a/	MAX [COR]	HI-COR/ [ATR]	SPEC-FT-[-ATR]	SPEC-FT [+ATR]	*[-ATR]	*[+ATR]
a. [tɨ̀.m-á]	*!			**	**	
b. [tì.m-á]		*!		**	**	
c. ☞[tì.m-á]			*	*	*	*

The output in (42a) is ruled out by MAX-[COR] because it fails to preserve the coronal feature in the input; (42b) incurs a fatal violation of HICOR/ATR. The constraint hierarchy derives (42c) as the optimal output in spite of its violation of SPEC-FT-[-ATR].

There is an important notion in OT known as Richness of the Base which shields the underlying form from the effects of constraints, restricting the effects of constraints to output forms. When determining what the surface form is, the constraints do not pre-determine what the input form is before the right output form is derived. For instance, the tableau in (42) does not need [i] in the input before *tì.m-á* can be derived. The result remains the same even with input [ɪ], which is also high and coronal. This is illustrated in (43).

(43) Richness of the Base illustrated (cf. Preceding tableau).

/tɪm-a/	MAX [COR]	HI-COR/ [ATR]	SPEC-FT-[-ATR]	SPEC-FT [+ATR]	*[-ATR]	*[+ATR]
a. [tɨ̀.m-á]	*!			**	**	
b. [tì.m-á]		*!		**	**	
c. ☞[tì.m-á]			*	*	*	*

The SPECIFY constraints do not affect the outcome for [-ATR] mid vowels in non-final positions, regardless of where they are ranked in the hierarchy already established. This is because mid vowel lowering preserves the [-ATR] value of /ɛ, ɔ/, the same effect achieved with the hierarchy SPEC-FT-[-ATR] » SPEC-FT-[+ATR]. However, SPEC-FT-[-ATR] conflicts with *MID[-ATR]. In a word with more than one mora, SPEC-FT-[-ATR] requires an output word-final mid vowel or a non-final mid vowel that precedes a final mid vowel to be [-ATR]. Thus SPEC-FT-[-ATR] ranks below *MID[-ATR], which bans such an output. The combined effects of *MID[-ATR], DEP[+HI], and *A-SPAN[ATR] yield a [+ATR] mid vowel both in final and non-final positions, against the demands of SPEC-FT-[-ATR], as shown in (44).

(44) Surface [e, o] with *MID[-ATR] » SPEC-FT-[-ATR]: (/dɛm ɔ/ → [dʲèmʷ ó])

/dɛm ɔ/	DEP [+LO]]$_{wd}$	MAX [COR]	*MID [-ATR]	*A-SPAN [ATR]	SPEC-FT-[-ATR]	SPEC-FT-[+ATR]
a. ☞dʲ(èmʷ ó)					**	

b. d^{j}(è)(m^{w} ɔ́)			*!	*	*	*
c. d^{j}(àm^{w} ɔ́)			*!			**
d. d^{j}(àm^{w} á)	*!					**
e. d^{j}(á)(m^{w} ó)				*!	*	*
f. d^{j}(ɛ̀m^{w} ɔ́)			*!*			**

The result also shows that with this hierarchy, Spec-Ft-[-ATR] does not affect surface final mid vowels as [+ATR] or as [+ATR] harmony triggers targeting preceding non-high vowels.

6. Summary and conclusions

This chapter has demonstrated how a variety of phonological processes interact to shape the surface inventory of Dagbani vowels. With the interaction of violable constraints in OT, each part of the vowel system is due to the force of one constraint category or another. It has also demonstrated the crucial role of different competing constraint hierarchies in the vowel system. The result of these and other patterns of alternation is a grammar with 6 underlying /i, ɨ, ʊ, ɛ, ɔ, a/ and 8 surface [i, ɨ, ʊ, u, e, o, ə, a] short vowels. In (45), the main patterns of alternation and the constraint hierarchies that derive them are shown. All vowels in '[ ]' are surface forms except those that are starred. The arrows show the directions of change.

(45) A Summary of vowel patterns and the constraint interactions producing them.

High vowels: /I/ → *[ɪ]: HiCOR/[ATR] (undominated)

/i/ → [i], *[ɪ, ɨ]: Max[COR], HiCOR/[ATR]
/ɨ, ʊ/ → [u, i]: *[-ATR] » *[+ATR]
/ɨ, ʊ/ → [ɨ, ʊ]: Spec-Ft-[-ATR] » *[-ATR] » *[+ATR]

Non-high vowels: /ɛ, ɔ/ → *[ɛ, ɔ] *Mid[-ATR] (undominated)

[e] [o]
↑ ↑ *[-ATR] » *[+ATR]
/ɛ/ /ɔ/
↘ ↙ *Mid, Max[-Hi] » Dep[+Lo] » Dep[+Hi]
[a]
↑ Lo/ATR » *[-ATR] » *[+ATR]
/a/ → [ə] *A-Span[ATR] » Lo/ATR

The analyses have highlighted the point that in spite of the inherent differences between markedness and faithfulness-based approaches, an eclectic approach to analysis of harmonic patterns within OT may not only be desired, but sometimes required.

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