Vowel raising in Mayak as compound opacity

Jochen Trommer*

Abstract

The Western Nilotic language Mayak seems to exhibit a purely morphologically triggered phonological chain shift in vowel height (Andersen 1999) which raises problems for a restrictive approach to the morphology-phonology interface based on the concatenation of morphemes and limited access of phonological constraints to morphosyntactic information. Here, I show that the Mayak vowel raising data actually instantiate a doubly opaque form of vowel harmony: The chain shift itself follows from two partially underapplying harmony processes naturally captured in the generalized markedness constraints of Colored Containment Theory (Trommer 2011, 2014, 2015), and the restriction of vowel raising to certain affixes from assigning it to the stem level of Stratal Optimality Theory (Kiparsky 2003, Bermúdez-Otero 2013).

1. Introduction

Andersen (1999) argues that Mayak (Western-Nilotic) has besides different patterns of [ATR]-harmony (cf. past -**u** in (1a)/the dashed arrows in (1b)) a morphological vowel raising process (VR) triggered by specific affixes which shifts high/low [–ATR] vowels to [+ATR], but mid [–ATR] vowels to high (cf. Antipassive, AP, -**ɪr** (1a)/the solid arrows in (1b)).

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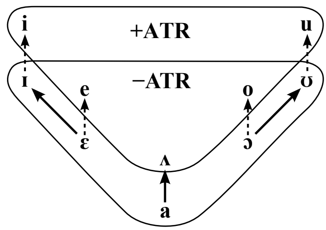
(1) *[ATR]-harmony and mutation (Andersen 1999:16)*

a.

			Past	AP	
[−ATR]	[ɪ]	ʔɪt̪	ʔið-u	ʔit̪-ir	'shape'
	[ɛ]	ɗɛc	ɗej-u	ɗɪj-ɪr	'grind'
	[a]	ʔam	ʔam-u	ʔʌm-ɪr	'eat'
	[ɔ]	kɔc	koj-u	kʊj-ɪr	'take'
	[ʊ]	gʊt̪	guð-u	gut̪-ir	'untie'
[+ATR]	[i]	tiŋ	tiŋ-u	tiŋ-ir	'hear'
	[ʌ]	nʌk	nʌɣ-u	nʌk-ɪr	'beat'
	[u]	t̪uc	t̪uj-u	t̪uc-ir	'send'

b.



If Andersen's claim is correct, Mayak vowel raising instantiates a striking case of chain-shifting and 'quirky' (phonologically non-uniform) mutation. This phenomenon – if existent – would be a major piece of evidence for the stipulation of mutation-specific rules/constraints (Lieber 1992, Zoll 1996, Wolf 2005) or the assumption of a basically unrestricted morphology component (Green 2006, Iosad 2008) and against the restrictive research program that limits morphological exponence to the concatenation of phonological representations and general processes of phonological alternations. I will call this research program, which implicitly underlies Classical Autosegmental Morphology (Goldsmith 1976, McCarthy 1979, Marantz 1982), is explicitly formulated under different names in Stonham (1994), Lieber (1992), Wolf (2005, 2007), Bye & Svenonius (2012), Bermúdez-Otero (2012), and which I will adopt here, the 'Concatenativist Hypothesis' (Trommer 2011, 2014, 2015, Zimmermann & Trommer 2014, 2015):

(2) *The Concatenativist Hypothesis:*
morphology = concatenation + phonological alternations

