Typological Variation Through Constraint Rankings: Low Vowels in Tongue Root Harmony

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1. Introduction*

One of the fundamental claims of Optimality Theory is that by varying the rankings of universal constraints, different grammars result (Prince & Smolensky 1993). Just as the ranking A >> B should define an occurring language, so should the ranking B >> A. In this paper, we examine this claim in the domain of tongue root harmony systems, specifically with respect to the behaviour of low vowels. We examine cases where the relative ranking of faithfulness conditions and alignment conditions is varied with respect to substantive conditions governing low vowels. Our primary conclusions are twofold. First, we find that the types of typological variation expected to occur do occur; six different types of harmony patterns are presented. Second, we note that a large degree of variation is attested in a very narrowly defined area of the phonology.

This paper begins by a basic discussion of the formal constraints assumed to govern vowel harmony, followed by a discussion of a case where low vowels harmonise in a manner comparable to other vowels (Degema). We then turn to six cases (five languages) where we observe asymmetric behaviour. First, we discuss cases involving constraints against feature "insertion" and feature "spreading", constraints of the faithfulness family (Yoruba, Kɔnni, Ngbaka-Ma'bo). Second, we turn to cases involving constraints of the alignment family, cases where harmony exhibits directional asymmetries (Ngbaka-Ma'bo, Ẹmalhẹ, Maasai).

2. Basic vowel harmony

A harmonic configuration is one where a feature is realised throughout an appropriately defined domain. In the cases of tongue root harmony that we examine, a fully harmonic form is one where all vowels are advanced (1a) or where all vowels are retracted (1b).

(1) *Basic harmonic configurations*

a. 

b. 

We assume an approach to harmony whereby the lexical specifications of morphemes vary as to the inclusion of a particular harmonic specification: morphemes may include a specification for ATR, a specification for RTR, or morphemes may be unspecified for the harmonic feature (Clements 1981, Archangeli & Pulleyblank 1994, etc.). For simplicity of exposition, we present representations with only a single harmonic feature, ATR in some languages, RTR in others. Following work such as Smolensky (1993) and Pulleyblank & Turkel (to appear), we assume that

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asymmetries between ATR and RTR are due to relative constraint ranking, not due to the "underspecification" of such representations. The asymmetries often accounted for by features being "specified" or "unspecified" are attributed instead to ranking the dominant feature's constraints above the recessive feature's. Hence the configurations where ATR is graphically represented in opposition to zero involve representations where the constraints on ATR are ranked above those governing RTR.

Where a feature value is specified, we attribute to the PARSE family (Prince & Smolensky 1993, Pulleyblank 1994, etc.) the enforcement of linking: the feature must be incorporated into prosodic structure in order to be phonetically realised. We do not want there to be random insertion of harmonic values, and we prohibit random insertion by the LEXF constraints, a family of constraints that requires that features be the expression of morphological content, satisfied by underlying specifications, violated by epenthetic feature values (Itô, Mester & Padgett 1994; Pulleyblank 1993,1994; Akinlabi 1995, to appear; etc.). Similarly, the random insertion of associations between features and anchors is prohibited by the LEXPATHF constraints. The ranking of this constraint effectively determines whether there is harmony or not. Ranked high, there is no harmony; features exhibit whatever arbitrary linkings are determined by their lexical associations. Ranked low, the prohibitions against associations can be overridden by the harmonic constraints, the constraints to which we now turn.

Harmony, we assume, is the result of *Generalised Alignment* (McCarthy & Prince 1993). Following work such as Kirchner (1993), Smolensky (1993), Pulleyblank (1993, 1994), Cole & Kisseberth (1994), Akinlabi (1995, to appear), we assume that harmony is achieved by requiring that the edges of a featural span line up with the edges of a morphologically or phonologically defined domain. For example, assuming that the brackets in (1) represent word boundaries, harmony in (1a) could be achieved by requiring that the span of vowels specified for ATR align itself with the left and right edges of the word: ALIGN[ATR, L, Word, L] & ALIGN[ATR, R, Word, R].

To illustrate this basic optimality theoretic approach to harmony, we turn to the examination of Degema, an Edoid language of Nigeria.

3. Degema: advanced low vowels

Elugbe (1984, 1986) and Kari (1995)[1] presents Degema as an example of a ten-vowel system, five basic vowels cross-cut by tongue root harmony: [i, ɪ, e, ɛ, ə, a, o, ɔ, u, ʊ]. Examples of the ten vowels are given in (2), data that also illustrate the properties of harmony:

(2) *Degema*

	ADVANCED			RETRACTED		
HIGH	i	ù-hír-ǃəm	"surrounding"	ɪ	ɔ̀-ɓí	"leaf"
	u	ù-súw-ǃəm	"ironing"	ʊ	ɔ̀-ɓɔ̀	"doctor"
MID	e	è-sén	"fish"	ɛ	ɔ̀-tɛ́v-ǃám	"descending"
	o	ù-vóy-ǃəm	"fetching"	ɔ	ɔ̀-sɔ́l-ǃám	"jumping"
LOW	ə	é-də̀	"river"	a	è-nám	"animal, meat"

[1] Thanks to Kay Williamson for making us aware of Kari's work on Degema.

As can be seen in (2), prefixes and suffixes are advanced when attached to an advanced root, and retracted when attached to a retracted root. Note in particular that even low vowel affixes harmonise, as can be observed with the suffix of the verbal noun, [əm/am].

We propose the following grammar for Degema. The ranking of PARSEATR above LEXPATHATR ensures that any lexically specified value of ATR must be associated. LEXATR is undominated, prohibiting the insertion of any ATR values; as a result, only those values underlyingly specified will appear on the surface. Constraints aligning ATR with the left and right edges of the word are crucially ranked above LEXPATHATR, ensuring that any harmonic specification will appear throughout the entire word.

(3) *Degema grammar: LEXATR, PARSEATR, ALIGNL, ALIGNR >> LEXPATHATR*

a. LEXATR: An ATR value must be morphologically affiliated.

b. PARSEATR: A feature ATR must be incorporated into prosodic structure.

c. ALIGN[ATR, Left; WORD, Left]: Align the left edge of the featural span for ATR with the left edge of the WORD.

ALIGN[ATR, Right; WORD, Right]: Align the right edge of the featural span for ATR with the right edge of the WORD.

d. LEXPATHATR: A path between ATR and a mora must be morphologically affiliated.

The effect of these constraints can be observed in examples such as (4) and (5), showing the optimal realisation of advanced and retracted forms respectively. Consider first the case of a root that includes an advancement feature, a root such as /də/ "river".

(4) *Harmony with the dominant feature*

UR: [ATR E - dA]	LEXATR	PARSEATR	ALIGNL	ALIGN R	LEXPATHATR
a. [ATR ɛ - da]		*!			
b. [ATR ɛ - də]			*!		*
c. [ATR e - da]				*!	*
d. [ATR e - də]					**

The candidate in (4a) is ruled out because the lexically specified ATR value is not associated, a violation of PARSEATR. The candidates in (4b,c) are ruled out because the ATR feature is not aligned with either the left edge (4b) or the right edge (4c). The optimal form is the one where ATR is both parsed and aligned (4d). Here and subsequently, crucial rankings are indicated in tableaux by separating the relevant columns by a double line. In cases like this where the relative ranking of certain constraints is not crucial (the top four in this case), boxes are not shaded in the portions of the tableau where relative rankings are not crucial.

