Initial prominence and progressive vowel harmony in Tutrugbu

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Abstract:

One of the key elements of constraint-based formalisms is their ability to derive a variety of effects from the interaction of general constraints. As for vowel harmony, one persistent question within Optimality Theory is how to encode directionality, directly through directional harmony-driving constraints, or indirectly through asymmetric prominence patterns. This paper presents present a typologically-unusual case of progressive harmony triggered by prefixes from Tutrugbu. We compare analyzing harmony as purely progressive in a direct sense with an indirect analysis that motivates harmony from initial-syllable prominence. Based on both language-internal and typological evidence, we argue that the prominence-based analysis is superior since it offers more explanatory adequacy than the purely progressive account. We generalize to suggest that progressive harmony should always be reducible to independent factors, and as a result, formalized indirectly through prominence.

Keywords: vowel harmony, prominence, directionality, typology, Kwa

1 Introduction

One of the key elements of constraint-based formalisms, most notably Optimality Theory (Prince & Smolensky 1993/2004; OT), it their ability to derive a variety of effects from the interaction of general constraints. As for vowel harmony, one persistent question within OT is how to encode directionality. One line of research has sought to derive directionality in vowel harmony from prominence. Under this approach, all directionality is epiphenomenal (Beckman 1997; Baković 2000; Walker 2011), and need not be encoded in the formalism. However, others have treated directionality as a theoretical primitive, which is directly and necessarily encoded in the analysis (Kirchner 1993; Padgett 1995; Mahanta 2007). Hyman (2002, 2008) pursues a hybrid analysis, arguing that directionality is typically determined by morphological prominence (i.e. root control), but when harmony is not reducible to root-control, it is always regressive. In this paper, we present evidence for progressive harmony that is not root-controlled. We demonstrate that labial harmony in Tutrugbu is prefix-initiated and progressive, counter to Hyman's claim.

In Tutrugbu, initial prefixes containing round vowels trigger rounding on following prefix vowels. Observe the data below in (1). In (1a,b) the future prefix surfaces as [ba] after unrounded initial vowels. In (1c,d) though, FUT is rounded to [bɔ] after initial [ɔ].

(1) Tutrugbu progressive labial harmony[1]

a.	$ɛ^{H}$-ba-bá		'1S-FUT-come'
b.	a-ba-bá		'3S-FUT-come'
c.	ɔ-bɔ-bá	*ɔ-ba-bá	'2S-FUT-come'
d.	nɔ-bɔ-bá	*nɔ-ba-bá	'2P-FUT-come'

[1] /$ɛ^{H}$/ represents a surface mid vowel that is phonologically [+hi]. This is further discussed in §2-3.

We lay out two possible analyses of the Tutrugbu data, either that progressive harmony falls out from asymmetrical prominence relations or that labial harmony in the language is the best evidence for purely progressive harmony that operates completely independent of prominence. If harmony derives from prominence relations, then we must recast Hyman's (2002, 2008) definition of prominence to account for the Tutrugbu data. If, however, harmony is best analyzed as purely progressive here, this suggests that we must allow for parametric variation for directionality, similar to derivational analyses (e.g. Chomsky & Halle 1968; Archangeli & Pulleyblank 1994; Nevins 2010). We compare the two analyses, ultimately arguing in favor of the prominence-based analysis based on language-internal facts, as well as the larger typology of prefix-initiated harmony patterns. As a result, we expand Hyman's analysis such that the directionality of harmony is either derivable from some source of prominence, including edge and morphological prominence, or it is purely regressive.

The paper is organized as follows. In §2, we describe labial harmony in Tutrugbu. In §3, we lay out the two competing analyses. We introduce four diagnostics to differentiate between the two, comparing Tutrugbu and several other prefix-initiated harmony patterns to purely regressive harmony in Karajá (Ribeiro 2002). In §4, we develop a correspondence-based analysis of harmony in the language. In §5, we address residual issues from the analysis and discuss the broader typology of directionality in harmony. Finally, in §6 we conclude the paper.

2 Tutrugbu

Tutrugbu is one of 15 Ghana-Togo Mountain languages of the Kwa (Benue-Congo) language family.[2] Tutrugbu is closely related to neighboring Tafi and Avatime.[3] These languages are surrounded by Ewe, the dominant regional language. The Ewe name for Tutrugbu is Nyagbo (also spelled Nyangbo), which is also the official name of the language.

The data presented throughout the paper derive from a corpus of natural speech collected during documentary fieldwork in southeastern Ghana, as well as formal elicitation conducted both in Ghana and the United States.

2.1 Vowel Inventory

The Tutrugbu vowel inventory consists of seven surface oral vowels, presented below in (2) (see also Essegbey 2009, 2010, 2012; McCollum & Essegbey 2018). In contrast to neighboring Tafi and Avatime, Tutrugbu has only two surface high vowels, [i] and [u] (see Bobuafor 2013:27-29 for Tafi; for the Avatime inventory, see Maddieson 1995; Schuh 1995:38-45). Tutrugbu also possesses a set of nasal vowels, but they behave just like oral vowels with respect to harmony, and are therefore excluded from discussion.

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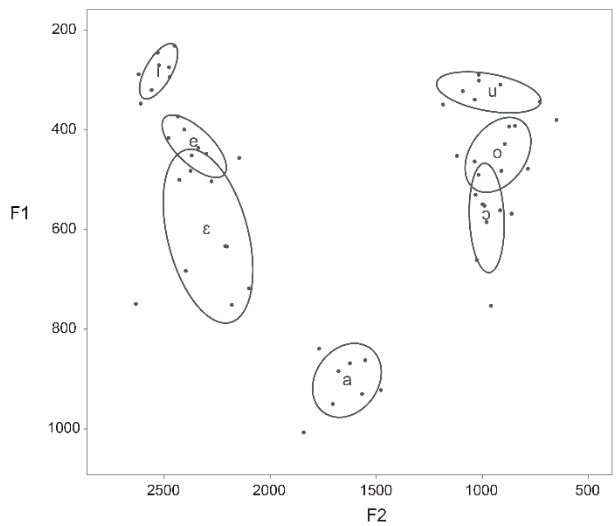
[2] We use the following glossing abbreviations in this section: 1= first person, 2= second person, 3= third person, CMX= class marker for class X, CONT= continuative, DEP= dependent pronoun, EXC= excessive, FUT= future, ITV= itive, NEG= negative, PFV= perfective, PL=plural, PROG= progressive, PST=past, REL= relativizer, SMX= subject marker for class X, TP= terminal particle, and VENT= ventive.
[3] In fact, Tutrugbu and Tafi are so closely related that they are sometimes treated as dialects of the same language (Heine 1968; Dakubu & Ford 1988), and some have treated Tutrugbu, Tafi, as well as Avatime as dialects of a single language (Dakubu 2009)

(2) Tutrugbu surface vowel inventory

i u
e o
ɛ ɔ
a

The surface vowel inventory is plotted below in Figure 1. Eight tokens of each vowel (n=56) in root-initial position were culled from an approximately 1,300-word audio dictionary produced by a single female speaker. F1-F2 measurements were made at the midpoint of each vowel.

Figure 1: F1-F2 Vowel plot of surface vowel inventory (in Hz, with 1 SD ellipses)



2.2 Labial harmony

Tutrugbu words typically consist of a morphological root, and in nouns and verbs, at least one prefix. Suffixation is very restricted in the language, and no suffixes or enclitics undergo labial harmony. In nouns, only a single class-marking is allowed. Among verbs, though, a number of prefixes may be concatenated to the root. For this reason, the paper focuses on Tutrugbu verbs. The basic harmony pattern is demonstrated in (3-4). In (3) and (4), the second person pronouns trigger harmony on the prefixes /ba/ 'FUT' and /ka/ 'not.yet'. These data illustrate two key aspects of labial harmony. First, [o] and [ɔ] may not be followed by prefixes containing [e] or [a]. Second, this co-occurrence restriction applies only to prefixes, as root vowels are immune to harmony.[4]

[4] Throughout this paper the acute accent represents high tone, while the macron represents a mid tone. Low tone is unmarked. As for contour tones, the circumflex represents a falling tone (high-to-low), while the caron represents a rising tone (low-to-high).

(3)	a.	o-bo-ʃẽ	'2S-FUT-grow'
	b.	no-bo-ʃẽ	'2P-FUT-grow'
	c.	e-be-ʃẽ	'3S-FUT-grow'
	d.	be-be-ʃẽ	'3P-FUT-grow'
	e.	o-bo-ji	'2S-FUT-appear'
	f.	no-bo-ji	'2P-FUT-appear'
	g.	e-be-ji	'3S-FUT-appear'
	h.	be-be-ji	'3P-FUT-appear'

(4)	a.	ɔ-kɔ-bá	'2S-not.yet-come'
	b.	nɔ-kɔ-bá	'2P-not.yet-come'
	c.	a-ka-bá	'3S-not.yet-come'
	d.	ba-ka-bá	'3P-not.yet-come'

In (5), 2S/P trigger rounding of a prefix with a long vowel, /zaa/ 'not.again.'[5] In (6), 2S/P trigger harmony on two prefixes, /kaá/ 'still' and /ba/ 'VENT.' Thus, labial harmony targets both short and long vowels, and iterates throughout the entire pre-verbal domain.

(5)	a.	ɔ́-zɔɔ-bá	'2S-not.again.FUT-come'
	b.	nɔ́-zɔɔ-bá	'2P-not.again.FUT-come'
	c.	á-zaa-bá	'3S-not.again.FUT-come'
	d.	bá-zaa-bá	'3P-not.again.FUT-come'

(6)	a.	o-koó-bo-wu	'2S-still-VENT-climb'
	b.	no-koó-bo-wu	'2P-still-VENT-climb'
	c.	e-keé-be-wu	'3S-still-VENT-climb'
	d.	be-keé-be-wu	'3P-still-VENT-climb'

The previous examples showed only prefixes containing [-high] vowels. In (7a,b), the [+high] vowel of the negation prefix does not undergo harmony, unlike the [-high] prefixes seen in (3-6).

(7)	a.	o-tí-ʃẽ	*o-tú-ʃẽ	'2S-NEG-grow'
	b.	no-tí-ʃẽ	*no-tú-ʃẽ	'2P-NEG-grow'
	c.	e-tí-ʃẽ		'3S-NEG-grow'
	d.	be-tí-ʃẽ		'3P-NEG-grow'

Furthermore, in (8) we see that [+high] prefixes are transparent to harmony. Harmony skips over NEG in (8a,b) to trigger rounding on FUT.

[5] This prefix includes a high tone that docks on the preceding vowel, thus the high tone on word-initial prefixes in (5).

(8) a. o-tí-bo-wu ‘2S-NEG-FUT-climb’
b. no-tí-bo-wu ‘2P-NEG-FUT-climb’
d. e-tí-be-wu ‘3S-NEG-FUT-climb’
e. be-tí-be-wu ‘3P-NEG-FUT-climb’

Thus far we have only observed harmony after 2S and 2P. Observe in (9) that the class 3 subject-marking prefix, SM3, also triggers harmony on following non-high vowels. In (9a), as above, the high vowel of NEG is transparent, allowing harmony to skip over it. SM3 is the only other [-hi, +rd] prefix in the language. Since all three [-hi, +rd] prefixes, 2S, 2P, and SM3, trigger harmony, we conclude that harmony is generally triggered by [-hi, +rd] prefixes.