What makes a phonological alternation analysis of Vowel Raising especially problematic is not only that it involves two distinct changes, raising along the [high] dimension and along [ATR], but that these two changes are in complementary distribution – vowels which become [+ATR] ([a] → [ʌ]) do not change to [+high], whereas mid vowels which are turned into [+high] vowels refrain from becoming [+ATR] (e.g. [ɛ] → [ɪ] → *[i]). An analysis in terms of vowel ([ATR]) harmony seems to be excluded not only because VR changes are not strictly predictable ([a] does not always become [ʌ] before high vowels), but also because the affixes triggering VR do not consistently exhibit [+ATR]. Thus it is hard to claim that the affixal [i] in present AP forms (1) is [+ATR] because it shows up as [−ATR] [ɪ] after underlying mid vowels and Mayak does not have general assimilation of [+ATR] to [−ATR] Vs (see section 3). However, if an analysis via phonological alternation is untenable, the only alternative given the Concatenativist Hypothesis is to view it as the result of affixing (possibly segmentally defective) phonological material such as floating vocalic features. Again this leads to an obvious problem since the changes triggered by VR are not uniform: Affixing floating [+ATR] would predict tensing across the board, and floating [+high] consistent raising to high vowels, and positing an affix specified as [+ATR +high] the raising of all stem vowels to high tensed vowels. Finally, Mayak VR can also *not* be captured as affixation of floating sonority grid marks (Trommer 2009, 2011) since it makes vowels *less*, not more sonorous.

In this paper, I argue that against all odds the Mayak data *are* compatible with the concatenativist hypothesis and follow in fact from the interaction of phonological alternations with floating affixal material, obscured by two factors inducing opacity: First, a chain shift in vowel harmony strictly parallel to better-studied patterns in varieties of Romance (Calabrese 2011, Walker 2005, 2011) and, second, the stratal organization of phonology (Kiparsky 2003, Bermúdez-Otero 2013), which restricts chain-shifting harmony to stem-level affixes such as antipassive -**ir** in (2) in contrast to word-level affixes as past tense -**u** that trigger only [ATR]-harmony.

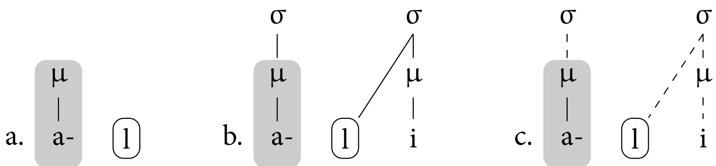
The rest of the paper is structured as follows: Section 2 introduces the theoretical framework I will assume here, Autosegmental Colored Containment Theory (Trommer 2011). Section 3 and section 4 provide detailed analyses of the vowel-alternation processes at the word level and the stem level respectively. Section 5 summarizes my conclusions.

2. The framework: Autosegmental Colored Containment Theory

My analysis is based on a version of Optimality Theory which is close to the original implementation of the theory proposed by Prince & Smolensky (1993) in adopting hierarchical autosegmental representations and the Containment restriction on candidate generation, but which adopts the representation of epenthesis by morphological colors from Colored Containment Theory (van Oostendorp 2006, Revithiadou 2007), and generalizes the Containment assumption to association lines (Radical Containment).

2.1. Morphological colors and epenthesis

Following van Oostendorp (2006) and Revithiadou (2007), I assume that morphological structure is minimally reflected in phonological representations by coloring. At the interface of morphology and phonology, every morpheme *M* of an underlying representation *UR* is assigned a unique color *C* (i.e., a color which is distinct from all other colors C' in *UR*), and every phonological component (i.e. every node and every association line) of *M* is also assigned *C*. The hypothetical representations in (3) illustrate coloring with two hypothetical morphemes **a** and **l**. Color is notated here and in the following by background boxes with distinctive (possibly white) shading. The representation in (3a) is an input form, hence all of its components have morphological colors (grey for the affix μ–a-, and white for the root morpheme [l]). Representation (3b) is a candidate based on (3a) which adds epenthetic [i], syllables, a mora, and epenthetic association lines; these consequently lack background boxes. Representation (3c) shows the same candidate in a slightly different notation which highlights the epenthetic character of association lines by dashing.

(3)


Colors have two consequences for phonological computation. First, they allow us to distinguish underlying material from epenthetic material: Epenthetic material is colorless (in (3): black), and by the Containment Assumption GEN does not license to change or remove the color of underlying material. Second, they make it possible to determine whether two phonological elements belong to the same morpheme or not. Crucially, colors do permit phonological constraints to distinguish morphemes, but not to identify them. Thus via coloring phonology cannot assess whether the segment **l** in (3) is a 3SG affix or a noun root, it just 'knows' that it is a morpheme which is distinct from the one realized by **a**.