Compare a case with a lexically specified ATR with one where the lexical entry does not contain any ATR value, exemplified in (5) with various candidates for [è-nám] "animal, meat". (The boxed ATR values in (5) are values that are not part of an underlying morpheme, that is, "inserted" values.)

(5) *Harmony in recessive forms*

UR: [E - nAm]	LEXATR	PARSEATR	ALIGNL	ALIGN R	LEXPATHATR
a. ☞ [ɛ - nam]					
b. [ATR | ɛ - nəm]	*!		*!		*
c. [ATR | e - nam]	*!			*!	*
d. [ATR ⌒ e - nəm]	*!				**

In this case, the form without an ATR value is optimal, (5a). Although a form like (5d) has an ATR value that is parsed and aligned, and therefore fully harmonic, the ATR value in question has no morphological affiliation. That is, the ATR value is not part of the root for "animal, meat" nor is it a part of the prefix. As such, LEXATR is violated in every case where an ATR value is present (5b,c,d), hence all such cases are suboptimal.

4. Imposing retraction on low vowels: a typology of behaviour

Although it is possible to have a language where harmony is unconstrained by substantive considerations, as in the case of Degema, it appears to be more common to find harmonic systems where low vowels are consistently retracted, even if that upsets the harmonic pattern (Archangeli & Pulleyblank 1994). This constraint on low vowels, which we refer to as the LO/TR constraint (the "low/tongue root" constraint), can be shown to play a variety of roles in an interesting variety of harmony systems.

(6) LO/TR: Low vowels are produced with tongue root retraction (RTR), not tongue root advancement (ATR).

Consider first a class of interactions between LO/TR and members of the *faithfulness* family. In Degema, it is crucial that LEXRTR dominates LO/TR. Advanced low vowels appear on the surface, as in the example [é-dɔ̀] "river". If LO/TR were to dominate LEXRTR, then all low vowels would have to be phonologically retracted whether or not the optimal candidate involved a LEXRTR violation. This would completely rule out the vowel [ɔ]. Interestingly, although not the pattern of Degema, this is indeed the pattern of Yoruba. As a second point, it is crucial in Degema that PARSELO and PARSEATR dominate LO/TR. If LO/TR dominated PARSELO, then [ɔ] would be impossible because it would be better to underparse LO, creating an advanced mid vowel such as [e], rather than parse LO and incur a violation of LO/TR -- as actually happens to get Degema [ɔ]. Similarly, LO/TR must dominate PARSEATR so that Degema [ɔ] surfaces rather

than [a] (in ATR contexts). In interesting contrast to the Degema pattern on each of this counts, other languages can be shown to rank LO/TR above the relevant faithfulness constraints.

(7) *Interactions with Faithfulness:*

a. LEXTR >> LO/TR	Degema	vs.	LO/TR >> LEXTR	Yoruba
b. PARSELO >> LO/TR	Degema	vs.	LO/TR >> PARSELO	Kɔnni
c. PARSEATR >> LO/TR	Degema	vs.	LO/TR >> PARSEATR	Ngbaka-Ma'bo

In a different vein, LO/TR can also interact with *alignment* in various ways. As already seen above, alignment can dominate LO/TR.[2] In three cases examined below, we show that it is also possible for LO/TR to crucially dominate alignment. It is possible for both left-edge and right-edge harmony to be prevented from producing low advanced vowels (Ngbaka-Ma'bo). It is possible that harmony to a left edge can result in the advancement of a low vowel while harmony to a right edge cannot (Ẹmalhẹ). Finally, it is possible for the inverse pattern to hold, that harmony to a left edge can result in the advancement of a low vowel while harmony to a right edge cannot (Maasai).

(8) *Interactions with Alignment:*

a. LO/TR >> ALIGNLEFT & ALIGNRIGHT	Ngbaka-Ma'bo
b. LO/TR >> ALIGNLEFT	Ẹmalhe
c. LO/TR >> ALIGNRIGHT	Maasai

We take up each of these cases in the following sections.

5. The domination of faithfulness by LO/TR

This section examines three cases where faithfulness constraints take precedence over the retraction of low vowels.

5.1. LO/TR triggering the insertion of RTR

If LO/TR dominates LEXRTR, then it becomes obligatory for low vowels to be retracted, whatever the feature specifications of the underlying form. Consider the example of low vowels in Yoruba, the Ijẹṣa dialect selected here for purposes of illustration (Akinlabi, Archangeli, Ọla & Pulleyblank in preparation).

In Ijẹṣa, a nonlow vowel to the left of a low vowel is invariably retracted. Hence forms like those in (9a) are wellformed, while the forms in (9b) are impossible.[3]

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[2]The cases given for Degema establish only that right-edge alignment dominates LO/TR. Elubge (1986) states that low vowel noun prefixes do not harmonise, and no examples are given in the comparative lexicon where low vowels appear in non-final position in advanced roots. It is therefore unclear whether there is any evidence in Degema for having more than right-edge alignment dominate LO/TR.

[3]For fuller discussion of the Ijẹṣa dialect, see (Akinlabi, Archangeli, Ọla & Pulleyblank in preparation). For general discussion of Yoruba vowel harmony, see Archangeli & Pulleyblank (1989, 1994). Note that dialects such as Ijẹṣa are problematic for reinterpreting this type of pattern in terms of LO, rather than RTR (Goad 1993, van der Hulst & van de Weijer 1995).

(9) *Yoruba, Ijẹsa dialect*

a.	ẹ̀fà	[ɛfa]	"six"	b.	*[efa]
	ẹja	[ɛʄa]	"fish"		*[eja]
	ụgbá	[ʊgba]	"calabash"		*[ugba]
	ịlá	[ɪla]	"okra"		*[ila]

To account for the impossibility of the forms in (9b), it is necessary that all low vowels be actively retracted, and that such retraction spread onto the preceding vowel. The active retraction of low vowels is ensured by ranking LO/TR over LEXRTR, while the spreading to the left is ensured by ranking ALIGNLEFT over LEXPATHRTR.

(10) *Yoruba low vowel grammar fragment*:
LO/TR, ALIGNL >> LEXRTR, LEXPATHRTR

Consider a form like [ʊgba] "calabash", where both vowels are retracted on the surface. This retraction could be due to the lexical presence of an RTR specification. For such a lexical representation, regular harmonic considerations would induce full harmony. The effects of the four constraints in (10) are illustrated in (11).

(11) *A NONLOW - LOW sequence, with a lexical RTR value*

		LO/TR	ALIGNL	LEXRTR	LEXPATHRTR
UR: [RTR UgbA] "calabash"	a. [RTR ugbə]	*!			
	b. [RTR ugba]		*!		*
	c. ☞ [RTR ʊgbà]				**

To correctly interpret LO/TR violations in this and subsequent tableaux, recall our assumption that asymmetries between RTR and ATR are due to constraint-ranking, not due to underspecification (section 2). The requirement imposed by LO/TR is satisfied when low vowels are retracted, not advanced; that is, low vowels must have an RTR specification. In languages where RTR is dominant, we represent RTR graphically. In the relevant tableaux, this means that low vowels must have an overt specification of RTR in order for LO/TR to be satisfied. This type of case is seen in (11). In languages where ATR is dominant, we do not represent RTR graphically in our representations. For such languages, a tableau where ATR does *not* link to a low vowel satisfies LO/TR, a link to RTR implicitly assumed in such a representation. An example can be seen in (23) below.