(9) a. o-ŋtí lo-tí-bo-ʃẽ ‘CM3-hawk SM3-NEG-FUT-grow’
b. o-hwi lɔ-gɔɔ-gagãlĩ ‘CM3-rope SM3-no.longer-be.strong’

Data in (7-9) demonstrate that [+high] vowels do not undergo harmony. In (10), we see that [+high] vowels also fail to initiate harmony. The first person plural prefix, which contains a [+hi, rd] vowel, does not trigger harmony on a following [+high] vowel.

(10) a. bu-tí-tĩ ‘1P-NEG-know’
b. bu-tí-wu ‘1P-NEG-climb’

Moreover, 1P does not trigger harmony on a following [-high] vowel either, as seen in (11). Note several things here. First, when preceded by an initial high vowel, the low vowel does not undergo regressive ATR harmony from the root.[6] To-date, Tutrugbu speakers have shown two patterns of low vowel neutrality in this context. For some speakers, /a/ following an initial-syllable high vowel blocks harmony while for others /a/ is transparent. The 1P prefix surfaces as [bu] before a [+ATR] root in (10). However, in (11) 1P may surface as either [bu] or [bɔ^{H}]. Second, when 1P surfaces as [-ATR], it is realized as a mid vowel, which we indicate with [ɔ^{H}]. When the realization of 1P in (11) is compared with that in (10), we see that the [+hi] vowel [u] alternates with [ɔ^{H}] for ATR harmony.[7]

(11) a. bɔ^{H}-ba-tĩ ~ bu-ba-tĩ ‘1P-FUT-know’
b. bɔ^{H}-ba-wu ~ bu-ba-wu ‘1P-FUT-climb’

The [u]-[ɔ^{H}] alternation above is mirrored in (12) below in the subject- and class-marking prefixes for class 8. The subject-marking prefix attaches to verbs while the class-marking prefix attaches to nouns. CM8 surfaces as [bu] before [+ATR] roots, but as [bɔ^{H}] before [-ATR] roots. SM8, like 1P, does not trigger harmony on a following [-high] verbal prefix. Thus, the inertness of 1P as a trigger for harmony appears to be a more general inertness of all [+high] vowels.

(12) a. bu-li bu-tí-ʃẽ ‘CM8-palm.tree SM8-NEG-grow’
b. bɔ^{H}-wa bɔ^{H}-ba-ʃẽ ~ bu-ba- ʃẽ ‘CM8-grass SM8-FUT-grow’

[6] For analyses of ATR harmony in Tutrugbu, see McCollum et al. (2018) and McCollum & Essegbey (2018).
[7] One might wonder whether the bilabial stop blocks harmony in (10-12), because in the related language, Nawuri, labialized consonants block regressive labial harmony (Casali 1995). It is clear above that FUT, /ba/ both undergoes and spreads harmony, demonstrating that the place feature of the consonant has no bearing on harmony in Tutrugbu.

The data in (10-12) show that the high vowels, including [ɔ^{H}], do not trigger harmony. In addition to [ɔ^{H}], one other vowel alternates with a high vowel for [ATR], [ɛ^{H}]. In the same way that [ɔ^{H}] patterns with [u] as a non-trigger, [ɛ^{H}] patterns with [i] as a non-undergoer of harmony. Like [i], [ɛ^{H}] is transparent to harmony, as seen in (13). In (13a), replicated from (8a), the negation prefix surfaces as [i] before a [+ATR] root, but in (13b,c) this same prefix surfaces as [ɛ^{H}] before a [-ATR] root. Significantly, in both [ATR] contexts, the vowel of the negation prefix is transparent to labial harmony.

(13) a. o-tí-bo-wu — '2S-NEG-FUT-climb'
b. ɔ-tɛ́^{H}-bɔ-bá — '2S-NEG-FUT-come'
b. nɔ-tɛ́^{H}-bɔ-bá — '2P-NEG-FUT-come'

In sum, [ɔ^{H}] and [ɛ^{H}] pattern like the high vowels, [u] and [i]. Further evidence suggesting the essential [+high] character of these vowels comes from related Tafi (Bobuafor 2013). In Tafi, observe that the [+high] vowel [ʊ] does not trigger labial harmony on the [-high] [a] of the future prefix in (14b). In contrast, harmony obtains after the non-high vowel, [ɔ], exemplified by (14c,d).

(14) Labial harmony in Tafi (Bobuafor 2013)

a.	á-ba-vɪ	'3S-FUT-go'	(ex. 97a, p. 42)
b.	bʊ́-ba-vɪ	'1P-FUT-go'	(ex. 4, p. 179)
c.	ɔ́-bɔ-vɪ	'2S-FUT-go'	(ex. 97b, p. 42)
d.	nɔ-bɔ-ɖí	'2P-VENT-look'	(ex. 184, p. 396)

The high vowels also fail to undergo harmony in Tafi, which is shown below. In (15a,b) the [-ATR] vowel [ɪ] fails to undergo harmony from an initial round vowel, and in (15c,d), the [+ATR] vowel [i] shows the same neutrality to harmony. Finally, in (15e), harmony skips [ɪ], showing that the [+high] vowels are also transparent in Tafi.

(15) High vowel neutrality in Tafi (Bobuafor 2013:215)

a.	bʊ́-tí-b^{h}ɪtɪ̄ʔ	'1P-NEG-do'	
b.	ɔ́-tí-b^{h}ɪtɪ̄ʔ	'2S-NEG-do'	
c.	bú-tí-huʔ	'1P-NEG-hit'	
d.	ó-tí-huʔ	'2S-NEG-hit'	
e.	lɔ́-tí-zɔ-ŋa	'3S.DEP-NEG-REP-eat'	(ex. 38, p. 423)

The basic Tutrugbu facts laid out above are schematized in Table 1. Non-high vowels both trigger and undergo harmony while high vowels do not participate in the process at all, either as triggers or undergoers. Since high vowels are additionally transparent to harmony, the pattern resembles labial harmony in Khalkha Mongolian (Svantesson 1985; see also Kaun 1995) and several Mbam languages of Cameroon (Boyd 2015).

Table 1: A summary of labial harmony in Tutrugbu

vowel height	triggers harmony	undergoes harmony
[+high]	✗	✗
[-high]	✓	✓

2.3 Harmony within roots

In general, labial harmony operates on verbal prefixes, but a static co-occurrence restriction is also evident within roots. We compiled all the disyllabic verbs in our dictionary that have two non-high vowels. Of the 40 verb roots that met these criteria, 39 were harmonic for the feature [round], as shown in Table 2. One exception was found, /bolé/ 'throw.'

Table 2: Root co-occurrence of [-high] and [round]

Disyllable Type	Count	Examples
[+rd] [+rd]	9	lɔkɔ 'take', ʃogo 'grow'
[-rd] [-rd]	30	g͡bǎna 'marry', béle 'finish'
[+rd] [-rd]	1	bolé 'throw'
[-rd] [+rd]	0	

Given the small number of disyllabic verbs and the presence of only one exception, we interpret the data in Table 2 as evidence for a static restriction without any discernable directionality.

2.4 Exceptional /téŋú/

Remember from the data above that roots do not undergo harmony from prefixes. There is one exception to this generalization. For some speakers, /téŋú/ 'be able,' a loanword from Ewe, undergoes harmony. The first vowel of this word undergoes harmony just like non-high medial prefixes, as the examples in (16) demonstrate. In (16a,b), the second person pronouns trigger harmony of both the FUT morpheme and the root. In (16c,d), the third person pronouns undergo ATR harmony, and having no rounded vowels, play no triggering role in labial harmony.

(16) a. o-bo-tóŋú '2S-FUT-be.able'
b. no-bo-tóŋú '2P-FUT-be.able'
c. e-be-téŋú '3S-FUT-be.able'
d. be-be-téŋú '3P-FUT-be.able'

There are two things to note about /téŋú/. First, for some speakers /téŋú/ does not undergo harmony. Second, for one speaker during data collection, this root consistently surfaced as /tóŋú/ regardless of preceding vowel quality.[8] In Tafi, /téŋú/ is a prefix and not a root (Bobuafor 2013:228-229).

[8] We cannot conclusively rule out phonological teamwork in (16), from the root-final round vowel and the round prefix to trigger the rounding of /e/ to [o] (Lionnet 2016). No other disyllabic roots found thus far have the shape CeCV[rd] or CaCV[rd].

Tutrugbu is not the first language described with some pattern of prefix-initiated vowel harmony. However, in the languages cited as potential evidence for purely progressive harmony, like Tuki and Tunen (Mous 1986; Hyman 2002; Boyd 2015; Moskal 2015), prefix-initiated harmony is somewhat exceptional. In these languages, the set of triggers and non-triggers are not featurally distinct, suggesting an exceptionality-based account. Moreover, the morphemes that undergo harmony in these languages are restricted to a small set of function items. Exceptional behavior is also found in Tutrugbu, but only as it relates to /téŋú/. Generally, harmony in Tutrugbu is very regular, which distinguishes Tutrugbu from other languages with prefix-initiated vowel harmony. We will return to this point in the next section, further comparing languages with attested prefix-initiated patterns with Tutrugbu.

2.5 Summary of harmony data

A list of morphemes elicited, their allomorphs and their participation in both ATR and labial harmony is shown below. In Table 3, we see the same generalizations presented throughout §2.2. First, harmony is triggered by non-high prefixes and targets following non-high prefixes. Second, high vowels are transparent to harmony. Third and finally, harmony does not target roots.

Table 3: Pre-verbal morphemes and their participation in vowel harmony

Prefix height	Morpheme gloss	ATR allomorphs	Labial allomorphs	Example	Gloss
	FUT	ba, be	bɔ, bo	ɔ-bɔ-bá	‘2S-FUT-come’
	not.yet	ka, ke	kɔ, ko	nɔ-kɔ-bá	‘2P-not.yet-come’
	VENT	ba, be	bɔ, bo	o-koó-bo-ku	‘2S-still-VENT-call’
	still	kaá, keé	kɔɔ́, koó	o-koó-bo-ku	‘2S-still-VENT-call’
[-hi]	used.to	kaa, kee	kɔɔ, koo	o-koo-tī	‘2S-used.to-know’
	not.again	gaa, gee	gɔɔ, goo	lɔ-gɔɔ-gagãlĩ	‘SM3-not.again-
	not.again.FUT[9]	zaa, zee	zɔɔ, zoo	ɔ́-zɔɔ-wɛ̃^{H}	‘2S-not.again.FUT-drink’
	EXC	gblá, gblé	gblɔ́, gbló	ɔ-gblɔ́-ɖɔ	‘2S-EXC-say’
	NEG.REP	gaa, gee	gɔɔ, goo	ɔ-gɔɔ-mɔ	‘2S-NEG.REP-see’
	ITV	dε^{H}, di		o-di-wu	‘2S-ITV-climb’
	NEG	tέ^{H}, tí		ɔ-tέ^{H}-bɔ-bá	‘2S-NEG-FUT-come’
[+hi]	NEG.PST	gε^{H}, gi		nɔ-gε^{H}-bá	‘2P-NEG.PST-come’
	PFV	tε^{H}, ti		ɔ-tε^{H}-bɔ-wɛ̃^{H}	‘2S-PFV-VENT-drink’
	CONT	vlέ^{H}, vlí		ɔ-vlέ^{H}-bā	‘2S-CONT-come’
[αhi]	PROG	á, é, έ^{H}, í,	ɔ́, ó, ɔ́^{H}, ú	o-tí-ó-wū	‘2S-NEG-PROG-climb’
	PROG.PST	zaa, zee, zε^{H}ε^{H}, zii	zɔɔ, zoo	ɔ-zɔɔ-bá	‘2S-PROG.PST-come’

The next section relates the harmony pattern found in Tutrugbu to the issue of directionality and prominence as theoretical primitives. We lay out three general hypotheses concerning prominence and

[9] This morpheme is also characterized by a high tone on the preceding vowel.

directionality, and compare a purely progressive account of labial harmony in Tutrugbu with a prominence-based account, discussing the divergent predictions of each analysis.