2.2. Containment and possible operations of GEN

By the Radical Containment Assumption, phonological material can never be literally removed from phonological input representations in the course of phonological computation (Prince & Smolensky 1993, van Oostendorp 2008: 1365). The candidate-generating function GEN is thus restricted to the following changes it may perform on underlying forms (phonetic visibility is conceived as an elementary attribute of association lines, but not of phonological nodes):

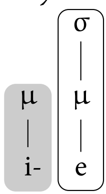
(4) *Possible operations of GEN*

a. Insert epenthetic nodes (prosodic nodes, feature nodes, segmental root nodes) or phonetically visible association lines between nodes
b. Mark a colored association line as phonetically invisible

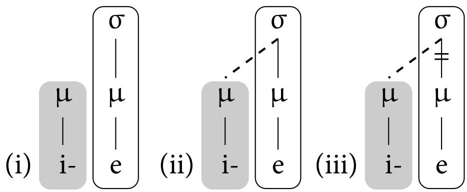
(4a) implements the slightly implicit assumptions held on Containment and GEN in the earliest version of Optimality Theory (Prince & Smolensky 1993), whereas (4b) replaces deletion of association lines by a less invasive operation: marking for phonetic invisibility (indicated in the following by '='). Example (5b) shows some representative candidates generated by GEN for the input in (5a). Example (5b-i) is identical to the input. The examples (5b-ii,iii) contain epenthetic association lines licensed by (4a). In (5b-iii), the association line between the second μ and [e] is marked as phonetically invisible according to (4b).

(5) *Candidates generated by GEN*

a. Input:



b. Candidates:



[e] [ie] [i]

2.3. Deletion as phonetic non-realization

(Non-)pronunciation of underlying material is implemented as phonetic non-interpretation of phonological material following the axioms in (6):

(6) *Axioms of phonetic realization*

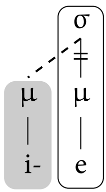
a. A phonological node is phonetically realized iff it is dominated by the highest prosodic node of the candidate through a path of phonetically visible association lines

b. An association line is phonetically realized iff it is marked as phonetically visible and connects two phonetically realized nodes

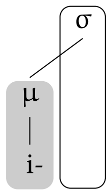
Thus the highest prosodic node in all examples of (5b) is the σ-node because the representations do not contain foot or word nodes. Example (7b) shows the part of (5b-iii) repeated as (7a) which is spelled out by phonetic interpretation. [e] and the second μ of (7a) are not in (7b) because the upper association line through which they are dominated by σ is phonetically invisible. Example (5b-i) instantiates a slightly different way of deletion: [i] and the first μ are not phonetically interpreted because they are not dominated by σ at all.

(7)

a. Phonological representation:



b. Phonetically realized substructure of (7a):



For convenience, I will abbreviate the term 'phonetically realized' in the following simply by 'phonetic' and will call colored (i.e., underlying) phonological material 'morphological' since it is interpreted by morphology as part of specific morphemes.

2.4. Markedness constraints and the Cloning Hypothesis

Following Trommer (2011), markedness constraints are subject to the hypothesis in (8):

(8) *The Cloning Hypothesis:*

Every markedness constraint has two incarnations, a phonetic clone and a general clone: The general clone refers to complete phonological representations. The phonetic clone refers to the phonetically realized substructure of phonological representations.

Phonetic clones are standard markedness constraints, whereas general clones evaluate input and output representations on a par (i.e., the combination of all input and output structure). Whereas these constraints are structurally identical, they refer to different sub-representations of candidates (or more exactly of input-candidate mappings), but can be ranked independently in individual grammars.

