Dagbani Tongue-root Harmony:

a formal account with ultrasound investigation

by

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Abstract

The aim of this dissertation is (i) to contribute to understanding of [ATR] harmony patterns with a formal account of Dagbani [ATR] harmony using the theory of Headed Spans (Span Theory) and (ii) to answer basic empirical questions about the relations between tongue-root phonological features and the articulatory gestures involved in producing vowels with these features.

In Dagbani [+ATR] harmony, there are three vowel triggers: the high front vowel /i/ triggers progressive assimilation of [+ATR]; the mid vowels [e] and [o] trigger regressive assimilation. Mid vowel triggers predictably surface in domain-final open syllables while /i/ is contrastive. I account for [+ATR] harmony using the theory of Grounded Phonology and the interaction of height-based markedness constraint hierarchies. In addition to the basic harmonic patterns, Dagbani [ATR] harmony is constrained by a height similarity condition limiting the trigger and target to vowels of the same specification for [±high]. Within Span Theory, this is argued to be a restriction on height featural combination in a [+ATR] span.

A unique part of the formal analysis is the account of direction-specific consonant opacity. Having challenged previous harmony theories, the account here demonstrates the relative strength of Span Theory and supports the assumption that intervocalic consonants are targets of vowel harmony features.

The second goal of the dissertation is achieved with an ultrasound imaging study testing the hypothesis that there is a direct mapping between tongue-root features and the articulatory positions of the tongue in producing vowels with different tongue-root feature specifications. It further investigates whether such a mapping also reflects which of the values of the feature [ATR]/[RTR] is dominant in a language. The results of 5 experiments show that in addition to the tongue-root position distinguishing [+ATR] from [-ATR] vowels, the dominant [+ATR] feature has a tongue-root position anterior to the neutral tongue-root rest position while the recessive [-ATR] vowels have a variable tongue-root position. The results support a direct mapping between the phonological feature [ATR] and the articulatory gestures that produce it.

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Dedication

To my family

Chapter 1

Introduction to Dagbani phonology and morphology

1.1 Introduction

The aim of this dissertation is twofold: (i) to contribute to understanding of patterns of [ATR] harmony with a formal account of Dagbani [ATR] harmony using the theory of Headed Spans (Span Theory) (McCarthy, 2004) and (ii) to answer basic empirical questions about the relations between tongue-root phonological features and the articulatory gestures involved in the production of vowels with these features.

While [ATR] harmony in many African languages has been well documented and analysed (e.g. Akan of Ghana, Yoruba of Nigeria, Kinande of the Democratic Republic of Congo), there remain many others which have received very little or no attention in linguistic research. Dagbani is one of such languages. According to Dakubu (1997), early researchers on Gur languages described the vowel system of Dagbani as eccentric. Dakubu (p.c.) also notes that some researchers on Dagbani concluded that the language does not have

[ATR] harmony in its phonology. Dakubu (1997) was the first to claim otherwise. Following her was Olawsky (1999, 2002) and Hudu (2005) who made similar observations. However, none of these presented a formal account of the [ATR] harmony in Dagbani. Olawsky (2002) even claims that the effects of [ATR] harmony in Dagbani are weaker than they are in some neighbouring languages. He described [ATR] harmony in Dagbani as 'a tendency for root vowels to affect suffix vowels'.

This dissertation is intended to fill that gap in the literature by providing a detailed account of [ATR] harmony in Dagbani. It shows that the effects of [ATR] harmony are much more than a mere tendency. Rather, apparent cases of disharmony (which may form the basis for Olawsky's description of the pattern as a tendency) are part of a systematic restriction on vowel features that may exist in trigger-target relations within a harmonic domain.

In providing a detailed account of the Dagbani vowel system and tongue-root harmony, broader issues in phonological theory such as markedness and faithfulness hierarchies, prosodic domain conditioning of phonological processes, the importance of phonetic grounding of phonological constraints, the formulation of similarity conditions in vowel harmony, formal treatment of opaque segments in harmony patterns and many others are discussed and assessed.

The second goal is of broader interest to theories of the phonetics/phonology interface. This dissertation investigates, using ultrasound imaging, whether there is a direct mapping between the phonological features and the articulatory behaviour of the tongue in the production of vowels with different tongue-root feature specifications. It further investigates whether such a mapping also reflects which of the values of the feature [ATR]/[RTR] is dominant in a language. The research question is thus of interest not only for Dagbani, but all languages that display some pattern of tongue-root harmony. It also goes beyond tongue-root harmony, demonstrating the role of discreet phonetic properties in defining phonological features in general.

This introductory chapter presents a brief background on Dagbani, its speakers, and some of the basic aspects of the phonology and morphology crucial to the understanding of [ATR] harmony. The chapter is mainly descriptive; it does not present formal accounts of the processes described. Analyses of these processes are reserved for future work.

1.2 Dagbani and its speakers

Dagbani belongs to the Oti-Volta subgroup, a major branch of Gur languages within the Niger-Congo family of Africa (Naden 1988; Naden 1989; Bendor-Samuel 1989). It is spoken in the northeastern part of Ghana. It is the mother tongue of two ethnic groups, the Dagomba and Nanumba, and highly intelligible to speakers of Mampruli. Even though there is no definite figure on the number of speakers of Dagbani, there are probably over two million people who speak the language natively. National censuses in Ghana group together four related ethnic groups who speak Gur languages. These are

Dagomba, Nanumba, Mamprusi and Maore (spoken mainly in Burkina Faso) into one language group called Mole-Dagbani. The 2000 Population Census released by the Ghana Statistical Service indicated that this language group constitutes 16.5 per cent of the population of Ghana which, by the current (2010) estimate of 22 million, should be over 3,600,000 people. The Dagomba and Nanumba ethnic groups who speak Dagbani clearly constitute over two-thirds of the Mole-Dagbani language group in Ghana.

The language has three main dialects. The Western Dialect is spoken in Tamale, the largest city in northern Ghana, and surrounding towns and villages, the Eastern Dialect is spoken in Yendi, the traditional capital of the Dagomba ethnic group. Both dialects are spoken in Dagbon, the traditional land of the Dagomba. The third main dialect is Nanuni, spoken in Bimbilla and other towns and villages in Nanung, the traditional land of the Nanumba.

The name Nanuni often gives the impression that this dialect is a separate language, an impression that is influenced by the fact that the Nanumba are a different ethnic group. However, there is complete mutual intelligibility between Dagomba and Nanumba speakers. Each of the three dialects has sub-dialects spoken in some towns and villages. Phonological differences between the dialects are reflected mainly in tone and intonation. There are also lexical and a few grammatical differences. Figure 1.1 shows the language map of Ghana indicating the location of native speakers of Dagbani.

I am the primary source of the data used in much of the phonological analysis in this dissertation, being a native speaker. The phonetic data in

Chapter 6 are based on articulatory data obtained from other native speakers of Dagbani during ultrasound imaging experiments in Canada.

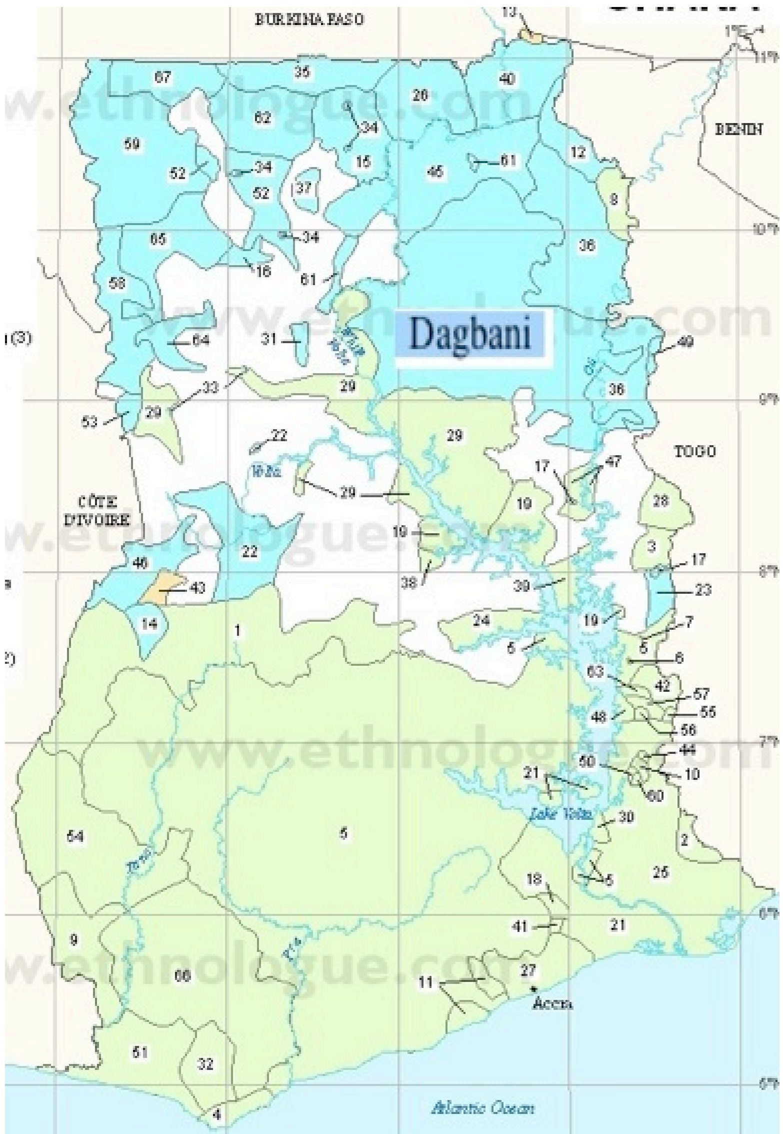


Figure 1.1: A linguistic map of Ghana, showing the location of speakers of Dagbani. Adapted from Lewis (2009) Ethnologue: Languages of the World, 16th Edition, web version, 2009, SIL International. Used by permission.

Tone marking and other minor lexical differences that may be observed reflect the Eastern Dialect, which is my native dialect. The sources of data cited from the literature are noted. I have also consulted native speakers to elicit their judgement on the meaning or pronunciation of words and phrases, especially to determine whether the spread of [+ATR] takes place. In a very few cases, I have consulted two Dagbani-English dictionaries by Ibrahim Mahama (Mahama 2003) and Roger Blench (Blench 2004) mainly for alternative English glosses of Dagbani words.

Of all three dialects, the Western Dialect has received the most attention in previous research. It is often regarded as the standard dialect because it is spoken in Tamale, the largest city in the northern part of Ghana. It is the dialect used in books written in Dagbani and teaching materials taught in schools. It is also used in the media and for recent translations of the Qur'an and Bible into Dagbani. There is somewhat less research focusing on the Eastern Dialect, while Nanuni has received the least attention. Because I have had very little exposure to the Nanuni Dialect, and none of the cited data is on Nanuni, there is nothing in the data used for this dissertation unique to this dialect.

The next sections describe the segment inventory of the language and phonological processes affecting vowels and consonants. Given that the dissertation is on phonology, transcribing the data is essential to the analysis. Unless otherwise noted, all original data is presented in IPA phonemic transcription. It would have been useful to present the data in both the orthography and IPA. However, because there is no standard orthography acceptable to all, and for ease of presentation of the data, I stick to the IPA transcription.

1.3 Consonants

1.3.1 Consonant inventory and distribution

Dagbani has as many as 32 consonants in its inventory, taking into account all variants of the Eastern and Western dialects. 20 of these are contrastive, the remaining 12 are surface variants of other consonants. In Table (1.1), all the consonants are shown, with the surface variants in square brackets. Discussion of the surface variation will follow.

All consonants occur in word-initial and onset positions, except those that are restricted by some phonological process. The most prominent are the phonemes /s, z, k, g, ŋ, kp, gb, ŋm/ which have surface variants before front vowels, discussed further below. The labial velar /w/ also does not occur before front vowels. Most of the variants in square brackets in (1.1) are the outputs of widespread lenition (Hudu 2008a) and palatalisation processes. Some of these alternations have been described in previous studies, notably Abu-Bakari (1977); Olawsky (1996, 1999); Wilson & Bendor-Samuel (1969). In 1.3.2 and 1.3.4, these processes are discussed, focusing on the Eastern and Western dialects, spoken in Dagbon. The differences between the present description and previous ones are noted.

Table 1.1: Consonant inventory

p	t		k [ʧ]	kp [tp]	[ʔ]
b	d [ɾ]		g [ʤ]	gb [db]	
f	s [ʃ]		[x]		[h]
v	z [ʒ]				
	l				
m	n	ɲ	ŋ	ŋm [nm]	
		j		w [ʋ]	

In word-final position, only /m/ and /ŋ/ occur (see also Olawsky 2002; Hyman & Olawsky 2004). Words that end in oral consonants get an epenthetic vowel (see Section 1.4.2 for further discussion on vowel epenthesis). There is another difference in the final distribution of the two nasals. Unlike /m/, some instances of final /ŋ/ are due to assimilation of a root-final /m/ or /n/ to the velar place of a /g/ suffix onset and deletion of the suffix vowel. An example is the word /lɔ̀n-gá/ → [lɔ̀ŋ́] 'frog-sg.' (see Hudu (2007b) for further discussion).[1] Evidence that there is an underlying *-ga* suffix comes from the plural form of the noun, [lɔ́n-sɨ́] which shows that there is a distinct

[1]This refutes Olawsky's (2002) claim that examples like this are part of an independent phonological process of velarisation of word-final /n/.

/lɔ́N/ root. Besides, all Dagbani nouns that take a *-sɨ* plural suffix have a *-ga* singular suffix (see Olawsky 1999 on Dagbani nominal classification).

1.3.2 Debuccalisation

The velar stop /g/ has [ʔ] as a variant in postvocalic position while [s] emerges as [h] in intervocalic position. In most of the early studies of Dagbani phonology (Wilson & Bendor-Samuel 1969; Abu-Bakari 1977; Olawsky 1996, 1999, 2002; Hyman 1993; Dakubu 1997), the postvocalic variant of /g/ is represented as [ɣ]. For many decades, <ɣ> was part of the orthography of Dagbani in all written literature. A proposed standard orthography in 1998 by the Dagbani Orthography Committee excluded it, leaving only <g>, though <ɣ> is still used by some writers. A closer observation of the lenited variant, including its acoustic features, however shows that its place of articulation is much lower in the vocal tract to be a velar. A more accurate representation of this sound would be a glottal stop in some contexts (e.g. following a low vowel) and pharyngeal in other contexts (e.g. following a front vowel). In this dissertation, I have transcribed it as a glottal stop for the sake of consistency.

Sample data illustrating both processes are shown in (1.1) and (1.3). In (1.1a–d), the loss of the buccal constriction takes place along with shortening of a preceding long vowel. In (1.1), the underlying long vowels appear as such on the surface in Mampruli. These contrast with (1.2), in which [s] is maintained when preceded by a nasal or some other consonant.

(1.1) Post-vocalic /s/ debuccalisation

	Underlying Vːs sequence	Surface Vh sequence	
a.	/biː-sɨ/	bí-hí	'child-pl.'
b.	/boːsɨ/	bɔ́hɨ̂	'ask'
c.	/anaːsɨ/	ánáhɨ́	'four'
d.	/kuːsɨ/	kʊ̀hɨ̀	'cry/prick'

(1.2) No /s/ debuccalisation after consonants

a.	bíːn-sɨ́	*bíːn-hí	'expert-pl.'
b.	bóːn-sɨ́	*bóːn-hɨ̂	'white-stripped cloth-pl.'
c.	ɟáːn-sɨ́	*ɟáːn-hɨ́	'grandchild-pl.'
d.	dúːn-sɨ	*dʊ̋n-hɨ̀	'mosquitoe-pl.'
e.	tɨ̀ɾsɨ̀	*tɨ̀ɾhɨ̀	'shift'
f.	tàɾ-sɨ́	*tàɾ-hɨ́	'boundary-pl.'
g.	tɔ̀ʔsɨ̀	*tɔ̀ʔhɨ̀	'speak'
h.	ɲàʔsɨ̀	*ɲàʔhɨ̀	'sparkle'
i.	gáb-sɨ́	*gáb-hɨ̂	'rope-pl.'
j.	tɨ̀bsá	*tɨ̀bhá	'be heavy'

The debuccalisation of /g/ into [ʔ] in postvocalic position limits /g/ to word-initial and post-consonantal positions, as the data in (1.3) show.

(1.3) /g/ debuccalisation

a.	/já-gʊ́/	[já-ʔʊ́]	'bead'
b.	/sɨ́g-ɨ́/	[sɨ́ʔɨ́]	'go down'
c.	/zʊ́g-gʊ̂/	[zʊ́ʔ-ʊ̂]	'head'
d.	/ʧɔ̀gɨ̀m/	[ʧɔ̀ʔɨ̀m]	'be weak'
e.	/gʊ̀hɨ̀/	*[ʔʊ̀hɨ̀]	'wait'
f.	/gɔ̀ɾɨ́m/	*[ʔɔ̀ɾɨ́m]	'journey'
g.	/gáɾgɨ̂/	*[ʔáɾʔɨ̂]	'interfere'
h.	/gbáɾ-gʊ́/	*[gbáɾ-ʔʊ́]	'cripple-sg.'
i.	/kɔ̀b-gá/	*[kɔ̀b-ʔá]	'hundred-sg.'
j.	/bàlgɨ̀/	*[bàlʔɨ̀]	'reduce'
k.	/dàmgɨ̀/	*[dàmʔɨ̀]	'squat'

There are exceptions to both alternations. In all dialects, [s] remains alveolar when it occurs in a closed syllable and preceded by a long vowel. (CVːsVC words).

(1.4) No [s] debuccalisation in CVːsVC forms

a.	bìː-sɨ́m	*bìː-hɨ́m	'hot-ness (heat)'
b.	nɛ̀ː-sɨ́m	*nɛ̀ː-hɨ́m	'awareness'
c.	màː-sɨ́m	*màː-hɨ́m	'cool/cold-ness'
d.	mìː-sɨ́m	*mìː-hɨ́m	'pain-ness (extreme pain/difficulty)'

In a sub-dialect of the Western Dialect spoken in some villages around Tamale, root-final coda /g/ coalesces with a following onset suffix /s/, producing [x] (Hudu 2008a). Thus words pronounced as tɔ̀ʔ-sɨ̀ 'speak', ɲàʔ-sɨ́m 'sweetness' and láʔ-sɨ́-bʊ̂ 'putting together' in other dialects are pronounced in this sub-dialect as tɔ̀xɨ̀, ɲàxɨ́m, and 'láxɨ́-bʊ̂.

In the same sub-dialect, /b/ + /g/ sequences coalesce into [ʋ] even across morpheme boundaries (e.g. /kɔ̀b-gá/ → [kɔ̀ʋ-á] 'hundred-sg.') and /g/ debuccalises in post-consonantal contexts such as those shown in (1.3g–j).

1.3.3 Spirantisation

The velar stops /k, g/ become affricates [ʧ, ʤ] before front vowels. This alternation is not affected by the quality of the preceding vowel, or whether the velar stop occurs in word-initial or non-initial position. These affricates are represented as [ʧ] and [ʤ] in this dissertation and all previous studies except Olawsky (1999), who represent them as [tɕ] and [ʥ]. Data illustrating these alternations are shown in (1.5).

1.3.4 Palatalisation

The two alternations noted in the preceding section are also part of a pattern of palatalisation that all consonants undergo before front vowels. The only exception is /w/, which does not occur before front vowels. Five of the consonants have surface variants before the front vowels. These are /s/ →

[ʃ], /z/ → [ʒ], and /ŋ/ → [ɲ], /k/ → ʧ and /g/ → [ʤ].[2] Unlike the others, the alternation between [ŋ] and [ɲ] is that of neutralisation, as both nasals are contrastive. The relevant data are shown in (1.5).

(1.5) Palatalisation of underlying /s, z, k, g, ŋ/

a.	/s/ →[ʃ]	/sí-â/	[ʃí-â]	‘bee-sg.
b.		/sɛ́-ʔʊ́/	[ʃɛ́-ʔʊ́]	‘rainy season’
c.		/sɛ́ɾ-gá/	[ʃɛ́ɾ-gá]	‘needle’
d.	/z/ →[ʒ]	/zɛ́-ʔʊ́/	[ʒɛ́-ʔʊ́]	‘storm’
e.		/zɛ́ɾ-gʊ́/	[ʒɛ́ɾ-gʊ́]	‘attacker-sg. (with horns)’
f.		/zì-lɨ̂/	[ʒí-lɨ̂]	‘load-sg.’
g.	/g/ →[ʤ]	/gɛ́-lɨ́nsɨ́/	[ʤɛ́-lɨ́nsɨ́]	‘hatred’
h.		/gɛ́bá/	[ʤɛ́bá]	‘hate them’
i.		/kìlɨ̀m/	[ʧìlɨ̀m]	‘delay’
j.	/k/ →[ʧ]	/kɛ̀-hɨ̀/	[ʧɛ̀-hɨ̀]	‘rip in pieces’
k.		/kɛ́-ʔʊ́/	[ʧɛ́-ʔʊ́]	‘broken piece’
l.		/kíhí/	[ʧíhí]	‘deny/belie’
m.	/ŋ/ →[ɲ]	/ŋìn-í/	[ɲìn-í]	‘you.sg. emphatic’
n.		/ŋɛ̀-hɨ́/	[ɲɛ̀-hɨ́]	‘noses’
o.		/ŋɛ́-ɾá/	[ɲɛ́-ɾá]	‘one who defecates’

Note that the transcription of the surface forms in (1.5) is very broad, especially with respect to the word-internal mid vowels. A narrower tran-

[2] See 1.3.5 for a similar effect of front vowels on labial velars.

scription is given in Chapter 2 which presents an analysis of the phonological processes these vowels undergo.

Other consonants get secondary palatal articulation before front vowels (e.g. bʲí-á ‘a child’, dʲíɾ-gʊ́ ‘a spoon’). This is discussed further in Chapter 2.

1.3.5 Other alternations

Three other patterns of alternation for consonants in Dagbani include:

a. Coronal articulation: The labial-velar consonants /kp, ɡb, ŋm/ become labial-coronal [tp, db, nm] before front vowels (see also Ladefoged 1968; Wilson & Bendor-Samuel 1969; Hudu et al. 2009). The labial-velar glide does not precede front vowels.

b. Labialisation: All consonants are labialised before round vowels [u, ʊ, o, ɔ]. Exceptions are the labial-velar consonants /w, kp, ɡb, ŋm/. The labial glide /w/ labialises vacuously. Back vowels lose their labial articulation when they follow the remaining labial-velars, surfacing as default /ɨ/ (see Hudu 2008a for further discussion and analysis.)

c. Post-vocalic flapping: /d/ becomes [ɾ] in post-vocalic positions (see also Olawsky 1999).

1.4 Vowels

1.4.1 Vowel inventory

Dagbani has 10 short vowels and 5 long vowels in its inventory. These are shown in (1.2). Like many languages in Africa, the vowels are divided into two classes based on the feature [ATR] as observed by Dakubu (1997) and Olawsky (1999). Class I vowels are [+ATR], Class II vowels are [-ATR]. Chapter 2 provides analyses of the general distributional patterns of these vowels. Chapters 4 and 5 account for the their distribution within the domain tongue-root harmony, while Chapter 6 tests the distinction between the two classes experimentally.

Table 1.2: Vowel inventory

Class I vowels			Class II vowels		
i iː		u uː		ɨ	ʊ
e eː		o oː	ɛ		ɔ
	ə			a, aː	

Dakubu (1997) and Casali (2002, 2008) observe that in many nine- and ten-vowel ATR harmony languages, [-ATR] vowels occur with a significantly greater frequency than [+ATR] vowels, sometimes by a margin of three or four to one. The same is the case for Dagbani. Even though no statistical figures are available, domains with only [+ATR] vowels are much fewer than those with [-ATR]. For Dagbani, this is partly due to /i/ being the only contrastive [+ATR] vowel and the only root vowel that triggers [+ATR] harmony affecting epenthetic and affix vowels. A detailed analysis of this is presented in Chapter 2.

The claim that Dagbani has a low [+ATR] vowel has not been made in previous studies. The low vowel in Dagbani as well as in many Niger-Congo languages has been claimed not to undergo [+ATR] harmony. In Chapter 2 and 4, data that show /a/ undergoing [ATR] harmony are shown and analysed. Results of ultrasound imaging study presented in Chapter 6 also show that in [+ATR] contexts, /a/ has a more advanced tongue-root than in non-harmonic contexts.

1.4.2 Vowel epenthesis

Vowel epenthesis occurs in verbs, nominal and adjectival roots that underlyingly have only one vowel. In verb roots, the epenthetic vowel is observed in citation forms of roots with the structure CVC, and CVCC. Data for these root forms are shown in (1.6). In all instances, the epenthetic vowel is [ɨ] except when the root vowel is /i/, in which case the epenthetic vowel harmonises with the root vowel, emerging as [i]. Analysis of this is presented in chapters 4 and 5.

(1.6) Epenthesis in verb roots

	CVC roots		CVCm roots		CVCC roots	
[i]	lìh[ì]	‘look’	tìh[ì]m	‘sneeze’	jíʔs[ɨ̂]	‘wake up’
[ɨ]	pɨ̀l[ɨ̀]	‘cover’	bɨ̀l[ɨ̂]m	‘roll’	bɨ̀ls[ɨ̀]	‘fondle with’
[ʊ]	ŋʊ̀b[ɨ̀]	‘chew’	bʊ̀h[ɨ̀]m	‘parasite’	bʊ̀ʔs[ɨ̀]	‘describe’
[ɛ]	fɛ̀b[ɨ̀]	‘whip’	bɛ̀h[ɨ̀]m	‘doubt’	bɛ̀ɾg[ɨ̀]	‘rotten’
[ɔ]	bɔ̀ʔ[ɨ̀]	‘split’	bɔ̀h[ɨ̀]m	‘learn’	tɔ̀ʔs[ɨ̀]	‘speak’
[a]	tàɾ[ɨ̀]	‘share for’	gbár[ɨ̀]m	‘besmear’	tàbl[ɨ̀]	‘stick to’

In nouns and adjectives, epenthetic vowels occur in roots with similar syllable structure. Vowel insertion in CVCC roots is shown in (1.7). All examples in (1.7) except (1.7e) are from Olawsky (1999), with many changes including tone marking (which is not in Olawsky’s data), changes to the tongue-root feature of some of the vowels, transcription of [ə] as [ɨ] and some glosses.

(1.7) Vowel epenthesis for CVCC roots (Olawsky 1999: 175)

	Root	singular		plural	
a.	/namd-/	námd[ɨ́]-lɨ́	*námd-lí	námd-â	'sandal'
b.	/ɲims-/	ɲíms[ɨ́]-lɨ́	*ɲíms-lí	ɲíms-á	'neem tree'
c.	/sabs-/	sàbs[ɨ̀]-gú	*sàbs-gú	sàbs-á	'gecko'
d.	/galm-/	gál[ɨ́]n-lɨ́	*gàlm	gálm-á	'blameworthy'
e.	/gbɨ́ʔm-/	gbɨ́ʔ[ɨ̀]n-lɨ́	*gbɨ́ʔn-lɨ́	gbɨ́ʔm-á	'lion'

An alternative interpretation of the data favoured by Dakubu (1997) is one in which all the vowels that are claimed to be epenthetic are underlyingly part of the root. In the plural forms of (1.7a–c), the suffixation of the plural morpheme -a creates VV hiatus which is resolved by deleting the root vowel (e.g. /námdɨ́-â/ → [námd-â]). However, it does not account for the patterns in (1.7d–e), where the second root vowel in the singular form is lost in spite of there being no hiatus with the suffix vowel. Under the insertion account, the vowel is inserted in the singular forms of (1.7d–e) to break a sequence of three consonants. Vowel insertion breaks what could otherwise be a tautosyllabic cluster of [l] and [n], providing the syllable with a more sonorous nucleus.

The second evidence in favour of an insertion account comes from the behaviour of the CVCV verbs in larger constructions. When any of the CVC[ɨ] verbs in (1.6) is followed by a CV clitic, the final vowel is not seen. Examples include *pɨ̀l lɨ́ *pɨ̀l[ɨ̀] lɨ́* 'start it', and *fɛ̀b tɨ́ *fɛ̀b[ɨ̀] tɨ́* 'whip us' (See 1.5.1 for more discussion on complex nouns). A deletion account cannot easily explain why a CVCV root maintains all vowels when it occurs in isolation but deletes the final vowel when it is followed by a CV clitic.

The next section completes the introduction to Dagbani phonology with a few notes on stress and tone.

1.4.3 Stress and tone

Dagbani has contrastive tone, as observed by almost all researchers on the phonology. Olawsky (1999, 2002) is the first to claim that Dagbani marks stress in addition to tone. He claims that Dagbani stress is correlated with a higher amplitude and longer duration; distinct from tone, which is correlated with a higher pitch. In his observation, Dagbani stress systematically falls on the penultimate syllable. However, results of a phonetic study of one speaker of the Eastern Dialect, (Hudu 2007c), show that vowels that Olawsky claims to be stressed are neither longer in duration nor higher in intensity than vowels that are supposed to be unstressed. This supports the widely held view among many linguists (e.g. Larry Hyman, p.c.) that Dagbani and other Gur languages are not stress marking.

Previous studies describe Dagbani as having two contrastive tones: high and low, with low tone as the default (Hyman 1993; Olawsky 1999; Hyman & Olawsky 2004 etc). Olawsky also notes the existence of contour tones formed out of level high and low tones, as well as downstepped high tones. What has not been observed is that the Eastern Dialect has a contrastive falling tone that falls on unsuffixed CV roots and some suffixes (e.g. *bá* ‘ride’, *bà-* 'river', and *bâ* 'father'). From my observation, syllables that bear falling tones in the Eastern Dialect bear a high tone in the Western Dialect. A more systematic crossdialectal study is required to determine whether the falling toneme is the result of a diachronic phonological process or not. In this dissertation, only the low, high and falling tonemes are marked. Other contours and downstepped high tones are not marked.

1.5 Dagbani morphology

The morphology of Dagbani has been fairly well described (see Benzing 1971; Wilson 1972; Olawsky 1996, 1999, Hudu 2005). A central theme in all previous analyses that is relevant for this study is the distinction between the structure of nouns and adjectives on one hand and verbs on the other. While words of all three categories consist of roots and non-roots, typically suffixes, a nominal/adjectival root is bound to a number suffix with which it must occur, whereas no such relation exists between a verb root and affix. The smallest free standing unit for a verb is a base uninflected root; that of a noun/adjective is a root that is inflected with a suffix. The behaviour of clitics is also crucial to the understanding of Dagbani vowel system and harmony. These categories are discussed in Sections 1.5.1 to 1.5.3.

1.5.1 Nominal/adjectival morphology

Dagbani (countable) nouns and adjectives have the same morphology. In its simplest form, a noun/adjective consists of a root and a suffix that marks singular or plural number. The lexical meaning is provided by the root, although the suffix may serve to disambiguate homophonous roots, as in (1.8a and b), and (1.8c and d). The number suffix generally shows the noun class to which the entire word belongs, as all previous accounts of the morphology show (e.g. Benzing 1971; Wilson 1972; Abu-Bakari 1977; Olawsky 1996, 1999; Hudu 2005).

(1.8) Regular number marking

singular form	plural form	
a. kɔ́b-lɨ́	kɔ́b-á	‘bone’
b. kɔ́b-gʊ́	kɔ́b-rɨ́	‘hair’
c. jíl-î	jí-jâ	‘house’
d. jíl-gú	jíl-á	‘horn’
e. páʔ-á	páʔ-bá	‘woman/wife’
f. ʧɔ́ʔɨ́ŋ-gʊ́	ʧɔ́ʔm-á	‘weak’
g. ʤí-á	ʤí-hí	‘short’

Irregular nouns are not overtly inflected with a singular suffix and take the default plural suffix *-nɨma*. Loanwords that are not integrated into Dagbani morphology and a few native words (e.g. *bâ* ‘father’ and *mà* ‘mother’) are marked with the default plural suffix (see Olawsky 1999; Hudu 2005 etc. for further discussion).

Complex nouns consists of two or more roots and a number suffix. In these forms, the number suffix of the final root becomes that of the entire word, as illustrated in (1.9). Each complex noun combines more than one of the nouns and adjectives shown in (1.8). The complex nominal/adjectival construction is a crucial source of evidence for understanding the surface distribution of vowels, as discussed in Chapter 2.

(1.9) Complex nouns and adjectives

a.	jíl ʤí-hí	‘short horns’
b.	jíl páʔ-á	‘woman of the house’
c.	pàʔ ʧɔ́ʔ-má	‘weak women’
d.	pàʔ ʤì ʧɔ́ʔ-má	‘weak short women’
e.	jíl pàʔ ʤì ʧɔ́ʔm-á	‘weak short house women’

The third type of nominal and adjectival forms, which does not receive any attention in this dissertation, is compound nouns and adjectives. They consist of two nouns/adjectives each with its root and number suffix. Olawsky (1999) has an extensive discussion of compounds.

Other morphemes are reduplicants that mark distributivity, intensity etc. The reduplicants in (1.10) are prefixes that copy the entire root. They maintain a fixed high vowel that is harmonic to the rounding and [ATR] specification of the root vowel (see Hudu, 2007b, for more discussion).

(1.10) Prefixing reduplication

a.	/kpɨ̀l-lɨ́/	‘round’	kpɨ̀-kpɨ̀l-lɨ́	‘portably round’
b.	/ɡbɨ̀l-lɨ́/	‘chubby’	ɡbɨ̀ɡbɨ̀l-lɨ́	‘very chubby’
c.	/dàŋ/	‘arrive early’	dɨ̀n-dàŋà-dáŋá	‘race’
d.	/bɔ̀n-ɡá/ [bɔ̀ŋ́ː]	‘wilderness’	bʊ̀m-bɔ̀ŋ́	‘extreme wilderness
e.	/kpàn-ɡá/ [kpàŋ́ː]	‘wing’	kpɨ̀ŋm-kpàŋ́ː	‘(mature) wing’
f.	/pɔ̀nɡó/ [pɔ̀ŋó]	‘now’	pʊ́m-póŋó	‘right now’
g.	/fíːŋ-ɡá/	‘tiny’	fí-fíːŋ-á	‘very tiny-sg.’
h.	/a-sɨ̀b-á/	‘morning’	a-sɨ̀-sɨ̀b-á	‘early morning’
i.			ɲɨ̀-ɲí-ʔʊ̂	‘bad temper’
j.			ɲí-ɲáŋ	‘motivation’

The nominal base forms of the reduplicants in (1.10i–j) are not used in isolation. However, there are verb root forms (ɲiː ‘show one’s temper’ and ɲâŋ ‘overcome’) which ultimately explain the source of the derived prefixes. The word in (1.10h) is unique in having an initial vowel. It is a fully nativised loan from Arabic, probably through Hausa. The final vowel behaves like a nominal suffix, while the CVC becomes the root, as part of its integration into the Dagbani nominal system. For the purpose of reduplication, the initial vowel is ignored, and the word behaves like a CVC-V noun. Thus it is common to hear the phrase *asɨ̀sɨ̀b máh-lɨ́* ‘very early/cool morning’ (cf. data in (1.9)).

The data in (1.11) has a suffixing reduplication pattern with a fixed *lɨ́n* suffix between the root and the reduplicant. The final CV is the nominal suffix.

(1.11) Reduplication with a fixed *lɨ́n* affix

a.	dí-lín-<u>dí</u>-hî	‘numbness’
b.	ʃí-líɲ-<u>ʃí</u>-hî	‘shadow-pl.’
c.	dɛ̀-lɨ̀n-<u>dɛ́</u>-ʔʊ̂	‘leech’
d.	kpí-lɨ́n-<u>kpí</u>-hî	‘epilepsy’
e.	ká-lɨ́n-<u>ká</u>-ʔʊ̂	‘crow’
f.	sá-lɨ́n-<u>sá</u>-hî	‘non-biting ant-pl.’

Alternatively, the data in (1.11) could be analysed as having prefixing reduplication, like the pattern in (1.10) with the initial syllable as the reduplicant, followed by the fixed *lɨ́n*, the base and the suffix. Evidence for the analysis here comes from non-reduplicated forms with the syllable *lɨn* which show that this syllable follows the root as a suffix; it does not precede the root. Sample data are shown in (1.12).

(1.12) Non-reduplicated words with *lɨn* morpheme

a.	ʒí]$_{rt.}$-lɨ́n-sɨ́	‘ignorance’	<	ʒí	‘not know’
b.	mí]$_{rt.}$-lɨ́n-sɨ́	‘familiarity’	<	mì	‘know’
c.	ká]$_{rt.}$-lɨ́n-sɨ́	‘absence’	<	ká	‘not there’
d.	ʤɛ́]$_{rt.}$-lɨ́n-sɨ́	‘hatred’	<	ʤé	‘hate’
e.	nɛ́]$_{rt.}$-lɨ́n-sɨ́	‘magical vision’	<	nè	‘be able to see’

In (1.12), *lɨ́n* is glossed as a separate morpheme from *sɨ́* because suffixes with more than one syllable are extremely rare in the language. The only example I am aware of is the default plural marker *-nɨma*. Given that *lɨ́n* is not part of the verb roots from which these nouns are derived, it has to be a separate morpheme. Understanding the patterns of reduplication is crucial to the analysis of consonant opacity presented in Chapter 5.

1.5.2 Verb morphology

A verb root is a free-standing word that may optionally take a suffix when inflected for aspect, or a preceding N infinitive particle when it is in the infinitive form. Verb roots may also be followed by post-verbal clitics, mainly locatives and person pronouns. For a root longer than CV (e.g. CVC, CVCC, CVCN), an epenthetic vowel is needed as in the nominal and adjectival forms. (1.13a-d) show roots with inflectional and derivational suffixes, while (1.13e-g) show root-clitic sequences. Epenthetic vowels are in square brackets.

(1.13) Verbs

a.	dì	‘eat’	dì-já	‘ate’
b.	kó	‘farm’	kɔ́-bʊ̂	‘farming (activity)’
c.	kɔ̀h[ɨ̀]	‘sell’	kɔ̀h-gʊ̂	‘commerce’
d.	tábg[ɨ̂]	‘kick’	tàbgɨ̀-rɨ̀	‘kicking’
e.	dʊ́ʔ[ɨ́]	‘cook’	dʊ́ʔ lɨ̂	‘cook it’
f.	gbíh[í]	‘sleep’	gbíh ní	‘sleep there’
g.	zú	‘steal’	zú ô	‘steal him/her’

1.5.3 Clitics

Clitics are non-lexical particles such as pronominal markers, locative particles, determiners, ordinal and cardinal number particles. Some of these are proclitics, preceding nouns, adjectives or verbs; others are enclitics following these lexical categories. Clitics come with the structure V, CV, or N.

The main distinction between clitics and affixes is that clitics can be made emphatic and become full words either in situ or through movement into focus position, with the introduction of other arguments (see Hudu 2009 for further discussion). When emphatic clitics such as pronominal markers take number suffixes, they become words with distinct roots and number suffixes. Affixes do not have this feature. Clitics that are of interest to the discussion in this dissertation are the pronominal and locative proclitics, as the behaviour of vowels in this position contributes to the understanding of

Dagbani vowel phonology and [ATR] harmony (see Chapter 4).

Examples of these proclitics are shown in (1.14) along with their emphatic forms in bold font.

(1.14) Emphatic form of proclitics

a.	[i] jíl nɨ́	'in a house'
	[ii] jíl **pú:ní**	'in a house'
b.	[i] dʊ̋ʔlɨ̂	'cook it'
	[ii] **dɨ́nɨ́** n dʊ̋ʔ (bí)	'it is the one that is cooked (well)'
c.	[i] gbíh ní	'sleep there'
	[ii] **ní** kà ó gbí-hí	'it is there that s/he slept'
d.	[i] zú tî	'steal us'
	[ii] **tɨ̀-nə̀má** kâ bɨ́ zú	'it is us who got stolen'

The next section outlines the structure of the dissertation.

1.6 Structure of the dissertation

The dissertation is organised as follows. Chapter 2 presents a detailed analysis of the Dagbani vowel system using Optimality Theory (Prince & Smolensky 1993/2004). It shows three broad patterns of neutralisations in Dagbani vowel phonology: (i) neutralisation of non-low vowels to [+ATR] feature value in CV words, (ii) neutralisation of all vowels to [-ATR] feature value in domains longer than a CV, and (iii) neutralisation of non-high vowels to low [a] in non-final position. The main argument in this chapter is that these patterns of neutralisation are determined by markedness and faithfulness considerations based on vowel height and [ATR], prosodic conditions, and [ATR] vowel harmony.

Chapter 3 reviews the literature on approaches to analysis of vowel harmony within Optimality Theory. The weaknesses of approaches such as alignment, spreading and agreement are discussed. The chapter demonstrates the relative strength of Span Theory (McCarthy 2004) and argues that it is ideal for the account of Dagbani [+ATR] harmony.

In Chapter 4, a formal account of [ATR] harmony in Dagbani is presented. Building on the theory of Grounded Phonology (Archangeli & Pulleyblank 1994), it shows that Dagbani [ATR] harmony is constrained by a height-based similarity condition restricting the trigger and target of [+ATR] harmony to vowels with the same specification for the feature [±high]. With this condition, a [+ATR] high [i] only triggers advancement to other high vowels while [+ATR] mid vowels [e] and [o] trigger advancement to other mid and low vowels.

Consonant opacity, a rare pattern of opacity in tongue-root harmony systems, is dealt with in Chapter 5. It demonstrates that there is indeed a clear pattern of direction-specific blocking effects contrary to arguments in the literature that such patterns may not exist. Analysis of consonant opacity also shows the relative strength of Span Theory approach to vowel harmony.

Chapter 6 is an ultrasound study, results of which show that (i) the distinction between [+ATR] and [-ATR] vowels both in harmonic and non-harmonic contexts is based on the position of the tongue-root, (ii) low vowels are targets of [+ATR] harmony, (iii) the distance between a trigger and target does not affect the level of assimilation, and (iv) the tongue-root position of vowels with the dominant [+ATR] feature is anterior to the neutral rest position of the tongue-root, while that of vowels with the recessive [-ATR] specification is more variable. The findings support a direct mapping between articulatory gestures and phonological features. Chapter 7 concludes the dissertation.

Chapter 2

Dagbani vowel phonology

2.1 Introduction

Previous studies of Dagbani vowel phonology (e.g. Dakubu, 1997; Hudu, 2005, 2007a; Olawsky, 1999; Wilson & Bendor-Samuel, 1969) have shown that surface variation in Dagbani vowels is shaped by phonological processes such as vowel harmony, vowel elision, and changes to vowel height. While this assessment seems to be accurate, no systematic account of surface variation between vowels has been given. All previous researchers seem to agree, without solid motivation, that the vowels [i, e, o, u] form part of the unrestricted set from which [ɨ/ɪ, ɛ, ɔ, ʊ] are derived as surface variants. This chapter re-examines these claims, with a formal account of the Dagbani vowel system. Using Optimality Theory (Prince & Smolensky 1993/2004; McCarthy & Prince 1993a; McCarthy & Prince 1995), it argues that the surface distributions of the vowels of Dagbani are constrained by height-based faithfulness and markedness constraint hierarchies, prosodic conditions, and [ATR] vowel harmony.

The standard view regarding which vowels form the contrastive set has never been well motivated. While studies such as Dakubu (1997) have assumed the vowels [u, o, e] to be underlying, without argumentation, those that have discussed vowel contrast and allophonic variation (e.g. Olawsky 1996, 1999; Hudu 2005) provide insufficient motivation for their analyses. Discussions on how various phonological processes shape the inventory have also been unsatisfactory. For instance, almost all previous accounts have noted the surface variation between [i] ∼ [ɪ], [ʊ] ∼ [u], [ɛ] ∼ [e], and [ɔ] ∼ [o]. Yet there has so far been no formal account of this variation beyond the claim that each emerges in patterns of tongue-root harmony. The analysis here shows that assumptions regarding which vowels are underlying are not necessary in providing an accurate account of the Dagbani vowel phonology. It shows that contrary to the impression created in the previous studies, surface variation in vowel quality is not always driven by [ATR] harmony. [ATR] harmony is only one of several phonological processes that determine surface alternations between [+ATR] and [-ATR] vowels.

The proposed analyses of several aspects of the vowel phonology are based on other proposals that are well motivated in the literature. The surface forms of Dagbani vowels emerge out of the interaction of faithfulness and markedness hierarchies based on sonority considerations, [ATR] and height features, prosodic conditioning and [+ATR] harmony. In non-final position, mid vowels neutralise to [a] because the mid vowels are the most marked in height specification, as discussed further below in Section 2.3.1. On the other hand, the preference for more sonorous vowels as syllable nuclei produces a hierarchy in which faithfulness to non-high vowels out-rank faithfulness to high vowels. This hierarchy explains why mid vowels neutralise with [a] through vowel lowering, not raising; and why the default epenthetic vowel in Dagbani is [+high].

Prosodic domain requirements produce the set [i, ɨ, a, ʊ] in words that are minimally bimoraic. In words that are sub-minimal, the [ATR] markedness hierarchy ensures that the only non-low vowels that surface are [i, e, o, u]. [+ATR] harmony produces a [+ATR] variant of [a], which, in non-harmonic contexts, does not occur. It also produces [+ATR] mid vowels 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, 1989, 1991; Clements & Hume, 1995, etc.). The analysis here departs from some of these proposals by maintaining the traditional features [high], [low] and [ATR] (see Sagey 1986; Hyman 1988; Odden 1991 etc.). These features have been used in many previous formal accounts of tongue-root patterns and discussions on the phonetic properties of tongue-root features, discussed in chapters 4 – 6. For the purpose of maintaining a consistent use of features in all the chapters, I use these features in this chapter. However, it does not presume that the feature [open] could not possibly be used in the present analysis. In Odden's proposal, these three features are dominated by a Height node under the Vowel Place node.

In this dissertation, the Vocalic node is assumed to dominate the Height node, which replaces the Aperture node of Clements & Hume. The major features are shown in Table (2.1). The rest of this introduction reviews the literature on previous studies of Dagbani vowel system.

Table 2.1: Dagbani vowel features

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

2.1.1 Vowel contrasts

Previous analyses of the Dagbani vowel system agree that the language has 6 phonemic vowels, which include the five vowels /i, u, e, o, a/. They differ on whether the sixth phonemic vowel is /ɨ/ or /ə/. Abu-Bakari (1977) and Dakubu (1997) represent it as /ɨ/. This is also the view of other researchers on other Gur languages, e.g. Tony Naden (p.c.). Wilson & Bendor-Samuel (1969) and Olawsky (1996, 1999) represent it, rather controversially, as /ə/. The fact that this vowel alternates with [i] in a pattern similar to other alternations between mid [e/ɛ, o/ɔ] and high [u/ʊ] vowels is an indication that it is a high vowel. The vowel [ɨ] is used here both as a phoneme and as a surface variant of /i/.

Other aspects of the vowel phonology are uncontroversial. First, there is phonemic vowel length distinction. The contrastively long vowels are /iː/, /uː/, /eː/, /oː/ and /aː/, as the minimal and near-minimal pairs in 2.1 show.

(2.1) Contrast between long and short vowels

	Short vowels		Long vowels	
a.	bì	‘be well cooked	bìː	‘heat up’
b.	tì	‘give’	tìː	‘take (something that’ rests on another)’
c.	tù	‘put beads in string’	tùːi	‘stumble on something’
d.	ʒè	‘scramble over’	ʒèː	‘exceed limit’
e.	tè	‘filter’	tèː	‘remember’
f.	gò	‘travel’	gòːi	‘stop a fight’
g.	báŋ-á	‘bangle-sg.’	báːŋ-á	‘praise singer-sg.’
h.	dáŋ-á	‘wound-sg.’	dàːŋ-á	‘hearth-sg.’

Second, there is allophonic variation of non-low vowels between [u] ∼ [ʊ], [e] ∼ [ɛ] and [o] ∼ [ɔ]. Third, [ɨ] neutralises with [i] in [ATR] harmony contexts. I return to both patterns later in this chapter with detailed discussion and analysis.

In addition to the 6 short vowels, Abu-Bakari (1977) also includes [ɛ] and [ɔ] among the vowel phonemes, citing the data in (2.2).[3]

(2.2) Distribution of [o] and [ɔ] (Abu-Bakari 1977)

a.	[i].	kʷóm	"water"	[ii].	kɔ́ŋ	"to lose"
b.	[i].	nóó	"hen"	[ii].	nɔ̀hí	"hens"
c.	[i].	ɲó	"to burn"	[ii].	ɲɔ́ʔú	"chest"
d.	[i].	tó	"pound"	[ii].	tɔ̀ʔú	"bitter"

Even though Abu-Bakari does not discuss the data further, the pairs in (2.2) are apparently meant to show that [o] and [ɔ] occur in similar, though not exactly the same environments. The two words in (2.2a) are supposed to be near-minimal pairs, (2.2b-d) show the two vowels occurring in open syllables.