For a satisfactory analysis of Yoruba, it is not sufficient to simply provide a way of deriving forms where a retracted nonlow vowel precedes a retracted low vowel. It is also crucial to make it impossible for a sequence to occur where an advanced nonlow vowel precedes a low vowel. We have seen that such a form is not possible if a nonlow-low morpheme includes a lexical RTR value; (11b) is nonoptimal. It must also be the case, however, that such an

advanced-retracted sequence is ruled out if the morpheme does *not* include a lexical RTR. That is, a form like *[ugba] should be ruled out no matter what underlying representation is assumed.

The required effect is derived by the high ranking of LO/TR. Specifically, because LO/TR dominates LEXRTR, the low vowel must be phonologically retracted, and once phonologically retracted, ALIGNLEFT ensures harmony. This is illustrated in (12), where we again consider a form like [ʊgba] "calabash", but this time under the assumption that the underlying representation does not contain an RTR value.

(12) *A NONLOW - LOW sequence, without a lexical RTR value*

		LO/TR	ALIGNL	LEXRTR	LEXPATHRTR
UR: [UgbA] "calabash"	a. [ugbə]	*!			
	b. [RTR ugba]		*!	*	*
	c. [RTR ʊgba]			*	**

Given the high ranking of LO/TR, either of (12b,c) are preferable to the first candidate, even though both (12b) and (12c) violate LEXRTR by inserting an RTR value. Of course, once the RTR value is present on the low vowel, the candidate satisfying alignment is optimal, that is, (12c).

To conclude, we have argued that in some languages, LEXRTR may be ranked above LO/TR to prevent feature insertion; this is the pattern of Degema. In other languages, for example, Yoruba, the reverse is possible, where ranking LO/TR above LEXRTR forces the presence of RTR on all low vowels, even at the expense of feature insertion.

5.2. LO/TR causing the underparsing of low

In this section, we examine data from Kɔnni, a Niger-Congo language of the Gur family (Cahill 1992, 1993a,b), arguing that the feature for lowness is underparsed if associating lowness would result in a low advanced vowel. That is, LO/TR dominates PARSELO.

Kɔnni has nine oral vowels, each of which can occur both short and long:

(13) *Surface vowels in Kɔnni*

ADVANCED	i / ii	u / uu	HIGH
RETRACTED	ɪ / ɪɪ	ʊ / ʊʊ	
ADVANCED	e / ee	o / oo	MID
RETRACTED	ɛ / ɛɛ	ɔ / ɔɔ	
	a / aa		LOW (RETRACTED)

Examples of these vowels are given in (14), with illustrations using long vowels.

(14) *Examples of the nine vowel qualities, long vowels*

a.	[ii]	tšíí	"carry"	f.	[ɔɔ]	pɔ̀ɔ̀lí	"divide"
b.	[ɪɪ]	yîɪ	"blindness	g.	[oo]	vóósì	"rest"
c.	[ee]	lèèmú	"orange"	h.	[ʊʊ]	vʊ̀ʊ̀tá	"person"
d.	[ɛɛ]	džɛ̀ɛ̀tí	"go fishing"	i.	[uu]	sùùlí	"be full"
e.	[aa]	bàà	"intend"				

In addition to the steady-state vowels given in (14), Kɔnni also has seven diphthongs, as illustrated in (15).

(15) *Diphthongs; rounding agreement*

a.	[ie]	zìé	"stand"	e.	[ɪa]	bìà	"what"
b.	[ɪɛ]	pìèsé	"ask"	f.	[ɛa]	tšɛ̀áŋ	"under-side"
c.	[uo]	ɲùòté	"stomach"	g.	[ʊa]	zʊ̀à	"friend"
d.	[ʊɔ]	kʊ́ɔ́-kʊ́	"the farm"				

An important observation can be made about the rounding, or lack thereof, in diphthongs. If is possible for neither component of a diphthong to be rounded; where present, however, the feature RD (ROUND) is realised on an entire diphthong, except where the second component of the diphthong is low.

We analyse this pattern by invoking four constraints. First, constraints of the alignment family require that a RD specification align with both the left and right edges of a syllable. Given these constraints, if RD is present, it should manifest itself on both components of a diphthong. Second, the exception to this pattern involves low vowels. Following work such as Kirchner (1993), Padgett (1995), we assume the existence of a constraint prohibiting the cooccurrence of RD and LO. This prevents harmony from including low vowels within its scope. As a final point, note that PARSELO interacts crucially with such alignment and cooccurrence possibilities. Although the impossibility of low round vowels (in Kɔnni) is being taken to force misalignment in an [ʊa] diphthong, an alternative would be to underparse the LO specification in such a case, resulting in the well-aligned [ʊɔ]. But while [ʊɔ] is possible, so is [ʊa], demonstrating that the parsing of low also takes precedence over alignment.

(16) Rounding constraints: LO/RD, PARSELO >> [ALIGNRD]σ

ALIGN(ROUND, Left; σ, Left): Align the left edge of a RD span with the left edge of a syllable.

ALIGN(ROUND, Right; σ, Right): Align the right edge of a RD span with the right edge of a syllable.

LO/RD: LOW vowels are not RD.

PARSELO: A feature LOW must be incorporated into prosodic structure.

The effect of these constraints can be seen by comparing the two diphthongs [ʊɔ], as in [kʊ́ɔ́-kʊ́] 'the farm', and [ʊa], as in [zʊ̀à] 'friend'.

(17) *Round harmony, no low vowels*

		LO/RD	PARSELO	[ALIGNRD]σ
UR: [RD kUE] "farm"	a. [RD kʊɛ]			*!
	b. ☞ [RD kʊɔ]			

In a case such as [kʊ́ɔ́-kʊ́] 'the farm', since there are no low vowels, LO/RD and PARSELO are vacuously satisfied, and the optimal candidate is determined solely by alignment, as seen in (17). Where there is a LO specification, on the other hand, the situation is more complex.

(18) *Round harmony, final low component*

		LO/RD	PARSELO	[ALIGNRD]σ
UR: [RD zUA LO] "friend"	a. ☞ [RD zʊa LO]			*
	b. [RD zʊɒ LO]	*!		
	c. [RD zʊɔ <LO>]		*!	

In the optimal candidate, both LO and RD are parsed, and no rounded low vowels are tolerated; the cost is that full round harmony is impossible (18a). Alternatives, where low round vowels are countenanced (18b) or where LO is underparsed (18c) are not winners.

Of interest in the present context is the interaction of round harmony with tongue root harmony (Cahill 1993a). Kɔnni exhibits tongue root harmony, words selecting either consistently advanced vowels (19a-f) or consistently retracted vowels (19g-l). Note in particular the alternating suffixes.

(19) *Tongue root harmony*

	ATR			RTR	
a.	tígí-rí	"house-the"	g.	kʊ̀ʊ̀-rí	"hoe-the"
b.	sìè-kú	"path-the"	h.	nɪ̀ɪ̀-kʊ́	"rain-the"
c.	dʊ̀ʊ̀m-bú	"horse-the"	i.	nyáá-bʊ́	"water-the"
d.	tókóró-sí-sí	"windows-the"	j.	nánjʊ́-sí-sí	"flies-the"
e.	nèn-ɗíí	"will eat"	k.	pɔ̀gɪ̀l-á	"is holding"
f.	n yé fù	"I saw you (sg)"	l.	n yí fʊ̀	"I gave you (sg)"

Of interest is the behaviour of suffixes. Unlike roots where vowels exhibit three different heights, as seen in (14), underlying suffixes exhibit only a two-way height contrast; they are either high or

low.[4] That is, abstracting away from the variants predicted by tongue root harmony, one would expect five vowels to be possible in a suffix, two high vowels [I, U], two mid vowels [E, O], and one low vowel [A]. The contrast between low and mid vowels is lost, however, and only [I, U, A] occur. Of these three suffixes, cases with high vowels have been exemplified by numerous examples in (19). Cases with low vowels are shown in (20).