I illustrate the Cloning Hypothesis with a constraint which plays a crucial role in the analysis of Mayak developed in this paper, the ban on [–ATR] mid vowels. The phonetic clone of the constraint in (9b) is a constraint which is reflected in many vowel systems across the world's languages which have a [±ATR] contrast and the mid vowels [ɛ] and [ɔ] but lack [o] and [e] (Archangeli & Pulleyblank 1994, Casali 2003). The general clone in (9a) generalizes this constraint to the full phonological structure. The phonetic clone is marked here, as throughout the paper by underlining,[1] whereas the general clone does not have any explicit marking.

(9) a. *$E_{\dashv}$: Assign ⁎ to every • which dominates [–h], [–l] and [⊣]

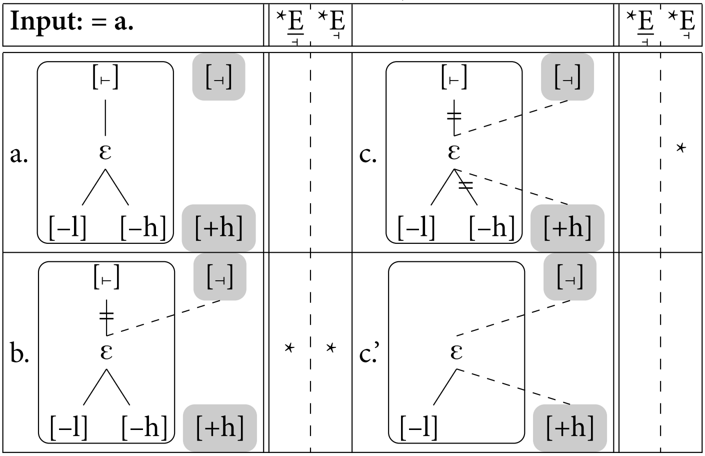
b. *$\underline{E}_{\dashv}$: Assign ⁎ to every • which **phonetically** dominates [–h], [–l] and [⊣]

To see where (9a) and (9b) substantially differ, consider the case of an underlying input mid vowel in (10a) which associates to floating vocalic features of an affix. The structure in (10b) which results from straightforward association of the vowel to both floating features (and concomitant phonetic invisibility of the respective underlying association lines), violates *$E_{\dashv}$ and *$\underline{E}_{\dashv}$, since all nodes and association lines here are phonetically interpreted (they are dominated by the highest prosodic node, σ). On the other hand, (10c) does not violate *$\underline{E}_{\dashv}$ because in the subrepresentation of the structure which is phonetically interpreted, (10c'), the vowel is not associated to [–h] (due to Radical Containment, (10c') itself is not a licit output candidate for (10a)). On the other hand, (10c) still violates *$E_{\dashv}$ because in its overall structure the V is associated to [–h], [–h] and

[1] In a slight departure from this convention, phonetic constraints on autosegmental association are marked by double arrows.

[⊣]. Thus the general version *$\text{E}_{⊣}$ effectively blocks association of the underlying mid vowel to [⊣] even under deassociation of its other height features, a point which will become crucial for the derivation of the vowel chain shift in section 4.

(10) *Constraint violations incurred by* *$\underline{\text{E}}_{⊣}$ *and* *$\text{E}_{⊣}$



3. Mayak word-level harmony

Mayak shows both regressive and progressive vowel harmony for [ATR]. Before high [+ATR] affix vowels, non-low [–ATR] root vowels get [+ATR]. The low vowel [a] remains unaffected:

(11) *Regressive [ATR] harmony (Andersen 1999:6)*

	Underlying Root Vowel	Present Tense	Past Tense	
	[ɪ]	ʔɪt̪	ʔið-u	'shape'
	[ɛ]	ɗɛc	ɗej-u	'grind'
[⊢]	[ɔ]	kɔc	koj-u	'take'
	[ʊ]	gʊt̪	guð-u	'untie'
	[a]	ʔam	ʔam-u	'eat'
	[i]	tiŋ	tiŋ-u	'hear'
[⊣]	[ʌ]	nʌk	nʌɣ-u	'beat'
	[u]	t̪uc	t̪uj-u	'send'

Low suffixal [ʌ] as in the 1SG suffix -**ʌr** does not trigger [ATR] harmony (12):