The problem with this analysis is that it lacks phonetic accuracy. In Dagbani, [+ATR] mid vowels do not occur in closed syllables. A more accurate transcription of "water" in (2.2a [i]) is *kʷɔ̀ḿ*, (with tone marking here reflecting the Eastern Dialect). Even in open non-final syllables, [o] and [e] do not occur except as targets of [+ATR] harmony, as Abu-Bakari accurately shows for the second of each pair in (2.2b-d). The generalisation is that [e, o] are in complementary distribution with [ɛ, ɔ]. The [+ATR] mid vowels [e, o]

[3]For purely expositional reasons, the data in (2.2) differ from the original data in Abu-Bakari (1977) in two ways. (i) Letters of the orthography used in Abu-Bakari (1977) are replaced with IPA symbols. (ii) "ʔ" in (2.2) is "ɣ" in Abu-Bakari (1977). Everything else remains the same.

occur in two contexts: (i) word- and phrase-final position as a suffix, clitic or part of root, as in (2.2b–d) and (ii) non-final position preceding another mid vowel in final position. The [-ATR] variants [ɛ] and [ɔ] occur phonemically in all other non-final open and closed syllables (although see further analysis in Section 2.3 to the effect that mid vowels are never realised phonetically as [ɛ, ɔ]).

2.1.2 Surface alternations

Accounts that have noted the surface alternation between the [+ATR[and [-ATR] variants of mid vowels claim that [e] and [o] are the phonemes from which [ɛ] and [ɔ] are derived. Olawsky (1999) uses the data in (2.3) and (2.4) as the basis for his analysis. (I have maintained here all the details as they appear in Olawsky's work, except tone marking, which is mine. I have also replaced Olawsky's ɣ with ʔ).

(2.3) Distribution of [e] and [ɛ] (Olawsky 1999: 236)

[e]	a.	ŋmè	'beat-V'
	b.	bè	'be, *copular*'
	c.	ʒè.má.nî	'generation-N'
	d.	dé.dé	'exactly, *adv.*'

[ɛ]	e.	jɛ̀.dá	'faith-N'
	f.	ʃɛ́.lí	'some, any, *indef. pron.*'
	g.	lɛ́.hú	'adze-SG'
	h.	kpɛ́.má	'elder-SG'

(2.4) Distribution of [o] and [ɔ] (Olawsky 1999: 238)

[o]	a.	pó.lô	'near; field-SG'
	b.	nó.lɔ́.ʔʊ́	'cock-SG'
	c.	bò.rò.bò.rò	'bread-N'
[ɔ]	d.	bɔ̀.rì	'want-V'
	e.	dɔ́.lî	'follow-V'
	f.	nɔ́.ŋá	'scorpion-SG'
	g.	kɔ̀.hì	'sell-V'

Olawsky (1999) says that [ɛ] and [ɔ] occur in closed and non-final open syllables, contexts where [e] and [o] do not occur. In word-final positions, [e] and [o] occur, the only exception being final positions of non-lexical categories, where [ɔ] also occurs.[4]

Dakubu (1997) claims that /e/ merges with [ɪ] and /ɨ/, such that in monosyllables they emerge as [e], and in polysyllables as [ɨ], or [ɪ] after palatal

[4](2.3c) is a loan word that could be more accurately transcribed as *ʒɛ̀.má.nɪ̂* while (2.4b) is a complex word with two lexical roots and two harmonic domains (*nó* 'chicken' *lɔ́ʔʊ́* 'masculine'). Note also that contrary to Olawsky's transcription, all word-final vowels with the exception of mid vowels are [-ATR] (e.g. lɛ́.hʊ́, ʃɛ́.lɪ́, and bɔ̀.rɪ̀, etc.).

consonants. In the presence of vowel length, she claims, these vowels merge into [eː]. In Dakubu's account, this explains why Dagbani does not have a long [ɨ]. To account for CV particles such as *tɨ* 'first person plural' and *dɨ* 'third person singular inanimate', which apparently contradict her account, Dakubu suggests that these particles be regarded as initial constituents in compound phonological words, not clitics. In this way, the particles in which [ɨ] occurs cease to be CV, but part of polysyllabic word. Dakubu's account thus seems to assume that clitics form separate phonological words.

Dakubu's observation that [ɨ] has a restricted distribution is a valid one. As discussed below, it does not occur in final position of unsuffixed lexical roots. In final position, it is either the nucleus of a suffix or an epenthetic vowel. What does not seem to be motivated is her claim that [ɨ] never occurs in monosyllabic forms and that [ɨ] and [ɪ] merge into [e]. Even if we assume that clitics form separate prosodic words, it is still necessary to make a distinction between the distribution of these CV forms and lexical words such as nouns. While lexical nouns are initial constituents in compounds with adjectives and other nouns, the pronominal CV form *tɨ* '1st person plural', only precedes verbs in subject position and follows verbs in object position. Thus for these CV forms to be constituents of compounds in the same sense as lexical words are, they will have to be initial or final constituents of compounds with verbs as the other constituents. However, there are no such compounds in Dagbani. Verbs are not constituents of compounds with other lexical forms.

A similar argument can be raised against Dakubu's use of the lack of [ɨː] to support the merger of [ɨ] with [e]. It ignores the fact that Dagbani lacks phonemic vowel length for retracted non-low vowels: [ʊː, ɔː, ɛː]. Given that the language lacks these vowels there is no basis to expect [ɨː] in the inventory. In other words, the fact that /ɨː/ does not exist in Dagbani phonology is part of its regular phonological pattern, not an exception.

There is little or no controversy in previous descriptions of the back high vowels. However, generalisations on the distribution of the high back vowels suffer the same descriptive inadequacy as those on mid vowels. Olawsky (1999) says that it is not a straightforward task to determine the contexts in which [u] and [ʊ] occur. His only observation is that vowel harmony plays an important role in the alternation. For the non-back vowels, Olawsky has three surface realisations for /i/: [i, ɪ, ɨ], [ɪ] and [ɨ] being the [-ATR] variants. Any claim that [ɪ] is part of Dagbani vowel inventory is difficult to motivate phonologically. A major argument against its existence in Dagbani is that the [-ATR] variant of /i/ does not trigger palatalisation of preceding onsets as the high and mid front vowels do (see Section 2.3.1 for further discussion on palatalisation and Section 2.4.3 for a discussion on the high front vowel). I consider all alleged cases of surface [ɪ] to be [ɨ].

For the low vowel there is a unanimous assumption in the literature regarding its distribution. All accounts either assume that [a] is the only low vowel the language has, with no surface variant, or fail to challenge that assumption. However, results of an ultrasound study in Chapter 6 show that

/a/ has an advanced variant when it precedes another [+ATR] vowel. In this study, the low vowel was found to have a more advanced tongue root in this environment even when it occurs two syllables away from the trigger. The study also shows that the alternation is similar to the allophonic variation between the high vowel pairs [i] ∼ [ɨ] and [u] ∼ [ʊ]. The nature of the assimilation and similarity to the alternations between high vowel pairs both support the argument that this surface realisation is a phonological harmonic pattern, not a result of phonetic interpolation. Sample data illustrating the alternation is shown in (2.5).

(2.5) Advanced low vowel before final mid vowel

a.	/dà ó/	$[\text{də̀}]_{rt.}$ $[\text{ó}]_{clt.}$	'buy it (animate)'
b.	/bá ó/	$[\text{bə́}]_{rt.}$ $[\text{ó}]_{clt.}$	'ride it (animate)'
c.	/kál-ó/	$[\text{kə́l}]_{rt.}$-$[\text{ó}]_{suf.}$	'door-sg.'
d.	/sàl-ô/	$[\text{sə̀l}]_{rt.}$-$[\text{ô}]_{suf.}$	'crowd of people'
e.	/tàdáb-ô/	$[\text{tə̀də́b}]_{rt.}$-$[\text{ô}]_{suf.}$	'writing ink'
f.	/tàtáb-ô/	$[\text{tə̀tə́b}]_{rt.}$-$[\text{ô}]_{suf.}$	'the like of'

Addressing the various claims in previous studies requires a phonological account of the vowel system and a detailed phonetic study of Dagbani vowel features. The latter is not covered in this dissertation. This chapter presents the much needed phonological account with formal analysis. Since the phonemic status of all long vowels is not a subject of controversy, and given that they do not display any surface variations, they will not be discussed any further in this dissertation. Only short vowels are covered.[5]

Section 2.2 argues that the distribution of [+ATR] and [-ATR] vowels is determined by markedness considerations. Only [+ATR] vowels occur in CV roots because the [+ATR] feature is less marked, compared to [-ATR]. An OT account of this is presented using the markedness hierarchy *[-ATR] » *[+ATR]. Section 2.3 focuses on the distribution of mid vowels, which, I argue, is also determined by markedness considerations. Specifically, a combination of [-ATR] markedness and the marked status of the mid vowels leads to the neutralisation of [ɛ] and [ɔ] with [a], emerging as a low vowel. This pattern is also observed in Nupe, a Kwa language of Nigeria (Hyman 1970). In Section 2.4, I argue that [-ATR] vowels only occur in a prosodic domain that is at least two moras, and provide a formal account of this restriction. Section 2.5 summarises the chapter.

2.2 [ATR] markedness

In has been argued in previous studies (Baković 2000), that the [-ATR] value is more marked than [+ATR]. A similar argument is presented here, using a pattern of structural neutralisation as the diagnostic for the markedness relations between the two [ATR] values.

[5] Vowel lengthening is observed in some aspects of the phonology, especially as a strategy for resolving hiatus. A future account of this will enrich our understanding of the Dagbani vowel phonology.

In Dagbani, a non-low vowel neutralises to the [+ATR] variant in unsuffixed CV lexical roots. In words larger than CV, other patterns of neutralisation take place, as discussed in sections 2.3 and 2.4. The low [-ATR] vowel /a/ also occurs in this position, but not the [-ATR] vowels [ɨ, ʊ, ɛ, ɔ], as the data in (2.6) show. All roots in (2.6) are verbs. Nominal and adjectival roots are avoided because unlike verbs, their citation forms require a suffix which may trigger some assimilatory process affecting segments in the root.

(2.6) 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 ugly'	tè 'filter'	ʤé 'dislike'	mé 'build'
[o]	bò 'seek'	tò 'pound'	gò 'travel'	ló 'tie'
[a]	bá 'ride'	tà 'smear'	ŋmá 'break'	là 'laugh'

The data in (2.6) show a pattern of structural neutralisation between [+ATR] and [-ATR] vowels in forms that are maximally CV. This structural neutralisation provides support for the markedness hierarchy [+ATR] $\succ$ [-ATR]. The [+ATR] vowel is less marked than the [-ATR] vowel because it is the output of the neutralisation between the two [ATR] values. The observation that structural neutralisation between two values counts as a markedness diagnostic has been made in previous work, including Troubetzkoy (1939, 1968), Jakobson (1941), Greenberg (1966), Cairns 1969, Paradis

& Prunet (1991), Rice (2006), de Lacy (2006). De Lacy states the generalisation as in (2.7).

(2.7) Neutralisation output as a 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]

This markedness difference is translated into the markedness constraint hierarchy *[-ATR] » *[+ATR], defined in (2.8). All constraints used in this dissertation are listed in Appendix A.

(2.8) ATR markedness constraints

a. *[+ATR]: A vowel must not be [+ATR]
b. *[-ATR]: A vowel must not be [-ATR]

A third constraint that is undominated is a constraint that ensures that surface forms of vowels have specification for a tongue-root feature. Following similar proposals in the literature (e.g Itô & Mester 1993; Pulleyblank 1997; Padgett 2002; Kim 2003; Beckman & Ringen 2004; Kim & Pulleyblank 2009), I propose the SPECIFY constraint in (2.9) to force a specification for [+ATR] or [-ATR] value on every output vowel. The ranking of these three constraints accounts for the emergence of [+ATR] as the default value for all ATR pairs. Without any confounding factors (e.g. prosodic domain conditioning, discussed in Section 2.4), all non-low vowels in Dagbani are [+ATR]. The tableaux in (2.10) and (2.11) show this.

(2.9) Constraint on output specification for [ATR]

Specify[ATR]

Every vowel must have a specification for [ATR]

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

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

(2.11) 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 (2.10b) and (2.11b) are ruled out by Specify[ATR] because they are not specified for any value of [ATR]. The third output form in each tableau is also ruled out by *[-ATR], leaving the forms with a [+ATR] vowel the optimal outputs.

For the low vowel, its [-ATR] feature is protected by the grounding condition Lo/ATR (Archangeli & Pulleyblank 1994, 2002), defined in (2.12).

(2.12) [-ATR] grounded in [+low] (Archangeli & Pulleyblank 1994: 174)

LO/ATR: If [+low] then [-ATR]

With LO/ATR crucially outranking *[-ATR], and the [+ATR] low vowel [ə] being phonologically low, a surface [+ATR] feature for an input low vowel is blocked, as shown in (2.13).

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

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

In the remaining tableaux in this dissertation, SPECIFY[ATR] is left out. Output forms that violate it are not shown.

The results in (2.10), (2.11), and (2.13) are the surface forms in unsuffixed CV roots. [+ATR] vowels occur mainly in unsuffixed words and phrase- and utterance-final positions. In all other positions, vowels surface as [-ATR]. In Section 2.3, I show that mid vowels in other positions become low, a process that does not affect other vowels. I argue that this is due to mid vowels having the most marked height specification. In Section 2.4, I argue that a surface [-ATR] vowel requires two moras as minimal prosodic unit.

2.3 Mid vowel phonology

There are three phonological processes unique to mid vowels: (i) mid vowels are lowered to [a] in non-final positions, (ii) only mid vowels surface as [+ATR] in final positions regardless of the prosodic profile of the domain in which they occur, and (iii) final mid vowels trigger [+ATR] harmony that targets preceding non-high vowels. Analyses of these patterns are presented in 2.3.1–2.3.4.

2.3.1 Non-final mid vowels

Olawsky (1999) observes that the front mid vowel is lowered before dorsals, [h] and [ʔ], surfacing as [a]. He supports this observation with the data in (2.14). Lowering occurs along with palatalisation of the preceding consonant.[6]

[6]Olawsky does not show the underlying forms of the front mid vowel in (2.14c-d), but mentions them in his discussion. The original data also lack bracketing to show morpheme boundaries. They are all included here for more clarity. Notice that unlike Olawsky, I do not consider /e/ the underlying form of the front mid vowel, as argued further below.

(2.14) [ɛ] lowering before dorsals and pharyngeals (Olawsky 1999: 236 – 237)

a.	/bje-gu/	[[bjɛ]$_{rt}$ -ʔʊ], [[bja]$_{rt}$-ʔʊ]	'bad/ugly-SG'
b.	/pje-gu/	[[pjɛ]$_{rt}$-ʔʊ], [[pja]$_{rt}$-ʔʊ]	'sheep-SG'
c.	/kpjeŋ/	[kpjɛŋ], [kpjaŋ]	'strength'
d.	/ʃeŋa/	[[ʃɛŋ]$_{rt}$-a], [[ʃaŋ]$_{rt}$-a]	'some, *indef.pron.*'
e.	/lehu/	[[lɛ]$_{rt}$-hu] / [[l^{j}ɛ]$_{rt}$-hu]/ [[l^{j}a]$_{rt}$-hu]	'adze'

Olawsky's presentation of the data in (2.14) has two generalisations: (i) /e/ is the underlying form of the front mid vowel and (ii) the lowering processes is only optional evidenced by his positing both [ɛ] and [a] as possible surface realisations of the front mid vowel. In his analysis, when an underlying /e/ surfaces as [ɛ], the alternation only leads to a change in the [ATR] specification of the vowel. In the discussion and analysis below, I argue that both generalisations are inaccurate. The [-ATR] [ɛ] is the underlying forms of the front mid vowel (as is [ɔ] the underlying form of the back mid vowel), not [e]. However, it is never realised on the surface. The actual surface forms in (2.14) are those with the low vowel [a].

Wilson & Bendor-Samuel (1969) also observe a process of lowering that results in neutralisation between root /ɛ/ and /a/. However, in their observation, this lowering only takes place when the vowel precedes the suffix *-hi*, as shown in the sameness of the surface forms in (2.15a-b) and those of (2.15c-e) (although see discussion below for evidence that the pattern is more pervasive than suggested by Wilson & Bendor-Samuel). Except for (2.15a), the rest of the examples are from Wilson & Bendor-Samuel (1969), with some changes to the transcription.

(2.15) Neutralisation between underlying /a/ and /ɛ/ (Wilson & Bendor-Samuel 1969)

a.	/da-/	[[dà]$_{rt}$-hɨ́]	'markets'
b.	/ʤa-/	[[ʤà]$_{rt}$-hɨ́]	'twins'
c.	/ɲɛ-/	[[ɲá]$_{rt}$-hɨ́]	'noses'
d.	/dɛ-/	[[dʲà]$_{rt}$-hɨ́]	'bush pig'
e.	/nɛ-/	[[nʲà]$_{rt}$-hɨ̀]	'awaken (many people)'

While the general observation that /ɛ/ lowers seems to be accurate, the lowering seems to be more pervasive than shown in previous accounts, as it occurs before other consonants, (2.16). In all non-final positions the only cue to the phonemic contrast between the low vowel and the retracted mid vowel in such words as the pairs in (2.16) is the secondary articulation on the onset of the latter, and not the height specification of the vowel.

(2.16) Minimal pairs with underlying /a/ and /ɔ/

	Underlying low /a/		Underlying mid /ɛ/		
a.	bàlɨ̀	'gather pieces'	/bɛ̀lɨ̀/	bʲàlɨ̀	'accompany'
b.	làbɨ̀	'return'	/lɛ̀bɨ̀/	lʲàbɨ̀	'change/become'
c.	pâm	'plait'	/pɛ̂m/	pʲâm	'arrow'
d.	bàḿ	'(bodily) odour'	/bɛ́m/	bʲám	'miserliness'
e.	dàm	'shake'	/dɛ̀m/	dʲàm	'play'
f.	tàɾɨ̀	'share'	/tɛ̀ɾɨ̀/	tʲà-ɾɨ̀	'filtering'

While Olawsky has [a] as the surface form of the lowered mid vowel, Wilson & Bendor-Samuel (1969) and Dakubu (1997) differ. Wilson and Bendor-Samuel claim that the surface form of lowered [ɛ] is [æ] before the glottal fricative, the only position where, in their analysis, [æ] occurs. Before [ʔ] (represented as [ɣ] in their analysis), Wilson & Bendor-Samuel say that the front mid retracted vowel surfaces as [a]. They illustrate this difference with the pair in (2.17a and b), both of which have the same underlying form. Wilson & Bendor-Samuel further argue that the alternations in the singular form of the vowel shown in (2.17c) provide evidence for three variants in the front mid vowel: [e], [ɛ] and [æ]. (In (2.17), alternative forms and glosses in brackets are mine).

(2.17) Variations in front mid vowel (Wilson & Bendor-Samuel (1969))

a. /bE-/ (bɛ) byæhi 'legs (shins)'

b. /bE-/ (bɛ) byaɣu 'bad'

c. /bE-/ (bɛ) bee 'leg (shin)'

Dakubu (1997) sees [æ] as a dialectal variant that occurs after palatalised consonants only in the Western Dialect and a variant of [ɛ] in the Eastern Dialect. In spite of these differences, all three previous accounts (Dakubu; Olawsky; Wilson & Bendor-Samuel) agree that the front mid vowel lowers in non-final position. The only difference between their analyses and the account presented here is that they restrict the process to only certain contexts, whereas I argue that there is no such restriction.[7]

What has not been noted in previous studies is that the back mid vowel has the same distributional pattern. In all contexts, the only cue that distinguishes /ɔ/ from /a/ is the rounding of the preceding consonant, as in (2.18).

[7]The question whether [æ] actually occurs as a variant of [ɛ] especially in the Eastern Dialect is not addressed here. It seems that a [Cæ] and [C^{j}a] are merely alternative transcriptions of the phonetic realisation of underlying /Cɛ/. Transcribing it as [C^j] has an advantage in that it captures the palatalisation that the onset undergoes. Another alternative is, of course, [C^{j}æ], which implies that the vowel remains a front vowel, and distinct from the vowel in [C^{w}a] (another process of underlying mid vowel lowering discussed below). I am not convinced that this distinction in the output of the two lowering processes exists. A detailed phonetic study is ultimately required for a more conclusive argument.

(2.18) Minimal pairs with underlying /a/ and /ɔ/

	Underlying low /a/		Underlying mid /ɔ/	
a.	tám	‘stand on’	/tɔ́m/ [tʷám]	‘bitterness’
b.	gábɨ́	mix’	/gɔ́bɨ̀/ [gʷábɨ̀]	‘wrap around’
c.	láʔɨ́	‘woo’	/lɔ́ʔɨ́/ [lʷáʔɨ́]	‘circumvent’
d.	kàb[ɨ̀]	‘break’	/kɔ̀bɨ̀/ [kʷàb[ɨ̀]]	‘get infected’
e.	láɾ[ɨ́]	‘laughter’	/lɔ̀-ɾɨ̀/ [lʷà-ɾɨ̀]	‘tying’
f.	bàɾ[ɨ̀]	‘set a trap’	/bɔ́ɾɨ́/ [bʷáɾ[ɨ́]]	‘muddy up water’

This shows that [-ATR] mid vowels are never realised phonetically as [ɛ] or [ɔ]. Even though these mid vowels exist phonemically, they neutralise to [a] in all non-final positions (see Hyman 1970 for a similar account of neutralisation between mid vowels and the low vowel in Nupe, a Kwa language of Nigeria). As already noted in Chapter 1, consonants are palatalised before front vowels, labialised before back (round) vowels and remain neutral before central vowels. These secondary articulations apply vacuously when the onset consonants already have the secondary articulation feature, /w/ for rounding and [j, ʃ, ʒ, ʧ, ʤ, ɲ] for palatalisation. Dagbani [w] is produced with a significant lip protrusion while the post-alveolar and palatal consonants are all [-anterior] coronals. Data showing the vacuous application of the rules are shown in (2.20) and (2.19).

(2.19) Lowering of underlying /ɛ/ with vacuous palatalisation of onset [j, ʃ, ʒ, ʧ, ʤ, ɲ]

a.	[j]	já$]_{rt.}$-ʔʊ́	‘bead-sg.’	< jè-$]_{rt.}$ ‘bead’
b.		jàɾ$]_{rt.}$á	‘wearing’	< jè$]_{wd.}$ ‘wear’
c.	[ʃ]	ʃá$]_{rt.}$-ʔʊ́	‘rainy season-sg.’	< ʃèːn-$]_{rt.}$ ‘rainy season’
d.		ʃá$]_{rt.}$-lɨ́	‘some-pl.’	< ʃé-$]_{rt.}$ ‘some’
e.		ʃár$]_{rt.}$-gá	‘needle-sg.’	< ʃè$]_{wd.}$ ‘sew’
f.	[ʒ]	ʒá$]_{rt.}$-ʔʊ́	‘storm-sg.’	< ʒè$]_{wd.}$ ‘blow’
g.		ʒár$]_{rt.}$-gʊ́	‘horn attacker-sg.’	< ʒè$]_{wd.}$ ‘attack’ (with horns)’
h.	[ʤ]	ʤá$]_{rt.}$-lɨ́nsɨ́	‘hatred’	< ʤé$]_{wd.}$ ‘hate’
i.		ʤá$]_{rt.}$ bá	‘hate them’	< ʤé$]_{wd.}$ ‘hate’
j.	[ʧ]	ʧà$]_{rt.}$-hɨ̀	‘rip in pieces’	< ʧèː$]_{wd.}$ ‘rip’
k.		ʧá$]_{rt.}$-ʔʊ́	‘broken piece-sg.’	< ʧé-$]_{rt.}$-[é$]_{suf.}$ ‘broken piece-sg.’
l.	[ɲ]	ɲà$]_{rt.}$-hɨ́	‘nose-pl.’	< ɲè-$]_{rt.}$ ‘nose’
m.		ɲá$]_{rt.}$-ɾá	‘one who defecates’	< ɲè$]_{wd.}$ ‘defecate’

(2.20) Lowering of underlying /ɔ/ with vacuous labialisation of onset /w/

a.	/wɔ́lɨ́gɨ̂/	[wálɨ́gɨ̂]	‘separate’
b.	/wɔ́ʔɨ́/	[wáʔɨ́]	‘hatch’
c.	/wɔ̀ʔɾɨ̀-lɨ̂/	[wàʔɾɨ̀-lɨ̂]	‘giant-sg.’
d.	/wɔ́ɾɨ̂/	[wáɾɨ̂]	‘cold temperature’
e.	/wɔ́bɨ́/	[wábɨ́]	‘harvest fruit’

With an inherently rounded /w/ in (2.20), rounding is not a distinct secondary articulation. The only distinct feature of the vowel that is perceived is the height feature of the vowel, which is low. In (2.19), [ʃ, ʒ, ʧ, ʤ, ɲ] are variants of [s, z, k, ɡ, ŋ] before front vowels. Morphologically, each of the forms is derived from an underlying root in the rightmost column that has a final mid vowel. The verbs in (2.19b, e–j, k, m) are full words with [e] in their unsuffixed forms. The nouns have the mid vowel in noun + adjective/noun constructions, shown in (2.21). With no number suffixes, noun + adjective/noun constructions provide evidence for the underlying form of vowels in nominal and adjectival roots.

(2.21) Surface [e] with onset [j, ʃ, ʒ, ʧ, ʤ, ɲ] in noun + adjective/noun constructions

	noun		noun + adjective construction	
a.	já]$_{rt.}$ʔʊ́	'bead-sg.'	jè pál-lɨ́	'new bead'
b.	ʃá]$_{rt.}$-ʔʊ́	rainy season'	ʃèːn tʊ́má	'rainy season work'
c.	ʒà]$_{rt.}$-ɾɨ́	'soup'	ʒè váʔʊ̂	'leaf of a vegetable'
d.	ʧá]$_{rt.}$-ʔʊ́	'broken piece-pl.'	ʧè ʃáŋá	'some broken pieces'
e.	ʤà]$_{rt.}$-hɨ́	'straw bangle-pl.'	ʤè pál-lɨ́	'a new straw bangle'
f.	ɲà]$_{rt.}$-hɨ́	'nose-pl.'	ɲè vʷálɨ́	'nose hole' (nostril)

(2.19k) has two alternative singular suffixes: -ʔʊ́ and -e. The vowel [e] is the root vowel when the suffix is -e, the effect of [e] as a trigger of [+ATR] feature to preceding non-high vowels. Any other suffix produces [a]. Other examples with mid vowel singular suffixes triggering harmony to root mid vowels are shown in the left column of the data in (2.22). The forms in the left column contrast with those in the right column which show the regular lowering of non-final mid vowels to [a] when there is no final [+ATR] trigger.

(2.22) Suffix-controlled realisation of root vowels

a.	ʧé]$_{rt.}$-é$_{suf.}$	‘broken piece-sg.’	ʧá]$_{rt.}$-ʔʊ́$_{suf}$	‘broken piece-sg.’
b.	bʲé]$_{rt.}$-é$_{suf.}$	‘bad person-sg.’	bʲá]$_{rt.}$-ʔʊ́$_{suf}$	‘bad/ugly thing-sg.’
c.	ʃé]$_{rt.}$-é$_{suf.}$	’waist-sg.’	ʃá]$_{rt.}$-hɨ́$_{suf}$	‘waist-pl.’
d.	ʒè]$_{rt.}$-é$_{suf.}$	‘red-sg.’	ʒà]$_{rt.}$-ʔʊ́$_{suf}$	‘reddish-sg.’
e.	ʧè]$_{rt.}$-è$_{suf.}$	‘(to) rip’	ʧà]$_{rt}$-hɨ̀$_{suf}$	‘rip several things/ several times’
f.	bʲè]$_{wd.}$	‘(to) pain’	bʲà]$_{rt}$-ɾɨ́m$_{suf}$	‘pain (noun)’
g.	jèːn]$_{rt.}$-dá$_{suf.}$	‘winnow-ing’	jál]$_{rt.}$ɨ́$_{suf.}$	‘(to) winnow’

The roots in (2.22a-b) have different singular suffixes, (2.22c) is a case with singular and plural suffixes, while (2.22d-f) show the effects of suffixes with different lexical or grammatical properties. The infinitive form of (2.22f) is not marked with a suffix. For all the examples in (2.22a-f), the surface form of the root vowel is determined by the shape of the suffix. The underlying root mid vowel surfaces as [e] in word-final position, and in harmony with the suffix [-e], and [a] elsewhere.

Note that ATR harmony could not be the cause of a possible change of a root low vowel to a mid vowel since harmony does not change the height feature of target vowels (see further discussion and analysis of ATR harmony in Section 2.3.4). Besides, if the vowel were underlyingly /a/, the root vowels in (2.21) would have remained low since there is no [+ATR] vowel in the noun + adjective constructions to trigger harmony.

In (2.22g), the underlying form is shown in the root that has the progressive suffix. A root with similar vowel alternation is shown (2.21b). Positing /ɛ/ as the underlying vowel is consistent with the generalisation that [-ATR] mid vowels become low in non-final positions. This lowering only affects short mid vowels. Long mid vowels are not lowered in non-final position, as Dagbani lacks long [-ATR] non-low vowels. By contrast, there is no easy account for how an underlying /a/ in (2.22g) can be raised to a mid vowel.

2.3.2 Account of non-final mid vowels: Markedness vs faithfulness hierarchies

In this section, I evaluate markedness and faithfulness constraint hierarchies as possible approaches to analysis of the mid vowel lowering in non-final position. From a markedness point of view, the fact that mid vowels are the only vowels that are lost in height neutralisation can be explained. Mid vowels have been analysed as having the most marked height specification because they combine features of both low and high vowels (Schane 1984; Alderete et al. 1999; Gnanadesikan 1997; Flemming 2002). Mid vowels have also been observed to be dispreferred from the point of view of dispersion (Gnanadesikan 1997; Flemming 2002), a point that is reflected in surveys of vowel inventory structure (Crothers 1978; Disner 1984). These surveys show that the presence of mid vowels in an inventory implies that of high and low vowels, but not vice versa. The marked status of mid vowels relative to low and high vowels is further demonstrated by the fact that mid vowels are rarely found as default or epenthetic vowels in languages. By contrast, low vowels are very common default vowels (e.g. Axininca Campa (Payne 1981), Makkan Arabic (Abu-Mansur 1987)), while high vowels are the epenthetic or default vowels in Dagbani (see Chapter 1), Yoruba (Pulleyblank 1988), Nancowry (Radhakrishnan 1981) some dialects of Arabic (Itô 1989) and others.

These crosslinguistic patterns can be captured in the universal harmony scale in (2.23) which translates into a height-based constraint hierarchy in which markedness constraints banning mid vowels from surface forms rank higher than those that ban high and low vowels. This hierarchy is shown in (2.25) (see Beckman 1997, 1998 for the use of this hierarchy in her analysis of Shona height harmony).

(2.23) Height-based harmony scale

[+high], [+low] $\succ$ [-high, -low]

(2.24) Height-based markedness constraints

a. *[-Hi -Lo]

A vowel must not be [-high], [-low] (= *Mid)

b. *[+Lo]

A vowel must not be [+low]

c. *[+Hi]

A vowel must not be [+high]

(2.25) Height-based vowel markedness hierarchy

*[-Hɪ -Lo] » *[+Lo], *[+Hɪ]

As long as *[-Hɪ -Lo] outranks all other constraints introduced so far, mid vowels will never surface, even under the present analysis that they are indeed underlying. This is shown in (2.26). [8]

(2.26) No mid vowels in non-final position

/bɛ̀hm/	*[Mɪᴅ]	*[-ATR]	*[+ATR]
a. bʲɛ̀hɪ̀m	*!	**	
b. bʲèhìm	*!		**
☞c. bʲàhɪ̀m		**!	
✗ d. bʲìhìm		*	*

When the height specification of mid vowels changes, the result is either vowel lowering, as in (2.26c), or raising, (2.26d). In (2.26) the candidate with a raised vowel is wrongly projected as the winner. Notice that this incorrect results is further predicted to be the right output form as it is congruous with the fact that a high vowel is the epenthetic vowel in Dagbani. Under approaches to vowel epenthesis based on markedness, various constraints have been proposed that characterise high vowels as less marked than mid and low vowels (e.g. Kirchner 1997, Archangeli & Suzuki 1997, Alderete et al. 1999,

[8] See Section 2.3.5 for arguments to the effect that [-ATR] mid vowels are underlying. In (2.26) and all other tableaux in this dissertation, '✗' marks a non-optimal candidate projected by the constraint hierarchy in a tableau to be optimal.

Kager 1999, Kurisu 2000, Buckley 2003). Given the dis-preference for surface mid vowels in Dagbani, underlying mid vowels would be expected to surface as high vowels under such approaches, contrary to the attested pattern in Dagbani.

Howe & Pulleyblank (2004) reject these approaches and their inherent claim that high vowels are intrinsically unmarked relative to non-high vowels. Citing evidence from vowel inventories of languages and the typology of syllabic segments, they argue that high vowels are relatively marked based on independently established vowel markedness hierarchy. Howe & Pulleyblank (2004) propose the use of a faithfulness constraint hierarchy based on vowel sonority for analysis of vowel insertion and other processes affecting vowels such as deletion. They show that unlike a markedness account, the sonority based faithfulness hierarchy FAITHLOW » FAITHMID » FAITHHI (or simply FAITH[-HI] » FAITH[+HI]) consistently recognises non-high vowels as more harmonic than high vowels, and successfully accounts for the fact that high vowels are targets of both insertion and deletion even within the same language.

The faithfulness account does explain why high vowels are the epenthetic vowels in Dagbani. A faithfulness constraint to non-low specification can also explain why mid vowels surface as [+low] and not [+high], as shown in the analysis below. However, an approach based solely on faithfulness cannot explain the pattern of height neutralisation affecting mid but not high vowels. To account for this, markedness considerations are essential, as in many grammatical patterns including vowel epenthesis, a point noted by Howe & Pulleyblank (2004).

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 as the most susceptible to deletion or neutralisation since they are specified for [-high, -low]. With an input mid vowel, any change in output height specification involves a change from a [-high] specification to [+high], or [-low] specification to [+low]. Within the theory of correspondence, (McCarthy & Prince 1995), the former incurs a violation of DEP[+HIGH] while the latter violates DEP[+LOW].[9] These are defined in (2.27) and (2.28).

(2.27) DEP[+HI]

An output [+high] feature value must have an input correspondent [+high] feature value

(2.28) DEP[+LO]

An output [+low] feature value must have an input correspondent [+low] feature value

Given that these constraints penalise changes to the height specification, the ranking DEP[+HI] » DEP[+LO] is required to ensure that lowering becomes the preferred repair strategy when *[MID] forces a change in the

[9] Following previous work such as Itô et al. (1995), Pulleyblank (1996, 1997) and Myers (1997), I assume a generalised notion of correspondence in which MAX and DEP constraints directly govern both segments and features.

height specification of mid vowels. However, this wrongly predicts [a] as the epenthetic vowel. The opposite ranking of the Dep constraints rightly predicts a high vowel as epenthetic, essentially the proposal of Howe & Pulleyblank (2004), but forces mid vowel raising instead of lowering. This ranking paradox can be resolved by a faithfulness constraint to the non-high specification of input vowels along with the ranking Dep[+Lo] » Dep[+Hi]. With faithfulness constraints to non-high specification outranking Dep[+Lo], underlying mid vowels cannot be raised to satisfy *Mid. Surface [+high] feature is only possible where there is an input correspondent [+high] or no input correspondent.

(2.29) Max[-Hi]

Every input [-Hi] feature must have an output correspondent [-Hi].

Assuming faithfulness to input [+high] and [+low] also undominated, the results will be mid vowel lowering, preservation of underlying high and low features, and high vowel epenthesis.

(2.30) No [ɛ, ɔ] in non-final position (/bɛ̀hɨ̀m/ → [bʲàhɨ̀m] ‘doubt’)

/bɛ̀hm/	*Mid	Max [-Hi]	Dep [+Lo]	Dep [+Hi]	*[-ATR]	*[+ATR]
a. bʲɛ̀hɨ̀m	*!			*	**	
b. bʲèhìm	*!			*		**
☞c. bʲàhɨ̀m			*	*	**	
d. bʲìhìm		*!		**	*	*
e. bʲàhàm			**!		**	

In (2.30), *bʲɛ̀hɨ̀m* and *bʲèhɨ̀m* both incur violations of undominated *[Mid] for maintaining the height specifications of the input, leaving output forms with raised or lowered mid vowels as the only two possible surface forms. Vowel raising violates Max[-Hi], also undominated, as in (2.30a). For inserting a low vowel, the output form in (2.30e) is ruled out by an extra violation of Dep[+Lo], compared to the optimal form. With this ranking, both mid vowel lowering and high vowel insertion are achieved.

While the analysis works, it overgenerates the ban on mid vowels to include both [+ATR] and [-ATR] mid vowels. As it stands now, mid vowels cannot surface in the language regardless of their other feature specifications or location in a word. This is certainly not the pattern in Dagbani. As discussed in sections 2.3.3 and 2.3.4, vowel height markedness interacts with [ATR] in such a way that only [-ATR] mid vowels are phonetically blocked entirely from the language. The hierarchy *[-ATR] » [*+ATR] suggests that a markedness constraint blocking the surface realisations of [-ATR] mid vowels needs to be ranked with respect to one that blocks [+ATR] mid vowels. In anticipation of the discussions in sections 2.3.3 and 2.3.4, the *[Mid] constraint is split into two separate constraints that are sensitive to the specification for the feature [ATR]. The two constraints are defined in (2.31).

(2.31) Markedness constraints combining height with [ATR] features

a. *[-Hi, -Lo, -ATR]
   A vowel must not be [-high, -low, -ATR] (*Mid[-ATR])

b. *[-Hi, -Lo, +ATR]
   A vowel must not be [-high, -low, +ATR] (*Mid[+ATR])

In order to completely block [-ATR] mid vowels, *Mid[-ATR] has to outrank *Mid[+ATR], which must in turn rank above Dep[+Lo]. With this hierarchy, only retracted mid vowels are blocked in all surface forms. Advanced mid vowels surface in some contexts, as demonstrated in Section 2.3.4 (see tableau in (2.38) and discussion that follows it).

2.3.3 Final mid vowels

In word-final position, mid vowels surface with a [+ATR] value. They trigger [+ATR] harmony targeting preceding low and mid vowels that are not in final position. These targets ([a, ɛ, ɔ]) surface as [ə, e, o]. What is covered in this section is the distribution of [e, o] in word-final position. Section

2.3.4 discusses mid vowels as triggers of [+ATR] harmony. A full analysis of ATR harmony in Dagbani including the position of mid vowels as triggers is presented in Chapter 4.

The data on final mid vowels are shown in (2.32).

(2.32) [o, e] in word-final position

	ROOTS	Root [-ATR] vowels	[ATR] harmony
a.	/dɔɾ-/	[dʷáɾ-tɨ́] 'diseases'	[dʷóɾʷ-ó] 'a disease'
b.	/ʧɔɾ-/	[ʧʷàɾ-tɨ̂] 'blows'	[ʧʷòɾʲ-ê] 'a blow'
c.	/bɛ/	[bʲáhɨ̀] 'shins'	[bʲé-é] 'shin'
d.	/pal-/	[pál-lɨ́] 'a new thing'	[pʲə́l-ó] 'new anim. thing'
e.	/dà/	[dà lɨ́] 'buy it'	[dʲə̀ ó] 'buy it (anim.)'
f.	/dɛm/	[dʲà m-a] 'a play'	[dʲèm ô] 'play with him'

On the face of it, the pattern in (2.32) may seem a bit confusing. In non-final position, (and without a final mid [+ATR] harmonic trigger) mid vowels completely neutralise with [a], in what may be attributed to the marked height feature specification of these vowels, as the examples under the column 'Root [-ATR] vowels' in (2.32) show. However, in final position, the neutralisation does not take place, as the data under 'ATR harmony' in (2.32) show. This suggests the role of positional effects in the non-final neutralisation.

Assuming, as it seems, that the distribution of the mid vowel is conditioned by the position in a word it occurs, I adopt two assumptions in analysing the distributional patterns of the mid vowels. The first is the principle of preservation of the marked proposed by de Lacy (2006). This is stated in (2.33).

(2.33) 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, while all high vowels have some restriction on their occurrence in this position. Only [+ATR] variants of high vowels, that is, [i,u] may occur in a word-final open syllable.[10] In words that are more than one syllable long, only [ʊ, ɨ] are found. The mid vowels are not subject to these restrictions in word-final position. The distribution of high vowels is discussed in Section 2.4.

The second assumption regards the nature of the word-final position. In a detailed study of positional neutralisation phenomena, Barnes (2006) notes that the final position is a domain of ambiguity with respect to the phonological processes that occur there. On the one hand, patterns of lengthening and gestural enhancement in this position make it phonetically and psycholinguistically prominent. It licenses vocalic and tonal contrasts, for instance,

[10]Note that CV non-lexical forms do not occur in isolation. They always occur with a lexical word with a default [-ATR] vowel. A non-lexical CV with a [+ATR] vowel is triggered by a [+ATR] root vowel.

and resists some patterns of assimilation and reduction. On the other hand, drops in F0 and intensity and laryngeal processes such as devoicing, all of which occur in word-final position, decrease the prominence of this domain.

Barnes' observations are reflected in the behaviour of the Dagbani mid vowels in final positions. With [e, o] in final position, a total of 7 vowels occur in this position: [i, ɨ, u, ʊ, e, o, a]. With only 4 vowels in non-final position, [i, ɨ, ʊ, a], the word-final position thus licenses more contrast than non-final position.[11]

On the other hand, mid vowels do not surface as [ɛ] or [ɔ], nor do they become low vowels, as they do in non-final position. The restriction of [-ATR] vowels from final position is not unique to only mid vowels. As discussed in Section 2.4, [-ATR] high vowels [ɨ, ʊ] do not occur in CV lexical words, only their [+ATR] variants do. Within the phonology of Dagbani, the only [-ATR] vowel that does not have any domain restrictions in its distribution is [a]. Assuming that the [-ATR] variants of the mid and high vowels are part of the vowel inventory of the language, the surfacing of [+ATR] vowels in final position indicates a drop in F1 in this positions, which, according to Barnes, is an indication that the word-final position is a weak domain.[12]

[11]Note that this comparison is limited to non-harmonic contexts, i.e. a word or phrase that lacks a [+ATR] harmony trigger. In a domain with a [+ATR] vowel, ATR harmony may results in the surface realisation of the [+ATR] vowels [ə, e, o] in non-final position. See further discussion in Section 2.3.4 and a detailed account of [+ATR] harmony in Chapter 4.

[12]For evidence that [+ATR] vowels have a lower F1 than their [-ATR] variants in many African languages, see Lindau (1978), Hess (1992) for Akan; Guion et al. (2004) for Nilotic languages; Fulop et al. (1998) for Degema; Przezdziecki (2005) for Yoruba; Gick et al. (2006) for Kinande.

I account for this asymmetry with a positional faithfulness constraint on the feature [low] in word-final position. The relevant faithfulness constraint, intended to block mid vowel lowering, is just a position-sensitive version of the Dep constraint already shown in (2.28), as defined in (2.34).

(2.34) Faithfulness to word-final [low]

Dep[+Lo]]$_{wd}$

An output word-final [+low] feature value must have an input correspondent word-final [+low] feature value

There is an effective conflict in the demands of Dep[+Lo]]$_{wd}$ and the *Mid[ATR] constraints. While the Dep constraint blocks mid vowel lowering, the *Mid[ATR] constraints effectively ban mid vowels from all positions. Since the mid vowel lowering only takes place in non-final position, no crucial ranking is required between *Mid[-ATR] and the Dep constraint. 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 vowels. The hierarchy *Mid[-ATR] » *Mid[+ATR] thus establishes that *Mid[+ATR] must rank lower than Dep[+Lo]]$_{wd}$ to derive word-final mid vowels. This is shown in (2.35) and (2.36).

(2.35) Final [+ATR] mid vowel (/sɨm-ɔ/ → [sɨ̀m-ó] ‘a dear friend’)

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

In (2.35), high ranking *MID[-ATR] rules out *sɨ̀m-ɔ́* for having a final [-ATR] mid vowel. There are only two ways to avoid violations of this constraint. One is to change the height specification of the mid vowel, as in (2.35c) and (2.35d). However, that is blocked by the MAX and DEP constraints. The other option left is to change the [ATR] value of the mid vowel, as shown in (2.35a).[13]

While *MID[-ATR] is able to derive the right output form with a root high vowel, it is not sufficient to derive a mid vowel in non-final position, (2.36).

[13] The analysis here only focuses on the distribution of the mid vowels. Chapter 4 deals with how an alternative candidate such as *sìmô* (which changes the root vowel from [ɨ] to [i] to achieve harmony with the suffix mid vowel) does not surface.

(2.36) Sequence of mid vowels with a final mid vowel (/dɔɾ-ɔ/ → [dóɾ-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. dʷá-ɾʷɔ́	*!				*	
d. dʷáɾʷ-á			*!		**	
e. dʷáɾʷ-ʊ́		*!			*	*
✗ f. dʷáɾʷ-ó				*	*	

(2.36b and c) are ruled out by *MID[-ATR], each for having a [-ATR] vowel, while (2.36d and e) incur fatal violations of the MAX and DEP constraints. Satisfying all the undominated constraints are (2.36a) and (2.36f). The output form *dʷóɾʷ-ó* is ruled out for incurring two violations of *MID [+ATR], leaving *dʷáɾʷ-ó*, the wrong output form as the projected winning candidate. In Section 2.3.4, I show that *dʷár-ó* is blocked by a constraint that derives [+ATR] harmony.

Note that the analysis presented thus far does not motivate the split of the *[MID] constraint into *MID[+ATR] and *MID[-ATR]. The results would be the same with one unsplit *MID constraint. The discussion in Section 2.3.4 presents a motivation for the split.

2.3.4 Mid vowels as [+ATR] harmony triggers

Dagbani has a pattern of right-to-left [+ATR] harmony triggered by word-final mid vowels that targets preceding non-high vowels [a, ɛ, ɔ]. In Chapter 4 and 5, where the formal account of Dagbani [ATR] harmony is presented, it is shown that the [+ATR] feature of the root vowel emerges due to the harmony driving constraint in Span Theory *A-Span[ATR] McCarthy (2004).

(2.37) No adjacent [ATR] spans (McCarthy 2004: 5)

*A-Span[ATR]

Assign one violation mark for every pair of adjacent spans of the feature [ATR] (= *A-Sp[ATR])

In Span Theory each value of a feature creates a span of that feature. With [ATR] as the harmonic feature, a [+ATR] vowel creates a span of [+ATR], a [-ATR] vowel creates a span of [-ATR] (see Chapter 3 for a more detailed discussion of this and other constraint types in Span Theory). All that the *A-Span[ATR] constraint requires is that within a harmonic domain, there should be only one [ATR] value. The only way to satisfy the demand of this constraint is for all vowels in a word to be either [+ATR] or [-ATR]. *A-Span[ATR] must rank crucially above *Mid[+ATR], but not necessarily below higher ranking constraints. The tableau (2.38) shows how [+ATR] vowels emerge in non-final position to achieve [+ATR] harmony. Span boundaries are marked with parentheses.

(2.38) Non-final [+ATR] mid vowel (/dɔ́ɾ-ɔ́/ → [dóɾ-ó] 'a disease')

/dɔ́ɾ-ɔ́/	*MID [-ATR]	DEP [+LO]]$_{wd}$	*A-SP [ATR]	*MID [+ATR]	*[-ATR]
☞ a. dʷ(óɾʷ-ó)				**	
b. dʷ(ó)(ɾʷ-ɔ́)	*!		*	*	*
c. dʷ(á-ɾʷɔ́)	*!				**
d. dʷ(áɾʷ-á)		*!			**
e. dʷ(á)(ɾʷ-ó)			*!	*	*

Each of the candidates in (2.38b–d) is ruled out by a violation of either *MID[-ATR] or DEP[+LO]$_{wd}$. The closest to the optimal output form is *dʷ(á)(rʷ-ó)*. This output form violates the demands of *A-SPAN[ATR], a violation that proves fatal, given the the ranking *A-SPAN[ATR] » *MID[+ATR].

Besides showing the role of the harmony driving constraint in the surface realisation of non-final mid vowels, the tableau also demonstrates the need for the *MID constraint to be split into two constraints that are sensitive to [ATR] value specification. With an undifferentiated *MID constraint, (2.40d) could have surfaced as the winning candidate depending on the ranking of the *MID constraint relative to *A-SPAN[ATR] and DEP[+LO]]$_{wd}$ constraints. More crucially, an output form with two [-ATR] mid vowels within one span such as the input in (2.40) would have been as optimal as *dʷ(óɾʷ-ó)*, the attested output form.

The same pattern of suffix-triggered harmony leads to the surface realisation of a [+ATR] variant of the low vowel, the only context in which a [+ATR] low vowel occurs.

(2.39) Advanced low vowel before final mid vowel

a.	/dà ó/	[[də̀]$_{rt.}$ [ó]$_{clt.}$]	'buy it (animate)'
b.	/bá ó/	[[bə́]$_{rt.}$ [ó]$_{clt.}$]	'ride it (animate)'
c.	/kál-ó/	[[kə́l]$_{rt.}$-ó$_{suf.}$]	'door-sg.'
d.	/sàl-ô/	[[sə̀l]$_{rt.}$-ô$_{suf.}$]	'crowd of people'
e.	/tàdáb-ô/	[[tə̀də́b]$_{rt.}$-ô$_{suf.}$]	'writing ink'
f.	/tàtáb-ô/	[[tə̀tə́b]$_{rt.}$-ô$_{suf.}$]	'the like of'
g.	/gaɾ-ó/	[[gə́ɾ]$_{rt.}$-ó$_{suf.}$]	'bed'

The tableau in (2.40), with the same constraint ranking as the preceding tableau, shows the need for the anti-span adjacency constraint in deriving a low vowel-targeted [+ATR] harmony.