(20) *Low vowel suffixes*

	ATR			RTR	
a.	kùrì-yé	"has pounded"	g.	pàsì-yá	"has peeled"
b.	dèmbì-ké	"man-the"	h.	gbàà-ká	"the dog"
c.	tíg-è	"houses"	i.	tàn-á	"stones"
d.	tígím-mé	"at house"	j.	mʊ́gʊ́m-mà	"at river"
e.	sùgùr-é	"is washing"	k.	pɔ̀gìl-á	"is holding"
f.	chìì-mé	"carry!"	l.	dɔ̀m-má	"bite!"

Two generalisations emerge from this data involving low vowels. First, even low vowels undergo tongue root harmony. Second, the vowel that corresponds to a low, retracted vowel is a mid, advanced vowel; that is, LO is underparsed.

The effects of basic harmony in Kɔnni, along with the harmony-induced raising of low vowels, are accounted for by the interaction of alignment, parsing, and the prohibition against low advanced vowels:

(21) *Tongue root harmony*: LO/TR, ALIGNATR >> PARSELO

ALIGN(ATR, Left; Word, Left): Align the left edge of an ATR span with the left edge of a word.

ALIGN(ATR, Right; Word, Right): Align the right edge of an ATR span with the right edge of a word.

PARSELO: A feature LOW must be incorporated into prosodic structure.

LO/TR: LOW vowels are RTR, not ATR.

The effects of these constraints are illustrated in (22) and (23), (22) illustrating a form with a high vowel suffix, (23) a form with a low vowel suffix. We restrict our attention to forms including an ATR value since the RTR forms are fully harmonic, hence straightforwardly accounted for.

[4]The observations concerning this asymmetry are taken directly from Cahill's work, but we differ in the treatment of the low mid asymmetry. Cahill (1993a) assigns the value [+low] by redundancy rule, analysing mid vowels as lexically marked either [–low] (for [e, ɛ]) or [+round] (for [o, ɔ]). Given this analysis, the asymmetry is expressed by restricting the values [–low] and [+round] from occurring in the underlying forms of suffixes.

(22) *Harmony in Kɔnni*

		LO/TR	ALIGNATRL ALIGNATRR	PARSEATR	PARSELO
UR: [ATR tIgI-rI]	a. [ATR tɪgɪ-rɪ]			*!	
	b. [ATR tigi-rɪ]		*!		
	c. [ATR tigi-ri]				

In a form where all the vowels are nonlow, PARSEATR ensures that an ATR value be linked, and the two alignment conditions ensure that the feature appear throughout the word domain. Of particular interest, however, is the type of case where a low vowel is included.

(23) *Harmony with low vowels*

		LO/TR	ALIGNATRL ALIGNATRR	PARSEATR	PARSELO
UR: [ATR kUrI-yA, LO]	a. [ATR kuri-ya, LO]		*!		
	b. [ATR kuri-yə, LO]	*!			
	c. [ATR kuri-ye <LO>]				*

As shown in (23a), failure to align the ATR feature all the way to right edge of the word causes a fatal violation of alignment. To align ATR but leave all features linked, however, causes a fatal violation of LO/TR (23b). Hence the optimal candidate in such a case involves an unavoidable violation of faithfulness: the LO value fails to parse (23c).

An alternative to this analysis might be one where the ATR value spreads all the way to the right end of the word, but where it is postulated that both ATR and LO remain linked -- the analysis presented and rejected in (23b). In order for this representation to successfully derive a surface form like [kùrì-yé] "has pounded", it would be necessary to assume that the phonetics interprets a low advanced vowel with sufficient advancement so as to produce a vowel comparable to [e]. According to such a hypothesis, the vowel that results when ATR is assigned to a low vowel remains low, it simply sounds nonlow. There is evidence in Kɔnni to show that such an analysis is impossible.

Recall the properties of round harmony, in particular, that round harmony cannot affect a low vowel (giving forms like [zʊ̀à] "friend", not *[zʊ̀ʊ̀]; see (15) and (18) above). Because of the inability of round harmony to affect low vowels, a simple test for lowness is available in cases

involving the [a/e] alternation. If the [e] in forms like [kùrì-yé] is phonologically low, then it should be impossible for round harmony to target such a vowel; on the other hand, if the vowel is phonologically mid, then round harmony should be applicable. Since round harmony itself applies only within the syllable (note, for example, the absence of round harmony between the round vowel [u] of [kùrì-yé] and any of the subsequent vowels), one must construct a case where the suffixal low vowel immediately follows a round segment within the same syllable. In such a configuration, the results are as in (24).

(24) *Low vowel suffixes after a round segment*

	ATR			RTR	
a.	tù-ó	"is digging"	d.	kʊ̀-á	"is killing"
b.	dígí-wó	"cooked"	e.	gá-!wá	"went"
c.	n yé wò	"I saw him"	f.	n yí wà	"I gave him"

As can be seen in the examples of (24a-c), when ATR harmony forces the delinking of the inherent LO value of the suffix, round harmony is applicable; when no such process forces the LO to underparse, as in the retracted forms of (24d-f), then round harmony is blocked.

The tableau in (25) illustrates this effect with the form [tù-ó] "is digging".

(25) *ALIGNATRRIGHT >> PARSELO*

UR: [RD ATR; tU-A; LO]	LO/RD	LO/TR	ALIGNATRL ALIGNATRR	PARSELO	[ALIGNRD]σ
a. [RD ATR; tu-a; LO]			*!		*
b. [RD ATR; tu-ə; LO]		*!			*
c. [RD ATR; tu-ɒ; LO]	*!		*!		
d. [RD ATR; tu-œ; LO]	*!	*!			
e. [RD ATR; tu-e; <LO>]				*	*!
f. ☞ [RD ATR; tu-o; <LO>]				*	

The constraints governing tongue root harmony interact with the constraints governing round harmony to derive the actually attested surface form. Because of its high ranking, ALIGNATRR must be satisfied, ruling out disharmonic forms like (25a,c). As already seen in (23), LO/TR rules out a fully harmonic form that involves an advanced low vowel, hence (25b,d) are eliminated. Candidates can be made even worse by postulating a low rounded vowel, as in (25c,d). Hence the only candidates that satisfy the requirements of tongue root harmony are those in (25e,f), in spite of the fact that both involve violations of PARSELO because of the unassociated LO value. Of these two candidates, (25f) is preferred over (25e) as a result of round harmony: in (25e), harmony is violated (specifically, [ALIGNRD]σ); in (25f), round harmony is satisfied.

To conclude, we have seen that tongue root advancement is incompatible with tongue body lowness, the LO/TR effect. Because of the high ranking of the constraints ensuring harmony, violations of LO/TR cannot be avoided in Kɔnni by simply failing to harmonise. Hence, to maintain the cooccurrence condition, faithfulness is violated by the underparsing of LO. Crucial evidence for this analysis can be seen through a comparison of the effects of round harmony, a process showing a similar cooccurrence restriction, but a different relative ranking of alignment and faithfulness.

5.3. The domination of PARSEATR by LO/TR

In Ngbaka-Ma'bo, an Adamawa-Ubangian language of the Central African Republic, low vowels are strictly retracted (Thomas 1963, Archangeli & Pulleyblank 1994).[5] The following seven vowels are attested on the surface:

(26) *Surface vowels in Ngbaka-Ma'bo*

i e ɛ a ɔ o u

As seen from an inspection of these vowels, high vowels are advanced, the single low vowel is retracted, and mid vowels exhibit both advanced and retracted variants.