3 Directionality and prominence

The most pressing question at hand is what motivates harmony in Tutrugbu. In this section we lay out two options, purely progressive harmony and prominence-based harmony. We propose four diagnostics of directional vowel harmony, discussing how these distinguish between purely progressive and prominence-based harmony. Based on the evidence on-hand, we suggest that prominence offers a more explanatorily adequate account of harmony in Tutrugbu than a purely progressive analysis. We move on there to discuss genetic and typological evidence in favor of our prominence-based account.

3.1 Theoretical background

Two theoretical primitives have been proposed to account for the directional behavior in vowel harmony patterns- pure directionality and prominence. Purely directional harmony involves rightward or leftward harmony without respect to potential sources of prominence. Early generative models of harmony, by formal necessity, invoked purely directional propagation of the harmonic feature (e.g. Chomsky & Halle 1968; Johnson 1972; Jensen & Stong-Jensen 1973; Vago 1973; Kenstowicz & Kisseberth 1977; cf. Lightner 1965). However, much subsequent work recognized the importance of morphological prominence for the analysis of harmony (Clements 1976; Mohanan 1982; Goldsmith 1985; Kiparsky 1985), particularly in Optimality Theory (e.g. Baković 2000).

In the three subsections below we discuss three hypotheses concerning prominence and directionality- the strong prominence hypothesis, which treats all directionality as emergent; the weak prominence hypothesis, which treats all progressive directionality as emergent; and the purely directional hypothesis, which allows for both purely regressive and purely progressive directionality in harmony.

3.1.1 The strong prominence hypothesis

Baković (2000) asserts that the use of prominence in the analysis of vowel harmony obviates the need for directionality. We call this the strong prominence hypothesis. Baković writes:

> If directionality were an independent assimilation parameter along which languages could arbitrarily differ, then one would expect to find at least the following two unattested vowel harmony patterns. *The first is a left-to-right pattern from the initial syllable, root or prefix, the other is a right-to-left pattern from the final syllable, root, or suffix….*A theory of assimilation with directionality as a theoretical primitive directly predicts the possibility of these kinds of unattested patterns (2000:7-8, emphasis ours).

As Baković makes clear, two types of languages would falsify his claim that directionality should be jettisoned in favor of prominence- purely progressive and purely regressive harmony. Problematically for Baković's claim, there are several attested cases of purely regressive harmony. For example, in Karajá (Ribeiro 2002), a Macro Jê language of Brazil, [+ATR] spreads leftward from any position in which it occurs, which is demonstrated below. In (17a), the leftmost vowel of the root, /ɗuhɔ/ 'curse', triggers leftward ATR harmony while the rightmost vowel of the root and all subsequent morphemes are unaffected. In (17b,c), though, a [+ATR] enclitic, triggers leftward harmony on roots as well as other underlying [-ATR] vowels. In (17c), an enclitic triggers leftward harmony while the word-final enclitic is unaffected.

(17) Karajá ATR harmony (Ribeiro 2002:482)

a.	/∅-r-ɔ-ɗuhɔ=rɛrɪ/	→	rotʃuˈhɔrɛrɪ	‘3-CTFG-ANTI-curse=CTFG-PROG’
			*rotʃuˈhoreri	
b.	/∅-r-ɔ-ɗuhɔ=r-e/	→	rotʃuˈhore	‘3-CTFG-ANTI-curse=CTFG-IMPERF’
c.	/b-ɛ-ɗɛhɛ=ikudĩ=hɛ/	→	beɗeˈheikunihɛ	‘2-INTR-look=IMPF=EMPH’

In addition to Karajá, regressive harmony is reported in other languages, including Assamese and Bengali (Mahanta 2007), as well as Gua (Obiri-Yeboah & Rose 2017). Given data from languages like Karajá and Assamese, it seems clear that the strong prominence hypothesis is incorrect. Since the strong prominence hypothesis does not predict languages like Karajá and Assamese, this suggests that some other force likely plays a role in the directionality of vowel harmony cross-linguistically.

3.1.2 Weak prominence hypothesis

Hyman (2002, 2008) proposes a weakened version of Baković’s (2000) strong prominence hypothesis. Acknowledging cases of truly regressive harmony, Hyman suggests that vowel harmony may be motivated by prominence or directionality, but that directionality is necessarily regressive. In other words, the only theoretical primitives necessary to drive harmony are regressive directionality and prominence. Hyman marshals evidence from coarticulation and phrasal harmony to support his case that regressive harmony is a universal default setting for harmony. For coarticulation, it has been found that even in languages with progressive harmony, coarticulation tends to be anticipatory (Beddor & Yavuz 1995; Conklin 2015, cf. Conklin & Dimitrieva 2018). In languages with phrasal harmonies, like Nawuri (Casali 2002) and Kinande (Mutaka 1995; Archangeli & Pulleyblank 2002), regressive phrasal harmony is far more extensive than its progressive counterpart.

Besides default regressive directionality, Hyman (2002, 2008) considers cases of morphological prominence, like root- or stem-control to be possible sources for harmony. Harmony derived from the prominence of roots over affixes is widely attested and uncontroversial (Clements 1976; Kirchner 1993; Baković 2000). However, there are at least two other sources of prominence reported from the world’s languages, metrical prominence and edge prominence. Since metrical prominence is not relevant for the analysis of Tutrugbu we do not discuss it (see Walker 2011; Kaplan 2015), and instead center our attention on edge prominence.

Barnes (2006) demonstrates that both edges of the word may exhibit privilege. Initial syllables are shown to host more contrasts and preserve contrasts more faithfully than other positions (Trubetzkoy 1969; Beckman 1998; Steriade 1994; Walker 2011; Kaplan 2015). Initial syllables are also argued to control hiatus resolution strategies in a number of languages (Casali 1997). Furthermore, initial syllables often resist lenition processes (Kirchner 2001; Becker et al. 2012, 2017).

For an example of initial-syllable prominence, consider the Esimbi data in (17; Stallcup 1980; Hyman 1988; Walker 2011; Kaplan 2015). In Esimbi, only three vowels are attested in roots, /i ɨ u/. In the initial syllable, though, eight vowel qualities are attested. Walker (2011) and Kaplan (2015) analyze this as featural licensing, where [-high] is only licensed by the initial syllable. When [-high] is underlyingly affiliated with a stem vowel, it delinks and reassociates to the initial syllable to satisfy the licensing requirement, resulting in the pattern below. The initial syllable, which is always a prefix, can host all eight vowel qualities, while roots can only host three.

(18) Esimbi height transfer

	underlying stem vowels	Infinitive	Gloss
a.	/i/	u-ri	'eat'
b.	/u/	u-mu	'drink'
c.	/e/	o-si	'laugh'
d.	/o/	o-mu	'go up'
e.	/ə/	o-dzɨ	'steal'
f.	/ɛ/	ɔ-rini	'be poor'
g.	/ɔ/	ɔ́-mu	'sit'
h.	/a/	ɔ-bɨ	'come'

Like initial syllables, final syllables also known to exhibit prominence. Final syllables are often lengthened, and host a larger variety of contour tones cross-linguistically (Zhang 2001). In truncated tokens of polysyllabic words, children have been shown to retain final, as well as stressed syllables, over medial and unstressed syllables (Kehoe & Stoel-Gammon 1997). Additionally, final vowels may also trigger assimilation. Hyman (1998) argues that height harmony in Yaka, a Bantu language of Cameroon is triggered by the word-final syllable. Walker (2011) lists several other languages where final syllables control harmony, notably Jaqaru and a number of Romance metaphony patterns (Walker 2005).[10] Final syllables also demonstrate prominence by resistance to assimilation. For instance, progressive height harmony and tonal spreading in Bantu often leave the final vowel unaffected (e.g. Hyman 1999:238; Bickmore & Doyle 1995; Bickmore 1996).

Walker (2011) and Kaplan (2015) expand Hyman's notion of prominence to include morphological, metrical, and edge prominence, resulting in four potential sources of prominence-triggered harmony, stems (typically, roots), stressed syllables, as well as initial and final syllables. If the weak prominence hypothesis is correct, then word-internal progressive harmony may only originate from morphological stems, stressed syllables, and initial syllables.[11] Crucially, the weak prominence hypothesis predicts that progressive harmony may not be triggered by a position other than these prominent positions, in contrast to the regressive harmony seen in Karajá, which can be triggered from any position.

[10] Note, though, that these additional cases involve putative weak post-tonic syllables affiliating with a stressed syllable, which should not be conflated with the harmony pattern in Yaka.

[11] We ignore potential progressive phrasal harmonies (e.g. where a word-final vowel could trigger harmony on a following word) simply due to a dearth of attested cases.

3.1.3 Pure directionality hypothesis

We argued above that the strong prominence hypothesis in Baković (2000) critically undergenerates since it cannot account for cases of purely regressive harmony that operate independent of any morphological, metrical, or edge prominence. The weak prominence hypothesis, then, admits the possibility of purely regressive directionality as a default setting that may occur in the absence of prominence-based harmony. If we assume that morphological roots, stressed syllables, and word edges may serve as prominent positions for harmony, then the type of pattern necessary to falsify the weak prominence hypothesis is prefix-initiated progressive harmony. Specifically, harmony that involves rightward spreading from any token of [+F], whether it be affiliated with a prominent position or not, would counterexemplify the weak prominence claim, since under Hyman's proposal, harmony must either fall out from positional prominence or be regressive.

3.2 Diagnostics of directionality

To differentiate between prominence-based and purely directional harmony, we propose three general diagnostics of progressive vowel harmony. First, the harmonic feature should spread from left to right. This is obvious, and does not require elaboration. Second, does the harmonic feature, [+F], occur in weak positions in the absence of [+F] in a strong position? In order to define strong and weak positions, it is first necessary to examine potential manifestations of prominence, like hiatus resolution, stress, morphology, among others, to determine if certain positions exhibit privilege independent of the harmony pattern. To demonstrate purely progressive harmony, [+F] should occur in weak positions apart from harmony. One language that clearly passes our second diagnostic (in the regressive direction, of course) is Karajá. Recall from (17) that [+ATR] may occur anywhere in the word, and not just roots or word edges. Similarly, for clear evidence in favor of purely progressive harmony, the harmonic feature should occur in non-prominent positions independent of harmony. Third, does the harmonic feature trigger rightward assimilation from all positions in which it occurs. In addition to occurring in weak positions, [+F] should also actually trigger harmony from those positions. For instance, McCollum & Kavitskaya (2018) finds that labial harmony in Central Crimean Tatar is triggered by root-initial syllables, but not by the infinitive suffix even though it is invariantly [+round]. Thus, if [+F] occurs in weak positions independent of harmony, but only triggers harmony from prominent positions, this does not offer conclusive evidence in favor of a purely directional analysis. In the Crimean Tatar case, McCollum & Kavitskaya's (2018) analysis requires harmony to originate in the prominent initial syllable. The best evidence for purely progressive harmony would come from cases where [+F] in weak positions triggers harmony on stronger (e.g. more morphologically interior, stressed) positions.