(2.40) Non-final [+ATR] low vowel (/gáɾ-ɔ́/ → [gə́ɾ-ó] 'a bed')

/gáɾ-ɔ́/	*MID [-ATR]	DEP [+LO]]$_{wd}$	*A-SP [ATR]	*MID [+ATR]	LO [ATR]	*[-ATR]
☞ a. g(ə́ɾ^w-ó)				*	*	
b. g(ə́)(ɾ^w-ɔ́)	*!		*			*
c. g(á-ɾ^{w}ɔ́)	*!					**
d. g(áɾ-á)		*!				**
e. g(á)(ɾ^w-ó)			*!	*		*

Each of the output forms in (2.40a) and (2.40e) incurs one violation of *MID [+ATR] and no violation of a higher ranking constraint except *A-SPAN [ATR], which rules out the latter. Without *A-SPAN[ATR], the constraint hierarchy would have favoured *(gá)(ɾ^w-ó)* as *(gə́)(ɾ^w-ó)* would have been ruled out by LO[ATR]. It is worth noting that as [+ATR] harmony triggers, final mid vowels only target low and mid vowels. Chapter 4 accounts for how a final mid vowel fails to trigger [+ATR] harmony onto preceding root high vowels.

With this hierarchy, the distribution of all non-high short vowels in Dagbani has been accounted for. The account of the mid vowels maintains the assumption in previous studies that there are indeed phonemic [-ATR] mid vowels, and argues on that basis, that in non-final position, the mid vowels neutralise with the low vowel. Although this is a very crucial argument on which the analysis rests, it is by no means the only possible analysis that could be given. In Section 2.3.5, I discuss an alternative analysis and show why it does not succeed in accounting for the distribution of Dagbani mid vowels.

2.3.5 Alternative analysis: No underlying mid vowels

An apparently less complicated alternative analysis is to make three assumptions about Dagbani surface vowel distribution: (i) [ɛ] and [ɔ] are not part of the vowel inventory of Dagbani, and thus no vowel lowering takes place, (ii) rounded and palatalised consonants contrast with their plain counterparts, and (iii) surface [e], [o], and [ə] are surface variant of /a/.

The data in (2.41) illustrate the first two assumptions.

(2.41) Contrastive secondary articulation?

	C	C^{j}	C^{w}
a.	pàlɨ̀ 'be full'	p^{j}álɨ́ 'group hunt'	p^{w}àlɨ̀ 'saturate'
b.	bàlɨ̀ 'vanish'	b^{j}àlɨ̀ 'accompany'	b^{w}àlɨ̀ 'call'
c.	fáhɨ́ 'constipated'	f^{j}àhɨ̀ 'blow (nose)'	f^{w}àhɨ̀ 'draw'
d.	válɨ́ 'swallow'	v^{j}àlɨ̀ 'be nice'	v^{w}álɨ́ 'hole'
e.	máɾɨ̂ 'pus'	m^{j}à-ɾɨ̀ 'building'	m^{w}áɾɨ́ 'swell'
f.	táɾɨ́m 'a non-royal'	t^{j}áɾɨ́ŋ 'rocky land'	t^{w}áɾɨ́-lɨ́ 'an eagle'
g.	dà-hɨ́ 'markets'	d^{j}à-hɨ́ 'bush pigs'	d^{w}à-hɨ́ 'locust trees'
h.	nàm-má 'create!'	n^{j}ám-má 'grind!'	n^{w}à-má 'step!'
i.	là-má 'laugh!'	l^{j}à-má 'fill (with liquid)!'	l^{w}àm-á 'tie!'

Under the third assumption, the low vowel would have the surface variants [a, e, o, ə] depending on the preceding consonant, whether it occurs in final or non-final position or presence of a following [+ATR] mid vowel. A final mid vowel [e, o] gets its coronal of labial feature from a preceding (contrastive) palatalised or labialised consonant. The [-low] realisation could be due to a ban against a rounded or palatalised low vowel. With an onset that is neither labialised nor palatalised, the (underlyingly) low vowel remains low.

In a word with more than one syllable and a final mid vowel, a preceding low vowel in addition to taking on the rounding or palatalisation of the preceding consonant also harmonises with the [+ATR] specification of the following mid vowel. This may result in a complete assimilation to the final mid vowel (as in *dʷórʷ-ó* 'a disease' and *bʲé-é* a shin), or a partial assimilation to only the [+ATR] value (as in *ʧʷòrʲ-ê* 'a blow'). If the onset of the penultimate syllable is neither rounded nor labialised, the only change observed in the low vowel is [ATR], producing a surface [ə] (e.g. gə́ɾ-ó 'bed').

With such a reductionist account, there would be only four contrastive vowels in dagbani: /a, i, ɨ, ʊ/. Combined with the alternation between [ʊ] and [u], the vowel inventory would be argued to contain only eight vowels [a, ə, e, o, i, ɨ, ʊ, u], not ten. The apparent advantage of such an account is that it simplifies the analysis of the Dagbani vowel system by eliminating /ɛ, ɔ/ which are never realised phonetically. In the rest of the discussion here, I refer to this alternative analysis as the 'eight-vowel account'.

For a word such as *bʲé-é* 'shin-sg.', the eight-vowel account may have to extend the assimilatory effect of a final mid vowel on what would be an underlying /a/ in two possible ways. One possible extension is to include vowels as triggers of palatalisation and labialisation (which also result in /a/-raising). The final mid vowel (an underlying low vowel in the eight-vowel account) would presumably have the preceding [e] as the trigger of palatalisation and resultant raising, in a chain effect. The other possible extension is to assume a long distance effect of the raising by maintaining the initial consonant as the trigger of the raising affecting both following vowels.

However, both possible extensions run into problems. First, any claim that an inherently low vowel changes its height features in harmonic contexts contradicts the unambiguous pattern in (2.39) which show that a low vowel does not change its height features due to the effect of a mid vowel trigger. Second, a long distance account does not explain the emergence of surface [o] as a second vowel in VV sequences such as *tə̀ ó* 'smear at him/her'. There is no consonant that could possibly raise it to a mid vowel, if it were underlyingly low, without causing the same raising effect on the preceding low vowel.

These weaknesses argue against the eight-vowel account as a plausible analysis of Dagbani vowel system. The only plausible analysis of the distributional pattern of mid vowels is one that includes the neutralisation of underlying [-ATR] mid vowels with the low vowel in non-final position and the realisation of these vowels as [+ATR] in word-final position.

The only vowels in the Dagbani inventory that are not covered in the above analysis are the high [-ATR] vowels [ɨ] and [ʊ]. Section 2.4 presents an account of their distribution.

2.4 Prosodic Conditioning

2.4.1 Distribution of [-ATR] high vowels

In Dagbani, [ɨ] and [ʊ] occur in three positions: (i) CVC roots, (ii) roots with more than one syllable and (iii) suffixed roots. These are shown in (2.42) to (2.44). To demonstrate that the surfacing of [-ATR] vowels is not due to any phonological process triggered by suffixes, the data in (2.42) present only un-suffixed CVC roots. Since no section in this chapter is dedicated to the distribution of [a], its distribution is included in these data to show that it has a similar distributional pattern to the [-ATR] high vowels.

(2.42) [-ATR] vowels in CVN words

[ɨ]	a.	dɨ̀m	'bite'
	b.	tɨ̀m	'send'
	c.	nɨ̀ŋ	'do'
	d.	zɨ̂ŋ	'miss'
	e.	vɨ́mː	'good (smell)'
[ʊ]	f.	dʊ̂ŋ	'enmity'
	g.	tʊ̀m	'work'
	h.	tʊ́ŋː	'easy'
	i.	kʊ́ŋ	'empty'
	j.	mʊ́m	'close (mouth)'

[a]	k.	tàm	'forget'
	l.	bàŋ	'know'
	m.	dâm	'alcohol'
	n.	mâm	'lover'
	o.	dàŋ	'be early'

(2.43) [-ATR] vowels in roots with more than one syllable (with epenthetic vowels in "[ ]")

[ɨ]	a.	bɨ̀l[ɨ̀]s[ɨ̀]	'fondle with'
	b.	bɨ̀l[ɨ̀]m	'roll'
	c.	bɨ̀ɾ[ɨ̀]m	'confuse'
	d.	mɨ́l[ɨ́]	'rub'
	e.	pɨ̀ɾg[ɨ̀]	'undress'
[a]	f.	tábs[ɨ̂]	'touch'
	g.	tábg[ɨ́]	'kick'
	h.	záh[ɨ̂]m	'measure'
	i	jàʔs[ɨ̀]	'toss'
[ʊ]	j.	bʊ̀ʔ[ɨ̀]s[ɨ̀]	'describe'
	k.	bʊ̀h[ɨ̀]m	'share'
	l.	kʊ́l[ɨ́]	'go home'
	m.	kʊ́ɾg[ɨ̂]	'unearth'
	n.	tʊ́ʔl[ɨ́]	'instigate'

(2.44) [-ATR] vowels in suffixed words

CV roots

[ʊ]	a.	[nʊ́]$_{rt}$ - hɨ̂	‘hand-pl.’
	b.	[pʊ́]$_{rt}$ - ɾɨ̂	‘farm-pl.’
	c.	[sʊ̀]$_{rt}$ - hɨ́	‘knives’
[a]	d.	[kpá]$_{rt}$ - lɨ́	‘occiput’
	e.	[dà]$_{rt}$ - hɨ́	‘markets’
	f.	[lá]$_{rt}$ - ɾɨ́	‘laughter’

CVC roots

[ʊ]	g.	[kʊ́h]$_{rt}$ - bʊ́	‘pricking’
	h.	[bʊ̀ŋ]$_{rt}$ - á	‘donkey-sg.’
	i.	[kʊ́ʔ]$_{rt}$ - lɨ̂	‘stone-sg.’
[ɨ]	j.	[bɨ́n]$_{rt}$ - ɨ̂	‘thing-sg.’
	k.	[nɨ̀ŋ]$_{rt}$ - bʊ́	‘doing’
	l.	[kpɨ̀l]$_{rt}$ - lɨ́	‘round thing-sg.’
[a]	m.	[páʔ]$_{rt}$ - bá	‘woman-pl.’
	n.	[kàʔ]$_{rt}$ - lɨ̂	‘stalk-sg.’
	o.	[dáŋ]$_{rt}$ - bʊ̂	‘advance-ing’

In terms of [±ATR] pairs, (2.42) to (2.44) show where the low vowel and [-ATR] variants of high vowels occur outside of harmonic contexts. However, not all these positions are exclusive to the [-ATR] variants. The [+ATR] high vowel /i/ also occurs in all non-final positions, as (2.45) shows.

(2.45) /i/ in non-final position

CVN word

a.	ʤìm	‘belch’
b.	ʒîm	‘blood’
c.	tìḿ	‘medicine’

CVCVC

d.	jíʔ[í]s[ɨ̂]	‘get up’
e.	jír[ɨ́]g[ɨ̂]	‘get frightened’
f.	ʧìʔ[ì]s[ɨ̀]	‘jump’

CVCV word

g.	pìl[ɨ̀]	‘start’
h.	ʒìn[ì]	‘sit’
i.	kpíl[ɨ̂]	‘protrude’

CV]$_{root}$

j.	[tì]$_{rt.}$ - á	‘tree-sg.’
k.	[bí]$_{rt.}$ - hí	‘child-pl.’
l.	[pí]$_{rt.}$ - á	‘ten-sg.’

Notice here that the epenthetic vowel becomes [i], in harmony with the root /i/, unless it is preceded by one of the coronals [l, ɾ, s], in which case it remains [ɨ]. Analysis of this is presented in Chapter 5. The restrictions on all low and high vowels (out of harmonic contexts) are summarised in (2.2).

Table 2.2: Distributional restrictions on [i, ɨ, a, u, ʊ] (in non-harmonic contexts)

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

Analyses of the distributional restrictions on [ɨ] and [ʊ] has been presented in Section 2.2. While these two vowels are only restricted from CV words, the analysis in that section does not leave room for their distribution any other context. In the remaining three prosodic positions in (2.2), only [-ATR] vowels and [i] occur, (except for [ɨ], which does not occur in CV roots, in what appears to be an accidental gap). Section 2.4.2 complements the analysis of Section 2.2 with analysis of the distribution of [ɨ] and [ʊ] in CV roots, CVC words and words with more than one syllable.

2.4.2 Analysis of surface [ɨ], [ʊ]

Analysis of the distribution of [ɨ] and [ʊ] presented here rests on two key related proposals. The first proposal is that, the mora exists as an active unit in Dagbani phonology. Recognising the active role of the mora leads to the generalisation that the distribution of [-ATR] vowels is prosodically conditioned in that they only occur in a constituent that is minimally bimoraic. Thus [ɨ] and [ʊ] occur in words with more than one syllable, or one closed syllable. They are restricted from a CV verb because even though it constitutes a complete word, it is sub-minimal. It has only one mora. However, [ʊ] occurs in nominal and adjectival CV roots because these roots either occur with a number suffix or in a noun + adjective construction. The licenser of the [-ATR] feature in a CV nominal or adjectival root is thus not the root, but the entire word or construction in which it occurs. The central vowel /ɨ/ does not occur in a bound nominal and adjectival CV roots, a gap in the distribution that does not affect the overall generalisation that the constituent in which /ɨ, ʊ/ occur must be minimally bimoraic.

Independent evidence in Dagbani phonology supporting the position of codas as moraic segments comes from compensatory lengthening and the position of nasal codas as tone-bearing units. In Dagbani, nasals are the only consonants that occur in CVC words. Example data are shown in (2.46).

(2.46) Compensatory lengthening and tone-bearing nasals

a.	[kɔ̀ŋá] / [kɔ̀ŋ́ː]		< /kɔ̀n-gá/	'leper-sg.'	cf.	[kɔ̀ŋ]	'lose'
b.	[zɔ́ŋá] / [zɔ́ŋ́ː]		< /zɔ́n-gá/	'bat-sg.'	cf.	[zɔ̀m]	'be blind'
c.	[sʊ̀ŋ́ː]		< /sʊ̀m-gá/	'good-sg.'	cf.	[tʊ̀m]	'work'
d.	[tàḿː]	'manure'	cf. tàm-á	'manure-pl.'	cf.	[tàm]	'forget'
e.	[dâm̀ː]	'wine'	cf. dám-â	'wine-pl.'	cf.	[dàm]	'shake'
f.	[kɔ̀ḿː]	'water'	cf. kɔ̀m-â	'water-pl.'	cf.	[kám]	'any'
g.	[làḿː]	'cow-itch'			cf.	[lâm]	'taste'

The words in (2.46a–c) show assimilation of a root-final nasal to the place of the suffix onset, deletion of the root vowel and compensatory lengthening of the preceding velar nasal. The vocalic deletion and nasal lengthening are optional in (2.46a–b). The final nasal also bears the tone left behind by the deleted suffix vowel. In (2.46d–g), the singular forms have no number suffixes, unlike the plural forms. However, the long and tone-bearing nasals suggest the existence, at least diachronically, of a singular morpheme that is elided and leaves behind these features, similar to the pattern in (2.46a–c).

The features of final nasals in the nouns contrast with those of the verb minimal pairs on the right column, which are short and toneless. The essence of the comparison is to show that nasal codas pattern with vowels in showing distinctive length and bearing tone, and to support the analysis that codas (both short and long) are moraic. The above data and the distributional patterns of [+ATR] and [-ATR] vowels in the language show that the mora is an active unit in Dagbani phonology, and that a domain with more than one mora has a unique phonological property.

The second proposal is that, any domain that has more than one mora has a prosodic foot. The fact that this domain has unique phonological property of blocking surface [+ATR] vowels supports its position as an active phonological unit in the language. The universal ranking SPECIFY[ATR] » *[-ATR] » *[+ATR] motivated in Section 2.2 is not sufficient to account for the distribution of [ATR] values. The SPECIFY[ATR] constraint needs to be modified to include specific values of the feature [ATR] as well as be sensitive to the foot. These are shown in (2.47) and (2.48).

(2.47) SPECIFY-FOOT-[+ATR]

In a phonological word that has a foot, every vowel must be specified for [+ATR] (= SPEC-FT-[+ATR])

(2.48) SPECIFY-FOOT-[-ATR]

In a phonological word that has a foot, every vowel must be specified for [-ATR] (= SPEC-FT-[-ATR])

In words with even-numbered syllables, the constraints in (2.47) and (2.48) ensure that syllables are exhaustively parsed into feet if the notions of binary footing and proper bracketing required in standard metrical theories (e.g. Liberman (1975) and Kenstowicz (1995)) are assumed. Using these notions however present challenges in words that are odd-numbered syllables.

An alternative approach that avoids these problems is to abandon both notions, or only proper bracketing and assume intersecting feet as proposed by Hyde (2002). A three syllable CVCVCV would be parsed as (CV[CV)CV], with "( )" and "[ ]" marking different foot boundaries. In this approach, a constraint demanding that every vowel in a foot must be specified for [-ATR] could be easily satisfied in all domains with more than one mora, with the appropriate ranking of other constraints on foot structure and maintaining foot binarity.

To satisfy the demands of (2.47), a vowel that occurs in a word with two or more moras has to have the feature [+ATR]. The demand of (2.48) is the exact opposite; it requires a vowel in such a domain to be [-ATR]. In addition to the constraints proposed here, the presence of other constraints and appropriate ranking need to be assumed to derive the patterns under discussion. These are (i) Foot Bin-μ, a constraint that requires all feet to have two moras, (ii) Dep-μ, a constraint that blocks the insertion of mora, and (iii) having both constraints outrank Proper Headedness, a constraint requiring every prosodic word to dominate a foot. With this hierarchy, only output forms with more than one mora will be affected by these constraints. In an output form with an odd numbered mora, I further assume a very low ranked Integrity constraint that permits the two moras in a heavy syllable to belong to different feet.

The ranking Spec-Ft-[-ATR] » Spec-Ft-[+ATR] is required for the [-ATR] vowels [ɨ] and [ʊ] to surface. Additionally, Spec-Ft-[-ATR] has to outrank *[-ATR] which has a conflicting demand. This is illustrated in (2.49) and (2.50). In all tableaux below which show the prosodic constraints, foot boundaries are marked with “[ ]”.

(2.49) [-ATR] vowels in words with more than one mora (/tim/ → [tɨ̀m] ‘send’)

/tɨm/	Spec-Ft- [-ATR]	Spec-Ft [+ATR]	*[-ATR]	*[+ATR]
☞ a. [tɨ̀m]		*	*	
b. [tìm]	*!			*
c. [tÌm]	*!	*		

(2.50) [-ATR] vowels in words with more than one mora (/dʊʔ-rɨ/ → [dʊ́ʔ-rɨ̂] ‘pot-pl.’)

/dʊʔ-rɨ/	Spec-Ft- [-ATR]	Spec-Ft [+ATR]	*[-ATR]	*[+ATR]
☞ a. [dʊ́ʔ.]-ɾɨ̂		**	**	
b. [dúʔ.]-ɾî	*!*			**
c. [dúʔ.]-ɾɨ̂	*!	*	*	*
d. [dÚʔ.]-ɾÎ	*!*	**		

The candidates in (2.49b–c) and (2.50b–d) are ruled out by the constraint Spec-Ft- [-ATR] because the vowel, which occurs in a closed syllable, is not specified as [-ATR]. The output form in (2.50b) 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 that it has a specification for [+ATR]. These violations leave the (2.49a) and (2.50a) the optimal output forms, in spite of their violations of SPEC-FT- [+ATR] and *[-ATR] constraints.[14]

This grammar correctly derives all vowels and their [ATR] variants in words of two or more moras except /i/. It incorrectly prevents the surfacing of underlying /i/, deriving all input high non-back vowels as [ɨ]. The tableau in (2.51) shows this effect.

(2.51) [+ATR] vowels blocked in words with more than one mora (/tim-a/ → *[tîm-á] 'medicine-pl.')

/tim-a/	SPEC-FT-[-ATR]	SPEC-FT [+ATR]	*[-ATR]	*[+ATR]
✗ a. [tɨ̂.m-á]		**	**	
☞ b. [tî.m-á]	*!		*	*

[14]Long vowels pattern in a way that does not satisfy the demands of this constraint. Even though a long vowel is bimoraic, long vowels consistently maintain a [+ATR] feature. There are no [-ATR] long vowels in Dagbani. I assume the conjunction of two markedness constraints, *[-ATR] and another markedness constraint banning long vowels, that outranks the SPECIFY constraints. With such a ranking, only short vowels in domains longer than one mora will be realised as [-ATR]. Since long vowels are not the focus of this chapter, I will not discuss this further.

The next section discusses how surface [i] is derived in domains with more than one mora.

2.4.3 Analysis of contrastive /i/ in words of more than one mora

The contrastive [+ATR] vowel /i/ is the only vowel that is [+high] and [COR]. The front vowels [ɛ, e] are [COR] but not high; the high vowels [ɨ, ʊ] are [+high] but not [COR]. In this regard it is worth noting that both features have been found cross-linguistically to enhance the feature [+ATR]. As discussed extensively by Archangeli & Pulleyblank (1994), fronting and raising the tongue, the two primary articulatory gestures involved in the production of front and high vowels respectively are in sympathetic relations with the advancement of the tongue root. Archangeli & Pulleyblank (1994) express these as the grounded path conditions High/ATR and Back/ATR, defined in (2.52) and (2.53). In (2.53), the Back/ATR condition is reformulated as COR/ATR in conformity with the feature theory assumed here.

(2.52) High/ATR Condition (Archangeli & Pulleyblank 1994: 174)

If [+high] then [+ATR]

(2.53) Coronal/ATR Condition

If Coronal then [+ATR]

To derive the pattern that only /i/ is contrastive, neither of these grounding constraints alone is sufficient. The High/ATR constraint does not trigger surface [+ATR] mid vowels, however, it does require high back vowels to surface as [+ATR]. On the other hand, COR/ATR forbids underlying /ɛ/ from surfacing as [-ATR] in any position. It forces this vowel to surface as [e] in all contexts, contrary to the observed pattern. In order to ensure that [i] is the only contrastive vowel in Dagbani, the emergence of surface [+ATR] has to be grounded on both [COR] and [+high] features. This is stated in (2.54).

(2.54) HiCOR/ATR

If [+high] and [COR] then [+ATR]

This constraint prohibits the surfacing of input /ɪ/ or /i/ as [ɪ]. Being undominated, HiCOR/ATR explains why Dagbani lacks [ɪ] in its vowel inventory. For the vowel [ɨ], the actual [-ATR] variant of [i], Max-COR, (2.55), ensures that it is not the surface form as long as the input is [COR], (2.56).

(2.55) [COR] faithfulness

Max-[COR]

An input [COR] feature must have an output correspondent [COR] feature

(2.56) Surface /i/ with MAX-[COR], HICOR/ATR » SPEC-FT-[-ATR]:

(/tim-a/ → [tìm-â] 'medicine-pl.')

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

In keeping with the principle of Richness of Base (Prince & Smolensky 1993/2004), the same result is obtained with an input [-ATR] vowel. What is important is that, the input vowel is [COR]. This is shown in (2.57).

(2.57) Surface /i/ with MAX-[COR], HICOR/ATR » SPEC-FT-[-ATR]:

(/tɪm-a/ → [tìm-â] 'medicine-pl.')

tɪma	MAX [COR]	HICOR/ [ATR]	SPEC-FT [-ATR]	SPEC-FT [+ATR]	*[-ATR]
a. [tɨ̂.m-á]	*!			**	**
b. [tì.m-á]		*!		**	**
☞ c. [tî.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 the lowering process mid vowels undergo preserves their [-ATR] feature, 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 mid vowel to be [-ATR], and must rank below *MID[-ATR], which bans such an output. The combined effects of *MID[-ATR], DEP[+HI, and *A-SPAN[ATR] yield a word-final [+ATR] mid vowel, against the demands of SPEC-FT-[-ATR]. The tableau in (2.58) repeats (2.35) with SPEC-FT-[-ATR] integrated into the hierarchy.[15]

(2.58) Final [+ATR] mid vowel with DEP[+HI], DEP[+LO]]$_{wd}$ » SPEC-FT-[-ATR] (/sɨm-ɔ/ → [sɨ̀m-ó] 'a dear friend')

/sɨ̀m-ɔ́/	*MID [-ATR]	DEP [+HI]	DEP [+LO]]$_{wd}$	*A-SPAN [ATR]	SPEC-FT- [-ATR]
☞ a. [(sɨ̀).(m^w-ó)]				*	*
b. [(sí.m^w-ɔ́)]	*!				*
c. [(sɨ̀.m^w-á)]			*!		
d. [(sɨ̀.m^w-ʊ́)]		*!			

Finally, it is important to show that the SPECIFY and HICOR/[ATR] constraints do not affect the surface realisation of final mid vowels as [+ATR] or as triggers of [+ATR] harmony with preceding non-high root vowels. The tableau in (2.59) shows the interaction of these constraints to derive the word

[15] Chapter 4 deals with why high vowels are not subject to mid vowel triggered [+ATR] harmony.

dèm ó, 'play with him'. In this tableau, I assume that output forms with final [a] are ruled out by DEP[+LO]]$_{wd}$ constraint. Similarly, any output form with [ɛ] is ruled out by *MID[-ATR]. These two constraints are never violated in Dagbani. For want of space, these constraints and output forms they rule out are left out of the tableau. Note also that the output form in (2.59a) satisfies MAXCOR with a palatalised onset for the first syllable.

(2.59) Surface [e] with HICOR/[ATR] and SPECIFY constraints: (/dem o/ → [dʲém ó] 'play with him')

/dɛm ɔ/	MAX [COR]	HICOR/ [ATR]	*A-SPAN [ATR]	SPEC-FT-[-ATR]	SPEC-FT-[+ATR]
a. [(dʲ**á**)(m**ó**)]			*!	*	*
☞ b. [(dʲém**ó**)]				**	

The next section sums up the analysis of the vowel system presented in this chapter.

2.5 Summary

This chapter has demonstrated how a variety of phonological processes interact to shape the surface inventory of Dagbani vowels, presenting an analysis that has so far been lacking. With the interaction of violable constraints in OT, it has demonstrated that each part of the vowel system emerges 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 markedness constraint hierarchy on the feature [ATR] (*[-ATR] » *[+ATR]) yields surface [+ATR] vowels in CV words. This is complemented by the higher ranking grounding constraint Lo/ATR which blocks surface [+ATR] low vowels in non-harmonic contexts.

In words that have more than one mora, I have argued for the constraint Spec-Ft-[-ATR], a context-sensitive variant of the independently motivated Specify constraint that enforces the surface realisation of the more marked [-ATR] specification. This constraint derives the [-ATR] high vowels [ɨ, ʊ], and potentially the mid vowels [ɛ] and [ɔ]. In words with more than one vowel and a [+ATR] trigger, [ATR] harmony yields a [+ATR] variant of the low vowel [a] and that of all other vowels in contexts where they would otherwise not occur.

The remaining patterns of alternation require a combination of markedness and faithfulness constraint hierarchies based on vowel height and sonority. The markedness constraint hierarchy *[-Hi -Lo] » *[+Lo], *[+Hi] successfully accounts for the position of the mid vowels as the most marked vowels in the language. Merged with the [ATR] constraint hierarchy, [-ATR] mid vowels never surface in the language while [+ATR] mid vowels only surface word-finally and as a result of [+ATR] harmony in non-final positions. The faithfulness hierarchy FaithLow » FaithMid » FaithHi can not account for the mid vowels as the most marked in Dagbani. However, it does account for the high vowel as the least marked segment in Dagbani, as well as the surfacing of underlying mid vowels as low, patterns that could not be accounted for with the markedness approach. Thus the position of [ɨ] as the default vowel and the pattern of vowel lowering as the repair strategy to avoiding surface mid vowels show the need for both faithfulness and markedness approaches to analysing the distributional patterns of vowels.

Chapter 3

Formal approaches to vowel harmony in OT: a review

3.1 Introduction

Among the central tenets Optimality Theory (OT) (Prince & Smolensky 1993/2004) is the interaction of universal, ranked violable constraints that are evaluated in parallel to define the grammar of a particular language. Within phonology, the central tenets of OT have made it possible to account for patterns that have proved to be of significant challenge in previous theories of phonology, including inventory effects, features, conspiracies, problems arising out of rule ordering etc. (Itô & Mester, 1995; Kager, 1999; Kiparsky, 2000; McCarthy & Prince, 1995; Prince & Smolensky, 1993/2004; Pulleyblank, 1997, etc.). However, some of these central tenets of the theory have come under critical review when applied to patterns of harmony. In many formal approaches to vowel harmony, parallel application of constraints has been shown to overgenerate phonological patterns. They predict language types that are not attested (see Wilson 2003; McCarthy 2003a, 2009 etc. for extensive discussion).

Three major alternative approaches that avoid such problems are targeted constraints (Wilson 2003), serial harmony and harmonic serialism (McCarthy 2009), and Span Theory (McCarthy 2004). The first two abandon parallelism in OT, and propose the incorporation of serial derivation in OT. The third proposes novel representational assumptions on how harmonic features are shared between segments within a domain. In this chapter, I review the literature on formal approaches to vowel harmony in OT. I argue that while these proposals are needed to avoid many of the problems with parallel OT, some of the most far-reaching modifications proposed in the literature may not be needed to account for patterns of vowel harmony, including [ATR] harmony in Dagbani. I adopt Span Theory, the more moderate of these proposals in my account of Dagbani [ATR] harmony.

While this chapter reviews the most recent and widely used approaches, it is neither intended to be exhaustive of all approaches to vowel harmony within OT, nor a detailed critique of any approach. It is also the case that some of the approaches have been proposed not only for vowel harmony, but other processes that involve feature interactions, including consonant harmony, disharmony and tone. The focus of this chapter is limited to how these approaches handle vowel harmony patterns. The main purpose is to establish a strong basis for the analyses of Dagbani [+ATR] harmony patterns presented in this dissertation.

The rest of this chapter is organised as follows. Section 3.2 presents formal approaches within parallel OT. These include feature Alignment and Optimal Domains Theory, Positional Faithfulness, Spreading, and Agreement. Section 3.3 highlights some of the problems with these approaches, mainly the failure to derive partial harmony and the unattested patterns they predict. Section 3.4 discusses the two approaches under serial derivation. These are Targeted Constraints and Harmonic Serialism, while Section 3.5 presents a detailed exposition on Span Theory, the approach used in this dissertation. Section 3.6 summarises the chapter.

3.2 Parallel OT approaches to vowel harmony

3.2.1 Featural Alignment and Optimal Domains Theory

Featural alignment constraints, proposed by Kirchner (1993), require that a phonological feature be aligned with the left or right edge of a phonologically or morphologically defined domain (see also Smolensky 1993; Akinlabi 1996; Pulleyblank 1996; Archangeli & Pulleyblank 2002). In these studies, a gradient alignment constraint is used to compel the spread of the harmonic feature from the trigger to target segments within the harmonic domain. The general schema of an alignment constraint is shown in (3.1).

(3.1) Featural alignment constraint

Align(F, L/R; PCat/MCat, L/R)

The left/right edge of a harmonic feature F is aligned with the left/right edge of a phonological/morphological category

Featural alignment constraints trigger directionally biased spread and opacity depending on their interaction with faithfulness and markedness constraints. A closely related theory is Optimal Domains Theory, proposed by Cole & Kisseberth (1994). This theory establishes abstract harmonic domains and output correspondents of input segments belong to domains which bear the relevant feature. Alignment constraints are used to align harmonic features to relevant prosodic or morphological domains. Another constraint, Express[F], requires the phonetic expression of harmonic features. The Express constraint ensures that the segments within featural domains have the appropriate values for [F]. Cole & Kisseberth (1994) show how Optimal Domains Theory accounts for patterns of transparency and opacity, which have challenged standard autosegmental phonology. In their proposal, transparency and opacity are the outcomes of the interaction between constraints that align harmony domains, constraints on the occurrence of the harmony feature within the domain, and feature co-occurrence constraints.

3.2.2 Positional faithfulness and markedness

Beckman (1997, 1998) proposes Positional Faithfulness Theory in an analysis of Shona height harmony. In this theory, faithfulness to prosodically and psycholinguistically prominent positions is used to enforce the preservation of contrast and resistance to neutralisation in these positions. In non-prominent positions, contrast is lost due to general markedness constraints. Beckman argues that height harmony and positional height neutralisation in Shona are the results of higher-ranked faithfulness constraints to the height features of root-initial syllables, and general markedness constraints that militate against the realisation of feature specifications in other positions.

The positional faithfulness constraints derive harmony through interaction with feature-driven markedness constraints, a proposal that markedness constraints assess candidates by the number of featural autosegments they contain, not by the number of segments that bear the feature. For instance, in the Dagbani word *bìh-ìlí* 'breast' there is only one violation of the constraint *[+ATR] if both [+ATR] vowels are dominated by one [+ATR] node; and two violations if each [+ATR] vowel is dominated by a separate [+ATR] node. Essentially, the best way to satisfy this constraint is for a single harmonic feature to spread to all segments within a domain from one node (see also Itô & Mester 1994; McCarthy & Prince 1994; Padgett 1995, 2002; Alderete et al. 1999 etc.)

The strength of Beckman's analysis of Shona lies in the use of independently motivated constraints to account for harmony. It does not require harmony-driving constraints as in other approaches. However, positional faithfulness theory itself is not sufficient to account for some patterns of harmony. It faces a challenge in terms of how to serially derive harmony patterns in languages in which non-prominent positions behave differently in harmonic contexts. Yucatec Maya is an example. According to Krämer (2003) clitics in Yucatec Maya form a separate harmonic domain and do not undergo root-triggered harmony. In the positional faithfulness approach, Krämer observes, Yucatec Maya clitics would be argued to involve a serial derivation, by which the clitics are added in a later step of derivation, after harmony has been applied (see Krämer, 2003, for more discussion). Besides, as discussed in Section 3.3, a positional faithfulness and markedness account predicts patterns that are unattested in any language, while feature-driven markedness constraints cannot distinguish between candidates with partial spreading.

3.2.3 Spread constraint

In her account of crosslinguistic patterns of nasalisation, Walker (1998) proposes that autosegmental spreading is enforced by the constraint Spread. It requires the leftward or rightward spread of the harmonic feature within a domain. Spread constraints take the form Spread-L/R([F], D), where D is the domain of spread, F is the harmonic feature and L/R encode directionality. This is defined in (3.2), using the feature [nasal].

(3.2) SPREAD [+nasal] constraints: (Walker 1998: 40 – 41)

Let n be a variable ranging over occurrences of a feature specification [+nasal], and S consists of the sequence of segments s_1 ...s_k in the prosodic word P. Let Assoc(n, s_i) mean that n is associated to s_i, where $s_i \in S$

Then SPREAD-R([+nasal], Pwd) holds iff

i. $(\forall s_i \in S)$ $[[\exists n(\text{Assoc}(n, s_i))] \rightarrow [(\forall s_j \in S)$ $[j>i \rightarrow (\text{Assoc}(n, s_j))]]]$ where $1 \leq i, j, \leq k$.

ii. For each feature occurrence n associated to some segment in P, a violation is incurred for every $s_j \in S$ for which (i) is false.

SPREAD-R([nasal], Pwd) enforces total spread of the feature [+nasal] to all segments in the prosodic word following any [+nasal] autosegment while SPREAD-L([nasal], Pwd) enforces a similar spread to all segments preceding a [+nasal]. A SPREAD constraint evaluates output forms gradiently. This means every output form with a non-nasalised segment within the same prosodic word as the nasal segment incurs one violation of the constraint for each such segment that it contains. An example is shown in (3.3) using the word */wãhida/* 'they went' from the language Epena Pedee (Walker 1998).

(3.3) Spread-L([+Nas], Pwd) and Spread-R([+Nas], Pwd) (Walker 1998: 51)

/wãhida/	Spread-L ([+Nas], Pwd)	Spread-R ([+Nas], Pwd)
a. wãhida	*	****
b. w̃ãhida		****
c. w̃ãh̃ida		***
d. w̃ãh̃ĩda		**
e. w̃ãh̃ĩd̃a		*
f. w̃ãh̃ĩd̃ã		

w̃ãh̃ĩd̃ã, (3.3f), is the only output form that satisfies both constraints fully, having spread the feature to all segments in the domain. The actual output form depends on the ranking of the spreading constraints with respect to markedness constraints on which segments can be nasalised (see Walker 1998 for further discussion).

3.2.4 Agreement

In rejecting the need for a directional Spread constraint in vowel harmony Baković (2000) argues that directionality in vowel harmony is dependent on morphological structure, and that there are only two vowel harmony processes in human language with respect to directionality patterns: (i) stem-controlled, and (ii) dominant-recessive processes. In a stem-controlled harmonic process, the harmonising feature of the stem determines that of other morphemes in the domain. In a dominant-recessive pattern, one feature, the dominant, determines the feature of the entire domain regardless of the morpheme in which it occurs. A morpheme with the non-dominant (or recessive) features undergoes harmony.

Baković accounts for the two patterns of harmony using transderivational correspondence theory (Benua 1995, 1997 and markedness constraints. In his account, what is needed to yield stem-controlled harmony is a relatively higher ranked faithfulness constraints on the correspondence relations between stems and their affixed forms enforced in a cyclic process. In dominant-recessive patterns, markedness constraints prevent segments with unmarked dominant-valued features from taking on the recessive feature value. In both cases, what is required is a directionless agreement constraint AGREE(αF), which demands that adjacent segments within some domain have the same specification for a harmonic feature (see also Lombardi 1999, 2001; Pulleyblank 2002 etc.). Unlike a SPREAD constraint which defines a specific segment as the source of the harmony feature associated with target segments in the domain, AGREE constraint simply requires that adjacent segments have the same specification for the feature. As Pulleyblank (2002) argues, this requirement can alternatively be met by simply disallowing any disagreement between a segment and another segment preceding or following it (see also McCarthy (2004) and discussion below on Span Theory for a similar mechanism adopted in Span Theory).

3.2.5 Other approaches

Baković's proposal has been challenged in subsequent studies. Mahanta (2007) discusses the vowel harmony pattern of Assamese and other languages in which directionality play a unique role, contrary to Baković's prediction. The spread of the feature [+ATR] in Assamese is strictly right-to-left. She uses sequential markedness, (Pulleyblank 2002 etc.) in her analysis of directionality. Unlike other markedness constraints, sequential markedness constraints only block a specific (marked) sequence of two features. Thus a constraint such as *[-ATR][+ATR] only bans a sequence of a [-ATR] vowel followed by a [+ATR] vowel. Candidates with the sequence [-ATR][-ATR] and more importantly [+ATR][-ATR] do not violate this constraint.

Krämer (1999, 2000, 2003) also shows that while root-control is dominant in morphologically controlled harmony patterns, there are cases in which harmony is controlled by the feature of the affix, (affix-controlled harmony). Krämer rejects the need for cyclic derivation, adopting various constraints under general correspondence theory (McCarthy & Prince 1995) to account for vowel harmony. Citing previous proposals such as Gnanadesikan (1997); Lombardi (1999); Pulleyblank (1997), he proposes an account driven by syntagmatic identity constraints.

3.3 Problems with parallel OT

A number of recent studies (e.g. Wilson 2003; McCarthy 2003b; McCarthy 2004 McCarthy 2009) have highlighted problems with the standard theories of harmony and assimilation outlined in the preceding sections. There are two problems with these theories. First, some of these theories have 'sour-grapes' property in that they are unable to account for partial spreading and opacity effects. Second they make pathological predictions that are implausible. In this section, I summarise these problems as presented in Wilson (2003) and McCarthy (2003b, 2004, 2009).

3.3.1 No partial spreading

The main limitation to local agreement and feature-driven markedness constraints is that they favour spreading that is fully successful, but weak at deriving output forms with partial spreading. McCarthy (2004) illustrates this with nasal assimilation in Johore Malay, a language in which liquids and less sonorant segments block the spread of nasality. The relevant agreement constraint for this language is Agree-R, defined in (3.4).

(3.4) Agree-R(+nas) If a segment bears the feature [+nasal], then the immediately following segment must also be [+nasal].

As shown in (3.5), the winning candidate, (3.5a), incurs the same number of violations as any other candidate that satisfies *[+nas, -son], even though the [s] is the real blocker of harmony.

(3.5) AGREE-R(+nasal) in blocked nasal spreading (McCarthy 2004: 14)

/pəŋawasa/	*[+nas, -son]	AGREE-R(+nas)
☞ a. pə[ŋãw̃ã]$_{[+nas]}$sa		*
✗ b. pə[ŋ]$_{[+nas]}$awasa		*
c. pə[ŋãw̃ãs̃ã]$_{[+nas]}$	*!	
✗ d. pə[ŋã]$_{[+nas]}$wasa		*

In (3.5), AGREE-R(+nas) only enforces agreement with respect to the feature [+nasal] between a consonant that is [+nasal] and the immediately following segment. It has the same effect as the sequential markedness constraint *[+nas][-nas] in that it does not see beyond the segment immediately following the [+nasal] segment. In this sense, AGREE constraint is non-gradient in its application.

AGREE-R(+nas) is unhelpful in deriving the optimal output because regardless of how many oral segments are targets of spreading in output form with partial spreading, only one nasal-oral sequence is left to incur a violation of the AGREE-R(+nas). The same limitations apply to feature-driven markedness constraint (Beckman 1997, 1998). Like AGREE, any candidate, except one with total spreading incurs one violation of *[-nasal] and one violation of *[+nasal].

3.3.2 Pathological predictions

Wilson (2003) and McCarthy (2004, 2009) discuss as many as seven different predictions of gradient Align and non-local Spread constraints. They argue that these predictions argue against alignment and spreading constraints because they are typologically implausible. In discussing some of these predictions, Wilson and McCarthy use hypothetical languages. In this section, I present some of Wilson and McCarthy's arguments illustrating the problems with Dagbani data. I show that in the analysis of Dagbani [+ATR] harmony, alignment constraints make four of the pathological predictions when confronted with opaque consonants and reduplicants.

3.3.2.1 Harmony by alteration of blockers

When an opaque segment stands in the way of [+ATR] spread, one possible means of satisfying Align-R/L[+ATR] or Spread-R/L[+ATR] is to change the opaque feature. With this measure, the opaque segment becomes an undergoer and complete harmony is achieved. This is illustrated below using Dagbani [ATR] opacity effects.

Dagbani [ɾ], [l] and [s] block the spread of a [+ATR] feature from the root to the suffix, as shown in (3.6).

(3.6) Opaque consonants

a.	ʒì]$_{rt.}$-ɾɨ̀	*ʒì]$_{rt.}$-ɾì	‘carrying’
b.	tí]$_{rt.}$-ɾɨ́	*tí]$_{rt.}$-ɾí	‘a vomit’
c.	bì]$_{rt.}$-lɨ̂	*bì]$_{rt.}$-lî	‘chicken breast’
d.	jíl]$_{rt.}$-lɨ́	*jíl]$_{rt.}$-lí	‘a song’
e.	bìː]$_{rt.}$-sɨ́m	*bìː]$_{rt.}$-sím	‘heat’
f.	bíːn]$_{rt.}$-sɨ́	*bíːn]$_{rt.}$-sí	‘experts’

I posit the featural implicational constraint CORCONT/[-ATR], (3.7), to block the consonants [ɾ, l, s] from undergoing harmony.

(3.7) Opacity constraint

CORCONT/[-ATR]

If [COR] and [+continuant], then [-ATR]

Two of the three opaque consonants have variants that are not opaque. As already noted in Chapter 1, the sibilant [s] lenites into [h] intervocalically, and as onset of a CV. It does not lenite in CVːsVN forms, with both preceding long vowel and following coda crucial to the pattern. The tap [ɾ] on the other hand is a surface variant of [d] in postvocalic position. Neither [h] nor [d] blocks the spread of [+ATR]. Examples with [h] are shown in (3.8).

(3.8) [+ATR] harmony across [h]

a.	/bí-sɨ́/	[bí]$_{rt.}$-hí]	'child-pl.'
b.	/pí-sí-nʊ́/	[pí]$_{rt.}$-hí-nʊ]	'ten-pl.-five (fifty)'
c.	/ʧìs/	[ʧìh[ì]]$_{rt.}$]	'break'
d.	/lís/	[lìh[ì]]$_{rt.}$]	'look'
e.	/ɲìs/	[ɲìh[ì]]$_{rt.}$]	'reveal a secrete'

By ranking a faithfulness constraint that blocks lenition below Align-R[ATR] or Spread-R[ATR], lenition could be blocked purposely to satisfy the demands of the alignment constraint. For instance, the surface realisation of /d/ as [ɾ] could be blocked to achieve an unbounded spread of [+ATR] from the root to the suffix vowel. The input form /tí$_{rt.}$-dí/, (3.6b), could surface as *[tí$_{rt.}$-dí] rather than the attested [tí-ɾɨ́].

The analysis of how the alignment constraint could block /d/ → [ɾ] lenition is shown below. For the purpose of the analysis here, lenition is triggered by the markedness constraint *d/V_, (3.9).

(3.9) *d/V_

In post vocalic position, the consonant /d/ is prohibited.

To derive the attested pattern of lenition and opacity, the constraints CORCont/[-ATR] and *d/V_ must outrank DepCOR[+Cont] in (3.10), which has the potential to block lenition.[16]

[16]Given the contexts in which /s/ debuccalisation takes place, its analysis is complicated. Using it for the purpose of illustration will take the discussion in this section off course.

(3.10) DEPCOR[+CONT]

For every output [COR] consonant that is [+cont], its input correspondent must also be [+cont]

The tableau in (3.11) shows how the three constraints interact to yield the attested pattern.

(3.11) Lenition and opacity (/tí-dí/ → [tí]-ɾɨ́] ‘a vomit’)

/tí-dí/	CORCONT/ [-ATR]	*d/V_	DEPCOR [+CONT]
a. [tí-ɾí]$_{[+ATR]}$	*!		
b. [tí-dí]$_{[+ATR]}$		*!	
☞c. [tí]$_{[+ATR]}$-ɾɨ́]			*

By changing /d/ into [ɾ] and maintaining its nucleus as a target of [+ATR] harmony, (3.11a) incurs a fatal violation of CORCONT/[-ATR]. The only way for the suffix vowel to be a target of root-triggered [+ATR] harmony is to avoid changing input /d/ into [ɾ]. However, avoiding the lenition violates the demands of *d/V_, (3.11b). With a violation of lowest ranked DEPCOR[+CONT], (3.11c) emerges as the optimal output form.

An alternative result is predicted when an alignment constraint is included in the hierarchy. With ALIGN-R[+ATR] outranking the constraint that triggers lenition, lenition is blocked to achieve an unbounded spread of the feature [+ATR] if the root vowel has a [+ATR] feature. The output form *[tí-dí]*$_{[+ATR]}$ in (3.11) becomes the optimal form. 3.12) defines the alignment constraint.

(3.12) ALIGN-R[+ATR]

The right edge of [+ATR] must be aligned with the right edge of the phonological word

The prediction of ALIGN/SPREAD constraint is shown in (3.13).

(3.13) Alignment constraint blocks lenition (/tí-dí/ → *[tí-dí] 'a vomit')

/tí-dí/	ALIGN-R [+ATR]	CORCONT/ [-ATR]	*d/V_	DEPCOR [+CONT]
a. [tí-ɾí]$_{[+ATR]}$		*!		
✗ b. [tí-dí]$_{[+ATR]}$			*	
☞c. [tí]$_{[+ATR]}$-ɾɨ́]	*!			*

The problem with the constraint hierarchy in (3.13) is that it only predicts the change from [-cont] to [+cont] if the root has a [+ATR] vowel. With a [-ATR] root vowel, ALIGN-R[+ATR] is inactive. Thus /d/ tapping takes place under the same constraint ranking. This is shown in (3.14).

(3.14) Lenition takes place with a [-ATR] root vowel (/tɪ̀d/ → [tɪ̀ɾɪ̀] 'point at')

/tɪ̀d/	Align-R [+ATR]	CORCont/ [-ATR]	*d/V_	DepCOR [+Cont]
a. [tɪ̀dɪ̀]			*!	
☞b. [tɪ̀ɾɪ́]				*

However, as Wilson points out, there is no evidence that any language changes segmental features solely to satisfy the demands of a long distance trigger of a harmony feature.

3.3.2.2 Harmony by deletion

Pro-spreading constraints also predict that segments in the output can be deleted to eliminate any violation of Align or Spread constraints. As in the preceding section, the three opaque consonants in Dagbani [+ATR] harmony make it a perfect example to test the prediction. In the discussion below, the prediction is tested for Dagbani opaque /l/, data for which are shown in (3.6) and repeated in (3.15) with more examples.