The distribution of the tongue root feature that distinguishes [ɛ, ɔ] from [e, o] is harmonic: all sequences of mid vowels agree in their harmonic value.[6]

[5] Thanks to Stefan Elders for pointing out the importance of specifying that the language under discussion is Ngbaka-Ma'bo. It is important to avoid potential confusion between Ngbaka-Ma'bo and the Ngbaka dialects of Gbaya (Bendor-Samuel 1989, p. 195).

[6] The first four patterns of (27), those involving sequences of completely identical vowels (27a-d), are common patterns while the four others (27e-h), are much less frequent. In fact, as noted in the table, the pattern [ɛ...ɔ] was not found by Thomas at all. For the purposes of the discussion here, the crucial point is that all patterns, both robust and rare, exhibit the effects of tongue root harmony. For an account of the distributional asymmetry between (27a-d) and (27e-h), see Archangeli & Pulleyblank (1994) and references therein.

(27) *Harmony in the mid vowels*

a.	e...e	yèlè	"étranger"	*e...ɛ
		kpetè	"gâté, abîmé"	
b.	ɛ...ɛ	kɛ́ɓɛ́	"vite"	*ɛ...e
		mɛkɛ̀	"appuyer, poser"	
c.	o...o	wolo	"femelle, femme"	*o...ɔ
		lòngò	"piège à éléphant"	
d.	ɔ...ɔ	kɔtɔ̀	"sortir"	*ɔ...o
		nɔkɔ̀	"neveu, oncle utérin"	
e.	e...o	sekò	"chimpanzee"	*e...ɔ
f.	ɛ...ɔ	no examples found		*ɛ...o
g.	o...e	ngòmbè	"fusil"	*o...ɛ
h.	ɔ...ɛ	kɔndɛ̀	"coeur"	*ɔ...e

Harmony in such forms is achieved by ranking the alignment of ATR above LEXPATHATR. That is, it is more important in Ngbaka-Ma'bo to align an ATR value with the edges of the word than to avoid the "spreading" of a feature. For reasons of space, we do not include representative tableaux; we note, however, that except for the restriction of harmony to mid vowels, tableaux would be entirely comparable to those seen above for Degema (see (4) and (5)).

The regular harmonic pattern, the direct result of ranking conditions on the alignment of ATR highly, is disrupted by the appearance of low vowels.[7] First of all, low vowels cannot ever be advanced. A form like "mère" can be realised with two retracted vowels; even if an ATR value were lexically posited, it could not be realised. Within the harmonic approach argued for here, this restriction follows from ranking LO/TR above PARSEATR.

(28) *LOTR >> PARSEATR*

		LO/TR	PARSEATR
UR: [ATR kAnA] "mère"	a. ☞ [ATR kana]		
	b. [ATR kanə]	*!	
	c. [ATR kəna]	*!	
	d. [ATR kənə]	*!	

This pattern completes the interactions of LO/TR with faithfulness as laid out in (7) above. Yoruba (section 5.1) was shown to require the ranking of LO/TR over LEXTR. Kɔnni

[7]High vowels can also disrupt a harmonic domain, but with a retracted span. As discussed in Archangeli & Pulleyblank (1994), high vowels in Ngbaka-Ma'bo must be advanced. When in combination with advanced mid vowels, the entire span is harmonic, for example, [sibè] "chanson" and [zèdi] "jeudi"; when in combination with retracted vowels, the word is disharmonic, for example, [ziè] "vomir" and [lèsi] "silure".

(section 5.2) was shown to require the ranking of LO/TR over PARSELO. Ngbaka-Ma'bo (this section) exhibits the ranking of LO/TR over PARSEATR.

6. Substantive Constraints on Alignment

In addition to its interaction with faithfulness, Ngbaka-Ma'bo illustrates the first of a class of interactions with alignment constraints, the constraints actually responsible for harmony. The Ngbaka-Ma'bo class is a case where harmony both to a right edge and to a left edge must respect the restrictions of LO/TR. Two additional cases, illustrated in the sections following the discussion of Ngbaka-Ma'bo, involve languages where alignment to one edge, but not to the other, is governed by LO/TR.

6.1. LO/TR governs both ALIGNLEFT and ALIGNRIGHT

Consider the distribution of low vowels with nonlow vowels in Ngbaka-Ma'bo. As seen in (29) and (30), low vowels may appear both with retracted vowels, a fully harmonic pattern, and with advanced vowels, a disharmonic pattern.

(29) *Patterns with low vowels: fully harmonic sequences*

a.	a...ɛ	wágɛ́	"espèce d'igname"
b.	a...ɔ	gazɔ̀	"grelots de chevilles"
c.	a...a	kanà	"mère"
d.	ɛ...a	listed as occurring in Thomas (1963) but no example found	
e.	ɔ...a	sɔyà	"espèce de banane à cuire" (polymorphemic?)

(30) *Patterns with low vowels: disharmonic sequences*

a.	a...i	bàli	"course"
b.	a...e	kákpe	"esclave"
c.	a...o	yàbo	"genette"
d.	a...u	nzámbú	"pulpe de noix de palme"
e.	i...a	títa	"grand-parent"
f.	e...a	ndeyà	"scorpion"
g.	o...a	kólá	"dette"
h.	u...a	dúká	"épaule"

The crucial pattern observable in (30) is that the presence of a low vowel can disrupt the harmony of a word, the *retracted* low vowel occurring adjacent to an *advanced* nonlow vowel. Phrased in terms of the alignment analysis proposed here, a low vowel cannot be advanced even if failure to advance results in misalignment. That is, Ngbaka-Ma'bo shows evidence of the constraint ranking in (31).

(31) LO/TR >> ALIGNL & ALIGNR

The effects of this ranking can be observed in the pair of forms given in (32). Note that PARSEATR must dominate the two alignment conditions since ATR is linked even if the optimal form is misaligned.

(32) *LO/TR >> ALIGNL & ALIGNR*

		LO/TR	PARSEATR	ALIGNR	ALIGNL
a. UR: [ATR yAbO] "genette"	i. [ATR yabɔ]		*!		
	ii. ☞ [ATR yabo]				*
b. UR: [ATR kOlA] "dette"	i. ☞ [ATR kɔla]		*!		
	iii. [ATR kola]			*	

6.2. LO/TR governs ALIGNRIGHT only

In Ẹmalhẹ, an Edoid language of Nigeria (Laniran 1985, Elugbe 1986), we see a pattern that diverges from that of Ngbaka-Ma'bo by virtue of being asymmetric. Like Ngbaka-Ma'bo, we observe evidence for the high ranking of LO/TR; unlike Ngbaka-Ma'bo, LO/TR governs alignment to the right edge only.

The vowel system of Ẹmalhẹ exhibits nine oral vowels on the surface: [ɪ, i, ɛ, e, ɔ, o, ʊ, u, a]. The eight nonlow vowels exhibit an unremarkable pattern of harmony, advanced vowels occurring with other advanced vowels, retracted with retracted.[8]

(33) *Basic harmonic patterns*

a. Non-low roots with advanced vowels		b. Non-low roots with retracted vowels	
nòmí	"bite"	kòné	"dig"
sùníe	"push"	mìné	"take off"
fie	"throw"	vɪɛ	"weep"
zeri	"be long (of stick)"	èrʊ̀	"eyes"
ìsò	"feaces"	úfɛ	"rat"
ìkù	"rubbish heap"	èdɔ̀	"meat"

Of interest here are the patterns involving low vowels. First, it can be observed that roots involving only low vowels are invariably retracted.