(18) Three diagnostics for progressive harmony
1. Does [+F] trigger left-to-right harmony?
2. Does [+F] occur in weak positions in the absence of [+F] in strong positions?
3. When in weak positions, does [+F] trigger left-to-right harmony?

If these diagnostics are adjusted for regressive harmony (reversing the direction of harmony), Karajá exemplifies all three. First, [+ATR] triggers leftward harmony, satisfying the first diagnostic. Second, [+ATR] occurs in weak positions in the absence of [+ATR] in strong positions, and third, [+ATR] triggers leftward harmony from weak positions. Other attested cases of purely regressive harmony, like

Assamese and Gua similarly pass all three diagnostics, suggesting their general utility for defining purely directional harmony.

3.3 Distinguishing between prominence-based and purely progressive harmony

The most pressing question, though, is how to analyze the pattern in Tutrugbu. Tutrugbu clearly passes our first diagnostic, since harmony propagates from left to right. As for our second and third diagnostics, since harmony is only triggered by initial positions, and we have no evidence to-date for invariantly [+round] vowels in medial positions, we cannot definitely say what would happen if [+round] were to occur in a medial prefix in the absence of an initial [+round] vowel. Since we can only say with certainty that labial harmony is triggered by initial [+round] vowels, we cannot definitively distinguish between the prominence-based and purely progressive accounts of harmony in the language. If appropriate medial prefixes were found, however, it should be straightforward to distinguish between the two, and in Table 4, we outline the predictions of each analysis. If [+round] triggers harmony from initial positions, the prominence-based and purely progressive analyses converge on a shared prediction, rightward harmony, as schematized in (A) and (G). The two analyses differ, though, when [+round] occurs in non-initial positions independent of harmony. In such a case, the prominence-based account predicts that progressive harmony will not occur and that one of five possibilities will occur. First, as in Crimean Tatar (McCollum & Kavitskaya 2015) the non-initial vowel may not trigger harmony at all, as in (B). Second, if all [+round] vowels must affiliate with the initial syllable as a licensing requirement, then the presence of [+round] in V2 could trigger regressive harmony on the initial syllable, as in (C; see Kaplan 2015). Second, the language could also exhibit bidirectional harmony to all prefixes, and both affiliate the [+round] feature with the initial prefix and all subsequent prefixes, as in (D). Alternatively, a language could repair this structure by unrounding or deleting the potential trigger and thus escaping the harmonic imperative, as exemplified by (E) and (F). These four possibilities are distinct from the prediction from the purely progressive account. If [+round] occurs in a non-initial position independent of harmony, the purely progressive account predicts that [+round] will spread rightward, as seen in (H).

Table 4: Predictions of prominence-based and purely progressive analyses

Context		Prominence-based harmony		Purely progressive harmony	
Initial trigger	Progressive Harmony	✓		✓	
	Possible surface forms	A.	[o...o…]	G.	[o...o…]
Non-initial trigger	Progressive Harmony	✗		✓	
	Possible surface forms	B.	[e…o…e] (no harmony)		
		C.	[o…o...e…] (regressive harmony)		
		D.	[o…o...o…] (bi-directional harmony)	H.	[e…o...o…] (progressive harmony)
		E.	[e...e…e] or [i…e…e] (unrounding)		
		F.	[e...∅…e] or [i…∅…e] (deletion)		

As detailed in the previous section, the only contexts found in the data involve harmony from an initial-syllable trigger. As such, the prominence-based harmony and purely progressive harmony analyses are not clearly distinguishable based on this data alone. That being said, there is still evidence available to decide between the two analyses. If harmony in Tutrugbu is prominence-based, the absence of medial [+round] prefixes is not necessarily a problem. If harmony among prefixes is controlled by the initial syllable and both values of the feature spreads(cf. Steriade 1995), then the absence of invariantly [+round] medial prefixes receives an explanation. Stated differently, if the initial syllable is [-round], then it could spread its [-round] feature to all medial prefixes, thereby unrounding prefixes that are underlyingly [-round]. Additionally, if harmony is prominence-based, this predicts that initial syllables should exhibit some signs of privilege distinct from the harmony pattern. On the other hand, if harmony is purely progressive, then the absence of invariantly [+round] medial prefixes must be construed as an accidental gap. There are several ways to address these predictions, and the rest of this section is devoted to determining whether the initial syllable is really prominent in the language and whether the lack of invariantly [+round] prefixes is likely to be an accident.

3.3.1 Contrast licensing

If the initial syllable is prominent, then it should be privileged relative to other syllables in the word. One piece of evidence that suggests that initial syllables are privileged comes from contrast licensing. The initial syllable can host eight of the nine underlying vowels. The [-hi] vowel, /ɛ/, does not occur in affixes. A similar distributional restriction holds for Tafi. In Avatime, Schuh (1995:38-39) reports that /ɛ/ does not occur in prefixes, but may occur in roots as well as suffixes.

If we assume that the nine surface vowels in Tafi correspond to the historical Tutrugbu vowel system, then roots allow all nine contrasts, as /ɛ/ and /$ɛ^{H}$/, as well as /ɔ/ and /$ɔ^{H}$/ are present in roots. This is demonstrated by comparing Tutrugbu and Tafi roots, as in /$kɛ^{H}$-lɛ/ 'CM5-air' with /kí-lɛ̄/ in Tafi, and /$vɛ^{H}$/ 'go' with /vɪ/ in Tafi. Non-initial prefixes can host six vowels, /a e $ɛ^{H}$ i ɔ o/; neither /$ɔ^{H}$/ nor /u/ may occur in non-initial prefixes. Lastly, suffixes, can only host underlying /a/ and /$ɛ^{H}$/. Clearly, roots are the most prominent position in terms of contrast licensing, but after roots, initial syllables host more contrasts than both medial prefixes and suffixes. Contrast licensing by-position is shown in Table 5 below.

Table 5: Contrast licensing by position

Underlying vowel	Roots	Initial prefixes	Medial prefixes	Suffixes
a	✓	✓	✓	✓
$ɛ^{H}$	✓	✓	✓	✓
ɔ	✓	✓	✓	
e	✓	✓	✓	
i	✓	✓	✓	
o	✓	✓	✓	
$ɔ^{H}$	✓	✓		
u	✓	✓		
ɛ	✓			

3.3.2 Hiatus resolution

A second piece of evidence for the privilege of initial syllables comes from hiatus resolution. Vowel-vowel sequences across word boundaries are resolved via the reduction of the initial vowel, as demonstrated in (20) below. As seen below, V1 is reduced to a glide when it is a front or round vowel (20a-d), but deleted when V1 is /a/.[12] Bobuafor (2013:40) and Schuh (1995:47-56) note similar patterns for Tafi and Avatime.

(20) Hiatus resolution across word boundaries

		Example	Gloss	Translation
a.	Ci o → C^{j}o	/e-ɖí o-si nɔ/ → [$eɖ^{j}$ósi nɔ]	3S-look.at CM3-tree DEF	"S/he looked at the tree."
b.	Ci a → C^{j}a	/e-ɖí a-gbɛ nɔ/ → [$eɖ^{j}$ágbɛ nɔ]	3S-look.at CM1-plate DEF	"S/he looked at the plate."
c.	Cɔ a → C^{w}a	/a-mɔ́ a-dɔ̃ nɔ/ → [am^{w}ádɔ̃ nɔ]	3S-see CM1-squirrel DEF	"S/he saw the squirrel."
d.	Cɔ i → C^{w}i	/a-mɔ́ i-boʃi nɔ/ → [am^{w}íboʃi nɔ]	3S-see CM4-sheep DEF	"S/he saw the sheep."
e.	Ca e → Ce	/a-ŋa e-li nɔ/ → [aŋeli nɔ]	3S-eat CM1-palm.fruit DEF	"S/he ate the palm fruit."
f.	Ca ɔ → Cɔ	/a-ta ɔ-ɲɛ nɔ/ → [atɔɲɛ nɔ]	3S-kick CM3-firewood DEF	"S/he kicked the firewood."

[12] Compensatory lengthening appears to optionally apply when /a/ is deleted.

Word-internally, the strategy for hiatus resolution depends on position. When V1 is non-initial, V1 is reduced, like in (20) above. In (21a,b), the negation prefix is reduced immediately before the onsetless progressive prefix. In (21c,d), the root vowel is reduced before the onsetless third-person object suffix.

(21)

a.	/a-tɛ́^{H}-á-bá/	→	[at^{j}ábā]	'3S-NEG-PROG-come'
b.	/o-tí-ó-tsí/	→	[ot^{j}ótsī]	'2S-NEG-PROG-crawl'
c.	/a-baka-ɛ́^{H}/	→	[abakɛ́^{H}]	'3S-ask-3S.OBJ'
d.	/a-mɔ́-ɛ́^{H}/	→	[am^{w}ɛ́^{H}]	'3S-see-3S.OBJ'

When V1 of a VV sequence is in the initial syllable, however, V1 is not reduced. In these contexts, V2 assimilates to V1. To see this, first observe the realization of the progressive prefix. The progressive prefix is underlyingly /ɛ́^{H}/ but assimilates in height to the initial-syllable vowel. In (22a-d), PROG surfaces as a high vowel that, like other prefixes, agrees with the root for [ATR]. Note that since the two adjacent vowel qualities are identical in these cases, there is no reduction of NEG. In (22e-f), PROG is [-high], like the initial prefix. Upon doing so, PROG is subject to labial harmony from the initial prefix in addition to ATR harmony from the root. As a result of these three processes, PROG surfaces as a copy of the initial prefix. Since in (25e-f), the vowel quality of PROG is not identical to NEG, NEG reduces.

(22)

a.	ɛ-tɛ́^{H}-ɛ́^{H}-bā			'1S-NEG-PROG-come'
b.	i-tí-í-wū			'1S-NEG-PROG-climb'
c.	bɔ-tɛ́^{H}-ɛ́^{H}-bā			'1P-NEG-PROG-come'
d.	bu-tí-í-wū			'1P-NEG-PROG-climb'
e.	a-tɛ́^{H}-á-bā	→	at^{j}ábā	'3S-NEG-PROG-come'
f.	e-tí-é-wū	→	et^{j}éwū	'3S-NEG-PROG-climb'
g.	ɔ-tɛ́^{H}-ɔ́-bā	→	ɔt^{j}ɔ́bā	'2S-NEG-PROG-come'
h.	o-tí-ó-wū	→	ot^{j}ówū	'2S-NEG-PROG-climb'

Now we can see the role of the initial syllable in hiatus resolution. The only context where the initial syllable may be V1 in a VV sequence is when the initial syllable is immediately followed by the progressive prefix. In these cases, the realization of PROG after the [+hi, +rd] vowels /ɔ^{H} u/ is most critical, (23c,d). In these instances, sequences of /ɔ^{H}-ɛ^{H}/ and /u-i/ are repaired by assimilating V2 to V1. These are the only instances where distinct vowel qualities may occur in this context, and in these cases V1 is preserved.

(23)

a.	ɛ^{H}-ɛ́^{H}-bā		'1S-NEG-PROG-come'
b.	i-í-wū		'1S-NEG-PROG-climb'
c.	bɔ-ɛ́^{H}-bā	→ bɔɔ́bā	'1P-NEG-PROG-come'
d.	bu-í-wū	→ buúwū	'1P-NEG-PROG-climb'
e.	a-á-bā		'3S-NEG-PROG-come'
f.	e-é-wū		'3S-NEG-PROG-climb'
g.	ɔ-ɔ́-bā		'2S-NEG-PROG-come'
h.	o-ó-wū		'2S-NEG-PROG-climb'

As we saw in (20-23), reduction of V1 is the general pattern in the language, found across word boundaries as well as word-internally. However, V2 is reduced when V1 is in the initial syllable. Based on this and the relatively large number of contrasts that the initial syllable can host, we conclude that the initial syllable in Tutrugbu is phonologically prominent. As a result, we conjecture at this point that harmony is motivated by prominence.