(3.15) Opaque consonants

a.	bì]$_{rt.}$-lɨ́m	*bì]$_{rt.}$-lím	‘childish’
b.	jìl[ɨ̀]ŋ]$_{rt.}$-gá	*jìl[ì]ŋ]$_{rt.}$-gá	‘a musical flute’
c.	bì]$_{rt.}$-lɨ̂	*bì]$_{rt.}$-lî	‘a chicken breast’
d.	jíl]$_{rt.}$-lɨ́	*jíl]$_{rt.}$-lí	‘a song’
e.	fíl[ɨ́]m]$_{rt.}$ tɨ́	*fíl[í]m]$_{rt.}$ tí	‘demean us’
f.	ʧíl[ɨ́]m]$_{rt.}$-bʊ̂	*ʧíl[í]m]$_{rt.}$-bû	‘delaying’
g.	pìl[ɨ̀]]$_{rt.}$-gʊ́	*pìl[ì]]$_{rt.}$-gú	‘beginning’

To satisfy the opacity-trigger CORCONT/[-ATR] and the the alignment constraint ALIGN-R[+ATR] (and there by achieve [+ATR] harmony), [l] must be avoided in an output form either through deletion or loss of one of the features [COR] and [+cont]. Either of these features can be lost with a fortition constraint or a markedness constraint against a [+cont] feature for coronals. For the purpose of the analysis here, I use the latter, defined in (3.16).

(3.16) *COR-[+CONT]

An output consonant must not be specified for both [COR] and [+cont]

Deletion comes at the cost of violation of MAX-IO constraint (McCarthy & Prince 1995), defined in (3.17).

(3.17) MAX-IO

Every segment in the input must have a correspondent in the output.[17]

As long as CORCONT/[-ATR] and ALIGN-R[+ATR] outrank the other constraints, deletion of the opaque consonant is predicted. This is shown in (3.18).

(3.18) Deletion triggered by an alignment constraint (/bì-lɨ̂/ → *[bì-î] 'chicken breast')

/bì-lɨ̂/	ALIGN-R [+ATR]	CORCONT/ [-ATR]	MAX-IO	*COR-[+CONT]
a. [bì-lɨ̂]$_{[+ATR]}$		*!		*
✗ b. [bì-î]$_{[+ATR]}$			*	
☞ c. [bì]$_{[+ATR]}$-lɨ̂	*!*			*

In a root with a [-ATR] vowel, harmony does not require deletion, as ALIGN-R[+ATR] is inactive, (3.19). Deletion is thus predicted to be based solely on the need to achieve long distance harmony, a pattern that is unattested in any language.

[17] 'Segment' in all definitions refers a vowel or consonant.

(3.19) No deletion with [-ATR] root vowels (/bàl/ → [bàlɨ̀] 'gather')

/bà-l/	ALIGN-R [+ATR]	CORCONT/ [-ATR]	MAX-IO	*COR-[+CONT]
a. bàɨ̀			*!	
☞ b. bàlɨ̀				*

3.3.2.3 Harmony by affix repositioning

Prince & Smolensky (1993/2004), Kager (1999) and others show that infixation may result from markedness constraints dominating affixal alignment constraints. Noyer (1993) and Fulmer (1997) even argue that such a ranking can result in an underlying prefix becoming a suffix, and vice versa. Given this effect, Wilson (2003) shows that ALIGN[F] constraints could change the position of an affix in order to get it out of its domain for the harmonic feature to spread unbounded. This makes the prediction that rules of harmony may determine the position of an affix relative to the stem, a pattern that is unattested in any language. I illustrate this using the Dagbani affixes *-lɨ, -ɾɨ* and *-lɨn-*.

The first two are regular suffixes that mark number, aspect, nominal derivation or other grammatical functions. *-lɨn-* is a fixed morpheme that remains unchanged between a root [+ATR] vowel and its reduplicant. The suffixes *-lɨ* and *-ɾɨ* were shown in (3.6). The data in (3.20) show the fixed syllable *-lɨn*. The pattern of reduplication is discussed in Chapter 1, with motivation for the initial syllable being the root. The reduplicants are underlined.

(3.20) Fixed *-lɨn* syllable in Dagbani reduplication

a.	kpí]$_{rt.}$-lɨ́n-kpí-hî	'epilepsy'
b.	dí]$_{rt.}$-lɨ́n- dí-hî	'numbness'
c.	ʃí]$_{rt.}$-lɨ́n-ʃí-hî	'shadow-pl.'
d.	dɛ̀]$_{rt.}$-lɨ̀n- dɛ́-ʔʊ̂	'leech'
e.	sá]$_{rt.}$-lɨ́n- sá-hî	'tiny ant-pl.'
f.	ká]$_{rt.}$-lɨ́n- ká-ʔʊ̂	'crown-sg.'

To ensure that the fixed syllable is located at the right place, the Align constraint in (3.21) is needed.

(3.21) Align-R]$_{Root}$(lɨ́n)

The left edge of *lɨn* must be aligned with the right edge of the root

However, when the harmony trigger Align-R[+ATR] outranks Align-R(lɨ́n), the fixed *-lɨn-* affix is realised as a prefix to a root with a [+ATR] vowel, (3.22), but not to a root with a [-ATR] vowel, (3.23). The implausible prediction here is that the location of the affix may be determined by the need to achieve an unbounded rightward spread of [+ATR].

(3.22) Prefixation resulting from ALIGN-R[+ATR] » ALIGN-R]$_{Root}$(lɨ́n)

/dí]$_{rt.}$-d̲í̲-hî + lɨ́n/	ALIGN-R [+ATR]	ALIGN-R]$_{Root}$ (lɨ́n)
☞a. [dí]$_{rt.}$]$_{+ATR}$ -lɨ́n- d̲í̲-hî	*!******	
✗ b. lɨ́n- [dí]$_{rt.}$-d̲í̲-hî]$_{+ATR}$		**

(3.23) No change in affix location with a [-ATR] vowel

/dɛ̀]$_{rt.}$-d̲ɛ̲́-ʔʊ̂ + lɨn/	ALIGN-R[+ATR]	ALIGN-R]$_{Root}$(lɨ́n)
☞a. dɛ̀]$_{rt.}$-lɨ̀n- d̲ɛ̲́-ʔʊ̂		
b. lɨ́n- dɛ̀]$_{rt.}$-d̲ɛ̲́-ʔʊ̂		*!*

3.3.2.4 Harmony by reduplicant shortening

In the Dagbani pattern of reduplication, the entire root is copied due to the constraint MAX-BR, (McCarthy & Prince 1995).

(3.24) MAX-BR

Every segment in the base must have a correspondent in the reduplicant

However, ALIGN-R-[+ATR] could trigger a reduplicant shorter than the root if it outranks MAX-BR. This is because such a ranking reduces the number of violations of ALIGN-R-[+ATR] in a root with a [+ATR] vowel.

For instance, the root vowel could be the reduplicant instead of the entire CV root, a measure that would reduce the violation marks of ALIGN-R-[+ATR] by one. Such a repair strategy is not needed with a [-ATR] root vowel, a pattern that is unattested in any language, (3.25) and (3.26).

(3.25) A shorter reduplicant triggered by ALIGN-R[+ATR] (dí-lɨ́n-<u>dí</u>-hî → *dí-lɨ́n-<u>í</u>-hî 'numbness')

/dí]$_{rt.}$-lɨ́n+ RED + hî/	ALIGN-R[+ATR]	MAX-BR
☞a. [dí]$_{rt.}$]$_{+ATR}$ -lɨ́n- <u>dí</u>-hî	*** **! **	
b. ✗[dí]$_{rt.}$]$_{+ATR}$-lɨ́n-<u>í</u>-hî	*** * **	*

(3.26) No reduplicant shortening with [-ATR] root vowels (dɛ̀]$_{rt.}$-lɨ̀n- <u>dɛ̀</u>-ʔʊ̂ 'a leech')

/dɛ̀]$_{rt.}$-lɨ̀n+RED+ʔʊ̂/	ALIGN-R[+ATR] /	MAX-BR
☞a. dɛ̀]$_{rt.}$-lɨ̀n- <u>dɛ̀</u>-ʔʊ̂		
b. dɛ̀]$_{rt.}$-lɨ́n-<u>ɛ̀</u>-ʔʊ̂		*!

3.3.2.5 Other predictions

Other pathological predictions of ALIGN and SPREAD constraints not illustrated with Dagbani data are discussed by (Wilson 2003) and (McCarthy 2009). To avoid or reduce violations, these constraints predict (i) the blocking of segmental epenthesis (ii) the selection of short allomorphs of morphemes in an affixation pattern where such a choice is available, (iii) the shifting of stress out of the domain of harmony in a language that prohibits stressed syllables from being targets of harmonic features, and (iv) the emergence of a less marked reduplicant which undergoes harmony.

In sum, while local agreement constraints are not capable of deriving partial harmony when there is an opaque segment, alignment constraints are too strong in dealing with opacity. The next section takes a look at two of the major alternative approaches to alignment and spreading constraints.

3.4 Serial derivation

Mainly in response to the weaknesses of the various harmony constraint types discussed in the preceding section, recent proposals for serial derivation within Optimality Theory have been made. Two such proposals are targeted constraints (Wilson 2003) and serial harmony (McCarthy 2009). I discuss these theories in turn in the next two subsections. It is important to note that these proposals are not limited to vowel harmony or processes of spreading alone, they are also meant for the analysis of other phonological processes.

3.4.1 Targeted constraints

(Wilson 2003) deals with the need for iterative application of spreading constraints within the framework of Targeted Constraints in Optimality Theory

(TCOT) to account for various patterns of harmony.[18] TCOT avoids the problem with unbounded spreading shown in section 3.3.1, by using 'targeted constraints' that specify how a constraint is violated, how the violation is repaired, and require assimilation only between adjacent segments. How assimilation is achieved is explained further below. Constraint evaluation in TCOT is shown in (3.27).

(3.27) Constraint evaluation in TCOT (Wilson 2003:10)

Let C be any constraint that specifies both the locus λ and a change δ, x and y be any two representations, and Δ be the change from x to y.

a. For every $\lambda \in \mathrm{C}(x)$, assign one mark to x, for every $\lambda \in \mathrm{C}(y)$, assign one mark to y

b. For every $\lambda \in \mathrm{C}(x)$ that is repaired in the way specified by δ, remove one mark from y.

b′. For every $\lambda \in \mathrm{C}(x)$ that is repaired in a way not specified by δ, remove one mark from x.

(3.27a) is a paraphrase of how familiar OT constraints are evaluated (see McCarthy, 2003b). (3.27b and b′) introduce mark removal, an important component of constraint evaluation in TCOT. Both are meant to ensure

[18]For (earlier) use of targeted constraints in other phonological processes, see Wilson (2000, 2001), Baković & Wilson (2000), and Hansson (2001). Also see McCarthy (2002) for response to Wilson's initial proposals, slightly modified in Wilson (2003).

that only a specific minimal change is effected at each stage in the derivation of an output form. A targeted spreading constraint thus takes the form in (3.28) ('T:' gives an indication that a constraint is targeted).

(3.28) Targeted SPREAD constraint (Wilson 2003: 15)

T:SPREAD-{L,R}([αF],D)

λ A non-[αF] segment immediately to the {left, right} of an [αF] segment in the same domain D.

δ [0F]/[-αF] $\rightarrow$ [αF]

Wilson also proposes modification to the GEN component of OT, as follows:

> "A targeted constraint C is a pairing of a locus of violation (λ) with a change (δ). For each C, there is a constraint-specific function GEN$_C$ (i.e., GEN$_{(\lambda,\delta)}$) that maps candidates to candidate sets. GEN$_C$ returns the set containing all and only the candidates that can be derived from the original candidate by applying the change δ to zero or more instances of the locus λ..." (Wilson 2003: 22).

Wilson illustrates how a targeted spreading constraint such as (3.28) works, using Malay nasal harmony. Malay has a left-to-right nasal spread that targets vowels but blocked by segments of lower sonority. He uses a targeted version of the constraint hierarchy of Walker (1998), shown in (3.29).

(3.29) Constraint hierarchy for Johore Malay nasal harmony (Walker 1998: 45)

*NasObstruentStop » *NasFricative » *NasLiquid »
Spread-R([+nasal], PrWd) » *NasGlide » *NasVowel

Given that targeted constraints derive output forms in serial steps, an input form passes through each constraint in the hierarchy and returns an output, which becomes the input for the next constraint in the hierarchy; much like rule ordering in rule-based phonology. If there is no locus of violation of the constraint or if the locus of violation is removed, the output is identical with the input form which lacks the violation. If, after applying a constraint, the locus of violation is not entirely removed, another iteration of the constraint is applied until the input is exactly the same as the output before it passes on to the next constraint in the hierarchy.

Wilson shows a long and detailed table of the derivation steps required to derive the Malay word [pəŋãw̃ãsan] from /pəŋawasan/. For the purpose of illustration, I show only the first iteration in the application of T:Spread-R([+nas],Pr.Wd). The tableau only shows this constraint and the constraints it dominates.

(3.30) First iteration of spreading (Wilson 2003: 27)

[pəŋawasan]	T:SPREAD-R([+nas])	T:*NAS GLIDE	T: *NASV	Ident ([nas])
a. [pəŋawasan]	*!			
☞b. [pəŋãwasan]	(*)		*	*

Both (3.30a and b) incur violations of the SPREAD-R([+nas]). However, compared with (3.30a), (3.30b) has a minimal change in the direction specified by the constraint. Its violation is therefore removed (indicated by the parentheses around the violation mark). The other marks are assigned as in the original OT formulation. The principle of strict domination is also maintained. (3.30b) emerges as optimal. The output becomes the input for the next iteration. This continues until all targets of nasalisation get the feature [+nasal] or blocked by a higher constraint.

In addition to solving the problem of unbounded spreading, Wilson also argues that TCOT provides a solution to other issues that have posed challenges to previous approaches of vowel harmony, including transparency and directionality. However, as McCarthy (2002) notes, this comes at the cost of far-reaching modifications to the fundamental tenets of Optimality Theory. By using Span Theory to account for the opacity and height condition in Dagbani [ATR] harmony, I show that these far-reaching modifications may not be necessary.

3.4.2 Serial Harmony and Harmonic Serialism

Serial harmony (SH) is also a derivational theory of autosegmental spreading. Like Wilson's targeted constraints, in SH, Gen can only make one change at a time (Harmonic Serialism). The input must differ from the output only in one respect. Every form that passes through Gen and Eval is resubmitted as the input to another round through Gen and Eval until all no changes are left to be effected on the output. This is one of three main elements of the theory, listed in (3.31).

(3.31) Elements of Serial Harmony (McCarthy 2009: 1 – 2)

a. Distinctive features are privative.

b. The motive of harmony is a constraint on autosegmental representations, Share(F), that is violated by any pair of adjacent segments that are not linked to the same [F] autosegment.

c. Harmony and all other phonological processes occur serially rather than in parallel. This assumption is a consequence of adopting Harmonic Serialism as the overall analytic framework.

The argument for privativity of features that participate in assimilation is also made in previous studies such as Steriade (1993a,b, 1995), and Trigo (1993) who argue that the most principled way to account for the fact that no language spreads [-nasal] is to assume that [nasal] is privative (see Lombardi, 1991, on similar arguments for laryngeal features). But as McCarthy notes, tongue-root features and backness present a real challenge to privativity, as argued in Archangeli & Pulleyblank (1994).

The second assumption regards autosegmental spreading. McCarthy proposes two constraints to derive feature spreading and directionality. The feature-spreading (Share[F]) constraint is similar to local Agree constraint in previous approaches in that it is directionless, but differs in the underlying assumptions on which it is based, as discussed below. This is defined in (3.32).

(3.32) Feature spreading constraint (McCarthy 2009: 8)

Share[F]

Assign one violation mark for every pair of adjacent segments that are not linked to the same token of [F]

Given the assumption about privativity of features, the only way to satisfy this constraint is for one feature to be linked to two segments, the original host and the segment with which it shares it, as shown in (3.33a). The other representations in (3.33) do not satisfy this constraint because they have the nasal feature linked to only the host (3.33b), different segments linked to different tokens, (3.33c), or there is no link between the segments and a [nasal] feature, as in (3.33d).

(3.33) Application of SHARE[nasal] constraint (McCarthy 2009: 8)

```
a.  [nas]          b.  [nas]       c.  [nas] [nas]       d.
     |\                  |                 \  /
     mã                  ma                 mã                  ba
```

To account for directionality, McCarthy proposes that leftward or rightward spreading is achieved through the interaction of faithfulness constraints. Left-to-right spreading is enforced by a faithfulness constraint (INITIAL(F)) that requires the host of an autosegment to be the leftmost segment associated with that autosegment, while right-to-left directionality is enforced by FINAL(F), making the host the rightmost segment associated with the feature. These faithfulness constraints are defined in (3.34) and (3.35).

(3.34) INITIAL(F) (McCarthy 2009: 9)

Let input F tier = $\mathbf{f}_1\mathbf{f}_2\ldots\mathbf{f}_m$.
Let input segmental tier = $\mathbf{s}_1\mathbf{s}_2\ldots\mathbf{s}_n$.
Let output F tier = $\mathbf{f}_1\mathbf{f}_2\ldots\mathbf{f}_o$.
Let output segmental tier = $\mathbf{s}_1\mathbf{s}_2\ldots\mathbf{s}_p$.
Assign one violation mark for every $\mathbf{s}_i \Re \mathbf{s}_j$, where:

$\mathbf{f}_k \Re \mathbf{f}_l$,

$\mathbf{f}_k$ is associated with $\mathbf{s}_i$, and there is no $\mathbf{s}_x$ that precedes $\mathbf{s}_i$ and is also associated with $\mathbf{f}_k$ and

$\mathbf{f}_l$ is associated with $\mathbf{s}_j$, and there is some $\mathbf{s}_y$ that precedes $\mathbf{s}_j$ and is also associated with $\mathbf{f}_l$

(3.35) FINAL(F) (McCarthy 2009: 9)

Let input F tier = $\mathbf{f}_1\mathbf{f}_2\mathbf{...f}_m$.
Let input segmental tier = $\mathbf{s}_1\mathbf{s}_2\mathbf{...s}_n$.
Let output F tier = $\mathbf{f}_1\mathbf{f}_2\mathbf{...f}_o$.
Let output segmental tier = $\mathbf{s}_1\mathbf{s}_2\mathbf{...s}_p$.
Assign one violation mark for every $\mathbf{s}_i \Re \mathbf{s}_j$, where:

$\mathbf{f}_k \Re \mathbf{f}_l$,

$\mathbf{f}_k$ is associated with $\mathbf{s}_i$, and there is no $\mathbf{s}_x$ that follows $\mathbf{s}_i$ and is also associated with $\mathbf{f}_k$ and

$\mathbf{f}_l$ is associated with $\mathbf{s}_j$, and there is some $\mathbf{s}_y$ that follows $\mathbf{s}_j$ and is also associated with $\mathbf{f}_l$

In plain language, if a candidate has the leftmost segment in the output linked to an autosegment such as [nasal] precede the correspondent of the leftmost segment linked to the autosegment in the input, such a candidate violates INITIAL([nasal]). Similarly, FINAL([nasal]) forbids rightmost segment in the output linked to an autosegment from following the correspondent of the rightmost segment linked to the autosegment in the input.

McCarthy makes the assumptions in (3.36) about how GEN manipulates autosegmental structures:

(3.36) Assumptions about GEN for autosegmental phonology in SH (McCarthy 2009: 15)

GEN's set of operations consist of:

a. Insertions:

-A feature and a single association line linking it to some pre-existing structure.

-A single association line linking two elements of pre-existing structure.

b. Deletions:

-A feature and a single association line linking it to some pre-existing structure.

-An association line linking two elements of a pre-existing structure.

The remaining assumption in McCarthy (2009)'s formulation of the theory regards IDENT constraints. IDENT(F) is violated whenever a segment gains or loses an association with an [F] autosegment. Thus feature delinking, deletion, spreading and insertion all violate this constraint.

(3.37) IDENT([F]) (McCarthy 2009: 10)

Let input F tier = $\mathbf{f}_1\mathbf{f}_2\mathbf{...f}_m$.
Let input segmental tier = $\mathbf{s}_1\mathbf{s}_2\mathbf{...s}_n$.
Let output F tier = $\mathbf{f}_1\mathbf{f}_2\mathbf{...f}_o$.
Let output segmental tier = $\mathbf{s}_1\mathbf{s}_2\mathbf{...s}_p$.
Assign one violation mark for every $\mathbf{s}_i \Re \mathbf{s}_{j,}$ where:

$\mathbf{f}_k$ is associated with $\mathbf{s}_{i,}$ and
there is no $\mathbf{f}_l$ such that $\mathbf{f}_k \Re \mathbf{f}_l$ and $\mathbf{f}_l$ is associated with $\mathbf{s}_j$

or

$\mathrm{f}_{l,}$ is associated with $\mathbf{s}_j$ and
there is no $\mathbf{f}_k$ such that $\mathbf{f}_k \Re \mathbf{f}_{l,}$ and $\mathbf{f}_k$ is associated with $\mathbf{s}_i$.

An example of rightward spreading is shown in (3.38), using the Malay word /pəŋawasan/ [pəŋãw̃ãsan]. This is achieved with INITIAL([nasal]) outranking SHARE([nasal]), which in turn outranks FINAL([nasal]). The markedness constraints are the same as those used in Walker (1998), shown in (3.29). In (3.38), I have maintained McCarthy's convention of using a vertical line to separate two segments that are not linked to the same [F] autosegment.[19]

(3.38) /pəŋawasan/ → [pəŋãw̃ãsan] (McCarthy 2009: 11)

p|ə|ŋ|a|w|a|s|a|n	INIT [nas]	SHR [nas]	FIN [nas]	*NAS GLI	*NAS VO	ID [nas]
☞a. p|ə|ŋãw̃ã|s|a|n		5	1	1	2	3
b. p|ə̃ŋãw̃ã|s|ãn	2!	3	1	1	4	4
c. p|ə|ŋ|a|w|a|s|a|n		8!				

While the right output form is derived in (3.38) in one derivation, in the actual formulation of Harmonic Serialism, harmony is achieved through series of derivations, each targeting one pair of adjacent segments. With the underlying form as the input, harmony is achieved between the segment that hosts the harmonic feature and another segment to its left or right, depending on the directionality of harmony enforced by the constraints. The next derivation takes the output of the first as its input, and harmony is achieved between the targeted segment in the first derivation and another

[19]To save space, I write the number of violations instead of using '*' to show violation marks.

segment that is adjacent to it. This continues until all eligible targets are affected. Derivation of [p|ə|ŋã w̃ã|s|a|n] is achieved in the order: [pəŋãwasan] then [pəŋãw̃asan] then [pəŋãw̃ãsan], each step taking as its input the output of the preceding derived form.

McCarthy argues that with the serial nature of the derivations, issues in vowel harmony patterns such as transparency, root-control, dominant/recessive patterns and trigger conditions are accounted for in a way that avoids the problem of 'sour-grapes' associated with AGREE constraints and the pathological predictions made by ALIGN constraints.

A major challenge to Serial Harmony is direction-specific blocking, where blocking effects are observed in one direction but not the other. To illustrate using nasal harmony, consider a word like /asamasa/. In a language of the Malay type in which fricatives block nasal harmony, the output will be [asãmãsa]. However, if fricatives in the language only block left-to-right but not right-to-left spread, the output will be [ãs̃ãmãsa]. Serial harmony cannot account for such blocking effects because the SHARE constraint is directionless. *NASFRICATIVE needs to outrank SHARE to derive opacity, but the blocking effect will be felt in both directions. McCarthy uses the tableau in (3.39) to illustrate the problem.

(3.39) No direction-specific blocking in Serial harmony (McCarthy 2009: 40)

/asamasa/	*NAS-FRIC	SHARE [nas]	IDENT [nas]	INITIAL NAS	FINAL NAS
☞ a. ãs̃ãmã|s|a	1	2	4	1	1
b. ãs̃ãmãs̃ã	2		6	1	1
c. a|s|ãmã|s|a		4	2	1	1
d. ãs̃ãm|a|s|a	1	3	3	1	

(3.39) has all the relevant constraints within Serial Harmony to derive the spread of nasality. In order to achieve a direction-specific spreading, there should be some ranking under which the output form in (3.39a) wins. However, there is no consistent ranking that can produce such an outcome. As McCarthy notes, (3.39a) is collectively harmonically bounded by (3.39b) and (3.39c).

In defence of Serial Harmony, McCarthy argues that there may not be a genuine case of direction-specific spreading in which the differences between leftward and rightwards spreading can solely be attributed to the blockers. He reviews previous claims in the literature, including emphatic spreading in Arabic (Davis 1995; McCarthy 1997) and [ATR] spreading in Akan, (Clements 1981; Archangeli & Pulleyblank 1994), Kinande, Maasai, and Lango (Archangeli & Pulleyblank 1994). McCarthy contends that some of these claims are spurious (e.g. Kinande and Maasai) while others are correlated with other differences such as gradient versus categorical assimilation (Akan and Arabic). Other claims on direction-specific blocking, he observes, have since been re-analysed. These include Archangeli & Pulleyblank (1994) versus Archangeli & Pulleyblank (2002) on rightward spreading of [+ATR] in Kinande and Archangeli & Pulleyblank (1994) versus Noske (1996, 2000) and McCrary (2001) on low vowel opacity of leftward [+ATR] spreading in Maasai.

Dagbani appears to be an exception, however, with a clear pattern of direction-specific blocking in its [ATR] harmony system. There are two directions of spread of [+ATR] and three consonants that block the spread of [+ATR] from a trigger to a target: [ɾ, s, l]. The limitation is that, these consonants only block a left-to-right harmonic spread, they do not block a right-to-left spread. Chapter 5 focuses solely on this. No detailed discussion is presented in this chapter.

Besides the pattern of direction-specific blocking, Serial Harmony is not considered for the analysis of [ATR] harmony in Dagbani because the resort to serial derivation within Optimality Theory does not seem to be necessary to derive vowel harmony patterns in Dagbani. For the analysis of Dagbani [ATR] harmony, the parallel application of constraints in traditional Optimality Theory is maintained. The next section discusses the theory of Headed Spans, also proposed by McCarthy (2004).

3.5 The theory of Headed Spans

The theory of Headed Spans (Span Theory (ST); McCarthy 2004) is an association-based theory of autosegmental feature spreading using Optimality Theory (Prince & Smolensky 1993/2004). It accounts for harmony by dividing harmonic domains into spans for each distinctive feature, a mechanism enforced by GEN. In addition, every span is headed by a segment whose feature is shared by all segments in the span. The mechanism for feature sharing in Span Theory is achieved though a number of representational assumptions, many of which are well motivated in previous theories, as noted below.

McCarthy (2004) defines a span as a constituent whose terminal nodes are segments in a contiguous string. No segment can be part of a string of segments that form a span unless that segment is part of the span. For instance, assuming a string of three segments x, y and z, with z between x and y (xzy); if x and y belong to the same span of a feature [F] z must also be part of that span. This assumption is equivalent to the effects of the locality condition in the autosegmental literature which prohibits gapped representations by ensuring that spreading is strictly local (e.g. Archangeli & Pulleyblank 1994; Gafos 1999; Walker 1998; Ní Chiosáin & Padgett 2001).[20]

[20] O'Keefe (2007) proposes that the requirement for a segment to be featurally associated with the span in which it occurs should be enforced by CON, not GEN. This will make it violable. O'Keefe argues that this proposal is needed to account for transparency in vowel harmony patterns. His proposal is essentially the same as the proposal of Cole & Kisseberth (1994) within Optimal Domains Theory, that harmony is enforced by a constraint called EXPRESS[F] which, when dominated by another constraint forcing the

There is no limit to the number of segments a span may have. There could be as many as every segment in the domain, with only one as the head; or as few as one segment, which is also the head. In McCarthy's formulation of the theory, a segment acquires span headship either by being the trigger of a harmonic spread or by having a specification for a feature that blocks the spread of a harmonic feature. In the former case, the trigger is span head because it is the trigger of the span feature that is shared by all segments in the span, in the latter, the opaque segment marks the boundary of a span of a feature that emerges by the failure of the harmonic feature spread. Thus while opaque segments can only be at one boundary of the span, a span head that triggers the harmony could be span-initial (as in left-to-right harmonic spread), span-final (as in right-to-left harmonic spread), or span-medial (as in bidirectional spread).

However, the analysis of [ATR] harmony in this dissertation shows that this conception of span headship needs some modification. When confronted with some fundamental principles in Optimality Theory such as Richness of the Base, it becomes difficult to consistently derive the trigger of the harmonic feature as the span head. This limitation is discussed in Chapter 4. Chapter 5 also discusses the need to broaden the mechanisms for deriving span headship in order to handle the pattern of opacity in Dagbani [+ATR] harmony.

ST shares other assumptions of autosegmental phonology. Like the tiers

insertion of a different feature, leads to transparency.

of autosegmental phonology, each distinctive feature has a unique span. Also, analogous to the association convention of autosegmental phonology (Goldsmith 1979; Goldsmith 1976) words are exhaustively parsed into spans. Every segment belongs to exactly one span for a given feature [F], with no overlap permitted between two spans of for of the same feature. McCarthy also draws support from earlier work such as Smolensky (1993) and some implementations of Optimal Domains Theory (Cole & Kisseberth 1994) in proposing the need to replace autosegmental representations with headed constituents (See McCarthy 2004 for further discussion and relevant citations). Thus while ST sets out a new way of analysing harmony, the assumptions on which it is based are not entirely novel.

To illustrate these assumptions using nasal harmony, consider the word *nisa* 'to buy' from the South American language Warao which shows nasal harmony (Peng 2000; Osborn 1966). In this language, vowels undergo nasalisation, while voiceless obstruents are opaque to the spread of nasality. Thus the surface form of the word is *nĩsa*. This creates two spans, *(**n**ĩ)(**s**a)*: a nasal span headed by the word-initial [n], the trigger, and an oral span headed by the voiceless fricative [s], the opaque consonant.[21] By contrast, all vowels, glides, liquids and voiced obstruents that undergo nasal harmony are part of the same span with a nasal trigger, as in the word *(**n**ãõỹã)* 'he comes'.

For a language such as Sundanese in which glides block nasal spread (McCarthy 2004), the surface form of this word would be *(**n**ãõ)(**y**a)*; and if

[21]Span boundaries are marked with parentheses and span heads are shown in bold font.

it were a word in Applecross Gaelic, in which even voiceless fricatives nasalise, (McCarthy 2004), *nisa* would have (***n***$\tilde{\tilde{\imath}}\tilde{s}\tilde{a}$) as its surface form. In short, the number of spans in a word depends on the constraints within the language that determine which segments take on a specific harmonic feature.

The assumption about GEN outlined above also implies that output forms such as *(**n**$\tilde{\tilde{\imath}}$)(**s**)a* (with a segment that is not parsed into a span) cannot surface as an output form as long as every segment in the word is part of the domain of harmony. Similarly, *(**n**ãõ)(ya)* (with a headless span) or *(**nã**õỹã)* (with a two-headed span) is not a possible surface form.

With this basic introduction, the next section discusses the constraints and further representational assumptions in ST.

3.5.1 Constraints in Span Theory

McCarthy outlines four basic constraint types in Span Theory, listed in (3.40).

(3.40) Constraint types in Span Theory

(i.) A markedness constraint that prohibits more than one adjacent spans of the same feature [F],

(ii.) a faithfulness constraint that requires an input feature value to head a span of that feature in the output,

(iii.) a markedness constraint that requires certain segment types to head spans with particular feature values, and (iv.) a constraint that stipulates the position of the span head relative to other segments within the span.

I elaborate on these constraint types below, using the feature [ATR]. I also show how, along with familiar faithfulness and markedness constraints of Optimality Theory, they avoid the 'sour-grapes' property of local agreement constraint and the pathological predictions of alignment constraints.

3.5.1.1 No Adjacent spans of [F]

In ST, harmony is achieved by forbidding disharmony. This is enforced by *A-Span[αF], defined in (3.41). It militates against multiple spans of the feature [F].

(3.41) No adjacent spans (McCarthy 2004: 5)

*A-Span[F]

Assign one violation mark for every pair of adjacent spans of the feature [F]

The number of violations is one less than the number of spans: two spans => one violation; three spans => two violations etc.). The effect of this constraint is similar to that of previous pro-spreading constraints such as Agree, Spread and Align. the difference is that it achieves the sameness of feature between segments in a domain by penalising a sequence of two spans with the same or different [F] values within one domain. In this respect, it is similar to previous proposals that harmony can be achieved simply by disallowing disharmony (Smolensky 1993; Pulleyblank 2002). *A-SPAN[F] also differs from these proposals in that it refers to spans, not adjacent segments, as in previous proposals. An undominated *A-SPAN[ATR] will result in the spread of the harmonic feature to all segments in the domain, as already shown in Chapter 2. If dominated by some markedness or faithfulness constraints, the spread of the harmonic feature will be restricted by the demands of the higher-ranking constraints. This is discussed further below.

3.5.1.2 Faithfulness to span heads

The second major constraint category is a faithfulness constraint that determines how a choice is made between two opposite feature values within the same domain for the purpose of (i) span headship and (ii) harmony with other segments in the span. FTHHDSP[αF] requires input [αF] segments to head [αF] spans in the output.

(3.42) Input [+ATR] faithfulness

FTHHDSP[+ATR]

The output correspondent of every input [+ATR] vowel is the head of a [+ATR] span

Unlike *A-SPAN[F], FTHHDSP[αF] militates against loss of a feature (as the span head). An output violates this constraint when it surfaces as a non-span head or as a span head but unfaithful (featurally) to the input. If it dominates all constraints, the result is one span for each input with the feature [αF]. For an input with multiple instances of [αF], the requirement of this constraint is in direct conflict with that of *A-Span[F].

3.5.1.3 Head-forcing constraint

In ST, a markedness constraint enforces feature restrictions by forcing segments with certain feature specification to head spans of harmonic features. McCarthy gives the general schema of this constraint in (3.43).

(3.43) Feature co-occurrence restriction (McCarthy 2004: 6)

Head([βG, γH,...], [αF])

Every [βG, γH,...] segment heads [αF] span

Being a markedness constraint, it does not respect input features. This causes a potential conflict with both *A-Span[αF] and FthHdSp[+ATR]. As discussed below, this constraint plays an important role in deriving opacity.

3.5.1.4 Directionality

In ST, directionality is derived with a constraint that enforces the location of the span head with respect to other segments in the span. The general schema is given in (3.44).

(3.44) Constraint on directionality [22]

SPHDL/R([αF])

The head segment of an [αF] span is initial/final in that span

For the feature [ATR], this produces four constraints, shown in (3.45).

(3.45) Directional [ATR] constraints with [ATR]

a. SPHDL([+ATR])

The head segment of a [+ATR] span is initial in that span

b. SPHDR([+ATR])

The head segment of a [+ATR] span is final in that span

c. SPHDL([-ATR])

The head segment of a [-ATR] span is initial in that span

d. SPHDR([-ATR])

The head segment of a [-ATR] span is final in that span

While a directionality constraint does nothing besides specifying the location of a span head within the span, it is not the only means of creating the effects of directionality. The span-head faithfulness and head-forcing constraints both have the potential to enforce some directional effects depending on the nature of harmony process. This is discussed further in the analysis of Dagbani [ATR] harmony presented in Chapter 4.

[22] See (McCarthy 2004: 12) for his formulation of this constraint using the feature [+nasal].

With these constraints, I now show how ST avoids the problems associated with previous theories.

3.5.2 Opacity in ST: no 'sour-grapes' property

In ST, opacity emerges from the ranking of *A-Span([αF]) relative to Head ([βG, γH,...], [αF]). An output form cannot satisfy both constraints if the feature value enforced by Head([βG, γH,...], [αF]) is different from the harmonising feature. McCarthy illustrates this with nasal harmony in Malay, using Walker's (1998) hierarchy of nasal incompatibility, shown as markedness constraints in (3.29) and repeated in (3.46).

(3.46) Constraint hierarchy for Johore Malay nasal harmony (Walker 1998: 45)

*NasObstruentStop » *NasFricative » *NasLiquid » Spread-R([+nasal], PrWd) » *NasGlide » *NasVowel

In ST, this is translated into markedness constraints that require features at each point in the hierarchy to be the head of an oral span. The oral headedness constraints are shown in (3.47).

(3.47) Oral headedness constraints (McCarthy 2004: 7)

a. HEAD([-cont, -son], [-nas])

Every obstruent stop heads an oral span (= OBSHDOR) »

b. HEAD([+cont, -son], [-nas])

Every fricative heads an oral span (= FRICHDOR) »

c. HEAD([+app, +cons], [-nas])

Every liquid heads an oral span (= LIQHDOR) »

d. HEAD([+app, -cons, -syll], [-nas])

Every glide heads an oral span (= GLIHDOR) »

e. HEAD([+app, -cons, +syll], [-nas])

Every vowel heads an oral span (= VOWHDOR)

Recall from Section 3.4.1 that in Johore Malay, fricatives are opaque to the spread of nasality. For any segment to show opacity in nasal harmony, the markedness constraint in (3.47) that forces oral span headship on that segment has to rank higher than *A-SPAN[NAS]. Thus to derive opacity of fricatives, FRICHDOR must rank higher than *A-SPAN[NAS]. In (3.48), I reproduce McCarthy's tableau with the Malay word *mãw̃ãsa*, to demonstrate how ST derives partial spreading. The last candidate, (3.48h), is added for further illustration.

(3.48) Partial spread of nasality with ST constraints (McCarthy 2004: 15)

/mawasa/	FricHdOr	*A-Span[Nas]	GliHdOr	VowHdOr
☞a. (**m**ãw̃ã)(**s**a)		*	*	***
b. (**m**)(**a**)(**w**)(**a**)(**s**)(**a**)		*****!		
c. (**m**)(**a**)(**w**a)(**s**a)		***!		**
d. (**m**ã)(**w**a)(**s**a)		**!		***
e. (**m**ã)(**w**asa)	*!	*		***
f. (**m**ãw̃)(**a**sa)	*!	*	*	**
g. (**m**ãw̃)(**a**)(**s**a)		**!	*	**
h. (**m**ãw̃ãs̃ã)	*!		*	***

In (3.48), violation of *A-Span[Nas] is unavoidable as long as the initial segment remains a nasal and /s/ remains an oral consonant. The only candidate that satisfies this constraint is (3.48h). However, that comes at the expense of a fatal violation of FricHdOr. The remaining markedness constraints are satisfied only by having every segment head a span. That would incur too many violations of *A-Span[Nas], as in (3.48b). (3.48e-f) show that FricHdOr and the other head markedness constraints do not only block nasalisation, they also demand that the specified features be the head of the spans in which they are. Thus they play a crucial role in defining span boundaries in harmony patterns that show opacity effects. The remaining candidates (3.48c, d, g) are ruled out by more violations of *A-Span than (3.48a).

3.5.3 No pathologies

This section shows that a Span Theory analysis of vowel harmony does not make the kind of pathological predictions identified with alignment and spreading constraints. Below, I discuss this using the same examples in Dagbani ATR harmony that were used to illustrate the predictions with previous theories of harmony. Following Ní Chiosáin & Padgett (2001) and others such as Ní Chiosáin & Padgett (1993), Padgett (2002), Itô et al. (1995), McCarthy (1994), Flemming (1995), Walker (1996) and Gafos (1999), I assume as McCarthy (2004) does, that consonants are targets of harmony when they occur between a [+ATR] vowel trigger and target. This means that all domain-medial onsets and domain-medial codas whose nuclei are triggers or targets of [+ATR] undergo the feature [+ATR]. Domain-initial onsets and domain-final codas are not part of the domain of harmony.

3.5.3.1 Harmony by alteration of blockers

In Section 3.3.2, Align/Spread constraints' prediction of feature alternation was demonstrated with the tableau in (3.49), where the feature [+continuant] was shown to be blocked in the output in order to avoid a violation of the alignment constraint.

(3.49) Alignment constraint blocks lenition (/tí-dɨ́/ → *[tí-dí] ‘a vomit’)

/tí-dɨ́/	ALIGN-R [+ATR]	CORCONT/ [-ATR]	*d/V_	DEPCOR [+CONT]
a. [tí-ɾí]$_{[+ATR]}$		*!		
✗ b. [tí-dí]$_{[+ATR]}$			*	
☞c. [tí]$_{[+ATR]}$-ɾɨ́]	*!			*

Span Theory does not make this prediction. The constraint that derives opacity is CORCONT-L[-ATR], defined in (3.50).

(3.50) SP-L([COR, +CONT], [-ATR]

A consonant that is [Coronal] and [+continuant] is initial in a [-ATR] span (= CORCONT-L[-ATR])

It is worth noting that in McCarthy's (2004) treatment of opacity in Span Theory, opaque segments head a new span, marking span boundary thereby. The constraint in (3.50) is formulated differently. The opaque segment only marks span boundary, it does not head the span. The analysis of consonant opacity in Dagbani [ATR] presented in Chapter 5 demonstrates why this modification is needed.

In order for the [+ATR] value to be dominant in the [ATR] harmony system of the language, FTHHDSP[+ATR] must outrank FTHHDSP[-ATR]. Surface opacity, on the other hand is the result of the ranking CORCONT-L[-ATR] » *A-SPAN[ATR]. With this ranking, an input with a [+ATR] trigger can not trigger harmony to eligible target vowels when there is an opaque segment between the trigger and target. This is shown in (3.51).

(3.51) CORCONT-L[-ATR] » *A-SPAN[ATR] leads to opacity with input [+ATR] (/bì-lɨ̂/ → [bìl-ɨ̂] ‘chicken breast’)

/bì-lɨ̂/	CORCONTL [-ATR]	FTHHDSP [+ATR]	*A-SP [ATR]
a. b(**ì**-lî)	*!		
☞b. b(**ì**)(-l**ɨ̂**)			*
c. b(**ɨ̀**)(l**ɨ̂**)		*!	*
d. b(ɨ̀lɨ̂)	*!	*	

However, the same ranking produces a new span of [ATR] for an input that lacks a [+ATR] trigger, as shown in (3.52).

(3.52) CORCONT-L[-ATR] » *A-SPAN[ATR] creates an extra span with no input [+ATR] (/bɨ́l-ɨ́/ → [bɨ́l-ɨ̂] ‘geminate’)

/bɨ́l-ɨ́/	CORCONTL [-ATR]	FTHHDSP [+ATR]	*A-SP [ATR]
a. b(**ɨ́**l-ɨ́)	*!		
☞b. b(**ɨ̀**)(l-**ɨ́**)			*

As in the alignment analysis, when a faithfulness constraint against lenition is ranked below *A-SPAN[ATR], the harmony deriving constraint could block an underlying /tí-dɨ́/ from leniting in order to achieve an unbounded spread of [+ATR]. The same effect is achieved when the constraint that drives lenition (*d/V_) is ranked below *A-SPAN[ATR]. This is shown in (3.53).

(3.53) CORCONT-L[-ATR] blocks lenition with a [+ATR] root vowel (/tí-dɨ́/ → *[tí-dí] 'a vomit')

/tí-dɨ́/	COR CONT L[-ATR]	FTHHD SP [+ATR]	*A-SP [ATR]	*d/V_	DEP COR [+CONT]
☞a. t(**í**)(-ɾ**ɨ́**)			*!		*
b. t(í-d**ɨ́**)		*!		*	
c. t(**í**-ɾí)	*!				*
✗ d. t(**í**-dí)				*	

(3.53c) is ruled out by the undominated CORCONT-L[-ATR] for spreading the feature [+ATR] to the suffix vowel with an onset [ɾ] while (3.53b and d) violate *d/V_ in order to satisfy *A-SP[ATR]. The output form in (3.53d) is the projected optimal form because it maintains the [+ATR] feature of the input vowel and, by failing to lenite the stop, achieves a single span of [ATR]. A reverse ranking of *A-SPAN[ATR] and *d/V_ would have yielded the attested output ***(tí)(-ɾɨ́)*** as the optimal form.

However, unlike the alignment account, the same result is obtained when the input lacks a [+ATR] trigger, i.e. lenition is still blocked, (3.54). Thus the Span Theory account does not make the prediction that a blocker may be altered in solely for the purpose of achieving an unbounded spread of a harmonic feature.

(3.54) CORCONT-L/[-ATR] blocks lenition with a [-ATR] root vowel (/tɨ̀d/ → *[tɨ̀dɨ̀] 'point at')

/tɨ́d/	COR CONT-L[-ATR]	FTHHD SP [+ATR]	*A-SP [ATR]	*d/V_	DEP COR [+CONT]
☞a. t(**í**)(ɾ**ɨ́**)			*!		
b. t(**ɨ́**ɾí)	*!				
✗ c. t(**ɨ́**dí)				*	*

In (3.54), all output forms satisfy FTHHDSP [+ATR] vacuously. (3.54b) is the only candidate that violates CORCONT-L[-ATR]. As in the preceding tableau, the attested output form is ruled out by *A-SP[ATR] for having two spans, triggered by CORCONT-L[-ATR]. With the ranking *A-SP[ATR] » *d/_, lenition is blocked and surface form with a single span is achieved. The difference between the results in (3.53) and the result with the alignment constraint is that the failure to lenite is not triggered by the presence of the dominant [+ATR] value in the input. Given the definition of the constraint that triggers opacity, it must initiate a new [ATR] span whether the input has a [+ATR] trigger or not.

A similar argument holds when the other implausible predictions of alignment and pro-spreading constraints reviewed in Section 3.3 are tested with Span Theory. The ranking needed to block deletion, trigger affix repositioning, shorten reduplicants etc. has the same effects regardless of the [ATR] specifications of the input vowels. This means that the generalisation governing these predictions are not linked to considerations of harmony. Patterns such as deletion, affixation, featural modifications do not surface solely if it would improve harmony.

In the next section, I illustrate this with the remaining predictions.

3.5.3.2 Harmony by deletion

The constraint CORCont-L[-ATR] triggers a new span different from the span of the preceding vowel and left bounded by the opaque segment. To avoid creating this additional span, the opaque segment could be deleted. This process will take place whether the root has a [+ATR] or [-ATR] vowel. This is shown in (3.55) and (3.56). In these tableaux, deletion comes at the expense of a Max-IO violation.

(3.55) CORCONT-L/[-ATR] triggers deletion with a [+ATR] root vowel (/bì-lɨ̂/ → *[bì-î] ‘chicken breast’)

/bì-lɨ̂/	CORCONT L[-ATR]	FTHHDSP [+ATR]	*A-SP [ATR]	FTHHDSP [-ATR]	MAX IO
a. b(**ì**-lî)	*!			*	
✗ b. b(**ì**-î)				*	*
☞c. b(**ì**)(-l**ɨ̂**)			*!	*	

(3.56) CORCONT-L/[-ATR] triggers deletion with a [-ATR] root vowel (/bàl/ → *[bàɨ̀] ‘gather’)

/bàl/	CORCONT-L[-ATR]	FTHHDSP [+ATR]	*A-SP [ATR]	FTHHDSP [-ATR]	MAX IO
a. b(**à**lɨ̀)	*!				
✗ b. b(**à**-ɨ̀)					*
☞c. b(**à**)(l**ɨ̀**)			*!		

3.5.3.3 Harmony by affix repositioning

In Section 3.3.2, ALIGN constraints were shown to influence the position of a morpheme only when the root morpheme has a [+ATR] vowel, as shown in (3.22) and (3.23). The tableaux in (3.57) and (3.58) show that this is not the case in ST. The wrong output emerges when *A-SPAN[ATR] ranks above ALIGN-R]$_{Root}$(lɨ́n). This happens in both [+ATR] and [-ATR] roots.

I assume, in these tableaux, the base-reduplicant faithfulness constraint IDENT-BR-[+ATR] that preserves the [ATR] feature of the base in the reduplicant, and that is ranked sufficiently high to block the reduplicant morpheme from being part of the same span as the fixed *lɨn* morpheme (i.e. it rules out from (3.57) the output form d(**í**]$_{rt.}$)-(l**ɨ́**n-d̲ɨ̲́-hɨ̂)). Due to space limitations, it is not included in the tableaux.

(3.57) CORCONT-L[-ATR] triggers prefixation with a [+ATR] root vowel:

(/di]$_{rt.}$-lɨn-d̲ɨ̲́-hɨ́/ → *[lɨn-di]$_{rt.}$-d̲ɨ̲́-hɨ́] 'numbness')

/di]$_{rt.}$-d̲í̲-hí + lɨn/	COR CONT-L[-ATR]	FTHHD SP [+ATR]	*A-SP [ATR]	ALIGN R]$_{Root}$ (lɨ́n)
a. d(**í**]$_{rt.}$-lín-d̲í̲-hî)	*!			
☞b. d(**í**]$_{rt.}$)-(l**ɨ́**n)-(d̲í̲-hî)			**!	
✗ c. l(**ɨ́**n)-(d**í**]$_{rt.}$-d̲ì̲-hî)			*	**

The attested output form in (3.57b) has three spans due to the demands of both CORCONT-L[-ATR] and ALIGN-R$_{Root}$(lɨ́n). This results in two violations of *A-SPAN[ATR]. Note that the form in (3.57c) satisfies CORCONT-L[-ATR] vacuously because the initial consonant is not part of the domain of harmony. In spite of two violations of the alignment constraint, it remains the predicted optimal form due to the ranking of the alignment constraint below *A-SPAN[ATR]. A similar contrast is observed between (3.58b) and (3.58c).

(3.58) CORCont-L[-ATR] triggers prefixation with a [-ATR] root vowel:

(/dɛ]$_{rt.}$-lɨn-<u>dɛ</u>-ʔʊ/ → *[lɨn-dɛ]$_{rt.}$-<u>dɛ</u>-ʔʊ] ‘leech-sg.’)