(34) *Low vowel roots are always retracted*

tʃà	*tʃə	"walk, go"
kpa	*kpə	"vomit"
ma	*mə	"build"
na	*nə	"give"
àgbà	*əgba	"jaw"
àlá	*əla	"cow"

[8]In addition to the behaviour of low vowels, which is discussed here, Ẹmalhẹ harmony shows interesting effects involving domains, arguably showing evidence for restricting harmony to the domain of the foot. For data and discussion, see Laniran (1985) and Ọla (1994).

Second, low vowels may be both preceded and followed by retracted nonlow vowels.

(35) a. *Low vowels may be preceded by retracted nonlow vowels*

sʊa	"carry (load on head)"
gbɪa	"laugh"
ɔ́-cà	"friend"
ɛ́-ca	"eggs"
whɛ́-bhà	"stone"

b. *Low vowels may be followed by retracted nonlow vowels*

kàsɛ́	"teach"
ʃàmɛ́	"touch"
rà-kɔ̀	"tooth"
whá-fɛ	"bird"
rà-ɨ̈ì	"penis"
tarɪɛ	"split"

An asymmetry arises, however, when the behaviour of low vowels with advanced vowels is considered. As seen in (36a), low vowels may be preceded by advanced vowels. In contrast, as schematised in (36b), low vowels may not be followed by advanced vowels within a harmonic domain.

(36) a. *Low vowels may be preceded by advanced vowels*

ù-vâ	*uvə	"fear n."
símà	*simə	"dance"
hùmá	*humə	"like"
whé-cà	*whecə	"housefly"
bueṇa	*bueṇə	"ask"
bia	*biə	"give birth"

b. *Low vowels may not be followed by advanced vowels*

*a...u
*a...i
*a...e etc.

We argue that four rankings are crucial to an account of these data. Consider cases where a low vowel *follows* a nonlow advanced vowel. Such cases show that LO/TR, prohibiting the linking of ATR to a low vowel, must be ranked above ALIGNR. In a form like [símà] "dance", the low vowel of the final syllable prevents the lexically specified ATR value of the first syllable from aligning with the right edge of the word, *[simə]. That is, right edge alignment is violated if satisfaction would require the advancement of a low vowel. The same type of case demonstrates that PARSELO must dominate ALIGNR: a low specification cannot be underparsed to satisfy ALIGNR; we observe [símà], not *[sime], for a form like "dance". In contrast, consider the unattested case where a low vowel would *precede* a nonlow advanced vowel, a form like *[a...i]. If ALIGNL was dominated by LO/TR and PARSELO, then such a form ought to be grammatical. If LO/TR was demoted, then an advanced low vowel ought to surface, which is not the case: *[ə...i]

We propose, therefore, that PARSELO is demoted below LO/TR and ALIGNL. By ranking PARSELO under LO/TR and ALIGNL, it is established that a low specification is not parsed if its parsing would force the cooccurrence of a low specification with advancement, *[əCi], or the misalignment of ATR, *[aCi]. The final constraint ranking required for the low vowel effects is given in (37).

(37) *Analysis*: PARSEATR >> ALIGNL, LO/TR >> PARSELO >> ALIGNR

We illustrate this analysis with two forms involving low vowels in morphemes specified for ATR. First, consider the pattern that results when a low vowel follows a nonlow vowel.

(38) *Asymmetric harmony: final low vowels*

UR: [ATR sImA LO] "dance"	PARSEATR	ALIGNL	LO/TR	PARSELO	ALIGN R
a. [ATR sɪma LO]	*!				
b. [ATR sima LO]					*
c. [ATR simə LO]			*!		
d. [ATR sime LO]				*!	

Given the high ranking of PARSEATR, the morpheme-level ATR specification cannot be left floating, thereby eliminating the candidate in (38a). A low vowel cannot be advanced due to LO/TR, hence a candidate such as (38c) is impossible. The remaining choice is between a candidate that violates right-edge alignment (38b) and a candidate that violates the parsing of LO: because PARSELO is ranked above ALIGNR, the candidate in (38b) is therefore selected as optimal.

Compare such a case with an example where a low vowel precedes a nonlow advanced vowel. For example, imagine that a form such as *zeri* "be long (of stick)" were to have a low vowel posited as its initial vowel.

(39) *Asymmetric harmony: initial low vowels*

UR: [ATR zArI, LO] "be long (of stick)"	PARSEATR	ALIGNL	LO/TR	PARSELO	ALIGNR
a. [ATR zarɪ, LO]	*!				
b. [ATR zari, LO]		*!			
c. [ATR zəri, LO]			*!		
d. ☞ [ATR zeri, LO]				*	

In this type of case, like the previous one, the ATR value must be parsed to satisfy the high-ranking PARSEATR (39a). Unlike the previous example, however, the optimal candidate may not violate the conditions on alignment. The crucial difference is that in this case, the putative low specification occurs at the left edge. As a result, were the form to be misaligned, then the candidate would violate ALIGNL. Since ALIGNL is ranked above LO/TR and PARSELO, however, such an alignment violation cannot be tolerated (39b). We are left with a choice between a violation of LO/TR (39c) and a violation of PARSELO (39d): the candidate violating PARSELO wins.

The net result is that a low specification to the left of an advanced vowel cannot be tolerated. The low value is lost in favour of a well-aligned representation that does not violate LO/TR.

It should be noted that the evidence so far presented for the ranking in (37) has been entirely distributional. In closing this discussion of Ẹmalhẹ, we present evidence from alternations in support of the proposed analysis.

First, consider the behaviour of suffixes following a low vowel. As expected, a low vowel is opaque, preventing the spreading of a root ATR value onto a suffix. (That the suffixes appearing as retracted in (40) are harmonic, not invariably retracted, can be seen from data such as in (41).)

(40) *Opaque low vowels in stems*

simá - lhè "danced"
humá - lhè "liked"

As seen in (38), a low vowel to the right of an advanced vowel cannot undergo harmony. Since we assume that gapped representations are excluded universally (Archangeli & Pulleyblank 1994), the automatic result is opacity.

Next, consider the case of low vowel prefixes. As observed in (41), a low vowel prefix remains low when preceding a retracted root, but raises to mid when preceding an advanced root. That is, when the low vowel undergoes ATR harmony as required by the left-edge alignment constraint, the low specification is forced to delink. (Roots in these examples are indicated by square brackets.)[9]

(41) *Advanced low vowels in proclitics*

a.	bà - [má] - lhɛ̀	"you (pl.) built"
	bè - [mú] - lhù	"you (pl.) caught"
b.	mà - [kɔ́] - lhɛ̀	"we washed"
	mè - [wó] - lhì	"we weaved"

In conclusion, we see that the pattern of Ẹmalhẹ embodies a systematic asymmetry. The prohibition against advanced low vowels governs and blocks the appearance of spreading to the right edge of a word domain. In contrast, spreading to the left edge of the word takes place without regard for the preservation of low vowels.

6.3. LO/TR governs ALIGNLEFT only

To complete the pattern of LO/TR interactions with alignment, we present a second type of asymmetric pattern, a mirror-image of Ẹmalhẹ where LO/TR governs alignment to the left edge, but not to the right edge. The case discussed is that of Maasai, a Nilotic language of Kenya and Tanzania (Tucker & Mpaayei 1955, Levergood 1984, Cole 1987, Archangeli & Pulleyblank 1994).