3.4. The absence of medial [+round] prefixes

In addition to the putative prominence of initial syllables, the lack of medial [+round] prefixes offers another way to distinguish between the two analyses at hand. Here we discuss both language-internal and typological evidence related to the distribution of [round] on initial and medial prefixes.

3.4.1 Language-internal statistical probability

If the lack of medial prefixes in Tutrugbu is purely accidental, this predicts that there is no relationship between position and the occurrence of invariantly round prefixes. To test this, we counted the number of morphemes found during fieldwork that occur in initial and medial prefix positions. In total, we found 24 initial prefixes, 6 pronominal subject prefixes, 9 noun class-marking prefixes, and 9 subject agreement prefixes. Of these, 7 are invariantly round (3 pronominal subject prefixes, 2 noun class prefixes, and 2 agreement prefixes). Of the 16 medial prefixes found in the language, none are invariantly round. Among the non-high medial prefixes, all alternate in accordance with harmony; among the high prefixes, all are invariantly unrounded. Using a Fisher's exact test, the distribution of [round] is not independent of position, $p = .03$. In other words, there is a significant relationship between prefix position and [round].

Table 6: The distribution of [round] in initial versus medial prefixes

	Initial	Medial	Total
[-round]	17	16	33
[+round]	7	0	7
Total	24	16	40

This result is not conclusive proof that round vowels on medial prefixes are licensed only by harmony. Instead, this result provides suggestive evidence that the distribution of round vowels in prefixes is not accidental.

3.4.2 Medial prefixes in the typology of prefix-initiated harmony

In addition to language-internal evidence, the distribution of round vowels in other Ghana-Togo Mountain languages, as well the distribution of harmony-triggering vowels in other languages with prefix-initiated harmony offer another way to evaluate the lack of invariantly round medial prefixes in Tutrugbu.

We have access to grammars of twelve other Ghana-Togo Mountain languages, which are shown in Table 7 below. In three of these languages, Tafi, Logba and Igo, labial harmony is triggered by the initial prefix, and round prefixes do not occur apart from harmony. In Tuwuli and Akebu, labial harmony is triggered by the root, and spreads regressively throughout the prefixal domain. In both of these languages, a round prefix may only occur in the presence of a round root. In contrast, in all seven Ghana-Togo Mountain languages that do not exhibit some form of labial harmony, invariantly round medial prefixes are attested. In languages with harmony, medial prefixes may only be round in the presence of a round vowel in a prominent position. Elsewhere in the language family, though, invariantly round medial prefixes are attested regardless of root or initial vowel quality.

Table 7: Labial harmony and [+round] medial prefixes in the Ghana-Togo Mountain languages

Language	labial harmony	[+round] medial prefixes	Example	Gloss	Citation
Tafi	yes, from V1	only due to harmony	ɔ́-bɔ-tã	‘2S-FUT-eat’	Bobuafor (2013:32,42-43)
Logba	yes, from V1	only due to harmony	ɔ́-bɔ́-kpɛ	‘SM-FUT-eat’	Dorvlo (2008:144-146)
Igo	yes, from V1	only due to harmony	o-no-zo-fo-nò	‘2-HAB-PST-AUX-weave’	Gblem-Podi (1996)
Tuwuli	yes, from root	only due to harmony	sɔ-mɔ	‘CM-neck’	Harley (2005:64)
Akebu	yes, from root	only due to harmony	lóó-pò-kó	‘3S-FUT-go’	Makeeva & Shluinskij (2013:363)
Avatime	no	yes	kíà-zɔ̌-ta	‘1P-REP-eat’	Defina (2016:56,61); van Putten (2014:53)
Anii	no	yes	gí-bʊ̀ŋà-dá	‘1P-PST-be’	Morton (p.c., 2002)
Buem	no	yes			Allan (1974)
Ikposo	no	yes	á-fɔ̀nǎ-fʊ́sʊ́	‘3S-HAB-seek’	Soubrier (2013:206-207)
Likpe	no	yes	è-bó-kpé	‘2S-FUT-put’	Delalorm (2016:328-329)
Sɛlɛɛ	no	yes	a-too-wola	‘3S-PFV-carve’	Agbetsoamedo (2014:24)
Siwu	no	yes	à-ɔ̀-ɲa	‘2S-PFV-see’	Dingemanse (2011:320)

If one claims that the absence of invariantly round vowels in medial prefixes is accidental in Tutrugbu, their absence in all other related languages with vowel harmony, and their presence in languages without harmony must be construed as accidental, too. This seems highly unlikely, and we interpret these facts from the language family as further evidence in favor of a prominence-based interpretation of harmony in Tutrugbu.

In addition to language-internal and genetic evidence, we examined unrelated languages with prefix-initiated harmony patterns to determine if the distribution of the harmonic feature, [+F], is independent of position. We know of five prefix-initiated labial harmony patterns outside the Ghana-Togo Mountain languages- one Kwa language, Nkami (Akanlig-Pare & Asante 2016), and four Bantu languages of Cameroon, Abo (Atindogbe 1996; Finley 2012), Gunu, Maande, and Mmala (Boyd 2015:251-253). As in Tutrugbu, [+round] medial prefixes may only occur due to harmony in these five languages. Thus, none of these languages present the evidence necessary to satisfy our second and third diagnostics, since [+round] does not occur in weak positions independent of harmony.

We also know of four prefix-initiated ATR harmony patterns, Tunen, Tuki, KiBudu, and Kinande (Mous 1986; Kutsch Lojenga 1994; Hyman 2002; Boyd 2015; Moskal 2015). We present data from Tunen below that is representative of these five languages.

In Tunen, a Mbam language of Cameroon, prefixes generally alternate based on the [ATR] value of the root, as shown in (24a-d; Dugast 1971; Mous 1986; van der Hulst et al. 1986; Boyd 2015; Moskal 2015).. In these examples, the class 3 and 4 suffixes agree with the nominal root for [ATR]. However, function words behave differently than content words. In (25a-e), we see the function words, /táná/ 'this', /mɔ̀tí/ 'one/some,' and /fà^{n}dì/ 'two', surface as [-ATR] when preceded by [-ATR] prefixes. However, in (25f-j), we see these same function words surfacing as /tə́nə́/ 'this', /mòtí/ 'one/some', and /fə̀^{n}dí/ 'two' after [+ATR] prefixes. Thus, in (25) these roots alternate based on the [ATR] value of the prefix. This prefix-initiated progressive harmony in Tunen is limited to function words only. When the root is a content word, harmony is regressive.

(24) Regressive ATR harmony in Tunen

a. mʊ̀-líŋí 'CM3-tail'
b. mù-lə́^{n}dù 'CM3-tendril'
c. mì-líŋí 'CM4-tail'
d. mì-lə́^{n}dù 'CM4-tendril'

(25) Progressive ATR harmony in Tunen

a. mɔ́-táná 'CM1-this'
b. ɔ̀-mɔ̀tí 'CM1-one/some'
c. pá-táná 'CM2-this'
d. pá-mɔ̀tí 'CM2-one/some'
e. pá-fà^{n}dì 'CM2-two'

f. mú-tə́nə́ 'CM3-this'
g. ú-mòtí 'CM3-one/some'
h. mí-tə́nə́ 'CM4-this'
i. í-mòtí 'CM4-one/some'
j. í-fə̀^{n}dí 'CM4-two'

Using our three diagnostics above, let us consider progressive ATR harmony in Tunen. First, does harmony spread from left to right? Yes. Second, does [+ATR] occur in weak positions apart from harmony? The feature value [+ATR] occurs in prefixes, roots, and suffixes in the language. However, the only prefixes that are invariantly [+ATR] are initial prefixes, like in (20f-j). There are no invariantly [+ATR] prefixes that occur word-medially. Therefore, we cannot conclusively say that [+ATR] occurs in weak positions apart from harmony. According to Boyd (2015), there are two [+ATR] dominant suffixes, and otherwise [+ATR] occurs only in roots or initial syllables. As for our third diagnostic, when in weak positions, does [+ATR] trigger left-to-right harmony? Since [+ATR] does not occur in any obviously weak positions, we cannot say with certainty that this harmony satisfies our third diagnostic. In sum, the results from Tunen are unclear. The language does not provide the contexts necessary to fully judge whether progressive harmony is prominence-based or purely progressive.

More generally, in all of these languages, a single prefix may trigger [+ATR] spreading on certain function words. Notably absent, though, are medial prefixes in these languages. In addition to these ATR harmonies, we know of one last prefix-initiated harmony, height harmony in Mmala (Boyd 2015:253-254). Just like the prefix-initiated ATR harmony patterns, though, only a single prefix may occur in these forms, and so there is no evidence for a purely progressive analysis.

In sum, we find no evidence of medial prefixes that may invariantly bear the harmonic feature for any of the prefix-initiated harmony patterns examined. Among the ATR and height harmony patterns, this was due to the lack of medial prefixes. However, in the nine languages that exhibit labial harmony from the initial prefix, invariantly round medial prefixes are unattested. If the lack of round medial prefixes in Tutrugbu is accidental, we should not expect any necessary correlation between prefix-initiated harmony and invariantly round medial prefixes. Yet, this is not what we have found. Instead, we have found a very strong correlation between prefix-initiated harmony and medial prefixes. In languages with harmony, medial round prefixes do not occur, but in languages without prefix-initiated labial harmony, invariantly round medial prefixes may occur. In one language, this sort of gap could be accidental. Perhaps even with the language family this could be accidental, although less likely. However, given that every language with prefix-initiated harmony, regardless of genetic affiliation and harmonic feature exhibits the same lack of invariantly [+F] medial prefixes suggests a more principled reason for this gap.

Taken together, all the evidence discussed in this section supports a prominence-based analysis. Initial syllables exhibit privilege in the language, as manifested in hiatus resolution and contrast licensing. Furthermore, given the number of morphemes discovered during fieldwork, the lack of medial [+round] prefixes is statistically significant. Within the language family, the fact that every language with harmony exhibits the same prohibition on medial [+round] prefixes while every language without harmony allows them provides even more evidence that invariantly [+round] prefixes are not accidentally absent in medial prefixes. Finally, the same absence of medial [+F] prefixes in all other languages with prefix-initiated harmony further reinforces the generalization- prefix-initiated progressive harmony may be triggered by initial syllables only. In conjunction, in languages with prefix-initiated harmony, [+F] is never allowed in weak (medial) positions apart from harmony, suggesting that initial syllables are prominent, and prominence drives progressive harmony from prefixes.

Before moving onto the Optimality Theoretic analysis, we want to reiterate that the proposed analysis is not the only possible analysis of the data. It is possible, as noted throughout, to construct an analysis that relies of progressive directionality without regard for prominence. The challenge for this analysis is accounting for the lack of [+round] medial prefixes in Tutrugbu, and more generally, the lack of [+F] medial prefixes in other languages with similar harmony patterns. Based on the data at hand, we argue that progressive directionality in Tutrugbu falls out from prominence, and by extension, that progressive directionality is more generally derivable from prominence. In other words, progressive directionality is epiphenomenal (see also Kaplan 2008).