/dɛ]$_{rt.}$-<u>dɛ</u>-ʔʊ + lɨn/	COR Cont- L[-ATR]	*A- Sp [ATR]	FthHd Sp [-ATR]	Align R]$_{Root}$ (lɨ́n)
a. d(**ɛ̀**]$_{rt.}$-lɨ̀n-dɛ̀-ʔʊ̂)	*!		***	
☞b. d(**ɛ̀**]$_{rt.}$)-(l**ɨ̀**n)-(<u>d**ɛ̀**</u>-ʔʊ̂)		**!	*	
✗ c. l(**ɨ́**n-d**ɛ̀**]$_{rt.}$-<u>dɛ̀</u>-ʔʊ̂)			**	**

3.5.3.4 Harmony by reduplicant shortening

Unlike alignment and pro-spreading constraints, shortening the reduplicant does not reduce the number of violations of the harmony driver in Span Theory. As long as the opaque segment remains, the result is the same whether the input vowel has the dominant or recessive value of the harmonic feature. A violation of the Max-BR constraint rules out the candidate with a shorter reduplicant. This is shown in (3.59) and (3.60).

(3.59) No reduplicant shortening with a [+ATR] root vowel:

(/di]$_{rt.}$-lɨn-dí-hɨ́/ → [di]$_{rt.}$-lɨn-dí-hɨ́] 'numbness')

/di]$_{rt.}$-dí-hɨ́ + lɨn/	COR CONT-L[-ATR]	FTHHD SP [+ATR]	MAX-BR	*A-SP [ATR]
a. d(**í**]$_{rt.}$-lín)-dí-hî)	*!			
☞b. d(**í**]$_{rt.}$)-(**lɨ́**n)-(dí-hî)				**
c. d(**í**]$_{rt.}$)-(**lɨ́**n)-(í-hî)			*!	**

(3.60) No reduplicant shortening with a [-ATR] root vowel:

(/dɛ]$_{rt.}$-lɨn-dɛ-ʔʊ/ → [dɛ]$_{rt.}$-lɨn-dɛ-ʔʊ] 'leech-sg.')

/dɛ]$_{rt.}$-dɛ-ʔʊ + lɨn/	COR CONT-L[-ATR]	*A-SP [ATR]	MAX-BR	FTHHD SP [-ATR]
a. d(**ɛ̀**]$_{rt.}$-lɨ̀n-dɛ̀-ʔʊ̂)	*!			***
b. d(**ɛ̀**]$_{rt.}$)-(**lɨ̀**n)-(d**ɛ̀**-ʔʊ̂)		**!		*
c. d(**ɛ̀**]$_{rt.}$)-(**lɨ̀**n)-(**ɛ̀**-ʔʊ̂)		**!	*	*
☞d. d(**ɛ̀**]$_{rt.}$)-(**lɨ̀**n-**ɛ̀**-ʔʊ̂)		*	**	**

Notice that the featural implicational constraint CORCONT/[-ATR] does not change the results in a Span Theory account even if it is included in the constraint hierarchy. This constraint is innocuous in a domain with only

[-ATR] vowels. In a domain with a [+ATR] trigger, violating this constraint would create the same effects as in the alignment-based accounts but for the assumption (within Span Theory) that the opaque segment must be the head or mark the boundary of the new span it creates, even in patterns that are non-assimilatory. Given this assumption, the CORCONT/[-ATR] constraint cannot replace the CORCONT-L[-ATR] constraint. Its violations are a subset of the violations of CORCONT-L[-ATR] in a domain with a [+ATR] trigger, making it unnecessary.

The tableaux in (3.53) – (3.56) are repeated in (3.61) – (3.64) to illustrate this point. In (3.61) and (3.63), additional output candidates introduced for the purposes of illustration violate FTHHDSP[+ATR] after being ruled out by violations of CORCONT-L[-ATR]. The results remain the same when there is no input [+ATR] vowel, as shown in (3.62) and (3.64).

(3.61) Harmony by alteration of blockers: No effects with CORCONT/[-ATR] constraint (/tí-dɨ́/ → *[tí-dí] 'a vomit')

/tí-dɨ́/	[COR] [CONT]/ [-ATR]	COR CONT-L[-ATR]	FTHHD SP [+ATR]	*A-SP [ATR]	FTHHD SP [-ATR]
☞a. t(**í**)(-ɾ**ɨ́**)				*!	
b. t(í-d**ɨ́**)			*!		
c. t(**í**-ɾí)	*	*!			*
✗ d. t(**í**-dí)					*
e. t(**ɨ́**-ɾɨ́)		*!	*		*

(3.62) Harmony by alteration of blockers: No effects with CORCONT/[-ATR] constraint: (/tɨ̀d/ → *[tɨ̀dɨ̀] 'point at')

/tɨ́d/	[COR] CONT/ [-ATR]	COR CONT-L[-ATR]	FTHHD SP [+ATR]	*A-SP [ATR]	FTHHD SP [-ATR]
☞a. t(**í**)(ɾ**ɨ́**)				*!	*
b. t(**ɨ́**ɾí)		*!			
✗ c. t(**ɨ́**dí)					

(3.63) Harmony by deletion: No effects with CORCONT/[-ATR] constraint: (/bì-lî/ → *[bì-î] 'chicken breast')

/bì-lî/	[COR] CONT/ [-ATR]	COR CONT-L[-ATR]	FTHHD SP [+ATR]	*A-SP [ATR]	FTHHD SP [-ATR]
a. b(**ì**-lî)	*!	*			*
✗ b. b(**ì**-î)					*
☞c. b(**ì**)(-l**î**)				*!	*
d. b(**ɨ̀**)(-l**ɨ̂**)			*!	*	*

(3.64) Harmony by deletion: No effects with CORCONT/[-ATR] constraint: (/bàl/ → *[bàɨ̀] 'gather')

/bàl/	[COR] CONT/ [-ATR]	COR CONT-L[-ATR]	FTHHD SP [+ATR]	*A-SP [ATR]	FTHHD SP [-ATR]
a. b(**à**lɨ̀)		*!			
✗ b. b(**à**-ɨ̀)					
☞c. b(**à**)(l**ɨ̀**)				*!	

3.6 Summary

The main objective of this chapter has been to lay out a firm theoretical framework for the account of ATR harmony presented in this dissertation. Within parallel OT, constraints such as alignment, spread and agreement either are not able to derive opacity or predict patterns that are unattested in any language. These problems highlight the need for an alternative, three of which have been proposed. They are Targeted Constraints, Serial Harmony and Span Theory. Targeted Constraints and Serial Harmony abandon parallelism in OT. While this measure may be necessary to handle the range of phonological issues these theories are proposed to handle, I have argued that this is not necessary for the account of a vowel harmony pattern such as Dagbani [ATR]. Besides, Serial Harmony does not have a way of dealing with direction-specific blocking, a pattern that is well attested in Dagbani [+ATR] harmony system. Chapters 4 and 5 demonstrate how Span Theory handles the formal account of Dagbani [ATR] harmony.

Chapter 4

Formal account of Dagbani [ATR] harmony

4.1 Introduction

This chapter presents a formal account of [ATR] harmony in Dagbani using Span Theory (McCarthy 2004). In the Dagbani [ATR] harmony system, [+ATR] is the dominant value of [ATR] while [-ATR] is recessive. A root with a high front vowel triggers [+ATR] harmony with other vowels in the harmonic domain as undergoers. Domain-final mid vowels also trigger advancement to preceding vowels. However, there are restrictions on these two harmonic patterns, which result in some opacity effects.

This chapter argues that [+ATR] harmony in Dagbani is controlled by vowel height features in that harmony is allowed only between vowels that are minimally different in their specification for height features. Harmony is permitted between two vowels only when the trigger and target are both [+high] or [-high]. The height similarity condition thus blocks harmony between a high vowel trigger and a mid or low vowel target but permits assimilation between a mid vowel trigger and another mid or low vowel target.

The claim that [+ATR] is the dominant feature value is uncontroversial. In [ATR] harmony systems of African languages, [+ATR] dominance is so common that some previous researchers have argued, rather controversially, that it is the only value of [ATR] that can be dominant (e.g. Hulst 1988; Kaye et al. 1985; Goad 1993; Hulst & Weijer 1995; Polgárdi 1998; Baković 2000). The general pattern of [+ATR] harmony requires a harmony-driving constraint for [+ATR] harmony to surface between two high vowels, two mid vowels, and between a mid and a low vowel. Harmony is triggered either by /i/, the only contrastive [+ATR] vowel, or [e, o] which are surface variants of /ɛ, ɔ/. While the /i/ trigger has a left-to-right directional effect, a mid vowel trigger targets preceding vowels.

The rest of the chapter is organised as follows. The next section describes the Dagbani vowel harmony patterns. It shows the domain of harmony, data and generalisations, and a basic account of [+ATR] harmony within ST. Sections 4.2.4 and 4.2.5 discuss the factors that constrain the general pattern of [+ATR] harmony. Section 4.3 presents a formal account of these restrictions, arguing that they are grounded in the height specifications of vowel triggers and targets. Section 4.4 summarises the chapter.

4.2 Dagbani [ATR] harmony patterns

4.2.1 Domain of [ATR] harmony

The domain of harmony is the phonological word. According to Dakubu (1997), the phonological word in Central Gur languages typically consists of a thematic CV syllable with full range of articulatory contrast and a mono- or bi-syllabic suffix with restricted vowels and consonants. Dakubu also observes that the vowels of suffixes 'tend to be at least partly determined by the features of the thematic syllable vowel' (Dakubu 1997: 83). The asymmetry between roots and affixes in terms of vowel distribution is obvious for Dagbani and other Gur languages such as Kɔnni (Cahill 2007). As discussed in Chapter 2, the vowels [i, u] do not occur in affixes or clitics except as products of [+ATR] harmony. The [+ATR] low vowel [ə] also occurs only when there is a following mid vowel, mainly in roots.

In addition to the root and suffix, the harmonic domain in Dagbani also includes pronominal and locative clitics. The only constituent that is obligatory is the lexical root. Inflectional suffixes mark number and aspect, derivational affixes derive nouns/adjectives from verbs and vice versa. For typical nouns and adjectives, a bound root and a number suffix is what is minimally required for harmony to take place. Other constituents are post nominal/adjectival locative clitics. For verbs, constituents that form part of the harmonic domain are the free root, aspectual suffixes and post-verbal locative and pronominal clitics. These constituents are shown in (4.1).

(4.1) The Domain of harmony

[[[root] number, aspect, derivational $]_{affix}$ pronouns, locative $]_{clitic}$

It is important to note that the domain of [+ATR] harmony is only restricted to vowels and intervocalic consonants that occur in these morphological constituents. Word-initial and final consonants are not part of the [+ATR] domain. While the vowels are harmonic triggers and targets of [+ATR], intervocalic consonants are only non-harmonic targets (See analysis of consonant opacity in Chapter 5 for evidence that peripheral consonants do not interfere with [+ATR] harmony).

4.2.2 Harmonic triggers and targets

The trigger of harmony can be a vowel in any of the three positions. A root /i/, the only lexically contrastive [+ATR] vowel in Dagbani, triggers [+ATR] targeting vowels in all other constituents, as shown in (4.2). An account of /i/ as the only contrastive [+ATR] vowel is given in Chapter 2.

(4.2) Root-triggered [+ATR] harmony

	Root-to-affix harmony			[-ATR] roots		
a.	[i]	pín-î	‘a gift’	[ii]	bɨ́n-ɨ̂	‘a thing’
b.	[i]	díʔ-í	‘a mirror’	[ii]	dʊ́ʔ-ʊ̂	‘a pot’
c.	[i]	tí-bû	‘vomiting’	[ii]	dá-bʊ̂	‘buying’
d.	[ii]	dí-h[í]-bû	‘feeding’	[ii]	dɔ́l[ɨ́]-bʊ̂	‘following’
e.	[ii]	vìh[ì]	‘investigate’	[ii]	gbáh[ɨ̂]	‘catch (many)’
f.	[i]	píh[í]g[î]	‘postpone’	[ii]	pɔ́h[ɨ́]g[ɨ̂]	‘pluck’
g.	[i]	jíʔ[í]	‘fly’	[ii]	jáʔ[ɨ́]	‘jump over’

The data in (4.2) show word pairs with the same suffixes or epenthetic vowels. In each pair, the second or third vowel, whether part of the root or suffix, is retracted except when /i/ is the first root vowel, in which case it is a [+ATR] vowel.

In all other cases of [+ATR] harmony, the trigger is the mid vowel suffix or clitic in domain-final position, as the data in (4.3) show.

(4.3) Word-final [o, e] as harmonic triggers

	[-ATR] roots		**suffix-to-root harmony**	
a[i]	dɔ́ɾ$]_{rt.}$-tɨ́$]_{af.}$	'diseases'	[ii] dóɾ$]_{rt.}$-ó$]_{af.}$	'a disease'
b[i]	ʧɔ̀ɾ$]_{rt.}$-tɨ̂$]_{af.}$	'blows'	[ii] ʧòɾ$]_{rt.}$-ê$]_{af.}$	'a blow'
c[i]	bɛ́$]_{rt.}$-hɨ̀$]_{af.}$	'shins'	[ii] bé$]_{rt.}$-é$]_{af.}$	'shin'
d[i]	pál$]_{rt.}$-lɨ́$]_{af.}$	'a new'	[ii] pə́l$]_{rt.}$-ó$]_{af.}$	'a new (anim.)'
e[i]	dà$]_{rt.}$ lɨ́$]_{clt.}$	'buy it'	[ii] də̀$]_{rt.}$ ó$]_{clt.}$	'buy it (anim.)'
f[i]	tàdáb$]_{rt.}$-tɨ̂$]_{af.}$	'writing inks'	[ii] tə̀də́b$]_{rt.}$-ô$]_{af.}$	'writing ink'

In (4.3), a final mid vowel is the trigger of a [+ATR] feature targeting root vowels, as shown in the second member of each pair. Recall from Chapter 2 that mid vowels are predictably [+ATR] in word-final position. The data in (4.2) and (4.3) thus show that the spread of [+ATR] takes place across a morpheme boundary. What they do not show is what delimits this spread. Harmony does not spread from one vowel to another if the two vowels belong to different lexical roots. (4.4) shows this limitation. Note that there is both a root and word boundary between the first CV and the following word in each of the forms in (4.4) given that the initial CV forms are unsuffixed.[23] What the data in (4.4) crucially shows is that, adjacency between two lexical roots does not make the vowel of one root the target of a [+ATR] spread from the vowel of the other root.

[23] See Chapter 2 on the realisation of non-low vowels in CV words as [+ATR].

(4.4) No harmony between vowels of different lexical roots

a.	[[tì]$_{rt.}$]$_{wd.}$ [[kʊ́ɾ]$_{rt.}$-lɨ́]$_{suf.}$]$_{wd.}$	*tì kúr-lí	*tɨ kʊ́ɾ-lɨ́	'old tree'
b.	[[bí]$_{rt.}$]$_{wd.}$ [[bɛ́]$_{rt.}$-ʔʊ́]$_{suf.}$]$_{wd.}$	*bí bé-ʔú	*bɨ́ bɛ́-ʔʊ́	'ugly child'
c.	[[pé]$_{rt.}$]$_{wd.}$ [[pɛ́l]$_{rt.}$-lɨ́]$_{suf.}$]$_{wd.}$	*pé pél-lí	*pɛ́ pɛ́l-lɨ́	white sheep'
d.	[[dò]$_{rt.}$]$_{wd.}$ [[kɔ̀]$_{rt.}$-ʔʊ́]$_{suf.}$] $_{wd.}$	*dò kó-ʔú	*dɔ̀ kɔ́-ʔʊ́	'slim man'
e.	[[dú]$_{rt.}$]$_{wd.}$ [[bɨ́l]$_{rt.}$-á]$_{suf.}$]$_{wd.}$	*dú bíl-á	*dʊ́ bɨ́l-á	'small room'

(4.4a-b) are similar to the data in (4.2) in that they have /i/ in the first root. However, unlike (4.2), they do not trigger [ATR] harmony. (4.4c-d) on the other hand show that mid vowels only trigger right-to-left harmony, but even then, only from a suffix/clitic to a root, not between two lexical roots, as shown by the failure of [ATR] to spread in (4.5a-c), in contrast with (4.5d-f).

(4.5) No harmony across boundaries of two lexical roots

a.	[[bá]$_{rt.}$]$_{wd.}$[[bó]$_{rt.}$]$_{wd.}$	*bə́ bó	*bá bɔ́	'father look for'
b.	[[mà]$_{rt.}$]$_{wd.}$[[kó]$_{rt.}$]$_{wd.}$	*mə̀ kó	*mà kɔ́	'only mother'
c.	[[fá]$_{rt.}$]$_{wd.}$[[só]$_{rt.}$]$_{wd.}$	*fə́ só	*fá sɔ́	'cheat someone'
d.	[[táb-]$_{rt.}$ [ô]$_{af.}$]$_{wd.}$	[tə́b-ô]		'a look-alike'
e.	[[dábó$_{af.}$][dáb-]$_{rt.}$[ó]$_{af.}$]$_{wd.}$	[də́b-ó də́b-ô]		'a fragile thing'
f.	[[tàdáb-]$_{rt.}$[ô]$_{af.}$]$_{wd.}$	[tə̀də̀b-ô]		'writing ink'

(4.4e) shows the only position in which [u] occurs, i.e. a CV root that neither has a suffix nor followed by a clitic (see analysis in Chapter 2).

Since [+ATR] harmony does not spread across the boundaries of two lexical roots/words, [u] is never a trigger of [+ATR] harmony.

In the analysis below, I show how the two harmony patterns emerge from the interaction of various constraints in ST. All constraints are limited in their locus to the domain restriction shown in (4.1).

4.2.3 Span Theory analysis

The analysis in Chapter 2 shows that the only [+ATR] vowels that emerge on the surface outside of harmonic contexts are [i, u, e, o]. The tableau in (4.6), repeated from Chapter 2 (2.57), shows that surface [i] is due to faithfulness to input [COR] feature and the grounded condition Hi-COR/ATR.[24]

(4.6) Surface [i] with Max-[COR], HiCOR/ATR » Spec-Ft-[-ATR]:
(/tɪm-a/ → [tìm-â] 'medicine-pl.')

tɪma	Max [COR]	HiCOR/ [ATR]	Spec-Ft [-ATR]	Spec-Ft [+ATR]	*[-ATR]
a. [tɪ̂.m-á]	*!			**	**
b. [tɪ̀.m-á]		*!		**	**
☞ c. [tî.m-á]			*	*	*

(4.7) shows that surface [e, o] are due to the ranking of Max[-Hi] and Dep[+Lo]]$_{wd}$ over Spec-Ft-[-ATR].

[24] An output form not included in (4.6) which would be more optimal is one with the final low vowel as a target of [+ATR] harmony (tìm-ɔ́). In Section 4.2.4, the restriction of /i/ from targeting /a/ in a [+ATR] harmony is discussed.

(4.7) Final [+ATR] mid vowel with MAX[-HI]]$_{wd}$, DEP[+LO]]$_{wd}$ »
SPEC-FT-[-ATR] (/sɨm-ɔ/ → [sɪ̀m-ó] 'a dear friend')

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

The constraints introduced in chapters 2 and 3 are sufficient to derive both patterns of [+ATR] harmony shown in (4.2) and (4.3). For a span with root /i/, the ranking of MAX[COR], HI-COR/ATR » SPEC-FT[-ATR] ensures that the [+ATR] feature, if specified in the input, is preserved. With the same input vowel, FTHDSP[+ATR] ensures that the [+ATR] value heads a span. The constraint *A-SPAN[ATR] drives harmony by prohibiting surface forms with more than one span of [ATR]. This is demonstrated in (4.10) for *víh[í]-bû* 'investigate-ing'. The constraints FTHDSP[+ATR] and FTHDSP[-ATR] are defined in (4.8) and (4.9).

(4.8) FTHDSP[+ATR]

The output correspondent of every input [+ATR] vowel is the head of a [+ATR] span

(4.9) FtHdSp[-ATR]

The output correspondent of every input [-ATR] vowel is the head of a [-ATR] span

(4.10) [+ATR] span for the root (/víh-bʊ/ → [víhí-bû] 'investigate-ing')

/vih-bʊ/	Max [COR]	Hi/ COR [ATR]	*A-Sp [ATR]	Spec-Ft [-ATR]	FthHd Sp [+ATR]	FthHd Sp [-ATR]
a. v(**í**hɨ́-bʊ̂)		*!				*
b. v(**í**hí)(-b**ʊ̂**)			*!	**		
c. v(íhí-b**û**)				***	*!	**
☞ d. v(**í**hí-bû)				***		**
e. v(**ɨ́**hɨ́-bʊ̂)	*!				*	*

In (4.10), *A-Span[ATR] forces the same [ATR] value on both root vowels and the suffix vowel by ruling out more than one span of different [ATR] values such as in (4.10b). Combined with the effects of FtHdSp[+ATR], only a [+ATR] word surfaces. This result comes at the cost of multiple violations of FtHdSp[-ATR] for not preserving the input [-ATR] specification or not making it the span head.

Notice that an input [+ATR] mid root vowel does not produce a surface [+ATR] mid vowel. This is because doing so leads to violations of Specify-Ft-[-ATR], as shown in (4.11).

(4.11) No surface [+ATR] mid vowel with SP-FT-[+ATR] and MID[+ATR]: (/be-hɨ/ → [b^j**à**h-î] 'shin-pl.')

/be-hɨ/	MAX [COR]	*A-SP [ATR]	SPEC-FT- [-ATR]	FTHHDSP [+ATR]	*MID [+ATR]
☞ a. b^j(**à**-hî)				*	
b. b^j(**é**)(-h**ɨ̂**)		*!	*		*
c. b^j(**é-**hî)			**!		*

The different results in tableaux (4.10) and (4.11), both with an input vowel with a specification for [+ATR], illustrate the difference in the behaviour of the two vowel triggers in Dagbani (see further discussion below). When there is no input specification for [+ATR], the effect of the ranking MAXCOR, HICOR/[ATR] » *A-SP[ATR] ensures that the coronal surfaces as a [+ATR] vowel heading a single span of [+ATR].

(4.12) Root /i/ as a [+ATR] span head: (/tɪ-bʊ/ → [tí-bû] 'give-ing')

/tɪ-bʊ/	MAX [COR]	HICOR/ [ATR]	*A-SP [ATR]	SPEC-FT-[-ATR]	FTHHD SP [+ATR]	FTHHD SP [-ATR]
a. t(**ɨ́**-bʊ̂)	*!					*
b. t(**í**-bʊ̂)		*!				*
c. t(**í**)-(b**ʊ̂**)			*!			*
☞ d. t(**í**-bú)				**		**

However, the constraint set does not rule out the suffix vowel as span head when the output suffix vowel is also coronal. An output form that is headed by a suffix coronal vowel incurs one violation of this constraint as does one headed by a root coronal. This is shown in (4.13).

(4.13) No clear [+ATR] span head with two high coronal vowels: (/tɪ-hɨ/ → [tì-hí] ‘tree-pl.’)

/tɪ-hɨ/	MAX [COR]	HICOR/ [ATR]	*A-SP [ATR]	SPEC-FT-[-ATR]	FTHHD SP [+ATR]	FTHHD SP [-ATR]
a. t(**ɨ̀**-hɨ́)	*!					*
b. t(**ì**-hɨ́)		*!				*
c. t(**ì**)-(h**í**)			*!			*
☞ d. t(ì-h**í**)				**		**
☞ e. t(**ì**-hí)				**		**

The output form in (4.13e), the expected winning candidate if the input had a [+ATR] feature, has the same number of violations of all constraints as the candidate in (4.13d), which has the suffix vowel as span head. Thus while the constraint hierarchy used so far is able to derive [+ATR] harmony, it does not force span headship onto one vowel when Richness of the Base is fully respected.

Similar results surface for an input with a final mid vowel. The combined effects of undominated DEP[+LO]$_{wd}$ and *MID[-ATR] constraints ensure that the final mid vowel surfaces as [+ATR], as already shown in Chapter 2 (2.40). The constraint hierarchy does not determine the position of the final mid vowel as span head when the input mid vowel lacks a [+ATR] specification. A surface form with the root vowel as span head is equally optimal.

(4.14) Non-final [+ATR] low vowel (/gáɾ-ɔ́/ → [gə́ɾ-ó] ‘a bed’)

/gáɾ-ɔ́/	DEP [+LO]]$_{wd}$	*MID [-ATR]	*A-SP [ATR]	SPEC-FT-[-ATR]	*MID [+ATR]	FTHHD SP [-ATR]
☞ a. g(**ə́**ɾ^{w}-ó)				**	*	**
☞ b. g(ə́ɾ^{w}-**ó**)				**	*	**
c. g(**á**)(ɾ^{w}-**ó**)			*!	*	*	*
d. g(**á**ɾ^{w}-ɔ́)		*!				*
e. g(**á**ɾ^{w}-á)	*!					*

In (4.14), *g(**á**)(ɾ^{w}-**ó**)* is ruled out by *A-SPAN[ATR] for having more than one span of the feature [ATR]. The dis-harmonic forms *g(**á**ɾ^{w}-ɔ́)* and *g(**á**ɾ^{w}-á)* are ruled out by constraints that do not necessarily enforce vowel harmony, as already demonstrated in Chapter 2. The remaining two output forms are equally optimal because the input form does not have a [+ATR] feature, leaving FTHDSP[+ATR] inactive. Similar results are obtained in a root with a final mid vowel preceded by more than one vowel. An input */tàdàb-ɔ̂/* ‘writing ink’, produces three possible output forms: *[t**ə̀**dəb-ô]*, *[tə̀d**ə̀**b-ô]*, or *[tə̀dəb-**ô**]*.

For an input that has neither a [+ATR] root feature nor a domain-final mid vowel, a [-ATR] span surfaces by default. Again the constraint hierarchy allows for any vowel as span head. An example is shown in (4.15).

(4.15) A [-ATR] span for the phrase (/bɔ́h tɨ/ → [bɔ̀hɨ́ tɨ́] 'ask us')

bʷoh tɨ	*MID [-ATR]	*A-SP [ATR]	SPEC-FT-[-ATR]	FTHHD SP [+ATR]	FTHHD SP [-ATR]
a. bʷ(**à**hɨ́)(t**ɨ́**)		*!		*	
b. bʷ(àh**ɨ́** tɨ́)				*	**!
c. bʷ(**ɔ**hɨ́ tɨ́)	*!			*	
☞ d. bʷ(**á**hɨ́ tɨ́)				*	*
☞ e. bʷ(àhɨ́ t**ɨ́**)				*	*

In (4.15), the failure of (4.15b) to surface shows that FTHHDSP[-ATR] can be active. This output form has the epenthetic vowel as span head. Given that this vowel has no input correspondent, (4.15b) incurs two violations of FTHHDSP[-ATR], one more than the violations of (4.15d–e). (4.15a) satisfies the span head faithfulness constraint by making each input vowel a span head. But it is ruled out by higher ranking *A-SPAN[ATR]. The remaining output forms are equally optimal because there is no constraint to determine which vowel should be made the span head.

The results in (4.13) to (4.15) show that in spite of the position of span headship as an important representational assumption in Span Theory, the span head is not necessarily the trigger of the harmonic feature. While it is intuitive to have the trigger (being the 'source' of the harmonic feature to which other segments in the span assimilate) as the span head, constraint ranking in OT, which ultimately determines span headship in a harmony pattern that lacks strong directionality effects, may produce output forms with ambiguous span structure or spans with the trigger as non-head. Such results can be avoided by using constraints on directionality to stipulate the span head. However, in a harmony pattern such as Dagbani, such stipulations are not needed.

4.2.4 Restriction on high vowel target

Preceding [+ATR] mid vowels, the high vowels [ʊ] and [ɨ] remain [-ATR]. This is contrary to the observed patterns in which (i) [a, ɛ, ɔ] all undergo harmony triggered by the mid vowels and (ii) [ɨ, ʊ] undergo harmony triggered by the high vowel /i/.

(4.16) High vowel opacity

a.	sɨ̀m-ó	*[sìm-ó]	'good friend-sg.'
b.	tɨ̀m ó	*[tìm ó]	'send him/her'
c.	pɨ̀l ó	*[píl ó]	'cover him'
d.	lɨ́ró	*[lír ó]	'attack him'
e.	gʊ̀b ó	*[gúb ó]	'gang up against him'
f.	dʊ́ʔ ô	*[dúʔ ô]	'cook it (animate)'
g.	pʊ̀h ó	*[púh ó]	'greet him/her'
h.	tʊ́m-ô	*[túm-ô]	'messenger-sg.'

The same pattern is observed in roots with more than one vowel, with [ɨ] as the epenthetic vowel. Neither underlying nor epenthetic root vowel harmonises with the mid vowel, even if the root vowel is targeted in other contexts (without an epenthetic vowel).

(4.17) High vowel opacity with two root vowels

a.	/sàʔm ó/	[sàʔ[ɨ́]mm ó]	*[sə̀ʔ[í]mm ó]	‘spoil him’
b.	/záhm ó/	[záh[ɨ́]mm ó]	*[zə́h[í]m ó]	‘measure him’
c.	/bɨ̀lm ó/	[bɨ̀l[ɨ́]mmó]	*[bìl[í]mm ó]	‘roll it (anim.)’
d.	/jɔ́hm ó/	[jʷá h[ɨ́]mm ó]	*[jʷóh[í]mm ó]	‘deceive him’
e.	/bɛ̀hmó/	[bʲà h[ɨ́]mmó]	*[bʲèh[í]mm ó]	‘doubt him’

In 4.17, the root low and mid vowels are potential targets of [+ATR] harmony triggered by the final mid vowel. The reason they remain [-ATR] is because of the epenthetic high vowel, which is opaque to the spread of [+ATR] from a mid vowel. Notice that the failure of root high [-ATR] vowels to be targets of [+ATR] harmony could not be attributed to a general ban on reducing vowel sonority within the root domain. This is because root mid and low vowels are subject to harmony triggered by final mid vowels. Rather, the pattern seems to be part of a broader restriction on which vowels can serve as triggers or targets based on their height specifications. Another such restriction is between [+high] and [+low] vowels, discussed in Section 4.2.5.

4.2.5 Restriction on low vowel target

The behaviour of low vowels in tongue-root harmony has attracted much attention in previous research. In languages with a dominant [+ATR] harmony, /a/ is often the only vowel claimed to be opaque to the spread of [+ATR] feature (see Archangeli & Pulleyblank, 1994; Casali, 2003, 2008, and citations therein for further discussion). It is also the vowel that often lacks a [+ATR] variant in languages with a nine vowel system. Typical of many descriptive studies of Gur languages, neither of the only two studies of Dagbani tongue-root harmony (Dakubu 1997; Olawsky 1999) make explicit assumptions about the phonological features of low vowels in harmonic contexts. The analysis here is that Dagbani /a/ undergoes [ATR] harmony in harmonic contexts. Chapter 6 presents a more detailed discussion of the theoretical issues relating to the low vowel in harmonic contexts and results of experimental studies that support the data and analysis in this chapter.

The low vowel is subject to some restrictions in harmonic contexts. In (4.18), the spread of [+ATR] from a root /i/ to a suffix /a/ fails. In (4.19), final mid vowels do trigger harmony onto root /a/. In the discussion below, I argue that the pattern in (4.18) is part of a broader restriction on the height specification of a trigger and target within a harmonic domain.

(4.18) Low vowel opacity

a.	pí â	*[pí ə̂]	‘bury you’
b.	bí-á	*[bí-ə́]	‘child’
c.	tì bá	*[tì bə́]	‘give them’
d.	dìm-á	*[dìm-ə́]	‘eat-imperative’
e.	kpím-á	*[kpím-ə́]	‘a dead person’
f.	vìh á	*[vìh ə́]	‘investigate you’

(4.19) Advanced low vowel before final mid vowel

a.	/dà ó/	[də̀ ó]	‘buy it (animate)’
b.	/bá ó/	[bə́ ó]	‘ride it (animate)’
c.	/kál-ó/	[kə́ló]	‘door-sg.’
d.	/pál-ó/	[pə́l-ó]	‘new-sg. (animate)’
e.	/sàl-ô/	[sə̀l-ô]	‘crowd of people’
f.	/tàdáb-ô/	[tə̀də̀b-ô]	‘writing ink’
g.	/tàtáb-ô/	[tə̀tə́b-ô]	‘the like of’

The position of the mid vowel could be used in a possible account of the differences between (4.18) and (4.19). The low vowel undergoes harmony as a root vowel, as in (4.19). It is opaque to harmony as a suffix or clitic. However, such an account has no support from other aspects of Dagbani phonology. As discussed in Chapter 2, variation in vowel features results in the reduction in sonority of domain-final vowels and increase in sonority of non-final position.

Since [+ATR] vowels are less sonorous than [-ATR] vowels, the pattern that is expected would be the exact opposite. If the position of the low vowel had a role in determining whether harmony occurs, word-final low vowels would be expected to undergo harmony while domain-internal ones would remain [-ATR]. A formal account of this restriction, based on vowel height, is presented in Section 4.3. I propose an account within ST of the restriction shown in this section.

4.3 Height-conditioned harmony

The distributional patterns in (4.16) to (4.18), suggest that what is at stake here must be a condition affecting the relation between the trigger and target, and not the target alone. The restriction is a height co-occurrence condition between the trigger and target. The trigger and target must have the same value for the feature [high]. The trigger and target must be both specified for [+high] or [-high]. The proposal here is supported by similar arguments in previous studies which demonstrate that similarity in some feature specifications between segments plays an important role in conditioning the spread of other features between them. For instance, Hare (1992) notes that the harmonic behaviour of Hungarian vowels can be predicted from similarity relationships among vowels. Much stronger effects have been noted in consonant harmony systems. Itô et al. (1995) observe that assimilatory effects involving place features are more likely between segments that are alike in other features such as stricture and sonority. Other studies on consonant harmony (Hansson 2001, Rose & Walker 2004 etc.) show that segments that interact in consonant harmony processes must share a certain degree of similarity. Similar observations on similarity have been made by Archangeli & Pulleyblank (1994), Ajiboye & Pulleyblank (2008), and Pulleyblank (In Press). The restrictions in Dagbani present a case for a similar argument. Vowels in a trigger-target relationship must share some level of similarity by avoiding some degree of dissimilarity. I express this as a Span Harmony height feature condition in (4.20).

(4.20) Height feature condition

*[+Hi, -Hi]Span[+ATR]

Within one span of [+ATR], combination of a [+high] feature value and a [-Hi] feature value is prohibited (= HeightCond)

As long as HeightCond outranks *A-Span[ATR], it is better to have two spans of [ATR] within a harmonic domain than combine a high and a low vowel within one domain.

(4.21) HEIGHTCOND results in [+ATR] and [-ATR] spans (/pi ba/ → [pi ba] 'bury them')

/pi ba/	HEIGHT COND	*A-SP [ATR]	SPEC-FT [-ATR]	FTHHDSP [+ATR]	FTHHDSP [-ATR]
a. p(**í** bə̂)	*!		**		*
☞ b. p(**í**)(b**â**)		*	*		

Note that the ranking HEIGHTCOND » *A-SPAN[ATR] is necessary because *A-SPAN[ATR] outranks LOW/ATR, as established in Section 4.2.3. Since LOW/ATR is the only other constraint that preserves [-ATR] in a low vowel, any other ranking would results in the low vowel being an undergoer in every context, contrary to its actual behaviour.

In a domain with a high root vowel and a mid suffix/clitic vowel, HEIGHTCOND ensures that each vowel stays in a span of its own whether the root has a [+ATR] specification or not. First, consider domains with CɨCo structure shown in (4.16). Without HEIGHTCOND, the spread of a [+ATR] feature from the final mid vowel to the root high vowel could not be blocked. This is illustrated in (4.22), where (4.22b) would have emerged the optimal output form.

(4.22) HEIGHTCOND results in [+ATR] and [-ATR] spans (/sɨm-o/ → [sɨ̀m-ó] 'good friend-sg.')

/sɨm-o/	HEIGHT COND	*A-SP [ATR]	SPEC-FT [-ATR]	FTHHDSP [+ATR]	FTHHDSP [-ATR]
a. s(**ɨ̀**m-ó)	*!		**	*	
b. s(ɨ̀m-**ó**)	*!		**		*
☞ c. s(**ɨ́**)(m-**ó**)		*	*		

Then there are domains with root [i] and final mid vowels. Surface [+ATR] harmony is achieved vacuously. The data are in (4.23).

(4.23) [+ATR] harmony with root [i] and affix/clitic [o]

a. pí bô 'bury what'

b. dì bò 'eat what'

c. bí só 'a certain child'

d. tì só 'give to someone'

e. lìh ó 'look at him/her'

f. vìːg ó 'reveal him/her'

g. ʧìʧìɾé 'a family name'

In (4.23), Surface [i] is due to undominated HI-COR/ATR constraint. Final [e] or [o] is due to undominated *MID[-ATR] and DEP[+LO]]$_{wd}$. While it would be accurate to describe these as [+ATR] domains with vacuous triggers and targets, HeightCond, which accurately predicts disharmony in (4.22), also blocks a single [+ATR] domain.

(4.24) Two [+ATR] spans due to HeightCond (/pi bɔ/ → [p(**í** bô)] 'bury what?')

/pɪ bɔ/	Hi-COR/ /ATR	*Mid [-ATR]	Height Cond	*A-Sp [ATR]	COR Hd [+ATR]	FthHd Sp [+ATR]
a. p(ɪ́ b**ɔ̂**)		*!				*
b. p(í b**ô**)			*!		*	
c. p(**í** bô)			*!			**
☞ d. p(**í**) b(**ô**)				*		*

4.4 Summary

The analysis in this chapter contributes to a subject matter established in numerous studies, viz. featural similarity is important in harmony systems. In the particular restriction discussed here, the enhancement relations between tongue-root and height features (Archangeli & Pulleyblank 1994) makes [+ATR] harmony the target of height restriction.

The restrictions on [ATR] harmony discussed in this chapter are by no means the only ones that determine the nature of harmony in the language. As already shown in Chapter 3, Dagbani displays consonantal opacity in its harmony system. Chapter 5 discusses this and provides further support to the argument that the restrictions observed in this chapter are not the typical pattern of opacity found in harmony processes.

Chapter 5

Direction-specific opacity in Dagbani [ATR] harmony

5.1 Introduction

In the review of the literature on theoretical approaches to vowel harmony presented in Chapter 3, it was shown that a class of consonants in Dagbani block the spread of [+ATR]. The review also demonstrated that the relative strength of various approaches to harmony lies in part in the extent to which they account for various patterns of opacity. ST was argued to be better than pro-spreading theories at handling opacity in that it does not make the unattested predictions discussed in that chapter. Harmonic Serialism was also rejected because it is unable to handle direction-specific opacity. This chapter completes the account of [ATR] harmony in Dagbani with analysis of consonantal opacity in the harmony system. It argues that with a few modifications to some of its fundamental representational assumptions, ST does better than most previous proposals in handling direction-specific spread of [+ATR] in Dagbani.

The pattern in Dagbani shows that when an opaque consonant lies between a [+ATR] root vowel trigger and an eligible vowel target, the spread of [+ATR] is blocked and harmony between the trigger and target fails. However, between a suffix/clitic [+ATR] trigger and a root target, no such blocking effects are observed. I account for this unhindered leftward spread of [+ATR] with two proposals. The first proposal regards the position of opaque segments in regular patterns of opacity. I argue that contrary to McCarthy's original proposal, opaque segments do not need to head the spans they create by blocking the spread of the harmonic feature. The second proposal is the need for a featural compatibility constraint that restricts [+ATR] span headship to vowels. When this constraint, which blocks consonants from span headship, is ranked above a harmony driving constraint that requires opaque segments to be in initial position of [-ATR] spans, affix-triggered [+ATR] harmony is achieved along with the regular pattern of opacity to root-triggered [+ATR] harmony.

The rest of this introduction presents previous claims regarding direction-specific opacity in different languages, as reviewed by McCarthy (2009) (Section 5.1.1) and the pattern of Dagbani consonant opacity (Section 5.1.2). Section 5.2 presents a basic analysis of opacity, showing how the constraint hierarchy used in Chapter 3 derives all the patterns of opacity. In Section 5.3, direction-specific opacity is shown to be the result of conflict between the demands of the harmony driving constraint and constraints that block harmony, an analysis of which is presented. Section 5.4 summarises the chapter.

5.1.1 Direction-specific blocking in harmony systems

One of the major challenges to some recent formal approaches to harmony is direction-specific opacity effects. These are opacity effects that are observed in one direction of spread of a harmonic feature but not in the other. Previous research that have noted this process include Davis (1995) who cited RTR harmony in Arabic as having an unhindered leftward spreading of the feature while rightward spreading is blocked by the vowel [i] and other high front segments. Other researchers who have discussed the Arabic pattern are McCarthy (1997), Watson (1999) and Davis (2000). For tongue-root harmony, Clements (1981) and Archangeli & Pulleyblank (1994) note Akan low vowel as showing opacity to [+ATR] harmony except when it precedes [+ATR] triggers, in which case it is a target of what appears to be a right-to-left [+ATR] spread. However, unlike Arabic, Archangeli & Pulleyblank (1994) argue that this right-to-left assimilatory pattern is phonetic interpolation, not phonological harmony.

McCarthy (2004) notes that ST can not account for such opacity effects, a point which, he indicates, constitutes a major weakness of ST. However, in McCarthy (2009), he reviews previous claims on these opacity effects and dismiss their accuracy. He notes that the actual pattern in both languages has to do with a distinction between categorical and gradient assimilation. In the case of Arabic, McCarthy cites results of an experimental study by Ghazeli (1977) which show that segments following what is supposed to be a blocking segment were pharyngealised, albeit to a lesser degree than those that were not preceded by the supposed blockers. For Akan, Clements (1981) notes that the effect of assimilation on preceding [a] is not categorical. Rather, syllables preceding the trigger display a greater degree of assimilation the closer they are to the trigger. McCarthy uses this observation as the basis for his argument that what is at stake in Akan is not phonological harmony that is blocked in one direction and permitted in the other. Rather, he argues, it is a gradient pattern of assimilation which does not easily lend itself to a theory of harmony based on autosegmental spreading.

In addition to these two cases, McCarthy cites other previous claims on direction-specific blocking which have later been reanalysed (e.g. blocking effects in Kinande (Archangeli & Pulleyblank 1994, 2002)), are spurious (e.g. blocking effects in Maasai (Archangeli & Pulleyblank 1994; McCrary 2001)) or due to some other factors besides the blocking segments (e.g. blocking effects in Lango (Archangeli & Pulleyblank 1994; Smolensky 2006)).[25] He concludes that none of the cases cited in the literature, and which he reviewed, constitutes a genuine case of direction-specific blocking which would threaten the strength of Harmonic Serialism.

The pattern of opacity in Dagbani appears to be a clear pattern of direction-specific blocking to which McCarthy's criticisms do not apply. As discussed below, the failure of opaque consonants in Dagbani to block leftward spreading of [ATR], as in rightward spreading, is neither spurious nor attributable to some other phonological process. Results of ultrasound ex-

[25]See McCarthy 2009: 40 – 43 for a more detailed discussion.

periments presented in Chapter 6 also show that the spread of [+ATR] in both directions is categorical. Thus the possibility of a distinction based on degree of assimilation does not arise. In addition to Dagbani, Hansson (2007) discusses a pattern of direction-specific blocking of vowel retraction triggered by retracted consonants in Tsilhqot'in that could further strengthen the argument that direction-specific opacity effects are well attested in harmony patterns. In this language, progressive assimilation of RTR from a sibilant trigger to a vowel target is blocked by a class of opaque (non-retracted) consonants. However, these consonants are not opaque to regressive assimilation, which is unbounded.

The analysis in this chapter is thus meant to challenge McCarthy's (2009) argument that there may not be a genuine phonological direction-specific opacity and McCarthy's (2004) observation that ST can not handle direction-specific blocking. It shows that with the modification to the assumptions regarding how opacity is achieved proposed in Chapter 3, ST displays some strength relative to other theories of harmony in analysing the direction-specific opacity of Dagbani. The remaining sections below show the generalisations and analysis of opacity in Dagbani. Since Chapter 3 already demonstrated the inability of Harmonic Serialism to analyse direction-specific blocking effects, discussion of Harmonic Serialism is not repeated in this chapter. This chapter is concerned solely with how Span Theory handles the pattern of consonantal opacity in Dagbani.

5.1.2 Pattern of consonant opacity

The table in (5.1) shows consonants that occur as lexical root codas or suffix onsets. These consonants stand in the way between a root /i/ trigger of [+ATR] and a suffix vowel target, and between a mid vowel trigger and a root vowel target. In the data used for the analysis of [+ATR] harmony presented in Chapter 4, all the consonants in (5.1) occur in root-triggered [+ATR] harmony as root codas or suffix onsets except [ɾ, l, s], noted in (5.1). Sample data of root-triggered [+ATR] harmony with these consonants are shown again in (5.1).

Table 5.1: Consonants between [+ATR] harmonic triggers and targets

	[Lab]	[Cor]	[Dor]	
		t		ʔ
[-cont]	b	d	g	
	m	n		
		ɾ		
[+cont]		l		
		s		h

(5.1) Root triggered [+ATR] harmony

a.	kpíb]$_{rt.}$-ú	'dying'
b.	ʧìb]$_{rt.}$-ì	'inject'
c.	o mì]$_{rt.}$ mî	'he knows'
d.	pín]$_{rt.}$-î	'a gift'
e.	bín]$_{rt.}$-dí	'faeces'
f.	díʔ-]$_{rt.}$í	'a mirror'
g.	dí-h[ɨ́]]$_{rt.}$-bû	'feeding'
h.	lìh[ɨ̀]]$_{rt.}$ tí	'look at us'

In affix/clitic-triggered harmony, there are no restrictions. Any of the consonants in (5.1) may occur between the root and the mid vowel trigger. This is shown in (5.2).[26]

[26] A consonant that precedes a domain-final mid vowel is typically preceded by another vowel. Since [d], [s] and [g] lenite respectively into [ɾ], [h] and [ʔ] in intervocalic position, there seem to be no data illustrating a domain-final mid vowel with onset [d], [s] and [g].

(5.2) Affix-triggered [+ATR] harmony

Affix/clitic-to-root harmony

a.	tədəb $]_{rt.}$-ô	'writing ink-sg.'
b.	tətəb $]_{rt.}$-ô	'a look-alike-sg.'
c.	dèm $]_{wd.}$ ó	'play with him/her'
d.	lə̀m $]_{wd.}$ ô	'laugh at him/her'
e.	dóɾ$]_{rt.}$-ó	'disease-sg.'
f.	mòl $]_{rt.}$-ô	'announcement-sg.'
g.	pə́l $]_{rt.}$-ó	'new (animate)-sg.'
h.	jèn $]_{rt.}$-ô	'a jaw'
i.	tòh $]_{rt.}$ ó	'increase for him/her'
j.	dòʔ$]_{rt.}$ ó	'give birth to him/her'
k.	bé $]_{rt.}$è	'shin'
l.	dè$]_{rt.}$é	'warthog'

The continuant coronal consonants [l, ɾ, s] block the spread of [+ATR] from the root vowel to targets such as epenthetic vowels, affix and clitic vowels. The data in (5.3) show this opacity. I discuss the interaction between these consonants and mid vowel triggers in Section 5.3.

(5.3) No [+ATR] harmony with opaque consonants

[l]	a.	píl[ɨ̀]]$_{wd.}$	*pìl[ì]	‘start’
	b.	dí]$_{rt.}$ lɨ́	*dì lí	‘eat/spend it’
	c.	bì]$_{rt.}$-lɨ́m	*bì-lím	‘childish’
	d.	jìl[ɨ̀]ŋ]$_{rt.}$-gá	*jìl[ì]ŋ-gá	‘musical flute’
[ɾ]	e.	jíɾ[ɨ́]]$_{rt.}$-gɨ̂	*jíɾ[í]-gî	‘get startled’
	f.	ʧìɾ[ɨ̀]m]$_{wd.}$	*ʧìɾ[ì]m	‘make a mistake’
	g.	dí]$_{rt.}$-ɾ[ɨ̀]-gʊ̀	*dı-ɾ[ì]-gú	‘spoon-sg.’
[s]	h.	jìn]$_{rt.}$-sɨ́	*jìn-sí	‘house-pl.’
	i.	bíːn]$_{rt.}$-sɨ́	*bíːn-sí	‘expert-pl.’
	j.	ɲím[sɨ̂]]$_{wd.}$	*ɲímsî	‘be frugal’
[l, s]	k.	ʒí]$_{rt.}$-lɨ́n-sɨ́	*ʒí-lín-sí	‘ignorance’
	l.	mí]$_{rt.}$-lɨ́n-sɨ́	*mí-lín-sí	‘familiarity’

These consonants also block the spread of advancement onto vowels in following affixes or clitics that would otherwise be affected by harmony, as (5.4) show.