Maasai exhibits nine surface vowels: [i, ɪ, e, ɛ, a, ɔ, o, ʊ, u]. The harmony system is a dominant-recessive one, where a derived form that includes an ATR morpheme surfaces as ATR throughout, while all the vowels of a form without an ATR morpheme surface as retracted. This basic pattern is illustrated in (42) and (43).[10]

(42) *Forms with a [+ATR] morpheme*

a.	/kI-ñorr-U/	kiñorru	"we shall love"
b.	/mI-kI-itoki/	mikintoki	"we shall not do again"
c.	/A-rOk-u/	aroku	"I become black"
d.	/A-tV-dOl-ie/	atodolie	"I saw it with something"
e.	/IsUj-IšO-re/	isujišore	"wash with something!"

[9]Harmony onto prefixes is restricted to a domain that Ọla (1994) argues to be a foot. As a result, the first person plural subject marker of (41b) does not harmonise when not adjacent to the root:

i.	ma - kɔ - ya - [kasɛ]	"we are going to show"
ii.	ma - kɔ - ye - [ve]	"we are going to send"

[10]The discussion here focusses on the particular problem of low vowels within the harmonic system of Maasai. For more general and comprehensive discussion, see the references cited in the text.

(43) *Forms without any [+ATR] morpheme*

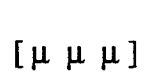
a.	/kI-IdIm-U/	kɪdɪmʊ	"we shall be able"
b.	/mI-kI-rAñ/	mɪkɪrañ	"let us not sing"
c.	/A-tV-rOk-A/	atɔrɔka	"I became black"
d.	/A-dOl/	adɔl	"that I could see"
e.	/IsUj-IšO/	ɪsʊjɪšɔ	"wash!/do the washing!"

Schematically, the dominant-recessive pattern can be seen to involve the complete alignment of an ATR specification, whether the specification has its source in a root morpheme (44a) or an affixal morpheme (44b). Where no such value is present, all vowels are retracted (44c).

(44) *Schematic dominant-recessive vowel harmony*

a. 

b. 

c. 

So far, such a harmony system is straightforwardly accounted for by the now familiar constraints on parsing and alignment. Of interest, however, is the behaviour of the low vowels. As shown in (45) and (46), low vowels are opaque, both when they occur in a prefix (45), and when they occur in a root (46). In the four pairs used as illustration, the first member of each pair gives a morpheme sequence without a low vowel, while the second member of the pair includes a low vowel.

(45) *Opaque /a/ in prefixes; forms including a dominant [+ATR] morpheme*

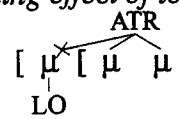
a.	/kI-dot-Un-ie/	kidotuñe	"we shall put it out with something"
	/kI-tA-dot-Un-ie/	kɪtadotuñe	"we pulled it out with something"
b.	/lE-m-E-niŋ/	lemeniŋ	"who does not hear him/her"
	/lE-m-AA-niŋ/	lɛmaaniŋ	"who does not hear me"

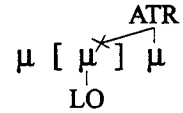
(46) *Opaque /a/ in roots; forms including a dominant [+ATR] suffix*

a.	/I-duŋ-IšO-re/	iduŋišore	"you cut with something"
	/I-As-IšO-re/	ɪasišore	"you work"
b.	/kI-duŋ-ie/	kiduŋie	"we cut with something"
	/kI-ŋAr-ie/	kɪŋarie	"we share with someone"

The blocking effect of low vowels is schematised in (47).

(47) *Blocking effect of low vowels*

a. 

b. 

Note that at the expense of left-edge alignment, ATR is parsed, LO is parsed, and LO/TR is respected. That is, the ranking in (48) is required.

(48) *Interim result*: LO/TR, PARSELO, PARSEATR >> ALIGNLEFT

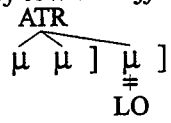
Suffixal vowels behave in a very different fashion. In a recessive form, a low-vowel suffix surfaces as retracted and low; with a dominant root, however, the form surfaces as an advanced mid vowel [o].[11]

(49) *Suffixal low vowels: harmonic targets*

a.	dominant	/AA-ipot-I-t[A]-I/	aaipotit[o]i	"I am being called"
	recessive	/AA-rIk-I-t[A]-I/	aarɪkɪt[a]ɪ	"I am being nauseated"
b.	dominant	/A-tV-dot-U-[A]/	atadotu[o]	"I pulled out (something)"
	recessive	/A-IŋOr-U-[A]/	aŋɔrʊ[a]	"I came looking for (something)"

This pattern can be schematised as in (50).

(50) *Loss of low in suffixes*



It is possible for the same suffix to exhibit both opacity and the loss of low. In the first member of each pair in (51), a low vowel suffix appears in combination with a following ATR suffix: opacity results. In the second member of each pair, the same suffix appears following an ATR root: the suffix undergoes harmony, losing its low value. The low vowels in focus in these examples are marked by square brackets.

(51) *Variable suffixal behaviour*

a.	/E-tV-nUk-[A]r-ie/	ɛtʊnʊk[a]rie	"s/he buried it with (something)"
	/E-ibuk-[A]r-ie/	eibuk[o]rie	"s/he poured it away with something"
b.	/A-IpUt-[A]kIn-ie/	aɪpʊt[a]kiñe	"I fill it for someone with something"
	/A-duŋ-[A]kIn-ie/	aduŋ[o]kiñe	"I cut for someone with something"

The crucial point to observe from such forms is that the right-edge alignment of ATR is unviolated. Such alignment cannot be achieved without the violation of one of PARSEATR, LO/TR or PARSELO. As seen from the data in (49) and (51), the loser is PARSELO. This therefore gives the following grammar for Maasai harmony.

(52) *Final grammar*: LO/TR, PARSEATR, ALIGNRIGHT >> PARSELO >> ALIGNLEFT

The effects of this grammar on low vowels can be observed in the examples of (53) and (54).

[11]Note that when a low vowel undergoes advancement in Ẹmalhẹ, the surface result is a front vowel [e]. In contrast, when a low vowel undergoes advancement in Maasai, the result is a back vowel [o]. We assume that this difference derives from differences in the way that backness interacts with lowness in the two language types, but we do not investigate the issue here.

(53) *Low vowel opacity*

UR: [ATR kI-ŋAr-ie, LO] "we share with someone"	LO/TR	PARSEATR	ALIGNR	PARSELO	ALIGNL
a. [ATR kɪ-ŋar-ie, LO]					*
b. [ATR ki-ŋər-ie, LO]	*!				
c. [ATR ki-ŋor-ie, LO]				*!	

When the low vowel appears to the left of an ATR specification, candidates are eliminated if they violate LO/TR (53b) or PARSELO (53c). The optimal candidate parses ATR and avoids low advanced vowels, but is forced to be misaligned with respect to the left edge (53a). The situation is very different when the low vowel *follows* an advanced vowel.

(54) *Low delinking*

UR: [ATR AA-ipot-I-tA-I, LO LO] "I am being called"	LO/TR	PARSEATR	ALIGNR	PARSELO	ALIGNL
a. [ATR aa-ipot-i-ta-ɪ, LO LO]			*!*		**
b. [ATR aa-ipot-i-tə-i, LO LO]	*!				**
c. [ATR aa-ipot-i-to-i, LO LO]				*	**

As can be seen from such a case, candidates are eliminated if they violate either LO/TR or ALIGNR. On the other hand, PARSELO and ALIGNL violations can be tolerated if necessary to avoid a violation of one of the more highly ranked constraints.