4 Formal analysis

In this section we present an analysis of labial harmony in Tutrugbu using Agreement-by-Correspondence (ABC; Rose & Walker 2004; Hansson 2010; Bennett 2015 a.o.). As a reminder of the data shown in §2, labial harmony in Tutrugbu exhibits the following four properties. It is triggered by the initial syllable. It is definable in terms of vowel height, both for triggers and targets. The domain of harmony is definable in terms of morphological constituency, since harmony is almost exclusively limited to prefixes. Finally, within roots harmony holds as a co-occurrence constraint without any discernible directionality.

ABC was developed to account for similarity-sensitivity and transparency in consonant harmony. Both similarity and transparency are crucial to the analysis presented below, making ABC a good fit for the analysis of Tutrugbu presented below. Note that for the formalization of harmony, we ignore ATR harmony (see McCollum & Essegbey 2018 for an analysis).

ABC uses two mechanisms to drive harmony, surface correspondence and surface identity. CORR constraints enforce correspondence between vowels that are featurally similar, which is indicated by subscript indices throughout. Thus, correspondence preferentially targets segments with more shared features. Since labial harmony in Tutrugbu is triggered by and targets non-high vowels only, the feature [-high] will play a key role in the analysis. In (26) we describe CORR-OE, which drives same-height correspondence among non-high vowels.

(26)	CORR-OE	let S be an output string of segments, and let X and Y be vowels in S with the feature [-high], assign a violation if X and Y do not correspond.

The CORR constraint above, CORR-OE, encodes two cross-linguistic generalizations regarding labial harmony made in Kaun (1995, 2004). First, non-high vowels are better triggers for harmony than high vowels, and second, same-height harmony is preferred over cross-height harmony. While a variety of other patterns exist, this type of pattern is found in a wide range of languages, including Mongolic (Svantesson 1985; Rhodes 2012) and Tungusic language families (Li 1996; Dresher & Zhang 2005; Walker 2001), as well as a number of Bantu languages (Boyd 2015). In the tableaux to follow, correspondence is marked with subscript indices.

Along with the similarity-sensitive correspondence constraint above, we need a constraint to enforce surface identity between correspondents. A general VV-IDENT[RD] constraint is defined below.

(27)	VV-IDENT[RD]	let X and Y be segments in the output, S. If X and Y correspond, then X and Y agree for the feature, [round].

In addition to these two constraints, three faithfulness constraints are necessary for the analysis. First, we need a constraint on harmony, for which we use DEP[+RD] (McCarthy & Prince 1995:265; Walker 1999).

(28) DEP[+RD] for every input-output correspondence pair, X-Y, assign a violation for every pair in which output Y is [+round] and input X is not.

We also need a constraint banning unrounding of underlyingly [+round] vowels.[13] We use MAX[+RD] for this purpose.[14]

(29) MAX[+RD] for every input-output correspondence pair, X-Y, assign a violation for every pair in which input X is [+round] and output Y is not.

We see the interaction of these four constraints in (30) below. Given an input pair of vowel, /ɔ…a/, harmony applies if DEP[RD] is outranked by the other three constraints. The vowels in candidate (a) do not correspond, and are ruled out by CORR-OE. The vowels in candidate (b) correspond, but fail to agree, critically violating VV-ID. Candidate (c) satisfies both CORR-OE and VV-ID, but unrounds /ɔ/ to [a], and since MAX[+RD] >> DEP[+RD], Candidate (c) loses to Candidate (d).

(30)

		/ɔ…a/	CORR-OE	VV-ID [RD]	MAX [+RD]	DEP [+RD]
	a.	ɔ…a	*!			
	b.	$ɔ_x…a_x$		*!		
	c.	$a_x…a_x$			*!	
☞	d.	$ɔ_x…ɔ_x$				*

Harmony has no inherent directionality in (30), since CORR-OE and VV-ID impose no restrictions on the direction of correspondence or identity (cf. Hansson 2010). To see this, consider (31), where the order of the inputs is reversed. Since all the constraints motivating harmony are symmetrical, the violation profiles below are identical to those in (30).

(31)

		/a…ɔ/	CORR-OE	VV-ID [RD]	MAX [+RD]	DEP [+RD]
	a.	a…ɔ	*!			
	b.	$a_x…ɔ_x$		*!		
	c.	$a_x…a_x$			*!	
☞	d.	$ɔ_x…ɔ_x$				*

[13] We assume that both values of the feature may be active, as we pointed out in §3.3. If, however, [round] is privative (Steriade 1995), the analysis presented in this section does not fundamentally change, necessitating only a slight modification to the constraints in (28) and (29).
[14] In Pater (1999) and Rose & Walker (2004), MAX[+F] and DEP[+F] are formulated as IDENT-IO[+F] and IDENT-OI[+F], respectively.

This basic set of constraints motivates harmony between non-high vowels. However, without the introduction of other constraints, this set of constraints predicts that a non-high round vowel anywhere in the word will trigger rounding on all other vowels. To constrain harmony to operate from initial to medial prefixes only, we introduce a positional faithfulness constraint (Beckman 1997).

As discussed in §3.3.1, both initial syllables and roots show prominence by licensing a larger number of contrasts. Initial syllables initiate progressive harmony and resist reduction in hiatus. Similarly, roots initiate ATR harmony and resist labial harmony. The positional faithfulness constraints below prevent vowels in both positions from undergoing harmony.

(32) IDENT-IO-PROM-[RD] for every input-output correspondence pair X-Y occurring in a prominent position (i.e. root or initial syllable), assign a violation for every pair in which the [round] feature value of X and Y is not identical.

To see the relative ranking of ID-PROM, consider the tableau in (33). Recall from §2.3 that if either vowel of a disyllabic root is round, then the other is, as well. In (33), we have assigned the root an underlying form with only one [rd] vowel. The two harmony-driving constraints, CORR-OE and VV-ID, are ranked in the top stratum above the three faithfulness constraints. ID-PROM, in turn outranks the two more general faithfulness constraints. Candidate (a), the faithful candidate, is ruled out because the two vowels do not correspond, incurring a violation of CORR-OE. Candidate (b) runs afoul of VV-ID because both vowels correspond but fail to agree. Vowels in candidates (c) and (d) both correspond and agree for [round]. Since roots are prominent, changing the value of either vowels input specification incurs a violation of ID-PROM. However, the ranking of MAX[+RD] >> DEP[+RD] favors rounding over unrounding. As a result, the constraint ranking below generates the attested output for vowel co-occurrence within roots. Note that it would not matter which vowel was specified for [rd] underlyingly. If one root-internal non-high vowel is assigned an underlying [rd] feature, then all root-internal non-high vowels will surface with rounding, which follows from the ranking CORR-OE, VV-ID >> MAX[+RD], DEP[+RD].

(33)

		/lakɔ/	CORR-OE	VV-ID [RD]	ID-PROM [RD]	MAX [+RD]	DEP [+RD]
	a.	lakɔ	*!				
	b.	$la_xkɔ_x$		*!			
	c.	la_xka_x			*	*!	
☞	d.	$lɔ_xkɔ_x$			*		*

The constraint ranking above also accounts for harmony between non-high prefixes, like (3e), [o-bo-ji] '2S-FUT-appear' In (34), the faithful candidate, Candidate (a) is ruled out by CORR-OE because the non-high vowels do not correspond. Candidate (b), is suboptimal because the non-high vowels correspond but do not agree for the harmonic feature, violating VV-ID. Candidate (c) incurs a fatal violation of ID-PROM by unrounding the initial syllable vowel. Candidate (d), the attested output, wins because non-high prefix vowels both correspond and agree, with the prominent position controlling harmony. Since /ɔ/ occurs in the prominent initial syllable, it is protected, and harmony proceeds rightward.

(34)

		/o-be-ji/	CORR-OE	VV-ID [RD]	ID-PROM [RD]	MAX [+RD]	DEP [+RD]
	a.	o-be-ji	*!				
	b.	o_x-be_x-ji		*!			
	c.	e_x-be_x-ji			*!	*	
☞	d.	o_x-bo_x-ji					*

If we assign the future prefix an underlying [rd] specification in the input to (35), /e-bo-ji/ '3S-FUT-appear', in accordance with OT's requirement that underlying representations are not constrained by the grammar, then ID-PROM is necessary to prevent regressive harmony on the initial syllable. Like Candidates (a) and (b) in (34), Candidates (a) and (b) below are ruled out due to violations of CORR-OE or VV-ID. Candidate (c) triggers regressive rounding on the initial syllable, and is suboptimal due to a violation of ID-PROM. Candidate (d), which unrounds the medial prefix, wins because unfaithfulness in a medial syllable is preferred over unfaithfulness in the initial syllable. For the first time, we see that ID-PROM must be ranked above MAX[+RD], since any change to a vowel in a prominent position is worse than unrounding.

(35)

		/e-bo-ji/	CORR-OE	VV-ID [RD]	ID-PROM [RD]	MAX [+RD]	DEP [+RD]
	a.	e-bo-ji	*!				
	b.	e_x-bo_x-ji		*!			
	c.	o_x-bo_x-ji			*!		*
☞	d.	e_x-be_x-ji				*	

In addition to CORR-OE, there are two other correspondence constraints that could figure into the analysis, CORR-UI, which motivates correspondence for [+hi] vowel pairs, and a general CORR-UE, which motivates correspondence for all vowel pairs. Since [+hi] vowel pairs do not participate in harmony we assume that the grammar distinguishes between these three, ranking CORR-OE above CORR-UI and CORR-UE.[15]

[15] A second way to mitigate against harmony would be to use CORR-αHI to drive same-height harmony among both high and non-high vowels in conjunction with a markedness constraint against [+hi,+rd] vowels. If *[+hi,+rd] outranked the harmony driving constraints, then harmony among high vowels could be curtailed.

As noted above, high vowels are transparent to harmony. Their transparency falls out from the ranking established above, which is demonstrated below. Candidates (a) and (b) in (36) are ruled out, as above, because they contain non-high vowels that either fail to correspond or fail to agree. Candidate (c) avoids harmony by unrounding the vowel in the initial syllable, incurring a fatal violation of ID-PROM. Candidate (d) assimilates the [+hi] prefix, in addition to the medial [-hi] prefix. Cross-height correspondence is not motivated by CORR-OE, and the additional violation incurred by DEP[+RD] for Candidate (d) dictates that Candidate (e) is the winner.

(36)

		/o-tí-be-ji /	CORR-OE	VV-ID [RD]	ID-PROM [RD]	MAX [+RD]	DEP [+RD]
	a.	o-tí-be-ji	*!				
	b.	o$_x$-tí-be$_x$-ji		*!			
	c.	e$_x$-tí-be$_x$-ji			*!	*	
	d.	o$_x$-tú$_x$-bo$_x$-ji					**!
☞	e.	o$_x$-tí-bo$_x$-ji					*

Thus far we have seen two examples with [+hi] roots, which have not entered into correspondence due to their height specification. However, under the current ranking, a [-hi,+rd] root vowel will trigger regressive harmony on non-high prefixes, which is unattested. This problematic prediction is seen below, in (37). Candidates (a-d) are eliminated by the top stratum of constraints. Note that in words with three non-high vowels, there are three vowel pairs (V1-V2, V2-V3, and V1-V3). As a result, a maximum of three violations of CORR-OE and VV-ID are possible. Candidate (e) violates ID-PROM by unrounding the root vowel. Candidate (f), on the other hand, violates ID-PROM by rounding the initial-syllable vowel. The next constraint, MAX[+RD] adjudicates between the two, favoring Candidate (f) because the ranking favors spreading [+round] over unrounding, all else being equal. In actuality, harmony does not obtain between roots and prefixes, so Candidate (f) is marked with a bomb, indicating that the current constraint set favors an unattested output.