(5.4) Effect of opacity on vowels of following constituents

[ɾ]	a.	ʧɪ̀ɾ[ɨ̀]m]$_{rt.}$-bʊ̂	*ʧɪ̀ɾ[ɪ̀]m-bû	‘erring’
	b.	jíʔ]$_{rt.}$-ɾɨ́-gʊ́	* jíʔ-ɾí-gú	‘fly-er-sg. (air plane)’
	c.	ʧíɾg[ɨ́]]$_{rt.}$-lɨ̀	*ʧíɾg[í]-lí	‘a chance’
[l]	d.	fíl[ɨ́]m]$_{rt.}$ tɨ́	*fíl[í]m tí	‘demean us’
	e.	ʧíl[ɨ́]m]$_{rt.}$-bʊ̂	*ʧíl[í]m-bû	‘delaying’
	f.	pìl]$_{rt.}$-gʊ́	*pìl-gú	‘beginning’
[s]	g.	jíʔs[ɨ́]]$_{rt.}$ tɨ́	*jíʔs[í] tí	‘get us up’
	h.	(n) ʧíʔs[ɨ̀]]$_{rt.}$ mɨ̂	*(n) ʧíʔs[ì] mî	‘(I) jumped’

Finally, in some patterns of prefixing reduplication described in Chapter 1, a fixed *lɨn* syllable that occurs between a root and its reduplicant copy maintains a [-ATR] vowel. This is shown in (5.5) with the reduplicant underlined. For arguments that the last syllable is the suffix, see Chapter 1.

(5.5) Non-advanced vowel between two advanced ones

a.	kpí]$_{rt.}$-lɨ́n-kpí-hí	‘epilepsy’
b	dí]$_{rt.}$-lɨ́n-dí-hí	‘numbness’
c.	ʃí]$_{rt.}$-lɨ́n-ʃí-hi	‘shadows’

Note that the failure of the high vowel in *lɨ́n* to undergo harmony is not a case of transparency since the relationship between the root vowel and the reduplicant is not a harmonic one. Even though both root and reduplicant vowels have the same vowel [i], this sameness of feature is achieved by exact copying of the root vowel features through base-reduplicant correspondence, not long distance feature assimilation. The only case of assimilation is between the reduplicant vowel and the suffix vowel. The examples in (5.5) thus have three spans: a [+ATR] span headed by the initial root, a [-ATR] span with *lɪ́n*, and another [+ATR] span with the reduplicant and the suffix, as already discussed in Chapter 3.

As expected from the theory of locality adopted in this dissertation, the opaque consonants only block [+ATR] harmony when they are domain-medial. Domain-initial opaque consonants do not block harmony because they are not located between the trigger and target. They are not part of the harmonic domain. Examples with these consonants as trigger onsets and target onsets are shown in (5.6) and (5.7). In (5.6), only /s/ and /l/ are shown in root-initial position because [ɾ] only occurs in post-vocalic positions. The data in (5.7) have only domain-initial /l/ because it is the only one of the three opaque consonants that occurs word-initially with /i/, the only root [+ATR] trigger. Also, examples with [e] following an initial /s/ are lacking because before front vowels, /s/ changes into [ʃ] (see Chapter 1).

(5.6) Domain-initial vowel target with onset opaque consonant

	I [+ATR] harmony	II No harmony	
a.	s(ə́b $]_{rt.}$ **ô**)	*s(**á**)(b $]_{rt.}$ **ô**)	‘write to him’
b.	s(ə̀l $]_{rt.}$-**ô**)	*s(**à**)(l $]_{rt.}$ **ô**)	‘crowd’
c.	s(ó $]_{rt.}$-**ó**)	*s^{w}(**á** $]_{rt.}$)(-**ó**)	‘frog’
d.	s(òm $]_{rt.}$ **ó**)	*s^{w}(**à**)(m$]_{rt.}$**ó**)	‘wear his ...’
e.	l(ə̀m $]_{rt.}$ **ô**)	*l(**à**)(m $]_{rt.}$ **ô**)	‘laugh at him!’
f.	l(ə̀b $]_{rt.}$ **ô**)	*l(**á**)(b $]_{rt.}$ **ô**)	‘throw at him’
g.	l(èb $]_{rt.}$ **ó**)	*l^{j}(**à**)(b $]_{rt.}$ **ó**)	become like him
h.	l(èm $]_{rt.}$ **ô**)	*l^{j}(**à**)(m $]_{rt.}$**ô**)	‘feed him’
i.	l(òm $]_{rt.}$ **ô**)	*l^{w}(**á**)(m $]_{rt.}$ **ô**)	‘tie him’
j.	l(ò $]_{rt.}$-**ó**)	*l^{w}(**à** $]_{rt.}$)(-**ó**)	‘field mouse’

(5.7) Domain-initial [+ATR] trigger onset opaque consonant

a.	lìh[ì]	*lɨ̀h[ɨ̀]	‘see’
b.	líl[ɨ́]	*lɨ́l[ɨ́]	‘vanish’
c.	líl[ɨ́]n-lɨ́	*lɨ́l[ɨ́]n-lɨ́	‘wild cherry tree (Blench 2004)’
d.	líl[ɨ́]gá	*lɨ́l[ɨ́]-gá	‘medicine that makes you vanish’ (Blench 2004)
e.	líb-lɨ́	*lɨ́b-lɨ́	‘a twin sibling’

In Section 5.2, an ST analysis of opacity is presented.

5.2 Deriving opacity: Analysis

In Chapter 3, where consonant opacity is used to evaluate various theories of harmony, it is shown that the opacity is derived with the constraint CORCONT-L[-ATR].

(5.8) SP-L(COR, +CONT], [-ATR]

A consonant that is [Coronal] and [+continuant], is initial in a [-ATR] span (= CORCONT-L[-ATR])

The basis for this constraint is that [coronal] and [+continuant] are the only features that define the class of blocking segments in the language. As shown in (5.1), all other root codas and suffix onsets are either non-coronal or [-continuant]. Opacity results from the ranking of the constraint CORCONT-L[-ATR] above the harmony driver *A-SPAN[ATR], as already demonstrated in Chapter 3. The tableau in (5.9), illustrates this.

(5.9) Opacity resulting from CORCONT-L[-ATR] » *A-SPAN[ATR]

(/jíʔs/ → [(j**í**ʔí)(s**ɨ̂**)])

/jiʔs/	FTHHDSP [+ATR]	CORCONT-L [-ATR]	*A-SPAN [ATR]
a. j(**í**ʔ[í]sî)		*!	
b. j(ɨ́ʔ[ɨ́]s**ɨ̂**)	*!	*	
☞c. j(**í**ʔ[í])(s**ɨ̂**)			*

(5.9a–b) satisfy the demands of *A-Span[ATR] by ensuring that inserted root-final vowels all surface with the same [ATR] value. However, satisfying *A-Span[ATR] implies that the coronal continuant [s] is not initial in the span, contrary to the demands of higher ranked CORCont-L[-ATR]. This is sufficient to rule out the output forms in (5.9 a and b). The output in (5.9b) also incurs a violation of FthHdSp[+ATR] for not preserving the input [+ATR] feature on the first root vowel. (5.9c) emerges optimal at the expense of *A-Span[ATR] violation.

The constraint hierarchy in (5.9) also derives the other opacity patterns shown in the above data. In cases where the syllable with the opaque consonant is followed by another syllable, as in (5.4), *A-Span[ATR] ensures that the following syllable is part of the same [-ATR] span as the syllable with the opaque consonant, (5.10).

(5.10) Opaque consonant blocks the spread of [+ATR] to vowel of a following syllable (/ʧiɾm]$_{rt.}$ -bʊ/ → ʧíɾɪ́m-bʊ̂) ‘making a mistake’)

/ʧiɾm]$_{rt.}$ -bʊ/	FthHdSp [+ATR]	CORCont-L [-ATR]	*A-Span [ATR]
a. ʧ(íɾɪ́m-b**ʊ̂**)	*!	*	
☞ b. ʧ(**í**)(ɾɪ́m-b**ʊ̂**)			*
c. ʧ(**í**)(ɾ**ɪ́**m)(-b**ʊ̂**)			**!
d. ʧ(**í**ɾím-bû)		*!	

When there are two or more opaque consonants, each consonant has a span of its own, (5.11).

(5.11) One span for every opaque consonant (/ʧiʔs-lɨ/ → ʧíʔsɨ̀]$_{rt.}$-lɨ̀) 'a jumping point')

/ʧiʔs]$_{rt.}$ -lɨ/	FthHdSp [+ATR]	CORCont -L[-ATR]	*A-Sp [ATR]
a. ʧ(**í**ʔ)(s ɨ̀]$_{rt.}$-l**ɨ̀**)		*!	*
☞b. ʧ(**í**ʔ)(s**ɨ̀**]$_{rt.}$)(-l**ɨ̀**)			**
c. ʧ(**í**ʔísì]$_{rt.}$-lì)		**!	

Finally, in the reduplicative forms, the [+ATR] feature in the reduplicant is preserved by a base-reduplicant faithfulness constraint, (McCarthy & Prince 1993b, 1995), blocking its inclusion into the same span as the opaque consonant. The option of parsing the final suffix into a span of its own is also blocked by *A-Span[ATR]. Thus the optimal form has three spans, with the root and *lɨn* forming spans of their own. The base-reduplicant faithfulness constraint is defined in (5.12).

(5.12) Max-BR[+ATR]

A base [+ATR] feature value must have a reduplicant correspondent [+ATR] feature value

The tableau in (5.13) shows the results with Max-BR[+ATR] undominated.

(5.13) Opacity in reduplicative forms (dí-lɨ́n-d̲í̲-hí) ‘numbness’)

/di]$_{rt.}$ -lɨn-RED-hɨ/	MAX-BR [+ATR]	FTHHD SPAN [+ATR]	COR CONT-L [-ATR]	*A-SPAN [ATR]
a. d(**í**]$_{rt.}$)-(lɨ́n-d̲ɨ̲́-h**ɨ̂**)	*!			*
☞b. d(**í**]$_{rt.}$)-(l**ɨ́**n)-(d̲í̲-h**í**)				**
c. d(**í**]$_{rt.}$)-(l**ɨ́**n)-(d̲**í̲**)-(h**ɨ̀**)				***!

In (5.13), failure to preserve the base [+ATR] feature rules out *d(**í**]$_{rt.}$)-(lɨ́n-d̲ɨ̲́-h**ɨ̂**)* even though it has the least violation of *A-SPAN[ATR] and no violations of any other constraint besides MAX-BR[+ATR]. Without MAX-BR[+ATR], it would have emerged the optimal candidate. The candidate in (5.13c) fails to harmonise between the reduplicant vowel and the suffix vowel, leading to an extra violation of *A-SPAN[ATR]. With only two violations of *A-SPAN[ATR], (5.13b) emerges as the winning candidate.

5.3 Featural compatibility and span headship

This section discusses a conflict between the ST constraint that drives harmony and the constraint that blocks it, proposing that (i) span headship in tongue-root harmony systems should be restricted to vowels, and (ii) an opaque segment only needs to mark span boundary, it does not need to head the span it creates. The two proposals are discussed in the next subsections.

5.3.1 Featural compatibility

In Chapter 2, it is shown that Dagbani final mid vowels surface as [+ATR] due to the undominated ranking of the markedness constraint *Mid[-ATR] and the faithfulness constraints Dep[+Lo]]$_{wd}$. With an opaque consonant as onset, CORCont-L[-ATR] demands that the syllable be part of a [-ATR] span and that the opaque segment be initial in that span. There are three possible output forms: (i) a [+ATR] harmony between the root and affix vowels, as in (5.14 I), (ii) no harmony as in (5.14 II), and (iii) a [-ATR] harmony, as shown in (5.14 III).

(5.14) Word-final mid vowel with [-ATR] onset

	I [+ATR] harmony	II No harmony	III [-ATR] harmony	
a.	d(óɾ]$_{rt.}$-**ó**)	*d(**ɔ́**)(ɾ]$_{rt.}$-**ó**)	*d(ɔ́ɾ]$_{rt.}$-**ɔ́**)	'disease'
b.	g(ə́ɾ]$_{rt.}$-**ó**)	*g(**á**)(ɾ]$_{rt.}$-**ó**)	*g(áɾ]$_{rt.}$-**ɔ́**)	'bed'
c.	k(ə́l]$_{rt.}$-**ó**)	*k(**á**)(l]$_{rt.}$-**ó**)	*k(ál]$_{rt.}$-**ɔ́**)	'gate'
d.	s(ə̀l]$_{rt.}$-**ô**)	*s(**à**)(l]$_{rt.}$-**ô**)	*s(àl]$_{rt.}$-**ɔ̂**)	'a crowd'
e.	p(ól]$_{rt.}$-**ô**)	*p(**ɔ́**)(l]$_{rt.}$-**ô**)	*p(ɔ́l]$_{rt.}$-**ɔ̂**)	'land/plot'
f.	p(ə́l]$_{rt.}$-**ó**)	*p(**á**)(l]$_{rt.}$-**ó**)	*p(ál]$_{rt.}$-**ɔ̂**)	'new-sg. (anim.)'

The opacity constraint as defined will block regressive harmony with the root vowel. However, with an undominated *Mid[-ATR], the opaque segment ends up in a single-segment span headed by itself. The tableau in (5.15) illustrates this result.

(5.15) A consonant-only span (/pal-ɔ/ → *[pal-ɔ] 'new-sg. (anim.)')

/pal]$_{rt.}$-ɔ/	*MID[-ATR]	CORCONT-L] [-ATR]	*A-SPAN [ATR]
a. p(**á**)(l]$_{rt.}$-**ó**)		*!	*
☞ b. p(ə́l]$_{rt.}$-**ó**)		*!	
c. p(**á**)(l]$_{rt.}$-**ɔ́**)	*!		*
✗ d. p(**á**)(l)]$_{rt.}$-(**ó**)			**

(5.15a) shows some opacity effect by not having a root [+ATR] vowel. However, like (5.15b), it does not satisfy the demands of the opacity constraint because the constraint demands that the opaque consonant is initial in a span of [-ATR]. While (5.15c) and (5.15d) satisfy the demands of CORCONT-L[-ATR], (5.15c) incurs a fatal violation of higher-ranked *MID[-ATR], leaving the output form with a consonant-only span the predicted optimal form.

The incorrect result is predicted because the opaque consonants are treated like vowels in feature specifications and behaviour in harmonic contexts. Even though consonants are assumed to undergo harmony in [+ATR] domains, there is no strong basis to treat them like vowels when it comes to the feature [ATR]. [ATR] is a vocalic feature, and vowels undergo harmonic variation depending on whether they are in [+ATR] or [-ATR] domain. By contrast, consonants do not have harmonic variants in [ATR] contexts because any changes they undergo are merely phonetic interpolation resulting from their location (between vowels with the relevant [ATR] value). Given this disparity, a consonant does not get a specification for any value of [ATR] if there is no vowel in the span in which the consonant occurs. By setting harmonic variation as the basis for headship of an [ATR] span, span headship is restricted to only vowels. Because consonants are only undergoers, there is little basis to postulate them as span heads. This disparity is captured by a constraint that restricts span heads to syllabic segments, stated in (5.16).

(5.16) HEAD([+SYLL], [ATR])

The head of an [ATR] span must be [+syllabic] = (VOHEAD[ATR])

5.3.2 Weakening the power of blockers

In Chapter 3, I have formulated the constraint that triggers opacity (COR CONT-L][-ATR]) as one that makes the opaque consonant the initial segment in a span of a [-ATR] feature. The discussion in this section is meant to motivate this proposal. In McCarthy's formulation of ST, a segment becomes span head either by having an underlying specification for the harmonic feature that is shared by other segments in the span through an assimilatory process or by blocking the assimilatory process that would otherwise change the feature it shares with other segments in the span. In both cases, the span head typically has two properties. First, all segments in the span share a feature for which the span head (especially harmonic triggers) has an underlying specification. Second, and especially for opaque segments, the span head occupies a unique position relative to other segments in the span.

The first property becomes a problem when viewed in light of Richness of the Base. If the span head has to have an input specification for the span feature, Richness of the Base can not be respected. The analyses in Chapters 2 and 4 have demonstrated the need to delink underlying specification from span headship. With the head-forcing constraint HiCOR/ATR replacing FthHdSp[+ATR], a Dagbani high front vowel can be derived both as a [+ATR] vowel and as the head of a [+ATR] span even if there is no input specification for[+ATR]. In the same vein, it is possible to delink span headship from opacity, given that the opaque segment does not need to head the span in order to block harmony. The only property that it needs crucially is to mark span boundary. This is what CORCont-L][-ATR] has done in the preceding analysis.

Combined with the featural compatibility constraint in (5.16), which must be undominated, the predicted output form in (5.15) is blocked. The tableau is repeated below, with VoHead[ATR] added to the constraint hierarchy.

(5.17) No consonant-only span with VoHead[ATR] »
CORCont-L[-ATR]

/pal]$_{rt.}$-ɔ/	VoHead [ATR]	*Mid [-ATR]	CORCont -L[-ATR]	*A-Span [ATR]
a. p(**á**)(l]$_{rt.}$-**ó**)			*	*!
☞b. p(ə́l]$_{rt.}$-**ó**)			*	
c. p(**á**)(l]$_{rt.}$-**ɔ̂**)		*!		*
d. p(**ə́**)(**l**)]$_{rt.}$-(**ó**)	*!			**

What the result in (5.17) shows is that, it is better for the blocking segment to be located in a [+ATR] span than to head be a span head. This is achieved to the ranking of CORCont-L[ATR] below the featural compatibility constraint.[27]

5.4 Summary

The main argument presented in this chapter is that featural compatibility is responsible for the pattern of direction-specific blocking of the feature [+ATR] observed in Dagbani. An important addition to the analysis here

[27]The analysis as presented here predicts that the opaque segments can block regressive harmony from a final mid vowel as long as the opaque segment is located further into the word than shown here. For instance, assuming a hypothetical word of CVCV root and a final mid vowel such as /bɛrɔd-o/, in a language with the same pattern of opacity as Dagbani, the analysis predicts that like the first root vowel, the second root vowel will remain retracted, even though the opaque segment does not intervene between it (the vowel [ɔ]) and the trigger. Dagbani does not have such words. However, such a prediction must be acknowledged as a limitation to present analysis.

is the claim that the feature [syllabic] plays a crucial role in determining the level of compatibility a segment has with the feature [ATR], and that blocking segments only need to mark span boundary to derive opacity. Such modifications are necessary with the adoption of a theory of harmony that assumes strict segmental locality along with the central role of span headship within the representational assumptions of Span Theory. The analysis in this chapter completes the formal account of Dagbani [ATR] harmony.

Chapter 6

Articulatory correlates of dominant tongue-root features

6.1 Introduction

The analyses in chapters 2, 4 and 5 account for the Dagbani vowel system and tongue-root harmony. The assumption in these chapters is that the relevant phonological feature distinguishing the vowels in each of the pairs i/ɨ, u/ʊ, e/ɛ, o/ɔ, and ə/a is advanced tongue-root ([ATR]). The first vowel in each pair is assumed to be [+ATR], the second, [-ATR]. While these assumptions have been made in previous research on Dagbani (Dakubu 1997; Olawsky 1999), no experimental study exists to support them. An assumption that these vowel pairs are distinguished by some other vowel feature such as height is quite conceivable. This chapter provides the much needed experimental study to fill the gap in the literature as well as back up the analysis in the preceding chapters. Two main hypotheses are tested: (a) that tongue-root features have distinct articulatory tongue-root positions, and (b) that the mapping between tongue-root features and articulatory gestures reflects which of the values of the feature [ATR]/[RTR] is dominant in a language.

Previous articulatory studies of tongue-root harmony systems (e.g. Ladefoged 1968; Lindau 1975, 1979; Tiede 1996; Whalen & Gick 2001; Gick et al. 2006) support the assumption in the preceding chapters that tongue-root position is a major articulatory property that distinguishes vowels in each pair. As this is an experimental study, I revert to the theory-neutral labels Class I for the first vowel in each of the pairs and Class II for the second vowel in each pair. The classes are shown in Table (6.1).

Table 6.1: Class I and Class II vowels

Class I vowels		Class II vowels	
i	u	ɪ	ʊ
e	o	ɛ	ɔ
ə		a	

While the present study is the first to test these hypotheses using Dagbani, Hypothesis (a) has been tested in previous experimental studies, reviewed shortly below. Lindau (1979) and Tiede (1996) in particular have shown that the position of the tongue-root is part of the expansion of the pharynx in the production of Class I vowels, giving them a larger pharyngeal volume than Class II vowels. With these studies focusing on the articulatory property distinguishing vowels in the two classes, Hypothesis (b) remains largely uninvestigated. The results of these studies contribute little, if any-thing, to our understanding of whether languages with different dominant tongue-root features have different tongue-root positions for vowels in either class. They do not give any indication whether the position of the tongue-root for vowels in either class depends on what the dominant tongue-root feature is. This question addressed in the present study, with a focus on Dagbani, a language with a phonologically active Class I feature.

Unlike other languages with [ATR] distinctions, in the Dagbani vowel system, Class I vowels surface both within and outside of harmonic domains, as discussed in Chapter 2. In the rest of this chapter, I refer to Class I vowels that surface as a result of [+ATR] harmony as harmonic Class I vowels. Vowels that surface as Class outside of harmonic contexts are referred to as non-harmonic Class I vowels. Hypothesis (a) addresses two fundamental questions on Dagbani [ATR] feature specifications. The first question addressed is whether tongue-root position defines the distinction between Class II vowels and non-harmonic Class I vowels; the second examines whether tongue-root position defines the distinction between Class II vowels and harmonic Class I vowels. The second question also determines whether the emergence of harmonic Class I vowels is phonological or merely co-articulatory. If the emergence of harmonic Class I variants is a phonological process, these vowels are expected to have the same tongue-root position as non-harmonic Class I vowels. If tongue-root advancement observed in harmonic contexts is a result of phonetic interpolation, harmonic Class I vowels may be significantly and consistently less advanced than non-harmonic ones. These questions are elaborated further in Section 6.1.3.

The rest of the chapter is organised as follows. In the next section, theoretical issues in ATR harmony, with a focus on articulatory studies and their predictions, are reviewed. Section 6.1.2 presents a brief sketch of aspects of the Dagbani vowel harmony that bear on the questions investigated in this study, while section 6.1.3 elaborates on the hypotheses tested in this study. The general methodology and procedure used in all the experiments are presented in section 6.2. Sections 6.3 to 6.7 report and discuss five experiments that test these hypotheses, while section 6.8 concludes the chapter.

6.1.1 Articulatory correlates of lingual harmony

Much of what is known on lingual vowel harmony in African languages comes from studies that do not have access to instrumental data. In many of these studies, the term advanced tongue-root (ATR), proposed by Stewart (1967), is often used as a phonological feature with little insight into the detailed phonetic properties of vowel pairs that are distinguished by this feature. [ATR] is assumed to distinguish vowel pairs such as i/ɪ, u/ʊ, e/ɛ, and o/ɔ. This assumption carries with it two possible implications. One implication is that the vowels in each pair have identical features except the feature that correlates with the position of the tongue-root, which is also the feature that spreads in tongue-root harmony. Alternatively, the term [ATR] could imply that vowels in each pair may differ in more than one feature including the feature that is phonetically realised as different tongue-root positions.

However, in tongue-root harmony, only the feature [ATR] spreads from one vowel to the other. Cross-height [ATR] harmony studies of Gur languages such as Kasem (Awedoba 2002); Deg (Crouch & Herbert 2003); Koromfe (Rennison 1997); Kɔnni (Cahill 1992); Buli (Akanlig-Pare 1994); Safaliba (Schaefer & Schaefer 2003); Dagbani (Dakubu 1997; Olawsky 1999), and many other studies on Niger Congo languages are often not explicit on the exact details of their assumptions.

For studies that have used instrumental data, investigation of the phonetic realisation of the feature [ATR] can be divided broadly into two categories. First, there are studies (e.g. Parkinson 1996; Tiede 1996; Gick et al. 2006) that adopt an articulatory view, arguing that vowels that show a phonological [ATR] feature have a unique tongue-root gesture or pharyngeal cavity volume. This view is supported by results of X-ray, MRI and ultrasound studies, discussed further shortly. Alternatively, Hyman (1988) and Salting (1998) argue for indirect mapping between an abstract phonological feature [ATR] and the articulatory gestures displayed by vowels with the feature. Hyman's view is based on instrumental study of Ateso, an Eastern Nilotic language, (Lindau 1975; Lindau & Ladefoged 1986), results of which show that the main articulatory difference between Class I and Class II vowels is tongue height adjustment rather than tongue-root position. In spite of this articulatory difference, vowels in these two classes in Ateso seem to show a harmony pattern that is comparable to other ATR systems in Nilotic.

This view does not question the need for phonetic investigation into tongue-root harmony. On the contrary, apparent exceptions such as Ateso question the accuracy of the use of the term ATR to describe all languages whose lingual harmony patterns have been claimed to be based on tongue-root articulation. In languages that show active tongue-root involvement, the use of the feature [ATR] has not always been shown to be accurate, especially in studies that claim a universally dominant [+ATR] feature (see for instance Hulst & Weijer 1995; Polgárdi 1998; Baković 2000). To be sure, tongue-root advancement has been claimed to be dominant in probably the overwhelming majority of Niger-Congo and Nilo-Saharan languages. Examples include the Gur languages already cited in the first paragraph of this section. Others include Akan (Kwa) (Stewart 1967; Clements 1981; Dolphyne 1988), Didinga (Surma) (Odden 1983), Kinande (Bantu) (Mutaka 1995), Lugbara (Central Sudanic) (Anderson 1986), Alur (Nilotic) (Kutsch Lojenga 1986), Mayogo (Ubangi) (McCord 1989), Komo (Bantu) (Thomas 1992), Akposso (Kwa) (Anderson 1999), Nawuri (Kwa) (Casali 2002), and Lango (Nilotic) (Woock & Noonan 1979, Archangeli & Pulleyblank 1994). (For an extensive survey of [ATR] harmony systems in African languages, see Casali 2003, 2008).

However, studies on Yoruba and Wolof (Archangeli & Pulleyblank 1989, 1994; Pulleyblank & Turkel 1996; Pulleyblank 1996), Ogori (Salting 1998) and many Bantu languages (Leitch 1996), show that these languages have a dominant [-ATR]/[RTR] feature (see Archangeli & Pulleyblank, 1994, for a more extensive discussion). Li (1996) has also argued that the dominant tongue-root feature in the canonical vowel harmony pattern of Tungusic is

[RTR], while Noske (2000) shows that both [ATR] and [RTR] are active in Turkana. Casali (2003, 2008) also argues that the dominant tongue-root feature of a language fundamentally depends on the structure of its vowel inventory. He argues, based on the results of a survey of many Niger-Congo and Nilo Saharan languages, that [+ATR] is dominant in languages that show [ATR] contrast among high vowels while [-ATR]/[RTR] is dominant in languages with [ATR] contrast restricted to non-high vowels.

A number of experimental studies on the articulatory properties of the tongue-root have been done since Stewart (1967), the first to propose [ATR] as the feature that distinguishes Akan vowels that belong to the two harmony sets. These include X-ray studies of Igbo (Ladefoged 1968) and Akan (Lindau 1979). Both studies reported tongue-root position as an articulatory property distinguishing vowels in the two classes, Class I vowels having a more anterior tongue-root position than Class II vowels. Lindau (1979) further shows that tongue root position combines with other articulatory properties such as larynx height to produce the effect observed in Akan. Her study shows that in addition to having a more anterior tongue-root position, Class I vowels are produced with a more lowered larynx, while Class II vowels lack both articulatory gestures. Lindau thus suggests that the relevant distinction lies in the pharyngeal volume, for which she uses the feature [expanded] as an alternative to [ATR].

In his discussion of Lindau's study, Tiede (1996) notes that a cineradiographic study only measures pharyngeal volume in the sagittal dimension of the pharynx, it does not provides a measure of the lateral dimension. Considering that pharyngeal expansion can also be achieved by the lateral dimension, Tiede investigates, in a magnetic resonance imaging study, whether Akan vowels in the two classes also differ in the lateral dimension. Results of his study show that compared to Class II vowels, Akan Class I vowels have larger tongue-root advancement and lower larynx height than in the sagittal dimension, and larger pharyngeal airspace in the lateral dimension. Tiede further observes that the difference in lateral width is almost as large as that of the sagittal depth, which suggests that control in both dimensions are equally important in producing vowel contrasts in Akan. But as Tiede notes, MRI studies involve a number of drawbacks. Among them, a major problem is having subjects sustain the gesture for vowels for a duration many times their duration in actual speech.

The present study uses ultrasound imaging to investigate the articulatory properties of vowels in the two classes. Although ultrasound imaging does not measure pharyngeal volume, it is the least invasive and safest alternative to MRI and X-ray. Ultrasound has been used in many recent studies to obtain images of the tongue shape for lingual measures of the tongue-root and the entire mid-sagittal region of the tongue. Recent ultrasound studies of phonological processes related to the tongue-root include Whalen & Gick (2001), Namdaran (2006), Gick et al. (2006), Miller et al. (2007), Miller (2008), Miller et al. (2009), Hudu (2008b) and Hudu et al. (2009). Whalen & Gick (2001) found that both tongue-root position and tongue body height interact with intrinsic fundamental frequency effects in the ATR systems of both Igbo and Kinande, spoken respectively in Nigeria and the Democratic Republic of Congo. Gick et al. (2006) observed a systematic variation in tongue root position across vowels in Kinande, with tongue-root position for vowels in Class I significantly more anterior than their variants in Class II. Similarly, results of Namdaran (2006) show that in St'át'imcets, a Salish language spoken in British Columbia, Canada, high vowels adjacent to retracted consonants are produced with the tongue body moving towards the rear pharyngeal wall. Hudu (2008b) shows the same articulatory results for St'át'imcets low vowel [a] when it occurs adjacent to a retracted consonant.

In separate studies of the Khoisan languages Khoekhoe and N|uu, Miller et al. (2007) and Miller et al. (2009) have also shown, using ultrasound imaging, that alveolar clicks have a uvular posterior constriction, and they involve a tongue-root retraction gesture. Palatal clicks were found not to involve a tongue-root gesture. The fact that different click types have different tongue-root properties could be linked to their phonological behaviour. Phonologically, the palatal clicks pattern with dental clicks, plain coronal and velar consonants. Results of an ultrasound study of Dagbani labial velar stops and their labial coronal variants (Hudu et al. 2009) show a fronted lingual constriction in the labial coronal [tp] variant. At the end of its closure, the tongue-root position for [tp] is same as the neutral tongue-root rest position. This suggests an inactive tongue-root advancement for the labial coronal, compared to the labial velar, which has tongue-root and tongue-dorsum position farther back from the neutral position. The results, Hudu et al. (2009) note, suggest that tongue-dorsum and tongue-root retraction may be active in the phonology of labial velars, just as advancement is an active feature for vowels in the language (more detailed discussion in Hudu et al. 2009).

A gap remains in the ultrasound studies of the languages that display ATR harmony: Hypothesis (b) remains largely uninvestigated. The only study that has tested whether phonological dominance is reflected articulatorily is Namdaran (2006), which tests the articulatory correlate of consonant and vowel retraction in St'átimcets, a language that does not display tongue-root harmony between vowels. There has so far been no such study on a language with a dominant [ATR] or [RTR] feature in a vowel harmony system.[28] Thus the prediction that [+ATR] vowels are produced with a more anterior tongue-root than [-ATR] vowels remains the same regardless of whether a language has [ATR] or [RTR] as the dominant feature. This is discussed further in Section 6.1.3 below. Section 6.1.2 discusses other core issues in the vowel harmony of Dagbani that are tested in this study.

6.1.2 Dagbani vowel harmony

It is shown in chapters 2, 4 and 5 that [+ATR] is the dominant harmonic feature and that with the exception of /i/, all [+ATR] vowels are derived in the phonology. For the purpose of the experiments in this chapter, it is important to note that in the Dagbani vowel harmony system, there are two

[28] Although see Hudu et al. (2009) for partial results of the present study.

degrees of assimilation. The first results in complete assimilation between the trigger and target. This emerges in two harmonic contexts: (i) when /i/-triggered harmony targets the central vowel [ɨ], and (ii) when both trigger and target are mid vowels that already agree in rounding.

The data in (6.1) illustrate how an /i/ trigger and /ɨ/ target produce an output with two high front Class I vowels. In all forms in (6.1), target vowels occur to the right of the trigger in a suffix or clitic while the trigger is a lexical root vowel. In addition to changing from [-ATR] to [+ATR], the [ɨ] target also becomes a front vowel, acquiring the feature [COR]. The target vowels of interest are shown in bold font.

(6.1) [ɨ] as the target of ATR harmony

	[-ATR] roots		Root-to-affix [+ATR] harmony	
a.	bɨ́n-ɨ̂	‘a thing’	pín-**î**	‘a gift’
b.	tʊ̀ʔ-ɨ̀	‘join’	díʔ-**í**	‘a mirror’
c.	dɔ́lɨ́-bʊ̂	‘following’	dí-h**í**-bû	‘feeding’
d.	kpáb-ɨ́	‘carry on the back’	kpìb-**î**	‘lice’
e.	bɔ́hɨ́ tɨ́	‘ask us’	lìh**ì** t**í**	‘look at us’
f.	o dà mɨ̂	‘he bought’	o mì m**î**	‘he knows’

With a Class II root vowel, the suffix vowel is a Class II [ɨ], as shown in the forms on the left column in (6.1). In the right column, suffix or clitic [ɨ] becomes [i] in a harmony triggered by the root [i]. The second context is shown in (6.2), with a trigger and target that are both mid vowels, the final vowel being the trigger of [+ATR].

(6.2) Mid and high vowel target

	[-ATR] roots		Affix-to-root [+ATR] harmony	
a.	mɔ́l-ɨ̂	'announce'	mòl-ô	'an announcement'
b.	dɔ́r-tɨ́	'diseases'	dór-ó	'a disease'
c.	bɛ́-hɨ̂	'shins'	bé-ê	'a shin'
d.	dɛ́m-bʊ̂	'playing'	déd-é	'exact'

With complete assimilation, there is hardly any doubt that the assimilation in (6.2) is categorical. However, it is not obvious if [ATR] is the harmonic feature that results in the complete assimilation, given that more than one featural change potentially takes place in the target. In all cases, the harmonic feature could be a height feature [high] or [low]. In (6.1), it could be the feature [coronal].

The second degree of harmony involves mid vowel triggers and low vowel targets, as shown in (6.3). The variant of the low vowel that emerges in this position is represented as [ə]. Unlike other vowel pairs in the two classes, this variant is only seen when the low vowel precedes a domain-final mid vowel, as the data in (6.3) show.

(6.3) Mid vowel trigger, low vowel target

a.	kál-tɨ́	'doors'	kə́l-ó	'a door'
b.	pál-lɨ́	'a new one'	pəl-ó	'a new one (animate).'
c.	tàdáb-tɨ̂	'writing inks'	tədə́b-ô	'a writing ink'
d.	tàtáb-tɨ̂	'look-alike-pl.'	tətə́b-ô	'a look-alike'
e.	gár-tɨ́	'beds'	gə́r-ó	'a bed'

Impressionistically, /a/ is raised before a domain-final mid vowel. However, it is not obvious exactly what feature of the low vowel changes in this context. The perceived raising suggests that the featural change that takes place is based on height. However, different changes in tongue-root position could produce the same effect. An acoustically advanced variant of [a] should be perceptually and acoustically higher than a non-advanced one. In addition to the question whether the harmonic feature is tongue-root advancement, as opposed to tongue-body height, there is the more fundamental question whether the featural change is phonological or mere phonetic interpolation.[29] The present study investigates both harmony types. Section 6.1.3 presents the hypotheses that are tested.

[29]This claim is not accurate for all speakers in all contexts. During the recording, participant IZD pronounced the word /gár-ó/ as [gór-ó], with complete assimilation of the low vowel to the final mid vowel. His [+ATR] [a] is 8.53mm more advanced than the [-ATR] variant, the greatest difference in mean value between any vowel pair for any of the participants tested (see Experiments 1 and 2, and Table 6.3 for a summary). However, the same speaker does not have a complete assimilation of any of the low vowels in */tàdáb-ó/* 'writing ink'. It seems that the preceding velar place of articulation in /gár-ó/ may have contributed to the complete assimilation.

6.1.3 Hypotheses

6.1.3.1 Hypothesis A

As already noted, given the patterns of distribution of [+ATR] vowels, Hypothesis A has two sub-hypotheses:

1. tongue-root position is the main distinction between Class II vowels and non-harmonic Class I vowels, (the Non-harmonic [ATR] Hypothesis), and

2. tongue-root position is the main distinction between Class II vowels and harmonic Class I vowels (the Harmonic [ATR] Hypothesis).

The Non-harmonic [ATR] Hypothesis predicts that (i) each non-harmonic [+ATR] vowel is produced with a tongue-root position that is anterior, compared to its [-ATR] variant, and (ii) that this difference is greater than any other articulatory differences such as tongue-body height. A significant difference in both tongue-root and tongue-body positions is not ruled out regardless of whether the feature distinguishing vowels in the two classes is [ATR] or a height feature. This is because being a muscular hydrostat, (with a fixed incompressible volume), (Kier & Smith 1985) any change in the shape or position of one part of tongue affects that of another (Stone & Lundberg 1996, Hironori 2001, Hiiemae & Palmer 2003 etc.). If the feature is [ATR], an anterior position of the tongue-root will cause an increase in tongue-body height. If it is a height feature, the acoustic or perceptual F1 decrease that characterises Class I vowels may results in both higher tongue-body and a more anterior tongue-root.

Thus in answering the question whether the active phonological feature is a height or a tongue-root feature, one of three possible outcomes is expected:

1. a difference in both tongue-root and tongue-body positions, with tongue-body difference dependent on tongue-root difference,

2. a difference in both tongue-root and tongue-body positions, with tongue-root difference dependent on tongue-body difference, and

3. a difference in both tongue-root and tongue-body positions, with neither dependent on the other.

The first outcome is predicted under Hypothesis A. Across all vowels for each speaker, the tongue-root positions are expected to show more significant and consistent differences compared to the tongue-body. The second and third outcomes are inconsistent with the hypothesis that [ATR] is the main feature distinguishing vowels in the two classes, with height being enhanced or dependent on tongue-root difference. The Non-harmonic [ATR] Hypothesis is tested in Experiment 1.

The Harmonic [ATR] Hypothesis also predicts (i) an anterior tongue-root position for harmonic [+ATR] vowels (those that surface through an assimilatory process) and (ii) a difference in tongue-root positions that is greater than any other articulatory differences such as tongue-body height. The Harmonic [ATR] Hypothesis is tested in Experiment 2.

To determine whether the level of assimilation observed in harmonic contexts is phonological, two subtests will be done. In the first subtest, results of Experiment 2 will be compared to those of Experiment 1 statistically to determine if the level of assimilation in harmonic contexts is neutralising. If the level of assimilation leads to a phonological neutralisation between underlying [-ATR] targets and surface [+ATR] triggers, we expect little or no difference between the tongue-root position of harmonic Class I vowels and Class I vowels that occur in non-harmonic contexts. If the assimilation is merely co-articulatory, the tongue-root position is expected to be less anterior for putatively [+ATR] vowels in harmonic contexts than non-harmonic [+ATR] vowels. This is tested in Experiment 3.

The second subtest investigates whether the level of assimilation is affected by distance. Following an approach used in Gick et al. (2006), it complements the mainly CV.CV cases that are investigated in the previous tests to determine if the vowel of the first syllable in a CV.CV.CV word with a final harmonic trigger shows the same level of assimilation as the vowel of the second syllable. A lack of distance effect will strengthen the conclusion that the assimilatory pattern observed in Dagbani is an instance of vowel harmony. This is tested in Experiment 4.

6.1.3.2 Hypothesis B

Hypothesis B says that in a language with a lingual harmony (e.g. [+ATR], [-ATR], [High]) there is a direct mapping between the phonologically active tongue-root harmonic feature and the position of the tongue-root. In other words, the dominant harmonic feature of a language with lingual harmony has a unique articulatory correlate independent of the recessive feature.

It is established from a large volume of research, including Honikman (1964), Laver (1978), Jenner (2001), Gick et al. (2004), and Wilson (2006) that there is an underlying or default position for articulators specific to every language. In Gick et al. (2004) and Wilson (2006), this default position has been linked to the speech rest position or inter-speech posture (ISP), the motionless position of the articulators during inter-utterance pauses. In this study, the ISP of the tongue-root is assumed to be the neutral position from where measures of the advanced and retracted positions of the tongue-root are made.

Hypothesis B predicts that for a language in which the tongue-root position distinguishes vowels in the two classes, the dominant phonological harmonic feature has a distinct articulatory position compared to a neutral position of the tongue-root. Assuming that α is the ISP of the tongue-root, β is tongue-root position for [+ATR] vowels, and γ is its position for [-ATR] vowels; the hypothesis makes three predictions on the tongue-root position for vowels of different values of [ATR] in three language types:

1. For a language Type A, with a dominant [+ATR] feature (e.g. Dagbani and Kinande), β is predicted to be significantly and consistently anterior to α, while γ conforms more closely to α. In other words, while the tongue-root position for advanced vowels is predicted to be

well anterior to that of the neutral position, that of retracted vowels may be the same as the neutral position, or show a difference that is insignificant and negligible.

2. For a language Type B, with [+RTR] as the dominant feature (e.g. Yoruba and Tungusic) γ is predicted to be significantly and consistently posterior to α, while β will conform closely to α.

3. For a language Type C, with both active [+ATR] and [-ATR] (e.g. Turkana), a significantly anterior position for β compared to α and posterior position for γ compared to α are predicted. The difference between α and β is not expected to be any greater than that between α and γ.

A common prediction for language types A and B is that a recessive feature, being phonologically inactive, is generally not expected to correspond to a distinct tongue-root position. For language Type A, [-ATR] vowels could have the same tongue-root position as the ISP; they could be anterior or posterior to the ISP. For language Type B, [-RTR] vowels could have a tongue-root position that is posterior or anterior to the ISP, or one that is not different from the neutral position.[30] What is important in all cases is

[30] It is possible that distinct gestures may be assigned to the opposite values of [ATR] and [RTR] in order to enhance the contrast between them. Such contrast enhancement could result in a consistently posterior tongue-root position for [-ATR] vowels in a language Type A or anterior position for [-RTR] vowels in a language Type B. A language (Type A or B) with such enhancement may not be different articulatorily from the predictions for language Type C, in which both tongue-root advancement and retraction are phonologically active.

that a dominant feature displays a tongue-root position that is consistently and significantly different from the neutral position.

On the contrary, if there is no correlation between the dominant harmonic feature of a language and the articulatory position of the tongue-root, and assuming that there are indeed different tongue-root positions for vowels in the two classes as found in previous studies (and tested in Hypothesis A), both β and γ could maintain a position posterior to α for a language Type A or anterior (to α) for language Type B. Either result will also be inconsistent with the prediction for a language type C. The present study only tests language Type A, using Dagbani. The test is shown in Experiment 5.

In the next section, the general methodology used for all experiments is shown.

6.2 General methodology

6.2.1 Participants

Five adult native speakers participated in the study. All participants grew up in Tamale, Ghana, and speak the Western Dialect. Having speakers of only one dialect as participants was not a deliberate decision. They happened to be the only speakers within reach in Canada to participate in the study. At the time of the experiments, participants resided in the Canadian provinces of Ontario or British Columbia. Participant AIM was recorded in a quiet private home in Mississauga, Ontario, IZD was recorded in the phonetics laboratory of the University of Victoria, while the remaining three participants (AAB, AB, and HS) were recorded in their private homes in Ottawa.

Initially, 8 participants were recorded in the cities of Mississauga and Toronto. The stimuli for this recording included the consonants [ɾ, s, l] between a [+ATR] root trigger and a suffix vowel target. The opacity of these consonants to the spread of [+ATR] was discovered during these recordings, as the spread of [+ATR] from a root [i] to a suffix vowel with any of these consonants as onset was consistently blocked. Due to time limitations, the recordings of the remaining participants are not included in the present study.

6.2.2 Procedure

The recordings in Mississauga and Victoria were done using a GE Logiqbook E portable ultrasound machine with an 8C-RS 5-8 MHz transducer. In Ottawa, a Sonosite Titan High-resolution portable ultrasound machine with a C11/8-5 MHz transducer was used because at the time of recordings the GE Logiqbook ultrasound machine was not available. All recordings were done at a standard rate of 29.97 frames per second (about 33 Hz).

The ultrasound transducer was set under the chin to image the entire mid sagittal region, from the tongue-tip to the tongue-root. Water-soluble ultrasound gel was applied to the head of the transducer and participants were also asked to drink water before the start of the recording session. Both measures were meant to enhance the clarity of the ultrasound image. To maintain its stability, the transducer was held by an adjustable microphone boom mounted on top of a table in front of the speaker. Real time ultrasound video was transmitted using an SVGA cable and recorded directly onto a Dell laptop computer using Adobe Premier Pro, via a Canopus audio-video mixer connected to the computer. Audio recording was done simultaneously using a head-mounted microphone connected to the Canopus via a Shure dual microphone pre-amplifier.

Further measures were taken to ensure accuracy in the data collection process and avoid any measurement errors. Head movement was restricted using a chair with a back rest holding the participant's head from the upper part of the neck. Previous studies (e.g. Gick et al. 2005) have shown that a headrest is effective in controlling most head movement. To ensure further stability of the transducer, a clamp was used to fasten the microphone boom stand to the table. In Mississauga, and Ottawa, where there was no standard laboratory chair that could restrain head movement, a back rest was constructed using a wooden board placed vertically on top of a chair's seat and fastened to its original backrest with a rope. An adjustable head rest was attached to the back rest to restrain head movement. The set-ups are shown in Figure 6.1. The recordings were visually monitored. If the transducer or participant's head was observed to have moved, the affected portion was re-recorded.

Target vowels were located in roots mainly with an onset /t/ or /d/, and embedded in the carrier phrase shown in (6.4). [+ATR] vowels occurred in CV roots, [-ATR] vowels in CVC roots. The difference in syllable structure for vowels in the two classes was needed to achieve the right context in which differences between some [±ATR] pairs are robust (See Chapter 2.).

(6.4) Carrier phrase

bɔ̀lɨ̀-mɨ̀	_ _	*tɨ́*	*má*
say-imperative	_ _	give	1sg.object

‘say _ _ for me’

The stimuli for the first two experiments (see below) were mixed in a random order to ensure that they served as distractors to each other. Additional distractor words were added. In Mississauga, both the stimuli and their translations in English were presented to facilitate their production of the words and phrases. Prior to the start of the recording, the stimuli were shown to the participant along with the English translation to ensure that he was comfortable with each word, its spelling and translation. He was given the option of changing the spelling or translation to one that he would be more comfortable with. This was necessary because there is no standard orthography for Dagbani acceptable to all speakers.

In Victoria and Ottawa, only the English translations of the stimuli were presented to participants, and participants were asked to embed the Dagbani translation in the carrier phrase. This was found to be more effective in ensuring a more natural pronunciation of the words without influence from the orthography. As in Mississauga, prior discussion was done with the participants to ensure that they were comfortable with the English translation

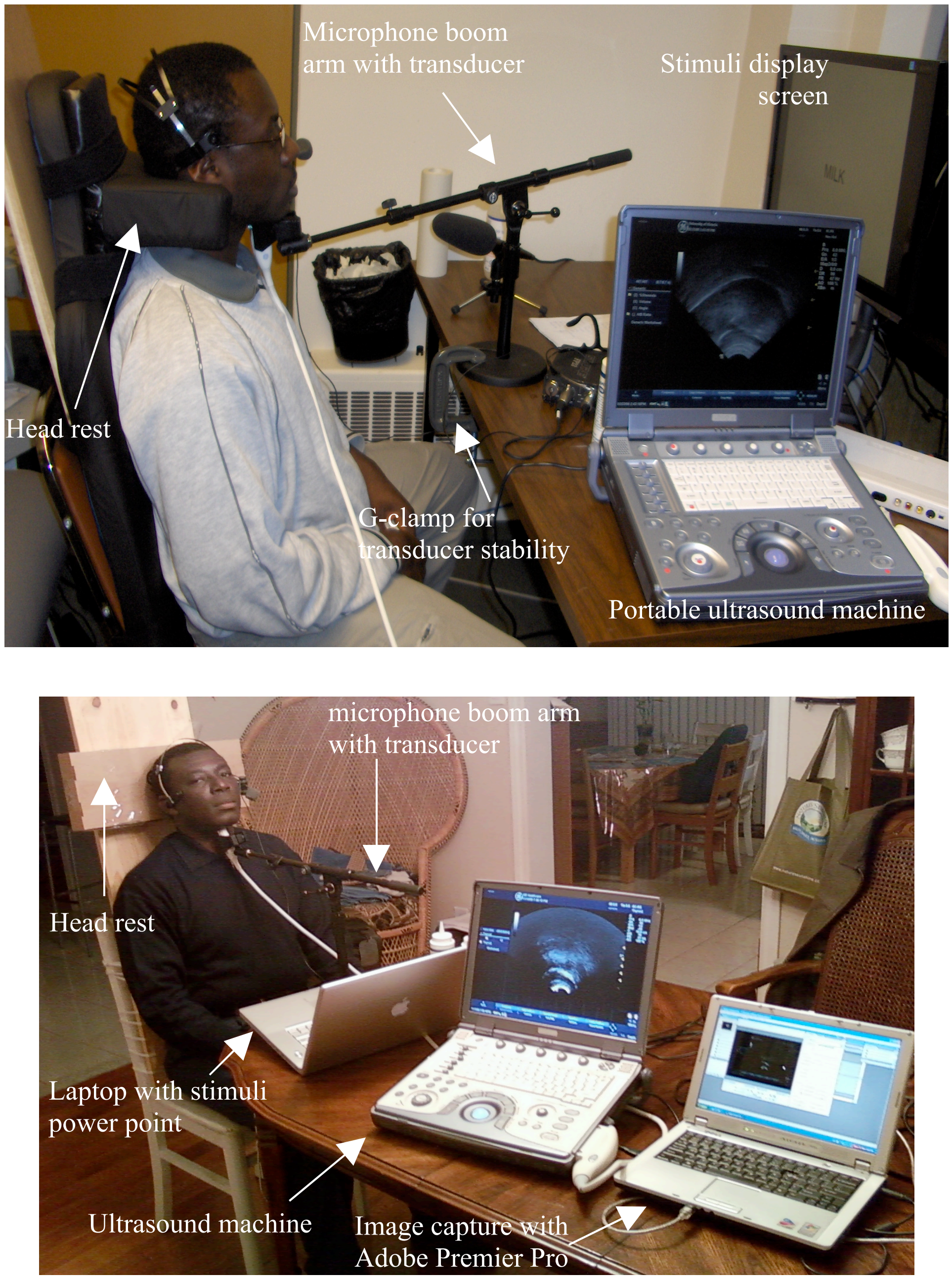


Figure 6.1: Experiment set up in Victoria (top) and Ontario (bottom)

of each word. In all recordings, each word was shown in a Microsoft Power Point slide in the middle of a screen directly facing the participant (see figure 6.1). Target vowels were repeated in 5 blocks with 4 or 5 repetitions in each block, producing a maximum of 25 tokens of each vowel. The same maximum number of tokens (25) was randomly extracted for [ɨ] and the ISP, each of which had as many repetitions as the combined sum of all vowel tokens. The actual number of tokens for some of the vowels were much lower for some subjects because some frames were discarded for not showing a clear image of the tongue. In some cases, (e.g. for participant IZD) entire blocks were discarded, leaving just enough to be statistically significant.