(12) *Regressive non-harmony with [ʌ] (Andersen 1999:8)*
(past tense forms with subject suffixes)

	Underlying Root Vowel	1SG	2SG	3SG	
[⊢]	[ɪ]	d̪ɪːm-b-ʌr	d̪iːm-b-ir	d̪ɪːm-b-ɛr	'weed'
	[ɛ]	tɛːg-ʌr	teːg-ir	tɛːg-ɛr	'spear'
	[ɔ]	pɔːg-ʌr	poːg-ir	pɔːg-ɛr	'wash'
	[ʊ]	ɟʊːɟ-ʌr	ɟuːɟ-ir	ɟʊːɟ-ɛr	'find'
	[a]	caːb-ʌr	caːb-ir	caːb-ɛr	'cook'
[⊣]	[i]	wiːn-ɖ-ʌr	wiːn-ɖ-i r	wiːn-ɖ-ɛr	'cook'
	[ʌ]	ʔʌːb-ʌr	ʔʌːb-ir	ʔʌːb-ɛr	'catch in the air'
	[u]	puːr-d̪-ʌr	puːr-d̪-ir	puːr-d̪-ɛr	'hoe'

After high [+ATR] root vowels, high [−ATR] suffix vowels such as 1SG -**ɪ** get also [+ATR]. Suffixal mid and low vowels remain in this context unaffected (cf. the 3SG suffix -**ɛ**):

(13) *Progressive [ATR] harmony on high vowels(Andersen 1999:10)*
(Non-possessed and singular possessive forms of nouns)

	Underlying Root Vowel	Non poss.	1SG	2SG	3SG	
[⊢]	[ɪ]	ŋɪn	ŋɪn-ɪ-k	ŋin-u-k	ŋɪn-ɛ-k	'eyes'
	[ɛ]	lɛk	lɛk-ɪ-k	lek-u-k	lɛk-ɛ-k	'teeth'
	[a]	pal	pal-ɪ	pal-u	pal-ɛ	'navel'
	[ɔ]	wɔŋ	wɔŋ-ɪ	woŋ-u	wɔŋ-ɛ	'eye'
	[ʊ]	t̪ʊk	t̪ʊɣ-ɪ	t̪uɣ-u	t̪ʊɣ-ɛ	'outer mouth'
[⊣]	[i]	ʔic	ʔiɗ-i	ʔiɗ-u	ʔiɗ-ɛ	'ear'
	[u]	ʔuŋ	ʔuŋ-i	ʔuŋ-u	ʔuŋ-ɛ	'knee'
	[ʌ]	ʔʌm	ʔʌm-ɪ	ʔʌm-u	ʔʌm-ɛ	'thigh'

There is however one suffix with a low vowel which also undergoes progressive [+ATR] harmony, the singulative affix -**at** (Andersen assumes that this is due to a different process which he calls 'progressive ATR' spreading):

(14) *Exceptional progressive [ATR] harmony on sing. -**at** (Andersen 1999:10)*

		Singular	Plural	
a.	[ɪ]	rɪm-at̪	rɪm	'blood'
b.	[a]	daːl-at̪	daːl	'flower'
c.	[ʊ]	kʊm-at̪	kʊm	'egg'
d.	[i]	ʔin-ʌt̪	ʔin	'intestine'
e.	[ʌ]	ʔʌːw-ʌt̪	ʔʌːp	'bone'
f.	[uu]	ruːj-ʌt̪	ruːc	'worm'

Taken together, Andersen identifies three distinct VH processes in Mayak: 1. regressive [+ATR]-harmony triggered by high vowels and undergone by non-low vowels, 2. progressive [+ATR]-harmony triggered and undergone by high vowels, and 3. [+ATR]-spreading from peripheral (high or low) vowels to singulative -**at** (note that Andersen does not discuss whether Mayak exhibits iterative harmony and provides few potentially relevant examples, hence I will also refrain from adressing this possibility here). In the following, I will develop a unified OT-analysis for all three processes. A crucial observation before we start is that, in the terms of Andersen, Mayak does not have underlying [+ATR] mid vowels. The crucial evidence for this is that [+ATR] mid vowels at the word level occur only if they precede a high [+ATR] vowel. For the time being, I assume that stem- and root-level phonology ensure that all morphological elements which enter the word-level evaluation have only [–ATR] mid vowel, the concrete implementation of this claim will be taken up in section 4.