(37)

		/a-ba-mɔ/	CORR-OE	VV-ID [RD]	ID-PROM [RD]	MAX [+RD]	DEP [+RD]
	a.	a-ba-mɔ	*!**				
	b.	a-bɔ$_x$-mɔ$_x$	*!*				*
	c.	a$_x$-ba$_x$-mɔ	*!*				
	d.	a$_x$-bɔ$_x$-mɔ$_x$		*!*			
	e.	a$_x$-ba$_x$-ma$_x$			*	*!	
💣	f.	ɔ$_x$-bɔ$_x$-mɔ$_x$					**

To curtail correspondence, Bennett (2015) introduces a family of LIMITER constraints, among which EDGE constraints curtail correspondence across certain morphological boundaries. These constraints are effectively equivalent to the earlier autosegmental family of CRISPEDGE constraints (Itô & Mester 1994, 1999). Using a version of this constraint, VV-EDGE(ROOT), introduced in (38), it is possible to prevent correspondence across a root boundary.

(38) VV-EDGE(ROOT) let S be an output string containing the two morphological categories, root, and affix, R and A, respectively. For each correspondent pair in S, X and Y, assign a violation if one correspondent is contained in the R and the other correspondent is not.

VV-EDGE(ROOT) prohibits roots and affixes from corresponding, effectively preventing roots from affecting affixes and vice versa. If VV-EDGE dominates CORR-OE, then we are able to rightly predict the optimal output from (37), which is shown in (39) below. VV-EDGE eliminates all candidates with correspondents across the root boundary, leaving only Candidates (e) and (f). Candidate (e) exhibits no correspondence between the two non-high prefixes, and is eliminated. The actual attested output, Candidate (f), wins because it exhibits correspondence between prefixes.

(39)

		/a-ba-mɔ/	VV-EDGE (ROOT)	CORR-OE	VV-ID [RD]	ID-PROM [RD]	MAX [+RD]	DEP [+RD]
	a.	a_x-b$ɔ_x$-m$ɔ_x$	*!*		**			
	b.	a_x-ba_x-ma_x	*!*			*	*	
	c.	$ɔ_x$-b$ɔ_x$-m$ɔ_x$	*!*			*		**
	d.	a-b$ɔ_x$-m$ɔ_x$	*!	**				*
	e.	a-ba-mɔ		*!**				
☞	f.	a_x-ba_x-mɔ		*!*				

By adding VV-EDGE to our constraint set, we successfully accounted for disharmony between a round root and unrounded prefixes in (39). In (40), we show that VV-EDGE also prevents harmony from a [+round] prefix onto a root. Crucially, VV-EDGE rules out Candidate (b), which involves progressive harmony from the initial syllable onto the root. Candidate (f) is optimal because the domain of correspondence does not extend across the root boundary, and within the domain delimited by VV-EDGE, harmony is dictated by the initial syllable.

(40)

		/ɔ-ba-bá/	VV-EDGE (ROOT)	CORR-OE	VV-ID [RD]	ID-PROM [RD]	MAX [+RD]	DEP [+RD]
	a.	$ɔ_x$-ba_x-$bá_x$	*!*		**			
	b.	$ɔ_x$-$bɔ_x$-$bɔ́_x$	*!*			*		**
	c.	ɔ-ba-bá		***!				
	d.	$ɔ_x$-ba_x-bá		**	*!			*
	e.	a_x-ba_x-bá		**		*!	*	
☞	f.	$ɔ_x$-$bɔ_x$-bá		**				*

Using the general ABC constraint set to encode similarity-sensitivity, along with constraints on domain edges, we have presented a formal analysis of progressive harmony in Tutrugbu. The above set of constraints can motivate root-internal vowel agreement, as well as prefix-internal harmony from the initial syllable, and significantly, these constraints do so without directly encoding progressive directionality.

In the next section we discuss the residual issue of vowel height in the analysis, noting a number of alternatives. We then go on to discuss the larger typology of directionality in vowel harmony.

5 Discussion

5.1 The height of [$ɔ^H$] and [$ɛ^H$]

Throughout the previous section we examined [+high] vowels in [+ATR] contexts only, as in (34-36). In [-ATR] contexts, though, homophonous 1P and CM8, [$bɔ^H$], do not trigger harmony despite surfacing as mid vowels. We argued in §2.2 that both [$ɔ^H$] and [$ɛ^H$] behave as [+high] vowels in Tutrugbu. Four pieces of evidence were discussed. First, these vowels alternate with [+high] vowels, [u] and [i] for ATR harmony. Second, [$ɔ^H$] does not trigger labial harmony, unlike the mid vowels [o] and [ɔ]. As such, [$ɔ^H$] behaves exactly like [u]. Third, [$ɛ^H$] does not undergo harmony, unlike [a] and [e]. Like [$ɔ^H$] above, [$ɛ^H$] behaves like its [ATR] counterpart, [i]. Fourth, these vowels correspond to [ʊ] and [ɪ] in closely-related Tafi.

As briefly noted in §2.2, ATR harmony also provides evidence that [$ɔ^H$] and [$ɛ^H$] are phonologically [+high] in the language. ATR harmony is blocked by the combination of an initial-syllable high vowel and a medial non-high prefix (McCollum & Essegbey 2018; McCollum et al. 2018). In (41a,b), two [-hi] prefixes surface as [+ATR] preceding a [+ATR] root. So, [-high] vowels do not block harmony on their own. In (41c,d), two [+high] vowels surface as [+ATR] before a [+ATR] root, indicating that [+high] vowels do not block harmony on their own. When the initial vowel is [-high] and is followed by a [+high] prefix, as in (41e,f), harmony similarly obtains. However, when the initial vowel is [+high] and is followed by a [-high] prefix, harmony is blocked, shown in (41g,h).[16] Most significantly, [$ɔ^H$] and [$ɛ^H$]

[16] As we noted in relation to (11), a second pattern involves a transparency rather than blocking in this context, e.g. [i-ba-wu] and [bu-ba-wu] for (41g,h). In this variety of the language, /a/ is conditionally transparent, but the same generalization holds, the behavior of medial /a/ depends on the height of the initial-syllable vowel.

pattern like [+high] vowels. Non-high vowels always undergo ATR harmony in initial syllables, but these two vowels do not. The behavior of [ɔ^{H}] and [ɛ^{H}] for ATR harmony provides further evidence in favor of an abstract [+high] feature.

(41) Conditional blocking in Tutrugbu ATR harmony

a.	e-be-wu		'3S-FUT-climb'
b.	be-be-wu		'3P-FUT-climb'
c.	i-tí-wu		'1S-NEG-climb'
d.	bu-tí-wu		'1P-NEG-climb'
e.	e-tí-wu		'3S-NEG-climb'
f.	be-tí-wu		'3P-NEG-climb'
g.	ɛ^{H}-ba-wu	*i-be-wu	'1S-FUT-climb'
h.	bɔ^{H}-ba-wu	*bu-be-wu	'1S-FUT-climb'

We have encoded the phonological height of [ɔ^{H}] and [ɛ^{H}] with superscripts to indicate an abstract [+high] feature. We have prioritized accounting for the phonological behavior of these vowels, skirting an analysis of these vowels in [-ATR] contexts. There are other possibilities, though, which to varying degrees account for both the phonological behavior of these vowels and their surface vowel quality. We discuss these in turn. First, the only way we see to account for both the phonological behavior of these vowels and their surface quality is to posit a derivational analysis, where |ɪ| and |ʊ| lower to [ɛ] and [ɔ] post-lexically. This sort of analysis allows these vowels to behave as [+high] during the phonology, but to surface as mid.

Another possibility is to directly encode the details of this alternation in OT. We would need a constraint, *[+hi, -ATR] ranked highly to ban output [ɪ] and [ʊ], and the ranking of the relevant faithfulness constraints would dictate that [i] alternates with [ɛ] (what we've labelled [ɛ^{H}]), and [u] with [ɔ] (our [ɔ^{H}]). We see one real issue with this approach. This would predict that these vowels participate in labial harmony in ATR contexts since they are non-high, but that they don't in [+ATR] contexts, since they are high. Perhaps this could be resolved via a paradigm uniformity constraint (Burzio 1996), but the machinery necessary to develop this would, like the derivational analysis just noted, lead us too far afield from the larger issue at hand, prominence and directionality.

Still a third way to account for these facts is to index the set of morphemes and trigger and undergo harmony in a manner consistent with (Pater 2000; Finley 2010) and other models of lexical indexation. Using a cloned set of constraints to dictate the (non-)participation of certain morphemes is conceptually similar to what we have proposed here, an abstract height feature. Problematically though, under a lexical indexation analysis, the morphemes that trigger and undergo harmony all coincidentally share a [-high] feature. The feature-based generalization is lost, and importantly, there is no independent evidence for treating the morphemes that participate in harmony as somehow distinct morphologically from those that do not. In contrast, there is good evidence that the vowels that participate in harmony are treated as [+high] elsewhere in the phonology.

One last possibility is that the surface vowels [ɛ^{H}] and [ɔ^{H}] derived from historical *ɪ and *ʊ are distinguishable from [ɛ] and [ɔ] by their surface phonetic properties, exemplifying a near-merger of these historically distinct vowel qualities. To assess the plausibility of a near-merger analysis, we culled thirteen initial-syllable tokens each of [ɔ^{H}] and [ɔ] from the class 8 prefix [bɔ^{H}] (which alternates with [bu]) and the class 3 prefix, [ɔ] (which alternates with [o]). All tokens were selected from the audio dictionary noted in §2.1.

If the merger of the historical *ʊ and *ɔ vowels is complete, then we should find no significant differences in F1, F2, or vowel duration. We conducted t-tests on each dependent variable, finding no significant differences for any of these three variables (for F1, t(24)= 1, p= .33; for F2, t(24)= 1.16; p= .26; for duration, t(24)= -.75; p= .46). Descriptive statistics are shown in Table 8. From these results we conclude that [ɔ^{H}] and [ɔ] are acoustically indistinguishable, suggesting complete merger of these vowels.

Table 8: Mean F1, F2 and duration for [ɔ^{H}] and [ɔ]

Vowel	F1 (SD)	F2 (SD)	Duration (SD)
ɔ^{H}	570 (45)	942 (118)	133.5 (27.7)
ɔ	585 (26)	983 (49)	126.5 (18.6)

To test the difference between [ɛ^{H}] and [ɛ] we culled ten examples of each phoneme from the same dictionary. In Tutrugbu (as well as in Tafi), [ɛ] does not occur as a prefix, so we examined these vowels in root-final position. Tokens were assumed to derive from historical *ɪ if the Tafi cognate possesses a surface [ɪ]. Similarly, tokens were assumed to derive from *ɛ if the Tafi cognate possesses a surface [ɛ]. We conducted t-tests on each dependent variable, and as above, found no significant differences in F1, F2 or duration (for F1, t(18)= 0.61, p= .55 ; for F2, t(18)= -0.60; p= .56; for duration, t(24)= 0.56; p= .58). Descriptive statistics are shown in Table 9.

Table 9: Mean F1, F2 and duration for ɛ^{H} and ɛ

Vowel	F1 (SD)	F2 (SD)	Duration (SD)
ɛ^{H}	536 (82)	2283 (126)	160.64 (25.5)
ɛ	559 (89)	2227 (269)	167.46 (29.0)

Based on these results, there is no phonetic difference we can appeal to in order to differentiate [ɔ^{H}] from [ɔ] and [ɛ^{H}] from [ɛ]. Since we cannot appeal near merger to escape the abstract behavior of these two vowels, we have chosen to differentiate these two contrasts with an abstract [+high] feature.