To conclude, we have shown that Maasai exhibits a harmony system that is essentially the mirror-image of Ẹmalhẹ. LO/TR plays a role in constraining harmonic alignment, but its blocking effect is restricted to left-edge alignment.

7. Conclusion

This paper has examined tongue root harmony patterns in six languages, focussing on the properties of low vowels. Even though the scope of the investigation is deliberately narrow, we have shown that there is considerable variation in such a specific domain, all six languages exhibiting harmonic patterns that differ in the details of the low vowel behaviour. These differences are summarised in (55).

(55) *Variable ranking of LO/TR*

Faithfulness

LEXTR >> LO/TR	*Degema*	LO/TR >> LEXTR	*Yoruba*
PARSELO >> LO/TR	*Degema*	LO/TR >> PARSELO	*Kɔnni*
PARSEATR >> LO/TR	*Degema*	LO/TR >> PARSEATR	*Ngbaka-Ma'bo*

Alignment

ALIGNMENT >> LO/TR	*Degema*	LO/TR >> ALIGNL & ALIGNR	*Ngbaka-Ma'bo*
		LO/TR >> ALIGNL	*Ẹmalhẹ*
		LO/TR >> ALIGNR	*Maasai*

A central tenet of Optimality Theory is that different grammars result from the ranking of constraints in different dominance relations (Prince & Smolensky 1993). This proposal receives support from the study reported on here. A considerable range of cross-linguistic variation is accounted for by the variable rankings of a small number of well-motivated harmonic constraints. The six languages examined within the scope of this paper do not, of course, exhaust the range of possible patterns predicted by a factorial typology. Neither, of course, do the six languages examined here exhaust the range of attested harmonic variation in even this very specific domain of linguistic behaviour.

References

Abiodun, M.A. (1989) 'The Class System of Igede Nouns,' *Journal of West African Languages* 2, 51-56.

Akinlabi, Akinbiyi (1995) "Featural Affixation," in Akinbiyi Akinlabi (ed.) *Theoretical Approaches to African Linguistics*, African World Press, Trenton, New Jersey, 217-237.

Akinlabi, Akinbiyi (to appear) "Kalabari vowel harmony," *The Linguistic Review*.

Akinlabi, Akinbiyi, Diana Archangeli, Ọlanikẹ Ọla & Douglas Pulleyblank (in preparation) "An Optimal Account of ATR Harmony in Yoruba Dialects," Rutgers University, University of Arizona, University of British Columbia.

Archangeli, Diana & Douglas Pulleyblank (1989) "Yoruba Vowel Harmony," *Linguistic Inquiry* 20, 173-217.

Archangeli, Diana & Douglas Pulleyblank (1994) *Grounded Phonology*, MIT Press, Cambridge.

Armstrong, R.G. (1983) 'The Idomoid Languages of The Benue and Cross River Valleys,' *Journal of West African Languages* 13:1, 13-25.

Bendor-Samuel, J. (1989) *The Niger-Congo Languages*, University Press of America, Lanham, MD.

Bergman, R. (1971) 'Vowel Sandhi and Word Division in Igede,' *Journal of West African Languages* 8:1, 13-25.
Cahill, M. (1992) *A Preliminary Phonology of the Kɔnni Language*, Institute of African Studies, University of Ghana.
Cahill, M. (1993a) "Underspecification and Vowel Harmony in Kɔnni," ms. Ghana Institute of Linguistics, Literacy and Bible Translation.
Cahill, M. (1993b) "Diphthongization and Underspecification in Kɔnni," ms. Ghana Institute of Linguistics, Literacy and Bible Translation.
Clements, G.N. (1981) "Akan Vowel Harmony: A Nonlinear Analysis," in G.N. Clements (ed.) *Harvard Studies in Phonology* 2, 108-77, Department of Linguistics, Harvard University.
Cole, J. (1987) *Planar Phonology and Morphology*, Doctoral dissertation, MIT.
Cole, J. & C.W. Kisseberth (1994) "An optimal domains theory of harmony," Cognitive Science Technical Report UIUC-BI-CS-94-02, University of Illinois.
Elugbe, Ben O. (1984) "Morphology of the gerund in Degema and its reconstruction in Proto-Ẹdoid," *Studies in African Linguistics* 15, 77-89.
Elugbe, Ben O. (1986) *Comparitive mЄdoid: phonology and lexicon*, University of Port Harcourt Press.
Goad, Heather (1993) *On the Configuration of Height Features*, USC Ph.D dissertation.
Hulst, Harry van der & Jeroen van de Weijer (1995). Vowel harmony. In J. Goldsmith (ed.) *The Handbook of Phonological Theory*. Cambridge, Mass.: Basil Blackwell. 495-534.
Itô, Junko, Armin Mester & Jaye Padgett (1994) "NC: Licensing and Underspecification in Optimality Theory," ms. University of California, Santa Cruz [to appear in *Linguistic Inquiry*].
Kari, E. E. (1995) "The Structure of the Degema Verb," M.A. thesis, University of Port Harcourt.
Kirchner, Robert (1993) "Turkish Vowel Disharmony in Optimality Theory," paper presented at the Rutgers Optimality Workshop #1, Rutgers University.
Laniran, Yetunde (1985) "Vowel merger and Èmálhẹ̀ vowel harmony," *Journal of the Linguistic Association of Nigeria* 3, 3-11.
Levergood, B. (1984) "Rule Governed Vowel Harmony and the Strict Cycle," *Proceedings of NELS* 14, GLSA, Amherst, 275-293.
McCarthy, John & Alan Prince (1993) *Prosodic Morphology I: Constraint Interaction and Satisfaction*, ms. University of Massachusetts, Amherst & Rutgers University.
Ọla, Ọlanikẹ (1994) "Optimizing Ẹmalhẹ Vowel Harmony," ms. University of British Columbia.
Oloruntoba, Christiana Iyetunde (1984) Aspects of the Generative Phonology of Igede, B.A. Thesis, University of Ilorin, Nigeria.
Padgett, Jaye (1995) "Feature Classes," ms., University of California, Santa Cruz.
Prince, Alan & Paul Smolensky (1993) *Optimality Theory: Constraint Interaction in Generative Grammar*. Technical Report #2 of the Rutgers Center for Cognitive Science, Rutgers University.
Pulleyblank, Douglas (1993) "Vowel Harmony and Optimality Theory," *Proceedings of the Workshop on Phonology*, University of Coimbra, Portugal, 1-18.
Pulleyblank, Douglas (1994) "Neutral vowels in Optimality Theory: a comparison of Yoruba and Wolof," ms, University of British Columbia.
Pulleyblank, Douglas & William J. Turkel (to appear) "Optimality Theory and Learning Algorithms: The Representation of Recurrent Featural Asymmetries," in Jacques Durand & Bernard Laks (eds.) *Current Trends in Phonology: Models and Methods*, University of Salford Publications, CNRS, Paris-X and University of Salford.
Smolensky, P. (1993) "Harmony, markedness, and phonological activity," paper presented at Rutgers Optimality Workshop 1, Rutgers University.
Thomas, J.M.C. (1963) *Le parler Ngbaka-Ma'bo de Bokanga: Phonologie, morphologie, syntaxe*, Mouton, Paris.
Tucker, A.N. and M. A. Mpaayei (1955) *Linguistic Analyses: The Non-Bantu Languages of North-Eastern Africa*, Oxford, London.