The three crucial constraints which capture the dependence of [ATR]-harmony on vowel height are formulated in (15). *[–h])˧ formalizes the generalization inherent in both Mayak progressive and regressive vowel harmony that the suffixal vowel involved is [+high], and $*(.\text{V}^{\text{Ⓢ}}_{-\text{h}}.)_{˧}$ captures the fact that in both processes, [+ATR] spreads from a [+h] vowel (a *sponsor* of a span for the feature *F* is the • which is associated morphologically to *F*, cf. Cassimjee & Kisseberth 1998). [–l] → [˧] restricts the targets of [ATR]-harmony to non-low Vs:

(15) *Markedness constraints*

a.	$^*[-\mathrm{h}])_{\dashv}$	Assign ∗ to every non-unary [+ATR] span whose rightmost • is not [+hi] in I
b.	$^*(.\mathrm{V}^{Ⓢ}_{-\mathrm{h}}.)_{\dashv}$	Assign ∗ to every non-unary [+ATR] span whose sponsor is not [+hi] in I
c.	$[-\mathrm{l}] \downarrow [\dashv]$	Assign ∗ to every [–low] vowel which does not dominate [+ATR] in I

While all three constraints in (15) hold without exceptions in progressive and regressive [ATR]-harmony, they are violated (or irrelevant in the case of (16c)) for [+ATR]-spreading to singulative -**at**. See below for further discussion.

The constraints in (15) interact with the basic constraints on faithfulness and basic feature association in (16):

(16) *Constraints on faithfulness and basic feature association*

a.	Dep [⊢⊣]	Assign ∗ to every [⊣] and [⊢] node which is in P, but not in M
b.	$\mathrm{Max}\,\underset{\vdash\dashv}{\downarrow}$	Assign ∗ to every morphological association line linking a •-node and a [⊣] or [⊢] node which is in M, but not in P
c.	$\mathrm{V} \downarrow [\vdash\dashv]$	Assign ∗ to every vocalic root node which does not dominate a [⊣] or [⊢] node

The tableau in (17) shows the ranking I assume for the Mayak word level, and illustrates regressive [ATR]-harmony of a non-low stem V with a high suffix-V. The constraints Dep [⊢⊣] and V → [⊢⊣] at the top of the ranking ensure that [–l] → [⊣] has no effects in the absence of underlying [⊣] and that all output vowels are specified either [⊣] or [⊢] . $\mathrm{Max}\,\underset{\vdash\dashv}{\downarrow}$ is dominated by all other relevant constraints.

Spreading of [+ATR] is driven by the desire of the non-low stem vowel to be specified as [⊣] – due to [–l] → [⊣] which crucially dominates $\mathrm{Max}\,\underset{\vdash\dashv}{\downarrow}$. Since both, the rightmost vowel and the sponsor of the resulting [⊣]-span, are [+h], spreading is unproblematic for higher-ranked $^*[-\mathrm{h}])_{\dashv}$ and $^*(.\mathrm{V}^{Ⓢ}_{-\mathrm{h}}.)_{\dashv}$:

(17) *Regressive [ATR]-harmony with non-low stem Vs*

Input: = b.	Dep [⊢⊣]	V ↓ [⊢⊣]	*[–h])⊣	*(.$V^{Ⓢ}_{-h}$.)⊣	[–l] ↓ [⊣]	Max$_{⊢⊣}$
☞ a. [⊢] ǂ lep [⊣] | u						*
b. [⊢] | lɛp [⊣] | u					*!	