This move parallels abstract underlying representations in analyses of languages like Yokuts (Kisseberth 1969; Kenstowicz & Kisseberth 1979), Hungarian (Vago 1973) and Inupiaq (Kaplan 1981; Compton & Dresher 2011). This approach to opaque interactions has a long history in generative phonology (see also work in the Toronto School; e.g. Dresher 2009; Compton & Dresher 2011; Mackenzie 2013). In many cases, like Yokuts (Kisseberth 1969; Kenstowicz & Kisseberth 1979) and the analysis proposed above, there is very good evidence for positing abstract underlying phonemes.

One last point related to the high vowels is worthy of discussion- our analysis requires that correspondence is not based entirely on acoustic vowel quality. This is distinct from much work within ABC, which assumes that correspondence is sensitive to surface information only (Rose & Walker 2004; Hansson 2010; Bennett 2015; see also Wayment 2009). If correspondence targets surface mid vowels only, without reference to other information, then /ɛ^{H}/ and would undergo harmony while its [+ATR] counterpart, /i/ would not. This problematic prediction of a surface-only correspondence relation mirrors the issue noted for the alternative OT analysis sketched above. In addition to ABC, tier- and projection-based models of phonology (Heinz 2010; Heinz et al. 2011; Hansson 2014; McMullin 2016) are also imminently reasonable alternatives to the analysis just presented. All three are able to model transparency and long-distance effects, which was a key part of the analysis just presented.

5.2 The typology of directionality and prominence

Under our analysis, the directional behavior of harmony in Tutrugbu is epiphenomenal. As discussed earlier, cases of purely regressive harmony are problematic for Baković's (2000) analysis, which we deemed the strong prominence hypothesis. Hyman's (2002, 2008) weak prominence hypothesis, that harmony is either regressive or derivable from prominence, is very similar to the analysis proposed here. However, Hyman allows for only one type of prominence, morphological prominence (i.e. root- or stem-control). We, like Walker (2011) and Kaplan (2015) treat stressed syllables and edges as sufficiently prominent to drive harmony, too, enlarging the scope of the scope of Hyman's analysis. This analysis makes certain predictions, and below we briefly discuss how those fare on the known typology of directionality in harmony.

For the typology presented below, we use eight constraints, which are listed below. First, we adopt a generic AGREE[F] constraint (Lombardi 1999; Baković 2000) below instead of the ID-VV and CORR constraints used in the analysis for two reasons. First, since the rankings below are largely schematic and ignore much of the feature-related specifics of these patterns, a generic ID-VV[F] and CORR-VV constraints operate very similarly to AGREE[F], since they enforce symmetrical harmony to all vowels without any inherent directionality. Second and related to our first reason, collapsing these two constraints, whose activity is only evident when they both outrank the relevant faithfulness constraints, to a single AGREE[F] constraint increases the readability of the typology below.

Second, we use a sequential markedness constraint (Mahanta 2007), *[-F][+F], to formalize purely regressive harmony. In tandem with these two harmony-driving constraints, we deploy a variety of faithfulness constraints, including two general constraints, MAX and DEP, alongside four positional faithfulness constraints to encode the privilege of edges, stems, roots, and stressed syllables. The typology below is not intended to be exhaustive, but simply a comparison between some of the rankings produced by the constraint set and their empirical counterparts.

(42) Constraint list for typology

a. AGREE[F]
b. *[-F][+F]
c. MAX[F]
d. DEP[F]
e. ID-IOσ1
f. ID-IO-FINALσ
g. ID-IO-STEM
h. ID-IO-ROOT

The world's languages exhibit at least the following 6 basic harmony patterns. The first pattern is stem-control, which triggers the assimilation of more morphologically peripheral morphemes to the feature value of [F] in more interior morphemes, often the root. This can be realized as bidirectional, progressive, or regressive harmony depending on the morphological structure of the language. Second, stress-controlled harmony triggers the assimilation of unstressed vowels to the feature value of [F] in stressed syllables. We know of two types of stress-controlled patterns, progressive and regressive patterns, shown below. We do not know of any bidirectional stress-controlled harmonies. Third, languages like Tutrugbu exhibit harmony derivable from initial prominence, where the first syllable controls the realization of [F] in subsequent syllables. Fourth, in some languages the final syllable controls the realization of [F] in preceding syllables, demonstrating final-syllable prominence. Fifth, in a number of African languages, [+F] spreads bidirectionally from a root or suffix. This is often called dominant-recessive harmony, and is not tied to morphological structure in the same way as stem-control, since suffixes may affect roots. Lastly, purely regressive harmony is attested in a number of languages, like Karajá and Assamese. All six of these general patterns are exemplified in (43).

(43)

Stem-control

a. Akan ATR harmony (Dolphyne 1988)
ɔ-bɛ-tʊ-ɪ '3S-FUT-throw-3S.OBJ'
o-be-tu-i '3S-FUT-dig-3S.OBJ'

b. Turkish labial harmony (Underhill 1976)
kɨz-ɨn 'girl-POSS.2S'
tuz-un 'salt-POSS.2S'

c. Yoruba (Orie 2001; Baković 2000)
ògèdè 'incantation'
ɔ̀gɛ̀dɛ̀ 'banana/plantain'

Stress-control

d. Claro total harmony (Delucchi 2013)
ˈli.mi 'file (masc)'
ˈla.na 'wool (masc)'
ˈtɛ.rɛ 'earth (masc)'

e. Brazilian Portuguese height harmony (Bisol 1989)
pe.ˈpi.nu ~ pi.ˈpi.nu 'cucumber'
for.ˈmi.ga ~ fur.ˈmi.ga 'ant'

Initial prominence

f. Tutrugbu labial harmony
a-ba-bá '3S-FUT-come'
ɔ-bɔ-bá '2S-FUT-come'

Final prominence

g. Yaka height harmony (Hyman 1998)
kel-umuk-a ‘flip.flop-REV.INT-FV’
kel-omok-ene ‘flip.flop-REV.INT-APP’

Dominant-recessive

h. Diola-Fogny ATR harmony (Sapir 1965)
nɪ-baj-ɛn-ʊ ‘1S-have-CAUS-2P.OBJ’
ni-bəj-ul-u ‘1S-have-VENT-2P.OBJ’

Purely regressive

i. Assamese (Mahanta 2007)
bɔx ‘settle’
box-oti ‘settle-NMLZR’

Looking at some of the patterns generated by our constraint set in Table 10, the first thing to note is that all the attested patterns in (43) are generated with these constraints. Second, there are two empirical patterns that can be generated with more than one constraint ranking. Observe that the Yoruba pattern is analyzable either as purely regressive harmony (as it is encoded in Pulleyblank 1996), or as a symmetrical stem-control pattern that happens to lack suffixes (see Bakovi̇c 2000). Since there is independent evidence for purely regressive harmony, some constraint enforcing regressive harmony is present in CON, resulting in analytical indeterminacy as to whether harmony in Yoruba is stem-controlled or purely regressive (though see Krämer 2003 for evidence in favor of purely regressive harmony).

The second pattern that is generated through two distinct constraint rankings is dominant-recessive harmony, as in Diola-Fogny. The first ranking that produces dominant-recessive harmony involves a high-ranking MAX[+F] constraint, preserving the harmonic feature wherever it occurs. Coupled with AGREE[F], these two constraints enforce bidirectional harmony from root or affix. The second possible constraint ranking, though, involves two harmony-driving constraints, symmetrical AGREE[F] and the regressive harmony-driver, *[-F][+F]. In this second ranking, harmony is modeled as a default regressive pattern plus stem-controlled harmony on suffixes. These two analyses are not identical, though. The first predicts that any prefix may host the harmonic feature and in turn, trigger assimilation on the root. This, to our knowledge, is unattested (see also Baković 2000:§5.3; Hall & Hall 1980). The second analysis predicts that a (non-initial) prefix bearing the feature [+F] cannot trigger rightward harmony, since harmony under this analysis must either fall out from pure regressive directionality or stem-control. This prediction more accurately accords with the empirical data attested to-date (see Baković 2000:§5.3; Hyman 2002; 2008). As for progressive harmony, as seen above and below, the attested patterns all fall out from morphological prominence (e.g. Turkish), metrical prominence (e.g. Claro), or initial prominence (e.g. Tutrugbu). Since all known progressive patterns are derivable from prominence in some way or another, the presence of some constraint directly encoding a preference for progressive harmony is doubtful at this point.

Table 10: A typology of directionality and prominence

Harmony type	Directionality	Constraint ranking	Example language	Citation
Morphological prominence (stem-control)	Bidirectional	ID-IO-STEM >> AGREE[F] >> MAX[+F], DEP[+F]	Akan	Clements 1985
	Progressive		Turkish	Underhill 1976
	Regressive*		Yoruba	Orie 2001
Metrical prominence (stress-control)	Bidirectional	ID-IO-STEM, ID-IOσ́ >> AGREE[F] >> MAX[+F], DEP[+F]		
	Progressive	ID-IO-STEM, ID-IOσ́ >> AGREE[F] >> MAX[+F], DEP[+F]	Claro	Delucchi 2013
	Regressive	ID-IOσ́ >> *[-F][+F] >> MAX[+F], DEP[+F]	Brazilian Portuguese	Bisol 1989
Initial prominence	Progressive	ID-IOσ1, ID-IO-ROOT >> AGREE[F] >> MAX[+F], DEP[+F]	Tutrugbu	
		ID-IOσ1 >> AGREE[F] >> MAX[+F], DEP[+F]	Tunen (for function words)	Boyd 2015
Final prominence	Regressive	ID-IOσFINAL >> AGREE[F] >> MAX[+F], DEP[+F]	Yaka	Hyman 1998
Dominant-recessive	Bidirectional	MAX[+F], AGREE[F] >> DEP[+F]	Diola-Fogny	Sapir 1965
		MAX[+F], *[-F][+F] >> ID-IO-STEM >> AGREE[F] >> DEP[+F]		
Purely regressive*	Regressive	MAX[+F], *[-F][+F] >> ID-IO-STEM, DEP[+F]	Assamese	Mahanta 2007
		MAX[+F], *[-F][+F] >> DEP[+F]	Yoruba	Orie 2001

Generally, the typology produced by these constraints appears to account for the general vowel harmony patterns found in the world's language. We interpret this as evidence in favor of our claim that harmony can be analyzed as prominence-based or regressive, without any need to directly encode progressive harmony as a theoretical primitive.

6 Conclusion

In this paper we have detailed labial harmony in Tutrugbu, demonstrating that it propagates rightward from initial to medial prefixes. In addition to data from harmony, we have adduced evidence from contrast licensing, hiatus resolution, and ATR harmony to argue that initial syllables are phonologically privileged in the language, and that prominence plays a key role in the harmony pattern. We have also shown evidence from other Ghana-Togo Mountain languages and other known languages exhibiting prefix-initiated harmony, and in all cases the harmony is triggered by initial-syllable vowels only. We generalize from these facts to suggest that prefix-initiated progressive harmony may only originate in initial syllables. By analyzing progressive harmony as prominence-based, we encode rightward harmony indirectly in the analysis. Generally, we suggest that harmony is either prominence-based and purely regressive, and progressive directionality does not need to be directly encoded in the formalism. While the pattern in Tutrugbu is the most robust case of prefix-initiated progressive harmony, it still reinforces the claim that progressive harmony is always derivable from some independent prominence in the language.

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