A practice run was done for participants to familiarise themselves with the experiment, data from which were discarded. Target vowel frames were extracted and measured for each test (see below regarding measurements for each test). The next three sections elaborate on the procedure specific to each experiment.

6.3 Experiment 1: Testing the Non-harmonic [ATR] Hypothesis

6.3.1 Introduction

This experiment tests the hypothesis that vowels in the two classes have different tongue-root positions. The stimuli for this experiment are shown in

(6.5). Notice that the low vowel pair [a/ə] are not part of the stimuli for this experiment because [ə] is derived only in harmonic context. The [+ATR] vowels tested in this experiment are those that surface in non-harmonic contexts. Tone markings show the actual tones that vowels bear when embedded in the carrier phrase, which may be different from their tone in isolation.

(6.5) Stimuli for advanced and retracted vowels

	Advanced vowels		Retracted vowels	
a.	tí	'vomit'	tɪ́ má	'for me
b.	tú	'insult'	tʊ́m	'work'
c.	tó	'bitter'	tɔ́m	'bitterness'
d.	té	'filter'	dɛ́m	'play'

The data in (6.5) show the exact stimuli used for the recording in Victoria and Ottawa. In Mississauga, where the first recording took place, the [-ATR] vowels [ʊ, ɔ, ɛ] appeared in the words *tʊ́l-lɪ́* 'hot-sg.', *tɔ́-lɪ́* 'mortar-sg.', and *tɛ́lɪ̂* 'to flood'. These words were replaced in the stimuli of the remaining four participants in order to stay clear of [l], which is opaque to the spread of [+ATR] (see analysis in Chapters 3 and 5), even though it was later found to not affect the tongue-root position of adjacent [-ATR] vowels.

6.3.2 Methods

The mid-point frame for each vowel token was extracted from the video as a still image. All measurements were done using ImageJ (Rasband 1997) (http://rsb.info.nih.gov/ij/), a software that measures images in pixels. The figures were then converted from pixels to millimetres at a ratio of 1 pixel = 0.265 millimetres. To obtain values for the various test conditions for each vowel, the mid point of the transducer arc was used as the base point for measuring various positions in the midsagittal arc. This was determined using the x and y co-ordinates in ImageJ. From this point, a straight measurement line was drawn to the tongue-root position at a specified angle for each vowel pair. For tongue-root measures, the lowest angle at which the tongue-root was visible for all tokens of a vowel pair was used. The lowest point in the tongue-root would have been a more ideal measurement point, especially for advanced vowels, which have a lower tongue-root. However, this point was not taken because many of the ultrasound frames have a shadow of the hyoid bone which obscures the image of the lowest point of the tongue-root. Using an arbitrary lowest point for each frame would mean taking a measure of the tongue-root at entirely different angles. The best alternative was to assume a consistent angle across each [ATR] pair for each participant.

The same procedure was followed in obtaining measures of the tongue-body height. The only difference is that the height and place specifications of vowels were the main factors used in determining the measurement points. For IZD, for instance, the tongue-body height for ISP and the low vowels were

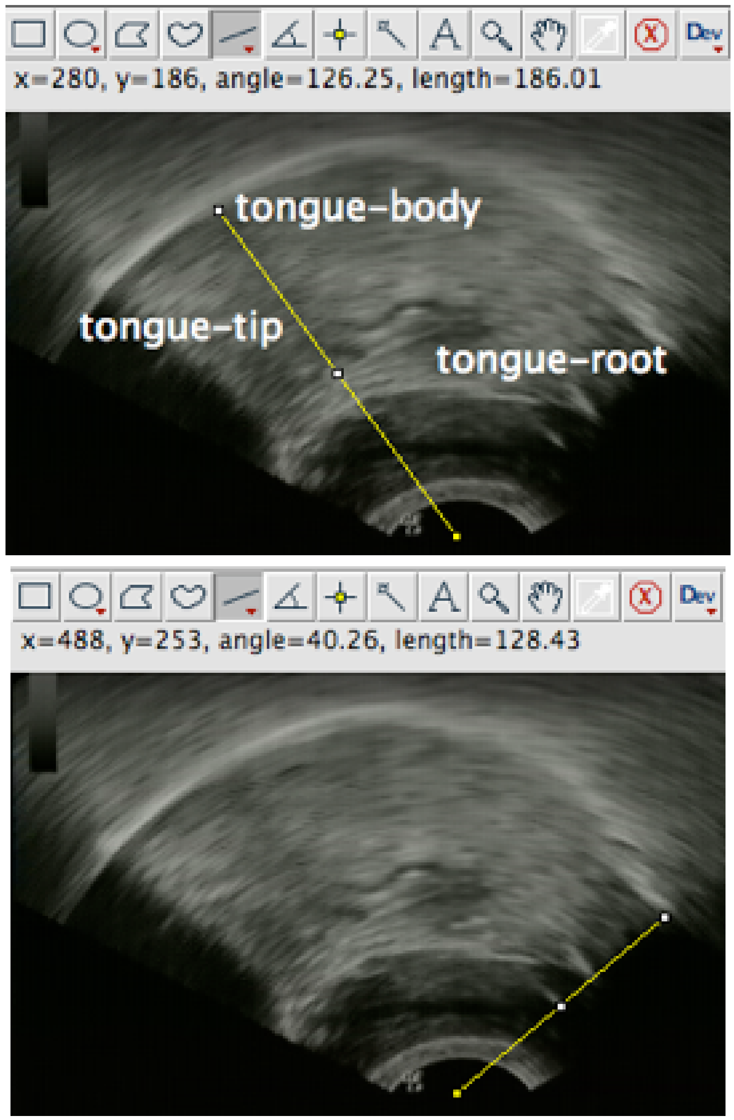


Figure 6.2: Sample frames showing measurements of the tongue-body(top) and tongue-root (bottom) positions in Image J for participant AIM

taken at about 113 degrees. The measurement angles were higher than the ISP for front vowels and lower than the ISP for back vowels (the measurement angle increases the closer the line is to the tongue-tip and decreases towards the tongue-root). Sample frames showing the measurements of the tongue-root and tongue-body positions for the ISP are shown in Figure 6.2. The frames show the neutral position of the tongue. The angle and length of the measurement lines can both be seen in the top part of each frame. Notice that the 'x' and 'y' co-ordinates change as the line is drawn.

In the results reported below, participant AIM, the first to be recorded, does not have a harmonic variant of the vowel /i/. This is because the target vowel, which occurred in the word *tíɾɨ́* 'vomit', was not a target of harmony due to the opacity of the onset /ɾ/. Also, no tongue-body measures are recorded for the three participants recorded in Ottawa because for all participants, the midsagittal image went out of the depth of the ultrasound at the highest point of articulation for some of the vowels. Thus tongue-body measures are available only for the two participants recorded with the Logiqbook ultrasound machine.

6.3.3 Results

The results of this experiment indicate that outside of harmonic contexts, the tongue-root position varies systematically across Dagbani vowels for all participants. Class I ([+ATR]) vowels exhibit a significantly more anterior tongue-root position than Class II ([-ATR]) vowels. By contrast, results for the two participants for whom tongue-body figures are available show that the tongue-body position of [+ATR] vowels is not consistently higher than that of [-ATR] vowels. For participant AIM, [i] is the only Class I vowel that has a higher tongue-body position than its [-ATR] variant. For each of the remaining three vowel pairs [u/ʊ, o/ɔ, e/ɛ], the Class II vowel has a higher tongue-body position than its Class I variant, contrary to what is predicted if different tongue-body positions were the main articulatory property distinguishing vowels in the two classes (see variability chart in Figure 6.7). For Participant IZD, the difference in tongue-body position for the back mid vowel pair [o] and [ɔ] is insignificant.

In Table 6.2, Student's t-tests comparing the individual vowel pairs for all participants are shown. In all comparisons, the tongue-root/body position of the first vowel/vowel class from the transducer is greater than that of the second by the value shown. Also in this and all other mean comparisons in this chapter, a significance level of .05 was used.

Difference in tongue-root position for vowels in the two classes was also compared to difference in tongue-body positions. While vowels in the two classes significantly differ in their tongue-root and tongue-body positions, results show that for AIM, Class I vowels are 5.28 mm more anterior than Class II vowels in tongue-root position. For the same speaker, Class I vowels are only 1.15 mm further from the transducer than Class II vowels in tongue-body height. For IZD, Class I vowels are 6.07 mm more anterior than Class II vowels in tongue-root position but 3.72 mm further from the transducer

Table 6.2: Mean differences (in mm) of TR and TB for all vowel pairs and participants. A shaded cell indicates no significant difference or a difference that is contrary to the prediction of the hypothesis.

Tongue root	Class II - Class I	[ɨ] / [i]	[ʊ] / [u]	[ɛ] / [e]	[ɔ] / [o]
AAB	5.14 p<.0001	5.99 p<.0001	5.37 p<.0001	5.29 p<.0001	4.25 p<.0001
AB	4.21 p<.0001	4.0 p<.0001	3.54 p<.0001	4.94 p<.0001	3.72 p<.0001
AIM	5.28 p<.0001	5.47 p<.0001	2.68 p<.0001	3.4 p<.0001	7.69 p<.0001
HS	3.32 p<.0001	5.55 p<.0001	1.87 p<.0001	1.72 p=.0003	3.30 p<.0001
IZD	6.07 p<.0001	8.32 p<.0001	6.83 p<.0001	5.35 p<.0001	2.82 p=.0002

Tongue body	Class I - Class II	[i] / [ɨ]	[u] / [ʊ]	[e] / [ɛ]	[o] / [ɔ]
AIM	1.15 P=.0073	5.52 p<.0001	-0.07 p=.8781	-1.28 p=.0019	-1.81 p=.0002
IZD	3.72 p<.0001	6.42 p<.0001	1.4 p=.262	5.13 p<.0001	0.07 p=.897

than Class II vowels in tongue-body height. The two comparisons are shown in Figure 6.3.

In the sections below, detailed results for each participant are shown. 2x4 ANOVAs were conducted to compare the two tongue-root feature values ([-ATR] and [+ATR]) across all four vowel pairs [i/ɨ, u/ʊ, e/ɛ, o/ɔ]; results of the [-ATR] vs. [+ATR] comparison are reported for each speaker.

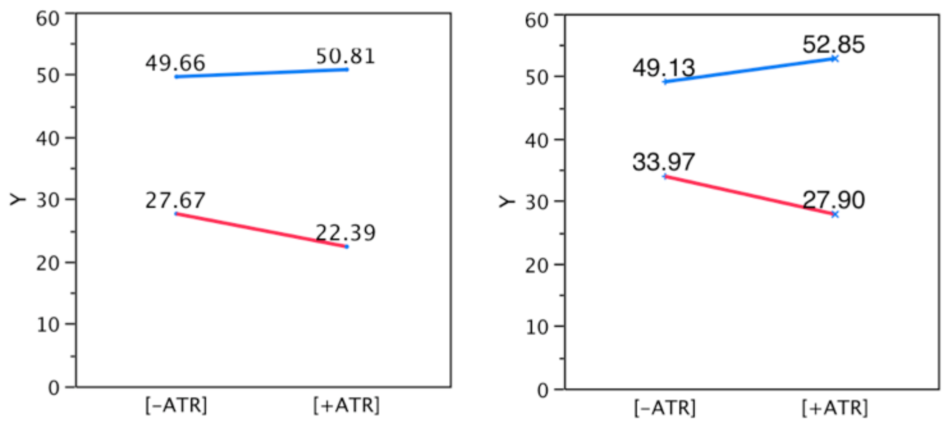


Figure 6.3: Mean comparisons of tongue-root and tongue-body differences for [-ATR] vowels and [+ATR] vowels for participants AIM (left) and IZD (right). The top line represents tongue-body measures, the bottom line represents tongue-root measures.

6.3.3.1 Participant AAB

A oneway analysis of tongue-root by [±ATR] for AAB shows that [+ATR] vowels are significantly different in tongue-root position from [-ATR]: (ANOVA: [$F(1, 182)=160.15$, $MSE=7.55$, $p<0.0001$]). The [+ATR] vowels are 5.14 mm more anterior than the [-ATR] vowels. A Student's t-test of individual pairs shows that each Class I vowel exhibits a significantly more anterior tongue-root position than its Class II variant, as shown in Figure 6.4.

In Figure 6.4 and all figures showing plots, horizontal lines in diamonds indicate mean values for each vowel, the vertical span of the diamond represents the 95 per cent confidence interval for the true mean for each vowel. The top and bottom dashes mark the highest and lowest range of distribution for each vowel. Lower values indicate greater degree of tongue-root advancement or lesser tongue-body height from transducer.

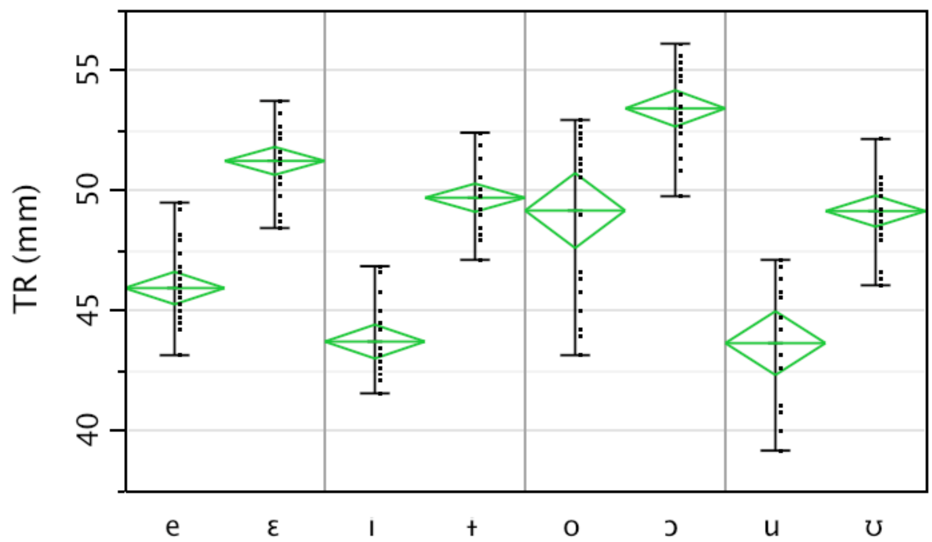


Figure 6.4: AAB: Tongue-root distance from transducer for Class II vowels and non-harmonic Class I vowels

6.3.3.2 Participant AB

Results of a oneway analysis of tongue-root by [±ATR] for participant AB also show a significant difference in tongue-root position between the two classes (ANOVA [F(1, 118)=178.41, MSE=2.97, p<0.0001]). Between individual pairs, a Student's t-test also shows significant differences in mean as the graph in Figure 6.5 and the mean differences in Table 6.2 show.

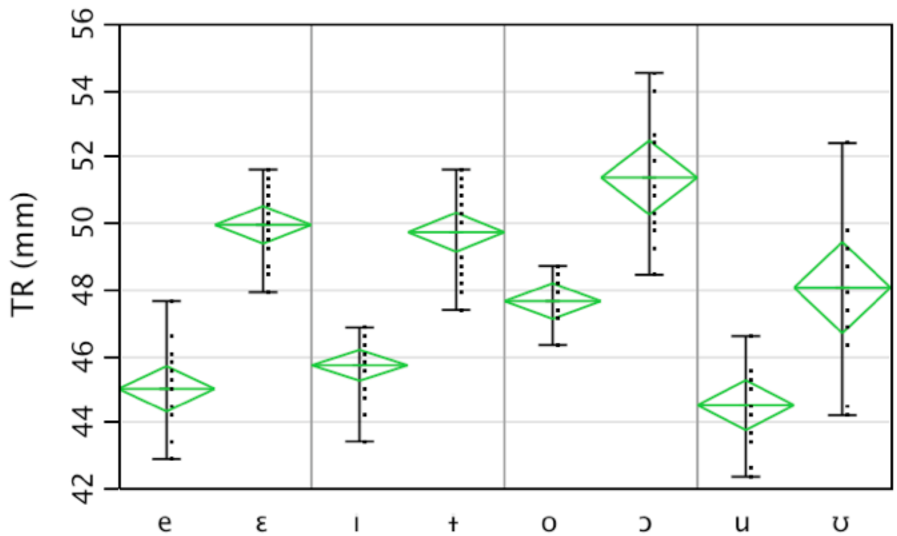


Figure 6.5: AB: Tongue-root distance from transducer for Class II vowels and non-harmonic Class I vowels

6.3.3.3 Participant AIM

For participant AIM, a oneway analysis of tongue-root by [±ATR] shows a significant difference between non-harmonic [+ATR] and [-ATR] vowels: (ANOVA: [F(1, 137)=114.36, MSE=8.47, p<0.0001]). [-ATR] vowels are 5.28 mm more anterior than [+ATR] vowels. A Student's t-test of the vowels in each pair also shows significant differences, as shown in Table 6.3 and the variability chart in Figure 6.6.

An analysis of tongue-body position by [±ATR] also shows a significant difference for this participant: (ANOVA: [F(1, 137)=7.43, MSE=6.24, p=0.0073]). The [+ATR] vowels are higher than the [-ATR] vowels by 1.15

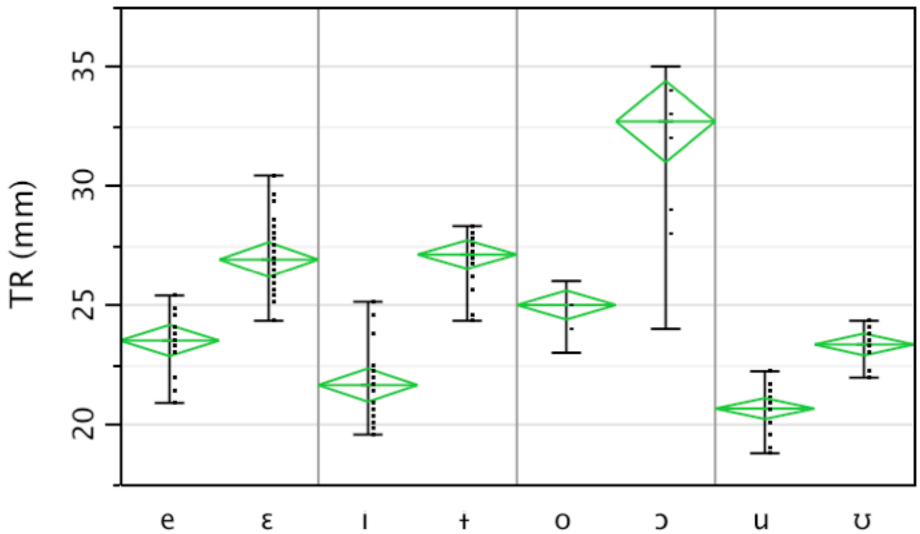


Figure 6.6: AIM: Tongue-root distance from transducer for Class II vowels and non-harmonic Class I vowels

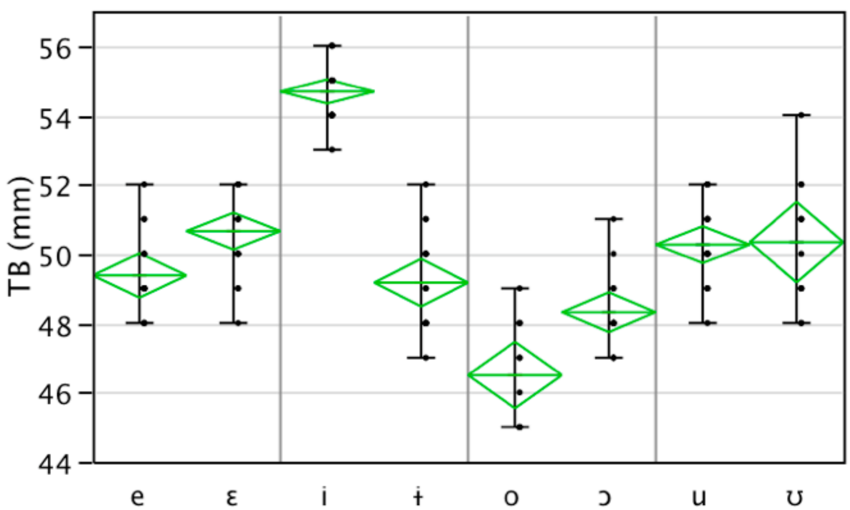


Figure 6.7: AIM: Tongue-body distance from transducer for Class II vowels and non-harmonic Class I vowels

mm. However, a Student's t-test of individual pairs shows that only [i] and [ɨ] are significantly different in the direction of the prediction, as shown in Table 6.2. The remaining pairs are either not significantly different or show significant difference opposite the direction of the prediction (i.e. the Class II variant is higher than Class I variant). Figure 6.7 also shows the results.

6.3.3.4 Participant HS

When the tongue-root positions of vowels in the two classes are compared, [+ATR] vowels show a significantly more anterior position than [-ATR] vowels: (ANOVA: [(1, 121)=94.33, MSE=3.56, p<0.0001]). Student's t-tests of the vowels in each pair also show significant differences between each [ATR] and [+ATR] variant, as Table 6.2 and Figure 6.8 show.

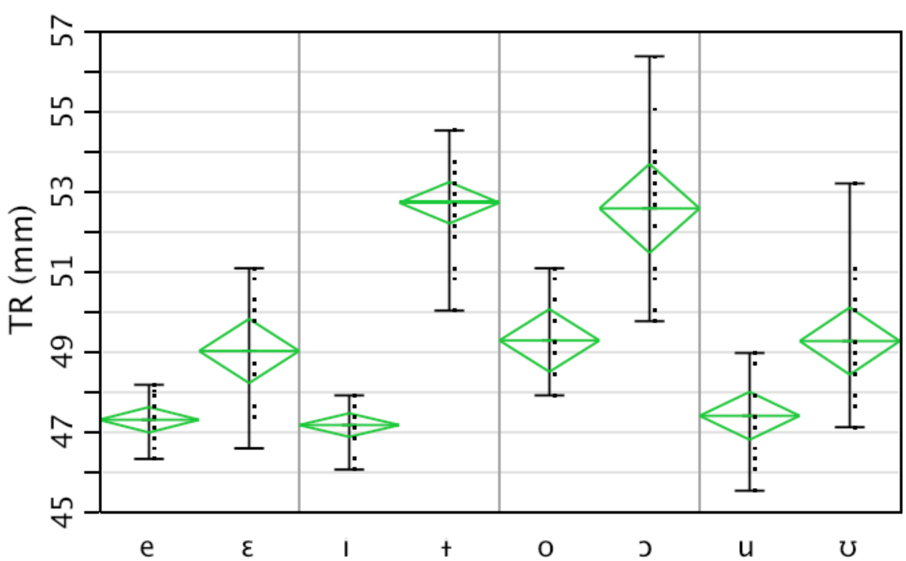


Figure 6.8: HS: Tongue-root distance from transducer for Class II vowels and non-harmonic Class I vowels

6.3.3.5 Participant IZD

Like the other participants, a oneway analysis of tongue-root by [± ATR] for IZD show significant differences between non-harmonic [+ATR] and [-ATR] vowels: (ANOVA: [(1, 141)=161.5, MSE=8.16, $p<0.0001$]). The results also show that tongue-body position for all Class I vowels is significantly different from that of Class II vowels: (ANOVA: [$F(1, 141)=55.14$, MSE=8.97, $p<0.0001$]).

A student's t-test comparing vowels in each pair also shows significant differences. Each Class I vowel exhibits a significantly more anterior tongue-root position than its Class II variant, as shown in Figure 6.9. For tongue-body position, significant differences are observed between all pairs except the back mid vowels [o, ɔ], as shown in Figure 6.10. A mean comparison between vowels in the two classes for both tongue-root and tongue-body measures was already shown in Figure 6.3.

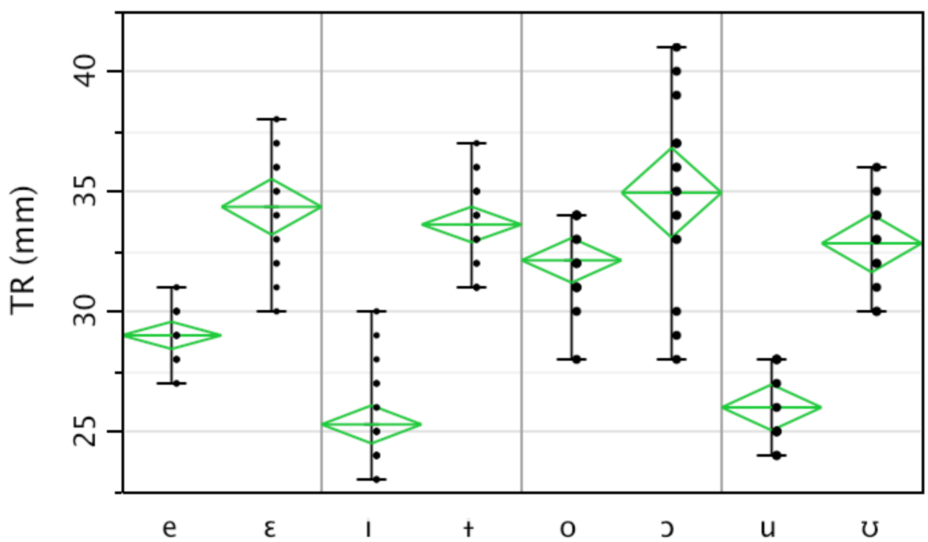


Figure 6.9: IZD: Tongue-root distance from transducer for Class II vowels and non-harmonic Class I vowels

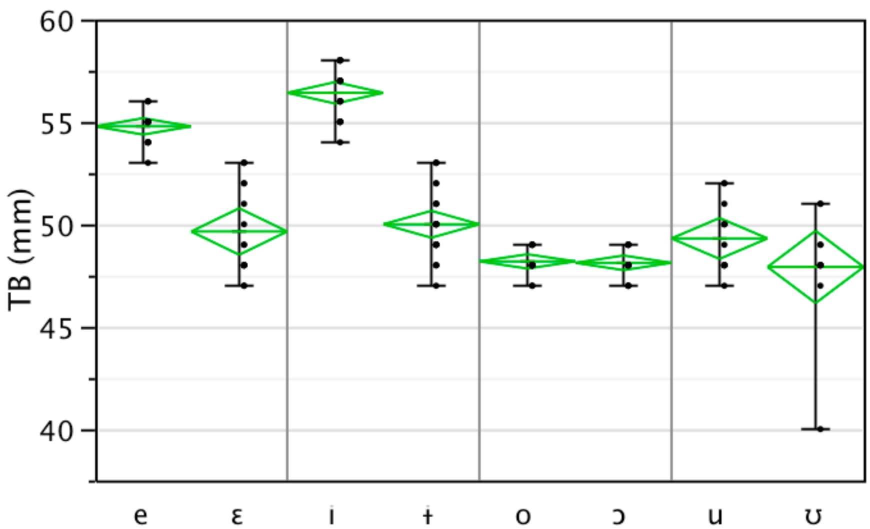


Figure 6.10: IZD: Tongue-body height distance from transducer for Class II vowels and non-harmonic Class I vowels

6.3.4 Discussion

The results of Experiment 1 are consistent with the hypothesis that vowel pairs within the two classes are indeed distinguished by a tongue-root feature. The differences between Class I and Class II vowels are very robust, with little or no overlap in most of the vowel pairs for many participants. This contrasts with the tongue-body measures for which there is no significant difference or a difference opposite the direction of the prediction for three of the four pairs for participant AIM, and one pair for participant IZD. The consistent difference in tongue-root position is consistent with the hypothesis that the tongue-root position is the main distinction between vowels in the two classes. It supports the analysis of these vowels using the feature [ATR].

6.4 Experiment 2: Testing the Harmonic [ATR] Hypothesis

6.4.1 Introduction

This experiment tests whether Class I vowels that emerge in [+ATR] domains differ from [-ATR] by the position of the tongue-root, as found for Class I vowels that emerge in non-harmonic contexts.

6.4.2 Methods

The methods for this experiment were the same as that of Experiment 1, except that the comparison was between Class II vowels and Class I vowels that emerge in harmonic contexts. This experiment thus includes measures of the low vowel pair, whose Class I variant only emerges in harmonic contexts. The stimuli are shown in (6.6). In (6.6g), the low vowel next to the final mid vowel in the word *tə́də́b-ó* is the only one used in this experiment. A comparison of the two target low vowels in that word is the subject of investigation in Experiment 4.

Since each vowel stimulus needs to occur in a word or phrase with at least 2 syllables, obtaining harmonic contexts with the same place feature for all consonants preceding and following the target vowel is not possible. In spite of the differences in place features, all surrounding consonants are either non-continuant coronal or bilabial, consonants that phonologically do not block the spread of [+ATR] harmony. In (6.6) the target vowels are shown in bold font. The remaining vowel in the harmonic domain is the trigger of the feature [+ATR].

(6.6) Stimuli for Advanced vowels in harmonic domains

UR ([-ATR])			**Surface [+ATR] harmony**	
a.	/ɨ/	/bíh-ɨ́/	[bíh-**í**]	'child-pl.'
c.	/ɛ/	/dɛ́dɛ́/	[d**é**dé]	'exact'
d.	/ʊ/	/tí-bʊ̂/	[tí-b**û**]	'giv-ing'
e.	/ɔ/	/dɔ́r-ɔ́/	[d**ó**r-ó]	'disease'
f.	/a/	/gár-ɔ́/	[g**ə́**r-ó]	'bed' (IZD only)
g.	/a/	/tàdáb-ɔ̂/	[tèd**ə́**b-ô]	'writing ink' (other participants)

6.4.3 Results

The results of this experiment indicate that within harmonic contexts, the tongue-root position varies systematically across Dagbani vowels for all participants. Harmonic Class I vowels exhibit a significantly more anterior tongue-root position than Class II vowels. A comparison of each vowel pair indicates that with the exception of the u/ʊ pair for three participants, each [+ATR] vowel has a significantly more anterior tongue-root position than its [-ATR] variant. For tongue-body measures, when all Class II vowels are compared to Class I vowels, the results show a marginally significant difference for participant IZD but not for AIM. The mean values for all participants are shown in Table 6.3.

Also for each participant, 2x5 ANOVAs were conducted to compare the two tongue-root feature values across all five vowel pairs [i/ɨ, u/ʊ, e/ɛ, o/ɔ, ə/a]). Results of this 2x5 ANOVAs are reported for the tongue-root positions of each participant as well as for tongue-body positions of participants IZD and AIM.

Table 6.3: Mean value differences in TR and TB (in mm) between [-ATR] vowels and harmonic [+ATR] vowels.

Tongue root	Class II - Class I	[ɨ] / [i]	[ʊ] / [u]	[ɛ] / [e]	[ɔ] / [o]	[a] / [ə]
AAB	2.97 $p<.0001$	3.86 $p<.0001$	0.52 $p=.407$	3.74 $p<.0001$	2.49 $p=.0001$	4.57 $p<.0001$
AB	5.30 $p<.0001$	5.02 $p<.0001$	5.48 $p<.0001$	7.57 $p<.0001$	6.09 $p<.0001$	2.73 $p<.0001$
AIM	3.61 $p<.0001$		1.38 $p=.064$	3.40 $p<.0001$	6.35 $p<.0001$	7.88 $p<.0001$
HS	5.56 $p<.0001$	7.87 $p<.0001$	2.48 $p<.0001$	5.50 $p<.0001$	6.38 $p<.0001$	5.33 $p<.0001$
IZD	5.50 $p<.0001$	5.43 $p<.0001$	0.72 $p=.477$	6.17 $p<.0001$	6.24 $p<.0001$	5.98 $p<.0001$

Tongue body	Class I - Class II	[i] / [ɨ]	[u] / [ʊ]	[e] / [ɛ]	[o] / [ɔ]	[ə] / [a]
AIM	-0.09 $p=.785$		-1.80 $p=.0013$	0.78 $p=.1193$	-2.15 $p=.0002$	2.17 $p<.0001$
IZD	1.15 $p=.0067$	3.82 $p<.0001$	0.81 $p=.273$	2.40 $p=.0003$	0.68 $p=.304$	0.46 $p=.39$

6.4.3.1 Participant IZD

For participant IZD, harmonic [+ATR] vowels have a significantly more anterior tongue-root position than [-ATR] vowels: (ANOVA: [F(1, 151)=110.22, MSE=9.81, p<0.0001]) and higher tongue-body position: (ANOVA: [(1, 151)=7.56.57, MSE=6.24, p=0.0067]). The harmonic [+ATR] vowels are

5.5 mm more anterior in tongue-root position and 1.15 mm higher in tongue-body position than [-ATR] vowels.

Results of student's t-test also show significant differences in tongue-root position between vowels in each pair except for the high back vowels [ʊ/u]. By contrast, only the front vowel pairs [i/ɨ] and [e/ɛ] have significant differences in tongue-body position. The remaining pairs have no significant difference. Figures 6.11 and 6.12 show the variability between each vowel pair for both tongue-root and tongue-body measures.

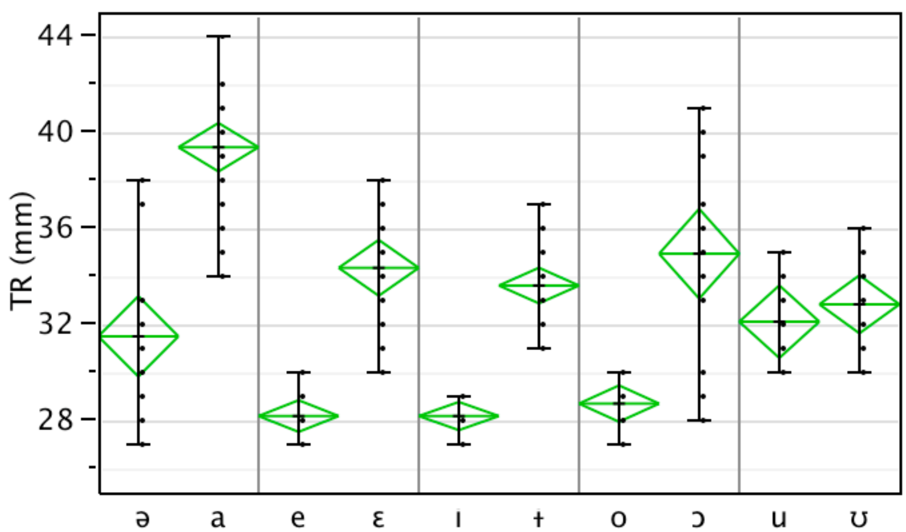


Figure 6.11: IZD: Variability chart of tongue-root distances from transducer for Class II vowels and harmonic Class I vowels

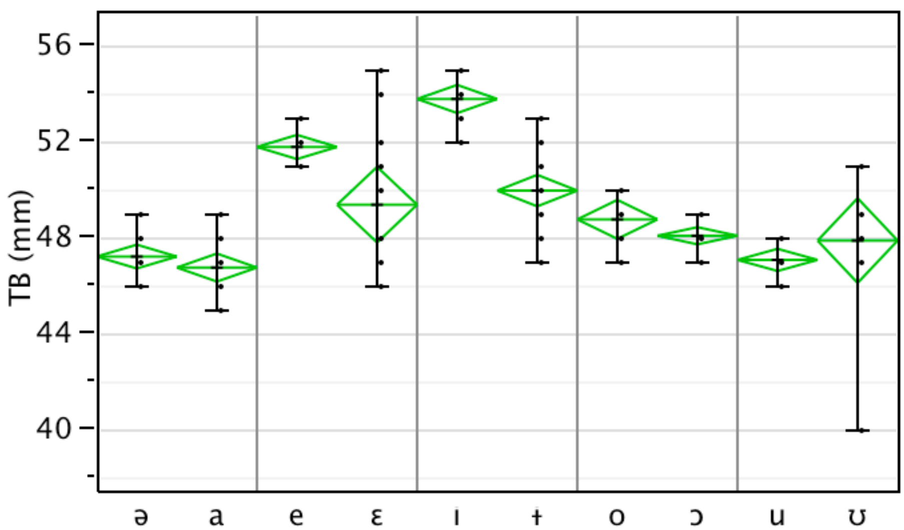


Figure 6.12: IZD: Variability chart of tongue-body distances from transducer for Class II vowels and harmonic Class I vowels.

When results of tongue-root and tongue-body measures are compared, the mean difference in tongue-root position is greater than that between tongue-body position. In tongue-root position, harmonic [+ATR] vowels are 5.37mm more anterior than [-ATR] vowels; in tongue-body position, they are 1.12mm further from the transducer than [-ATR] vowels. These results are shown in Figure 6.15.

6.4.3.2 Participant AIM

When the [+ATR] vowels from all four vowel pairs for which harmonic [+ATR] variants are available (a/ə, e/ɛ, o/ɔ, and u/ʊ) are compared to the [-ATR] vowels in these pairs, the results show a significant difference in tongue-root position: (ANOVA: [(1, 139)=37.34, MSE=12.32, $p<0.0001$]).

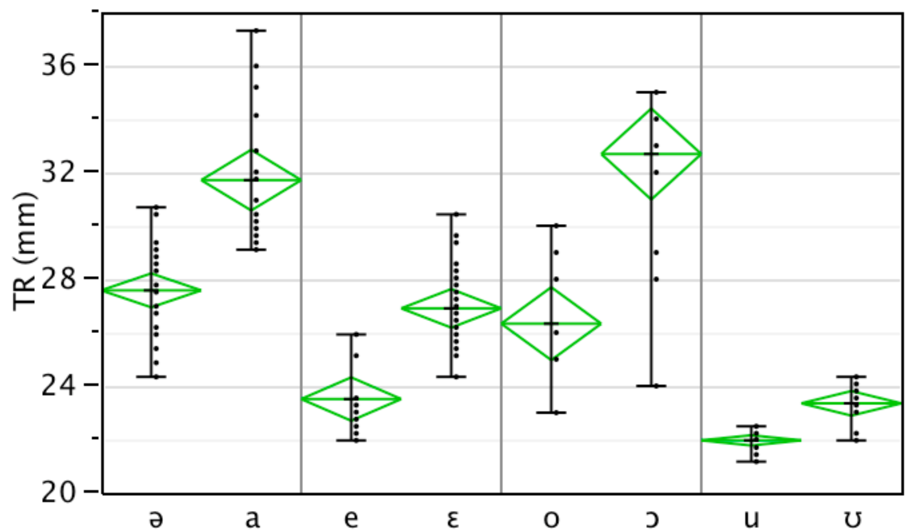


Figure 6.13: AIM: variability charts of tongue-root distances from transducer for Class II vowels and harmonic Class I vowels

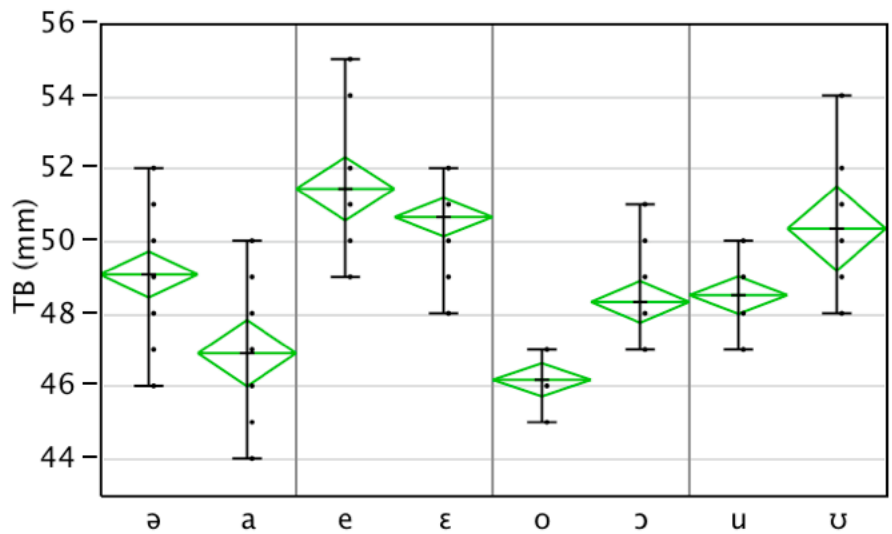


Figure 6.14: AIM: variability charts of tongue-body distances from transducer for Class II vowels and harmonic Class I vowels

However, results of a Student's t-test comparing each pair separately show that there is no significant difference between [u] and [ʊ], as already shown in Table 6.3. The rest of the vowel pairs show significant difference in the position of the tongue-root as predicted.

For the same participant, there is no significant difference between the tongue-body position of the [-ATR] vowels and harmonic [+ATR] vowels from all pairs, as Table 6.3 already shows. The charts in Figure 6.13 and Figure 6.14 show the difference between each vowel pair for both measures. The graphs in Figure 6.15 show the difference in tongue-root and tongue-body measures for vowels in the two classes.

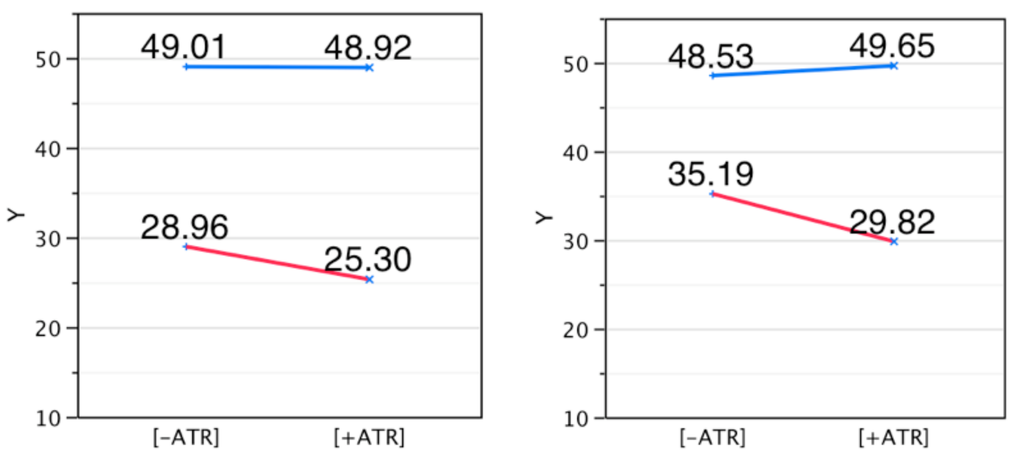


Figure 6.15: Mean comparisons of tongue-root and tongue-body differences for [-ATR] vowels and harmonic [+ATR] vowels for participants AIM (left) and IZD (right). The top line represents tongue-body measures, the bottom line represents tongue-root measures.

6.4.3.3 Participant AAB

Within harmonic contexts, Class I ([+ATR]) vowels have a more anterior tongue-root position than [-ATR] vowels: (ANOVA: [F(1, 241)=60.29, MSE=8.89, p<0.0001]), with a significant difference between vowels in each pair except [ʊ/u]. A variability chart of this is shown in Figure 6.16.

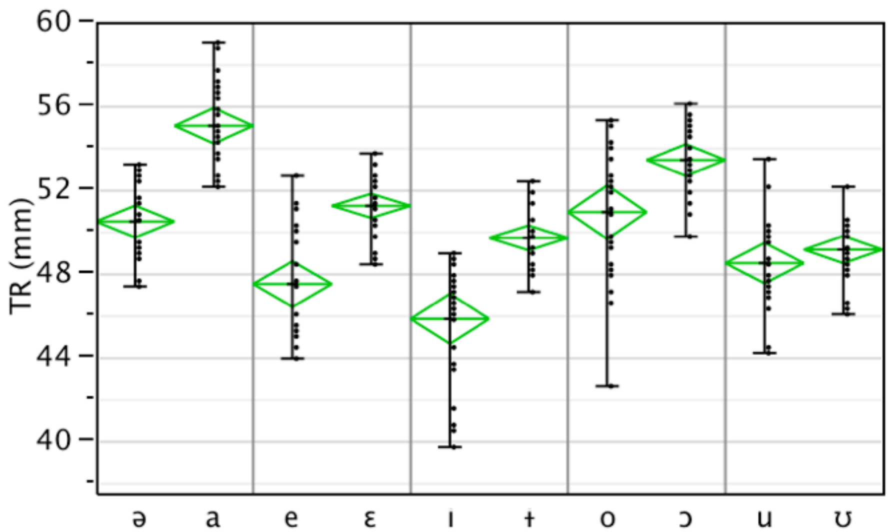


Figure 6.16: AAB: Tongue-root distance from transducer for Class II vowels and harmonic Class I vowels.

6.4.3.4 Participant AB

Participant AB also has a significant difference in tongue-root position between [-ATR] vowels and harmonic [+ATR] vowels: (ANOVA [F(1, 149)= 254.05, MSE=4.17, p<0.0001]). The harmonic [+ATR] vowels are 5.3 mm more anterior than [-ATR] vowel. Between individual pairs, there are significant differences in the direction of the prediction, as Table 6.3 shows. The variability chart in Figure 6.17 also shows the difference between the vowels in each pair.

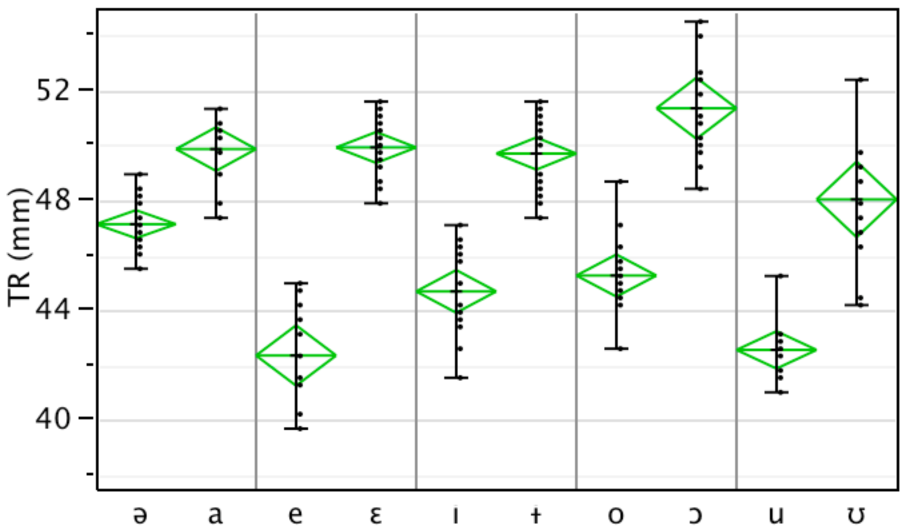


Figure 6.17: AB: TR distance from transducer for Class II vowels and harmonic Class I vowels

6.4.3.5 Participant HS

For HS, harmonic [+ATR] vowels have a significantly more anterior tongue-root position than [-ATR] vowels: (ANOVA: [F(1, 158)=258.22, MSE=4.78, p<0.0001]). Between individual pairs, this differences is seen for all pairs, as results of student's t-test show. Table 6.3 shows both results. The variability chart in Figure 6.18 shows the difference between each vowel pair.

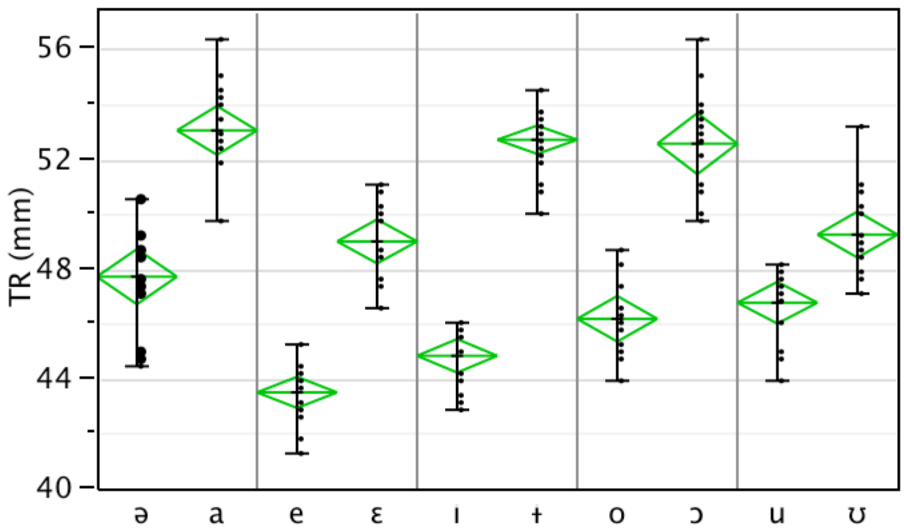


Figure 6.18: HS: Tongue-root distance from transducer for Class II vowels and harmonic Class I vowels

6.4.4 Discussion

The significantly more anterior tongue-root position for Class I vowels, compared to Class II vowels is exactly what we expect if tongue-root position is the main difference between vowels in the two classes. By contrast, the less consistent and less significant results for tongue-body position are indications that the raising of the tongue-body depends on the advancement of the tongue-root, not an independent gesture.

The results show further evidence that support this conclusion. First, two of the participants that lack a significant tongue-root difference for the high back vowels also lack a tongue-body difference for these vowels in the direction of the prediction. What is crucially needed to argue for an independent tongue-body difference is a case where a speaker has a non-significant tongue-root difference but a significant tongue-body difference for the same vowel pair. However, such a result is lacking. Second, while all participants show a significant tongue-root difference for all vowel pairs except [ʊ, u], there is no significant tongue-body difference for back vowels in the direction of the prediction that Class I vowels have a higher tongue-body than Class II vowels.

Given the varying nature of the results, the significant difference in tongue-body position found for IZD is likely part of the phonological tongue-root gesture. As reviewed earlier in this chapter, the hydrostatic nature of the tongue means that any change in the position of the tongue-root may result in a change in the tongue-body position. Thus even though tongue-root is the main feature, any change from [-ATR] to [+ATR] may be accompanied by the raising of the tongue-body position.

While results of the two preceding experiments support tongue-root position as the main distinction between vowels in the two classes, the same results also reveal varying degrees of robustness in the extent to which vowel pairs are distinguished by a tongue-root position. Experiment 1 shows that all [-ATR] vowels are significantly different from their non-harmonic variants for all participants. By contrast, in Experiment 2, harmonic [u] is not significantly different from [ʊ] for some speakers. Could it be that the change in tongue-root position observed in harmonic contexts is merely a result of phonetic co-articulation?

The next two experiments address this question. Experiment 3 compares harmonic and non-harmonic [+ATR]; Experiment 4 investigates whether the assimilation observed in harmonic [+ATR] vowels extends over a longer distance.

6.5 Experiment 3: Harmonic versus non-harmonic [+ATR] vowels

6.5.1 Introduction

In this experiment, the tongue-root positions of harmonic and non-harmonic [+ATR] vowels are compared to determine the extent to which the assimilatory pattern can be argued to be phonological. If the assimilation is phonological, we expect little or no difference between the tongue-root positions of harmonic and non-harmonic [+ATR] vowels. If the assimilation is merely coarticulatory, the tongue-root position of non-harmonic [+ATR] vowels must be systematically more anterior than that of harmonic [+ATR] vowels.

6.5.2 Methods

The methods, procedure and stimuli used for Experiment 1 were the same as for this experiment, i.e. the same recorded data was used for both experiments. The only difference is that the statistical comparison was between two Class I vowel types: one occurring in harmonic contexts, the other occurring in non-harmonic contexts.

6.5.3 Results

Results of this experiment show that there are some differences in tongue-root position between harmonic and non-harmonic [+ATR] vowels. However, these differences do not systematically show which of the two vowel sets have a more advanced tongue-root position than the other across all participants. For participants AAB, AIM, and IZD, the tongue-root position of non-harmonic [+ATR] vowels is more anterior than that of harmonic [+ATR] vowels. However, for AIM, this difference does not seem to be really significant. The significance level at p=.0354 could possibly be a Type 1 error given the lack of significant differences between individual pairs. The remaining participants (AB, HS) each has a more advanced tongue-root position for harmonic than non-harmonic vowels.

A Student's t-test of individual pairs shows that only two participants, AAB and AB, have significantly more advanced non-harmonic and harmonic vowels respectively for each pair. For participant AIM, there is no non-harmonic [+ATR] vowel that is significantly more anterior than its harmonic variant. For IZD, significant differences only exist for the high vowels. IZD's harmonic mid vowels are more advanced than non-harmonic ones, while HS lacks significant differences for [u]. The results are summarised in Table 6.4.

Table 6.4: Mean value differences in TR (in mm) between harmonic and non-harmonic [+ATR] vowels.

Non-harmonic vowels more advanced

	All vowels	[i]	[u]	[e]	[o]
AAB	2.56 p<.0001	2.12 p=.0037	4.85 p<.0001	1.56 p=.016	1.76 p=.0745
AIM	0.98 p=.0354		-1.30 p<.0001	-.005 p=.992	1.33 p=.062
IZD	1.27 p=.022	2.89 p<.0001	6.11 p<.0001	-0.82 p=.0586	-3.43 p<.0001

Harmonic vowels more advanced

	All vowels	[i]	[u]	[e]	[o]
AB	1.75 p<.0001	1.006 p=.0217	1.93 p=.0004	2.63 p=.0002	2.36 p<.0001
HS	2.33 p<.0001	2.32 p<.0001	0.61 p=.193	3.78 p<.0001	3.08 p<.0001

Variability charts for all participants are shown in figures 6.19 to 6.23.

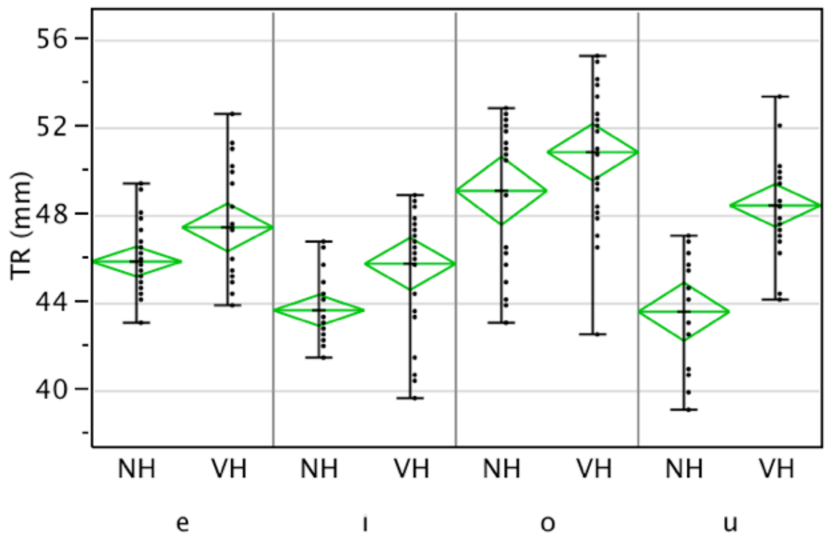


Figure 6.19: AAB: Chart of harmonic (VH) and non-harmonic (NH) [+ATR] vowels

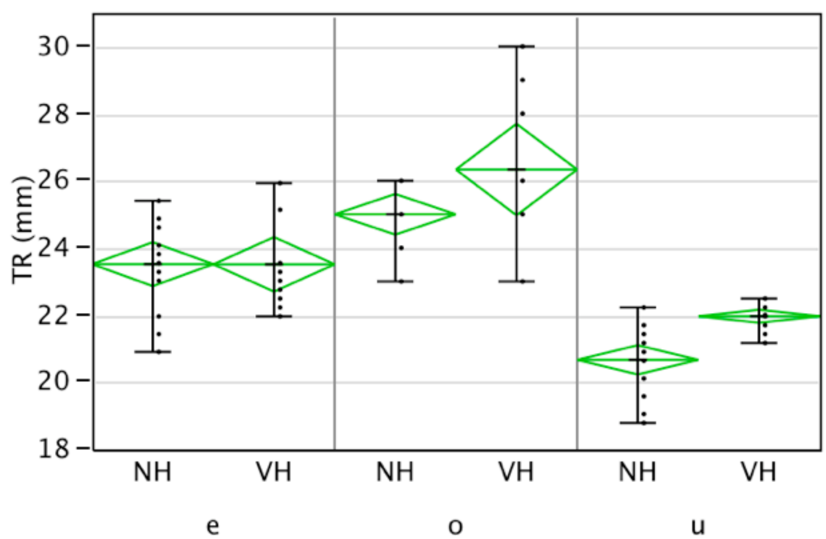


Figure 6.20: AIM: Chart of harmonic (VH) and non-harmonic (NH) [+ATR] vowels

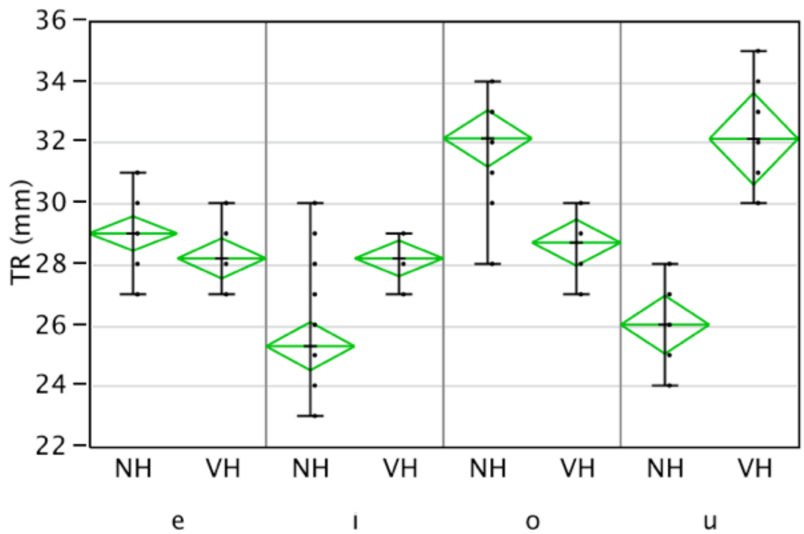


Figure 6.21: IZD: Chart of harmonic (VH) and non-harmonic (NH) [+ATR] vowels

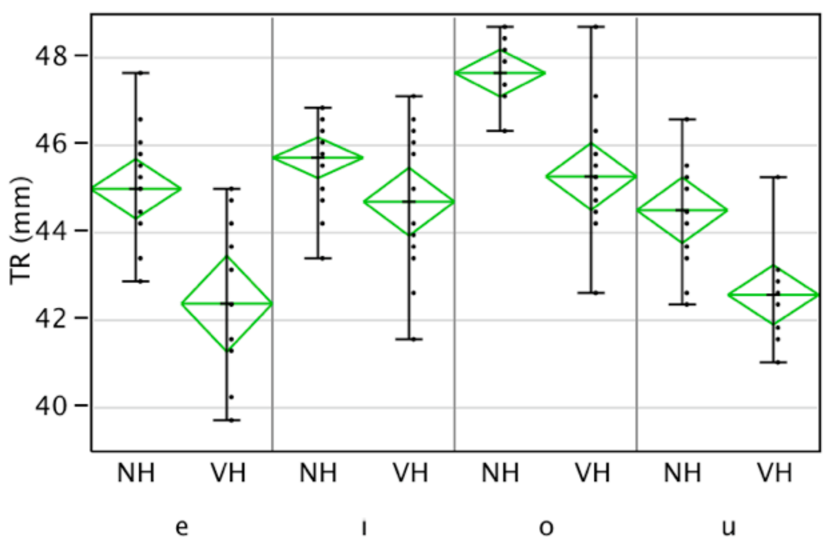


Figure 6.22: AB: Chart of harmonic (VH) and non-harmonic (NH) [+ATR] vowels

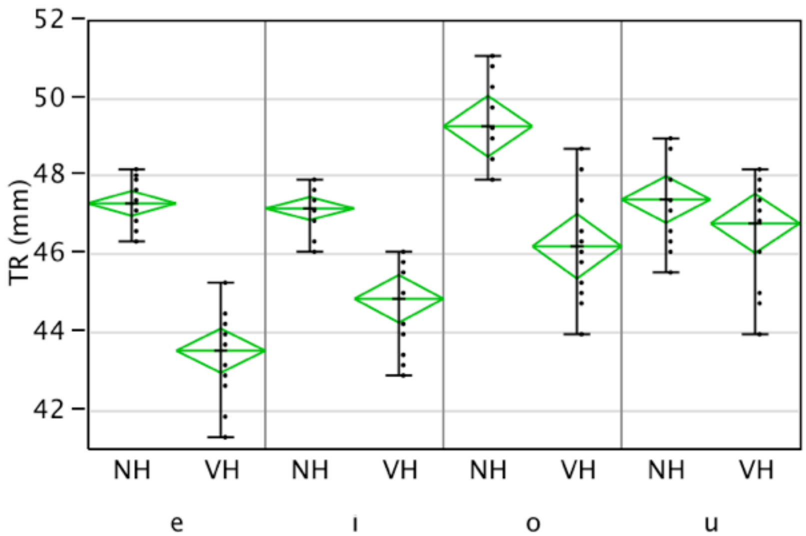


Figure 6.23: HS: Chart of harmonic (VH) and non-harmonic (NH) [+ATR] vowels

6.5.4 Discussion

Results of Experiment 3 indicate that the phonological contexts in which a [+ATR] vowel occurs does not determine the position of the tongue-root. If context were a factor, we would expect (1) a systematic variation in the position of the tongue-root for all vowel pairs, and (2) the same variation for all participants. The fact that there is a lot of variation across and within individual speakers is an indication that harmonic [+ATR] vowels are not less advanced than non-harmonic ones. It supports the conclusion that the assimilation observed in harmonic contexts is not co-articulatory. The constraints that derive the assimilatory pattern are not less phonological than those that derive [+ATR] vowels in non-harmonic contexts.

6.6 Experiment 4: Distance effects

6.6.1 Introduction

This experiment also tests whether the assimilation observed in harmonic contexts is phonological. It examines whether harmony takes place when the target vowel is more than one syllable away from the trigger. Because the presence of any diminishing effects in advancement over a longer distance could be an indication that the pattern of assimilation is not phonological; the lack of such effects strengthens the conclusion that the assimilation is indeed phonological.

6.6.2 Methods

The recorded data used for this experiment were the same as those of the previous experiments except that the target vowels were the low vowel at different positions from the final mid vowel trigger in the word /tàdáb-ó/ 'writing ink' the plural form of which is /tàdáb-tɨ̂/. The tongue-root position of the vowel two syllables away from the trigger (V2), in the syllable *ta*, was compared to that of the vowel one syllable away from the trigger (V1), in the syllable *da*. This is shown in (6.7).

(6.7) Stimuli for distance test.

UR	**Plural suffix (No [+ATR] trigger)**	**singular suffix ([+ATR] harmony)**
/tadab/	[tàdáb-tɨ̂]	[tə̀ dә́b- ô]
		| | |
		V2 V1 [+ATR] trigger

The results below report on 4 participants only. For participant HS, the tongue-root images for the two target vowels in */tàdә́b-ó/* were not visible at the same angle, making it impossible to do an accurate comparison.

6.6.3 Results

Results of this experiment show that for participants AAB, AB, and AIM, there is no significant difference in the tongue-root position of the two target vowels. Only IZD has a significant difference between the two vowels. His V1 was 5.28 mm more anterior than V2 (p=0.0002)[31]. Variability charts for all participants are shown in Figure 6.24.

[31] It is worth pointing out that due to problems relating to the quality of the ultrasound images, only 8 frames could be used for IZD's V1 measures and 9 frames for his V2 measures. This also explains why his Class I variant of the low vowel was drawn from a different stimuli in Experiment 2. While the mean difference between the two vowels are significant, a much larger data for each vowel would have yielded a stronger statistical result.

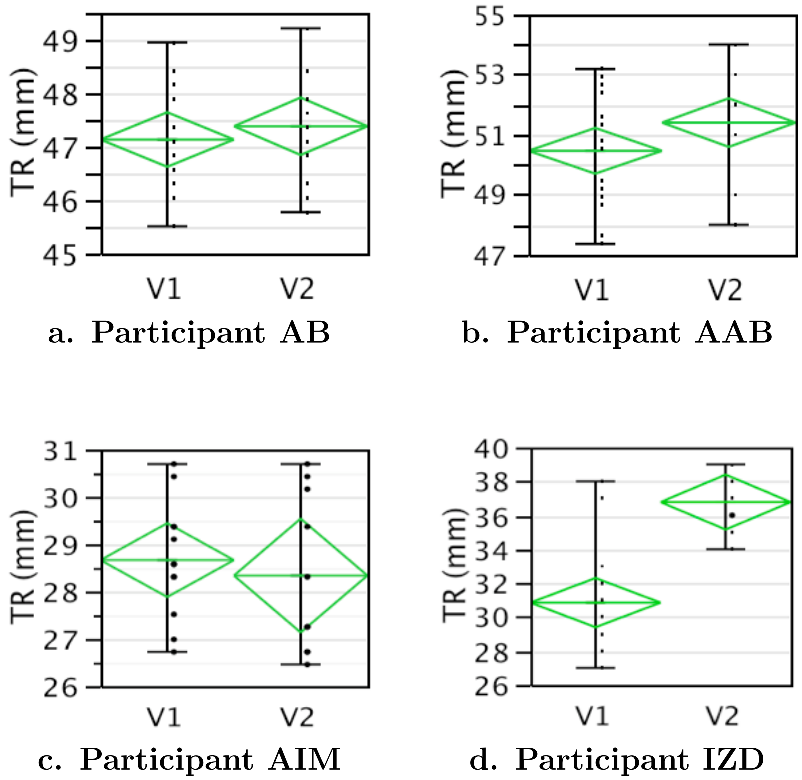


Figure 6.24: Variability charts of tongue-root distance from transducer for V1 and V2 for all four participants

6.6.4 Discussion

The results for the participants AAB, AB, and AIM in Experiment 4 strongly support the prediction that distance from the trigger does not significantly reduce the level of assimilation of a target vowel. The results for participant IZD differ from the other participants, as it shows a significant difference between the two target vowels. In IZD's grammar, assimilation is affected by distance effects. Further evidence in support of this is the almost complete assimilation between the final mid vowel trigger [o] and the immediately preceding [a], as reflected in the huge mean difference of 8.53 mm shown in Table 6.3. Since distance effects are not ruled out in harmony patterns, the two assimilatory patterns in IZD's grammar seem to support rather than undermine the possibility that he has phonological harmony at both shorter and longer distances. Compared to other speakers, IZD's assimilation is more robust at a shorter distance, close to a complete assimilation with the trigger. However, at a longer distance, it is less robust compared to other speakers, while maintaining a significantly different tongue-root position from the non-advanced variant. The results of all participants taken as a whole support the view that the emergence of [+ATR] in harmonic contexts is phonological, not co-articulatory.

The results of Experiment 4 are significant in other respects, given that the low vowel [a] was the target of investigation. First, in the phonology of Dagbani, it does not assimilate completely to a [+ATR] vowel trigger in harmonic domains. Affix [ɨ] neutralises with [i] trigger, while the mid vowels neutralise with final mid vowel triggers if both trigger and target have the same specification for [COR] and [round]. While being neutralising is not the basis for an assimilatory pattern to be considered phonological, it does make a stronger case for arguing that is it phonological harmony. Thus compared to other vowels in the language, the behaviour of the low vowel in harmonic contexts potentially raises doubts as to whether the assimilation should be considered phonological. The categorical nature of the assimilatory effect observed in Experiment 4 however erases such doubts. It further supports the conclusion that regardless of distance from the trigger, all [-ATR] vowels undergo phonological harmony.

Second, the low vowel is the only vowel that is most often claimed to lack an advanced variant in many languages with [ATR] harmony. Some theories of harmony (e.g. Goad, 1993) even claim that the low vowel cannot bear the feature [+ATR] (see Gick et al., 2006, for a more extensive discussion). The results support Gick et al.'s study which show that like other vowels, the low vowel bears the same phonological tongue-root feature that distinguishes all vowels in the two harmonic classes.

The final hypothesis to be tested is Hypothesis B. This is investigated in Experiment 5.

6.7 Experiment 5: Articulatory correlate of dominant tongue-root feature

6.7.1 Introduction

This experiment tests the hypothesis that the active [+ATR] feature is directly correlated with a tongue-root position anterior to the neutral rest position. As discussed in Section 6.1.3, to support this hypothesis, the tongue-root position of [+ATR] need to be significantly anterior to that the ISP while the tongue-root of [-ATR] vowels may be located in any position relative to the neutral position.

6.7.2 Methods

The general methods used in all the preceding experiments were also used in this experiment, except that in addition to measures of the tongue-root and tongue-body positions for Class I and Class II vowels, measures were also taken of the default position of the tongue-root. This is rest position when a speaker completes one sentence and waits for the stimuli to begin the next sentence. Given that the same carrier phrase was used for all participants, the preceding and following contexts were fully controlled for. Values for the ISP were compared to each of the positions for [-ATR] and [+ATR] and analysed statistically.

6.7.3 Results

The results of Experiment 5 show that for all the speakers, Class I vowels have a significantly and systematically anterior tongue-root position compared to the ISP. Class II vowels for 4 of the participants were also significantly anterior to the ISP. However, for participant AAB, the tongue-root position of Class II vowels was significantly posterior to the ISP. The results are summarised in Table 6.5.

Note that in the second and third columns of Table 6.5, the mean neutral tongue-root position is greater than the mean Class I or Class II vowels by the value shown. In the third column, the advancement of Class I vowels from the neutral position is greater than that of Class II vowels by the value shown.

Table 6.5: Mean differences (in mm) of TR positions between vowels in each class and the neutral position for all participants

	ISP-Class I	ISP-Class II	Class II-Class I
AAB	2.10 ($p=.0088$)	-1.79 ($p=.0057$)	3.89
AB	6.62 ($p<.0001$)	2.1 ($p<.0001$)	4.52
AIM	7.75 ($p<.0001$)	3.36 ($p<.0001$)	4.39
HS	6.89 ($p<.0001$)	2.11 ($p<.0001$)	4.78
IZD	11.24 ($p<.0001$)	5.18 ($p<.0001$)	6.06

Student's t-tests of individual vowels show more variability than shown in Table 6.5. While no [+ATR] vowel is significantly posterior to the ISP, within some of the participants, some [-ATR] vowels are not anterior to the neutral position. For instance, all participants except IZD have a significantly posterior [ɔ]. In addition to this vowel, AIM's [a] and HS' [a, ɨ] are about the same position or posterior to the neutral position.

Figure 6.25 shows a sample midsagittal tongue tracings of the high front vowel pair [i] and [ɨ] with the ISP for speaker HS. It illustrates a clearly anterior tongue-root position of the [+ATR] vowel from the neutral position and a [-ATR] variant that has the same tongue-root position as the neutral vowel.

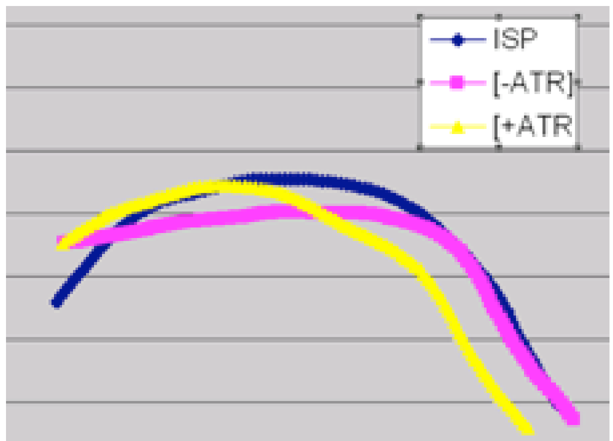
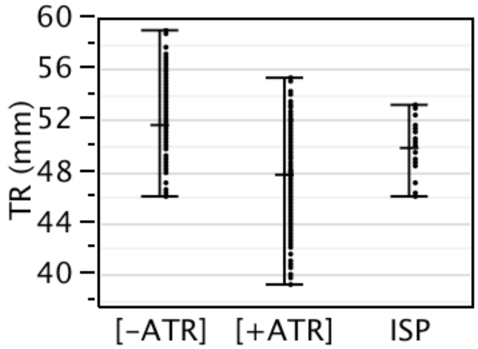
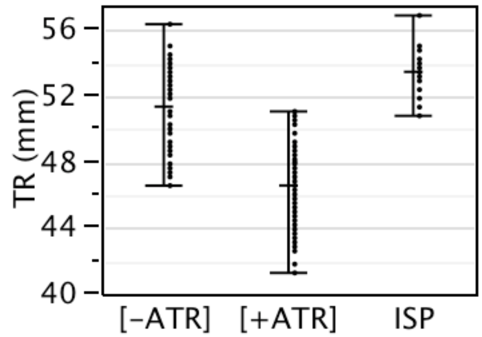


Figure 6.25: Midsagittal tongue tracings of a single token of [i], [ɨ] and ISP for participant HS. The left end of the arc is the tongue-tip, the right end is the tongue-root

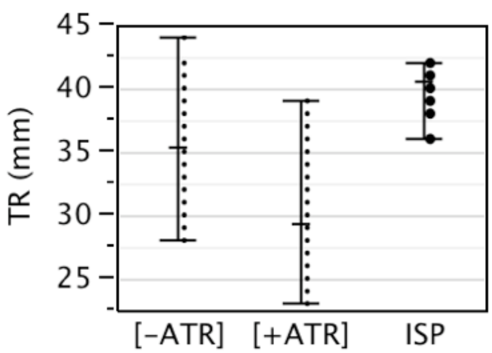
Variability charts for all participants are shown in Figure 6.26, while figures 6.27 to 6.31 show charts for all vowels and the ISP.



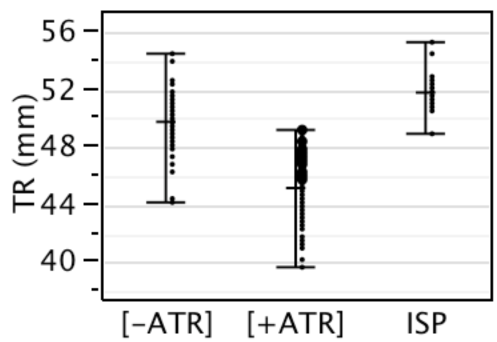
a. Participant AAB



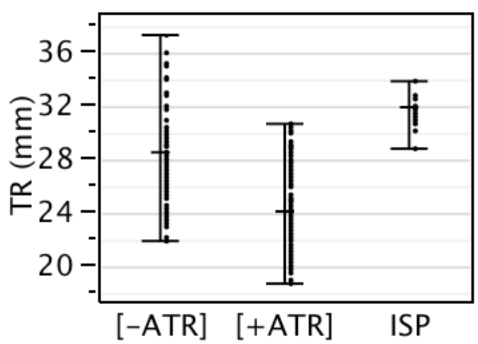
b. Participant HS



c. Participant IZD



d. Participant AB



e. Participant AIM

Figure 6.26: Charts of tongue-root distance from transducer for Class I, Class II and ISP for participants AAB, HS, IZD and AB

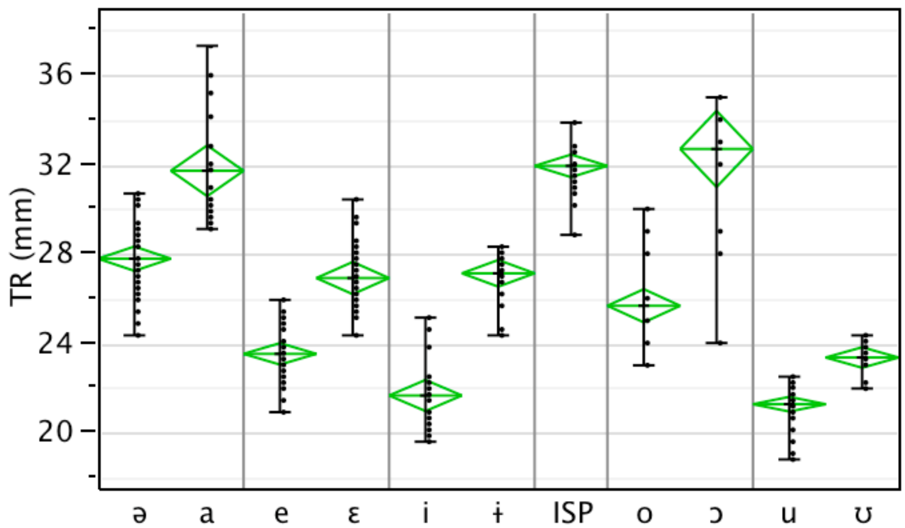


Figure 6.27: AIM: A variability chart of tongue-root distance from transducer for all vowels and the ISP

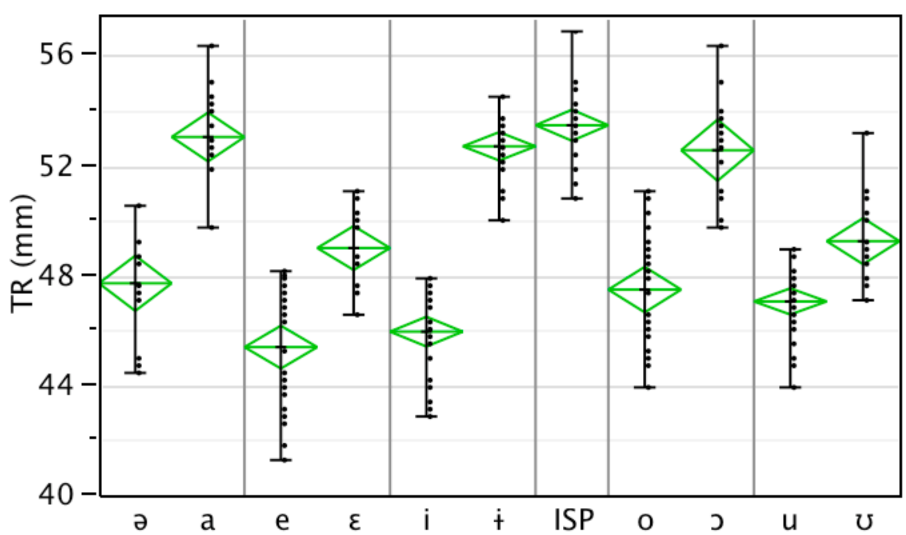


Figure 6.28: HS: A variability chart of tongue-root distance from transducer for all vowels and the ISP

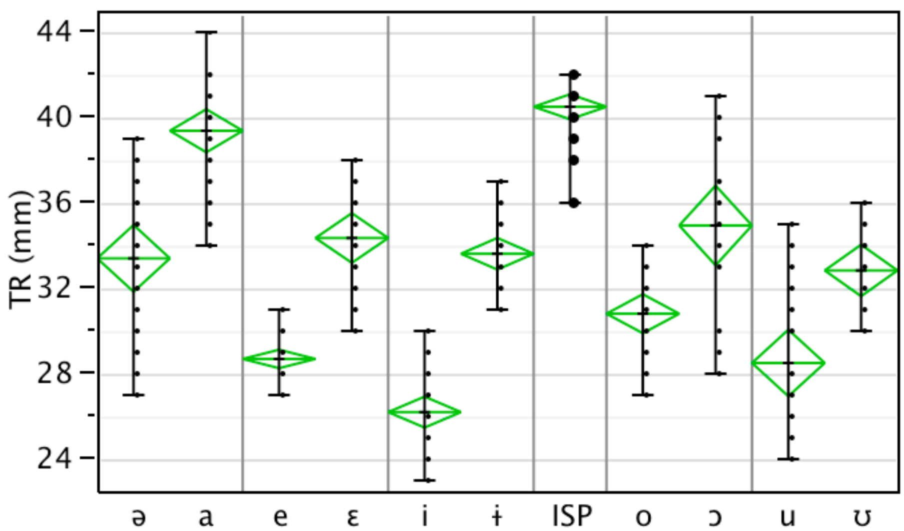


Figure 6.29: AAB: A variability chart of tongue-root distance from transducer for all vowels and the ISP

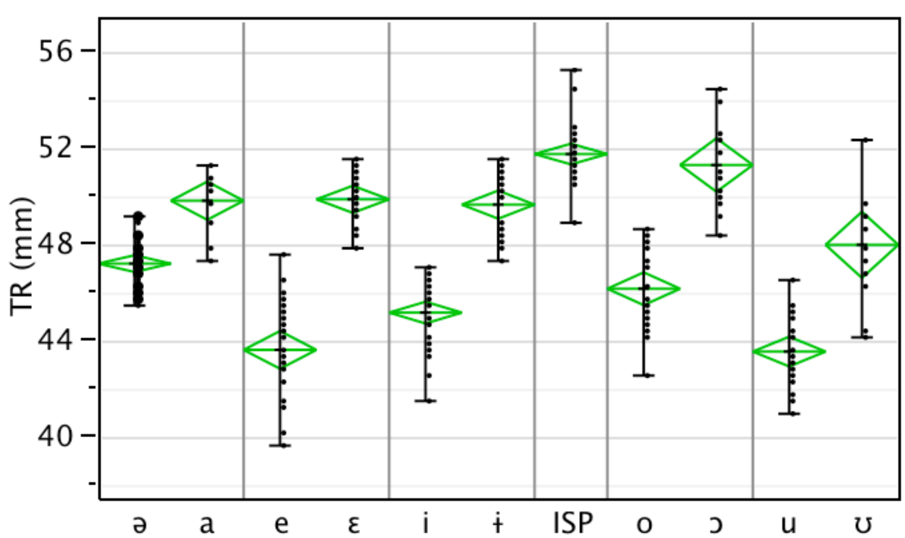


Figure 6.30: AB: A variability chart of tongue-root distance from transducer for all vowels and the ISP

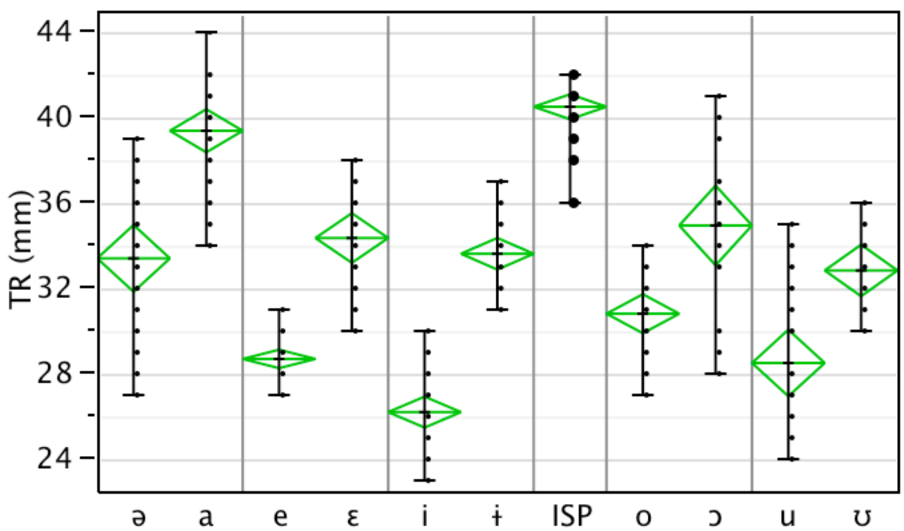


Figure 6.31: IZD: A variability chart of tongue-root distance from transducer for all vowels and the ISP

6.7.4 Discussion

The results of participant AAB are crucial in drawing any conclusion from the above experiment. [+ATR] vowels have a consistently anterior tongue-root position from the neutral position. By contrast [-ATR] vowels may be posterior to the ISP, (as for AAB), or anterior to it, as in the remaining participants. Variation in the positions of individual [-ATR] vowels relative to the ISP within each participant also give a strong indication that [-ATR] vowels do not have a unique displacement from the neutral position.

The results are consistent with the hypothesis that the dominant [+ATR] feature of Dagbani maps directly onto an anterior position of the tongue-root while the recessive [-ATR] feature has a more variable tongue-root position. The emergence of the feature [+ATR] both in harmonic and non-harmonic contexts involves an anterior movement of the tongue-root from a neutral position. Vowels that lack the feature [+ATR] largely also lack a unique tongue-root position. Measured from the neutral position, the tongue-root may be anterior, posterior or neutral.

6.8 Summary and conclusions

This chapter set out to answer basic empirical questions relating to the articulatory basis for tongue-root features as they manifest in languages with tongue-root harmony. Two hypotheses were tested. Results of the four experiments testing Hypothesis A (that vowels of different tongue-root feature specifications have distinct tongue-root positions) confirm the findings of many previous articulatory studies, viz. advanced vowels are produced with a more anterior tongue-root than non-advanced vowels. For Dagbani in particular, the results confirm that (1) the distinction between all vowel pairs in the two classes is indeed based on the position of the tongue-root as assumed in chapters 2 to 4, not some other lingual feature such as tongue-body height, (2) Class I vowels that surface in harmonic contexts have the same tongue-root position as those that surface in non-harmonic contexts, (3) the harmonic pattern affects vowels of all height specifications, including the low vowel, and (4) tongue-root harmony in Dagbani takes place regardless of the relative distance between the trigger and target.

Using the inter-speech posture as the position of the tongue-root with no specification for any value of a tongue-root feature, results of the experiment testing Hypothesis B (that the phonological dominance of a feature or feature value is reflected articulatorily) support a direct mapping between the articulatory position of the tongue-root and the position of [+ATR] vowels in a language with dominant [+ATR] feature. While the results of Experiment 5 are consistent with the prediction of Hypothesis B, it only tests one of three language types. The detailed predictions of the hypothesis can only be fully tested with articulatory studies of languages with dominant [-ATR] feature and those in which both values of the tongue-root feature are active.

Chapter 7

Summary and conclusions

7.1 General summary

This dissertation set out to provide the first ever formal account of [+ATR] harmony in Dagbani as well as investigate experimentally whether there is a direct mapping between the feature [ATR] and the articulatory positions the tongue-root assumes in the production of vowels. Given a previously inadequate phonological description and virtually no theoretical work focusing on the language, a formal account of [ATR] harmony in Dagbani also required a general analysis of the Dagbani vowel system. The overall goal was to show that contrary to previous descriptions, the Dagbani vowel system is not eccentric and that the language displays a systematic pattern of [+ATR] harmony.

The bulk of the analysis in this dissertation can be broadly categorised into four. The first is the predictable patterns of vowel alternations devoid of harmony considerations. This is the focus of Chapter 2. In addition to the contrastive distribution of the high front vowel /i/, three broad patterns of neutralisations in Dagbani vowel phonology were discussed in this chapter.

These are (i) the surface realisation of all non-low vowels as [+ATR] in CV words, (ii) the surface realisation of all vowels as [-ATR] in domains longer than a CV, and (iii) the realisation of non-high vowels as low [a] in non-final position.

Also of significant interest is the fact that mid vowels, unlike low and high vowels, are never phonetically realised on the surface as [-ATR], a pattern that was argued to be due to the marked status of mid vowels relative to low and high vowels. I have also argued that competition between markedness and faithfulness constraint hierarchies on [ATR] and height specifications and their interactions with prosodic conditions and rules of Dagbani [ATR] harmony are responsible for these patterns of neutralisation.

The second category in the bulk of analysis focuses on the patterns of [+ATR] harmony covered in Chapter 4. Details on [ATR] harmony including the domain of harmony in Dagbani, vowel triggers and targets and directionality of [+ATR] harmony in Dagbani were covered. The major argument presented in this chapter was that a similarity condition based on vowel height restricts vowels in trigger-target relations to vowels that have the same specification for [±high].

Preceding the analysis in Chapter 4 is a review of the literature on formal approaches to vowel harmony in Optimality Theory, presented in Chapter 3. While not exhaustive, it provided the basis for the choice of Span Theory for the analysis of ATR harmony presented in chapters 4 and 5. The analyses in these subsequent chapters have demonstrated the usefulness of ST in handling patterns of Dagbani [+ATR] harmony. Patterns such as trigger-target relations, height restrictions on harmonic triggers and direction-specific blocking effects could have posed a significant challenge to many pro-spreading approaches to harmony. The ST account has shown that a good theoretical approach is as important as an accurate understanding of the vowel system in doing a successful phonological account of Dagbani [ATR] harmony.

Chapter 5 covers the third major analysis, the pattern of consonant opacity in vowel harmony. It provides data on Dagbani that attests to direction-specific phonological blocking effects in harmony patterns. The analysis in this chapter has demonstrated that by implementing proposed changes to Span Theory made in Chapter 3, the theory can handle the opacity effects in Dagbani. This is achieved with a featural compatibility constraint that limits span headship to vowels, making the pattern of unhindered leftward spread of [+ATR] possible.

The ultrasound investigation in Chapter 6 constitutes the final bulk of the major analysis in this dissertation. Results of the experiments, the first ultrasound investigation of [ATR] in a Gur, demonstrated that the dominant [+ATR] feature in Dagbani corresponds to a distinct anterior position of the tongue-root compared to the neutral position. Of further interest also are the findings that [+ATR] harmony takes place regardless of the relative distance of the trigger from the target, and that it affects vowels of all height specifications, including the low vowel.

7.2 On the integration of phonetics and phonology

Much of the analysis in Chapter 4 and the results of the articulatory study in Chapter 6 support a growing body of research that show that phonological features directly feed on discrete phonetic properties, and that reference to these phonetic correlates (or their combination) is essential in defining phonological features. In research on tongue-root features, experimental studies (e.g. Lindau (1979), Tiede (1996)) have demonstrated that the different tongue-root features or feature values are marked by distinct tongue-root positions which may form part of an overall enlargement of the pharynx. The results of the present study further support such a direct mapping.

In particular, the results of Experiment 5 which show that [+ATR] vowels are produced with tongue-root advancement from a neutral position implies that tongue-root position indeed plays a distinct role in defining phonological tongue-root features. The results of all the experiments as a whole are significant in light of previous assumptions on the nature of tongue-root features in general as well as assumptions on tongue-root harmony in Dagbani. For instance, previous proposals that question or reject the possibility of low vowels bearing phonological [ATR] indirectly reject the presence of an unhindered cross-height [ATR] harmony. Results of the present study support harmony across all height specifications.

On Dagbani, the results of the present study dismiss the widely held view (prior to Dakubu (1997)), that the language does not display tongue-root harmony. In addition to supporting the views of Dakubu (1997) and Olawsky (1999), the present study has shown that the language has a complex [ATR] harmony system that is phonetically grounded on but not inhibited by vowel height.

The conclusions of Experiment 5 obviously need to be supported by further studies of different tongue-root harmony patterns. However, regardless of what the results of such future studies might be, the broader conclusion in previous studies that is replicated in the present study is that, contrary to previous claims such as Hyman (1988) and Salting (1998), articulatory positions of the tongue-root should not be ignored in any accurate definition of these features.

7.3 A final look at Span Theory

I have argued in Chapter 3 that Span Theory is ideal for the analysis of the Dagbani [+ATR] harmony system. While the analyses in subsequent chapters have supported this argument, it may be argued that this has been achieved partly due the over all strength of Optimality Theory, which allows language-specific patterns to be expressed as a universally ranked constraint hierarchy. In chapters 4 and 5, new constraints on trigger-target conditions and direction-specific opacity effects were needed. The representational assumptions of Span Theory made it relatively easier to express these patterns, some of which could have posed a significant challenge to other formal theories of harmony, as OT constraints.

To account for the direction-specific blocking effects, there was the need to take another look at some of the key assumptions proposed by McCarthy. The two proposed modifications argued for in Chapter 5 were the restriction of blocking segments to the role of span boundary markers and limiting span headship to segments that are compatible with the harmonic feature. Both proposals are harmless to the fundamental goal of the theory, and may be argued to be the logical consequence of using the theory to account for harmony patterns not considered in McCarthy (2004), rather than a weakness of McCarthy's original formulation. The modifications ultimately strengthen the theory to account for a wide range of issues in harmony patterns.

7.4 Contributions

Broadly, this dissertation makes three significant types of contributions to knowledge. First, it contributes to understanding of Dagbani and Gur Linguistics in several ways. It is the first comprehensive account of Dagbani vowel system and vowel harmony, it presents theoretical and experimental work that is more detailed than most existing work on the phonology and phonetics of Gur languages; and it is probably the first ultrasound work on tongue-root harmony on a Gur language.

Second, by evaluating various harmony theories, markedness and faithfulness hierarchies, and proposing major modifications to Span Theory, the dissertation contributes significantly to understanding of phonological theory in general. Third, the dissertation contributes to understanding of theories of the phonetics-phonology interface. In addition to replicating results of previous studies that support a direct being the first ever articulatory study of tongue-root harmony that supports direct mapping between articulatory positions and dominant harmonic features.

7.5 Limitations and future research

As expected from a theoretically based phonological study focusing on an under-described language, many aspects of the phonology of Dagbani were put aside to achieve a focused study. A formal analysis of many of the phonological patterns described in Chapter 1 and others deserves attention in future research. Of some relevance to the theme of this dissertation is the behaviour of long vowels, vowel epenthesis and compensatory lengthening, none of which received a formal account. An acoustic study of Dagbani vowels is also needed for a fuller understanding of aspects of the vowel system such as surface realisations of front vowels and the featural specifications of variants of high non-back vowels.

In the ultrasound investigation, the hypotheses were only tested using Dagbani, a language with a dominant [+ATR] feature. Future investigation of languages with a dominant [-ATR]/[RTR] feature and those in which both

[+ATR] and [-ATR] features are active is required to test all the predictions of the hypothesis.

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Appendix A

List of Constraints

The constraints are presented in a rough alphabetical order as they appear in the tableaux. Note that only constraints that are proposed or used for the analysis presented in this dissertation are listed here. Constraints quoted from the literature that are not part of the analysis in this dissertation are not included.

***[+ATR]** A vowel must not be [+ATR].

***[-ATR]** A vowel must not be [-ATR].

ALIGN-R[+ATR] The right edge of [+ATR] must be aligned with the right edge of the phonological word.

ALIGN-R]$_{Root}$(lɨn) The right edge of *lɨn* must be aligned with the right edge of the root.

***A-SPAN[ATR]** Assign one violation mark for every pair of adjacent spans of the feature [ATR].

***COR-[+CONT]** A consonant must not be specified for both [COR] and [+cont].

Cor/ATR If Coronal then [+ATR].

CORCont/[-ATR] If [COR] and [+cont] then [-ATR].

CORCont-L[-ATR] A consonant that is [Coronal] and [+continuant] is initial in a [-ATR] span (Sp-L[COR, +cont], [-ATR]).

***d/V _** In post vocalic position, the consonant /d/ is prohibited.

DepCOR[+Cont] For every output [COR] consonant that is [+cont], its input correspondent must also be [+cont].

Dep[+Lo] An output [+Low] feature value must have an input correspondent [+Low] feature value.

Dep[+Lo]]$_{wd}$ An output word-final [+Low] feature value must have an input correspondent word-final [+Low] feature value.

Dep[+Hi] An output [+High] feature value must have an input correspondent [+High] feature value.

FthHdSp[+ATR] The output correspondent of every input [+ATR] vowel is the head of a [+ATR] span.

FthHdSp[-ATR] The output correspondent of every input [-ATR] vowel is the head of a [-ATR] span.

HeightCond Within one span of [+ATR], a combination of [+high] and [+low] feature values is prohibited ([+Hi, +Lo] Span [+ATR].)

Hi/ATR If [+high] then [+ATR].

HiCOR/ATR If [+high] and [COR] then [+ATR]

Lo/ATR If [+Low] then [-ATR].

Max-BR Every segment in the base must have a correspondent in the reduplicant.

Max-BR[+ATR] A base [+ATR] feature value must have a reduplicant correspondent [+ATR] feature value.

Max[COR] An input [COR] feature must have an output correspondent [COR] feature.

Max[-Hi] Every input [-Hi] feature must have a correspondent [-Hi].

Max-IO Every segment in the input must have a correspondent in the output.

***Mid[-ATR]** An output [-ATR] vowel must not be [-high, -low].

***Mid[+ATR]** An output [+ATR] vowel must not be [-high, -low].

***Mid** An output vowel must not be [-high, -low] (*[-Hi -Lo]).

Specify[ATR] Every vowel must have a specification for [ATR].

Specify-Foot-[+ATR] In a phonological word that has a foot, every vowel must be specified for [+ATR].

Specify-Foot-[-ATR] In a phonological word that has a foot, every vowel must be specified for [-ATR]

SpHdL([+ATR]) The head segment of a [+ATR] span is initial in that span.

SpHdR([+ATR]) The head segment of a [+ATR] span is final in that span.

SpHdL([-ATR]) The head segment of a [-ATR] span is initial in that span.

SpHdR([-ATR]) The head segment of a [-ATR] span is final in that span.

VoHead[ATR] The head of a span must be [+syllabic] (Head([+Syll], [ATR])).

Appendix B

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL- MINIMAL RISK RENEWAL

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC BREB NUMBER:
Douglas Pulleyblank	UBC/Arts/Linguistics	H02-80447

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Vancouver (excludes UBC Hospital)

Other locations where the research will be conducted:
N/A

CO-INVESTIGATOR(S):
Bryan W. Gick

SPONSORING AGENCIES:
Social Sciences and Humanities Research Council of Canada (SSHRC) - "Orsil title - Harmony" - "Harmony and the phonetic basis of phonological features"

PROJECT TITLE:
Orsil title - Harmony

EXPIRY DATE OF THIS APPROVAL: January 26, 2010

APPROVAL DATE: January 26, 2009

The Annual Renewal for Study have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board