The low stem vowel [a] vacuously satisfies [–l] → [⊣], hence regressive spreading/harmony is excluded by Max$_{⊢⊣}$:

(18) *Regressive [ATR] non-harmony with low stem V ([a])*

Input: = b.	Dep [⊢⊣]	V ↓ [⊢⊣]	*[–h])⊣	*(.$V^{Ⓢ}_{-h}$.)⊣	[–l] ↓ [⊣]	Max$_{⊢⊣}$
a. [⊢] ǂ ʌm [⊣] | u						*!
☞ b. [⊢] | am [⊣] | u						

Low-vowel suffixes do not spread [+ATR] since the resulting span would violate both *[–h])⊣ and *(.$V^{Ⓢ}_{-h}$.)⊣:

(19) *Regressive [ATR] non-harmony with suffix [ʌ]*

Input: = b.	Dep [⊢⊣]	V ↓ [⊢⊣]	*[−h])$_{⊣}$	*(.V$^{Ⓢ}_{-h}$.)$_{⊣}$	[−l] ↓ [⊣]	Max$_{⊢⊣}$
a. [⊢] ǂ tɛ:g ╌ [⊣] | ʌr			*!	*		*
☞ b. [⊢] | tɛ:g [⊣] | ʌr					*	

If both stem and suffix V are [+hi], there is also progressive [ATR]-harmony (20). Again, spreading is driven by [−l] → [⊣] and the resulting [⊣]-span satisfies both *[−h])$_{⊣}$ and *(.V$^{Ⓢ}_{-h}$.)$_{⊣}$:

(20) *Progressive [ATR]-harmony: [+hi] root + [+hi] suffix*

Input: = b.	Dep [⊢⊣]	V ↓ [⊢⊣]	*[−h])$_{⊣}$	*(.V$^{Ⓢ}_{-h}$.)$_{⊣}$	[−l] ↓ [⊣]	Max$_{⊢⊣}$
☞ a. [⊣] | ʔuŋ ╌ [⊢] ǂ i						*
b. [⊣] | ʔuŋ [⊢] | ɪ					*!	

On the other hand, progressive [+ATR]-spreading to a low/mid vowel is excluded since it would result in a violation of *[−h])$_{⊣}$ ranked above Max$_{⊢⊣}$:

(21) *Progressive [ATR] non-harmony with [−hi] suffix*

Input: = b.	Dep [⊢⊣]	V → [⊢⊣]	*[−h])$_⊣$	*(.V$^{Ⓢ}_{-h}$.)$_⊣$	[−l] → [⊣]	Max ↓̇$_{⊢⊣}$
a. [⊣] ʔuŋ | [⊢] ǂ e (⊣ linked to e)			*!			*
☞ b. [⊣] ʔuŋ | [⊢] ɛ					*	

Similarly, a low-vowel stem cannot spread [+ATR] to the suffix because this would fatally violate *(.V$^{Ⓢ}_{-h}$.)$_⊣$ (recall that there are no [+ATR] mid-vowel stems in Mayak which could induce spreading):

(22) *Progressive [ATR] non-harmony with [−hi] root*

Input: = b.	Dep [⊢⊣]	V → [⊢⊣]	*[−h])$_⊣$	*(.V$^{Ⓢ}_{-h}$.)$_⊣$	[−l] → [⊣]	Max ↓̇$_{⊢⊣}$
a. [⊣] ʌm | [⊢] ǂ i (⊣ linked to i)				*!		*
☞ b. [⊣] ʌm | [⊢] ɪ					*	

Let us finally turn to exceptional [+ATR]-spreading to the singulative suffix -**at**. I follow Andersen in ascribing the exceptionality of this affix to the fact that its vowel is underlyingly unspecified for [ATR]. As a consequence, undominated V → [⊢⊣] enforces assignment of a [ATR]-value to it. Since this cannot be provided by epenthesis as in (23b) which would violate equally undominated Dep [⊢⊣], progressive spreading applies even though this violates *[−h])$_⊣$ and *(.V$^{Ⓢ}_{-h}$.)$_⊣$ (23a):

(23) *Exceptional progressive [ATR] harmony with singulative **-at***

Input: = c.	Dep [⊢⊣]	V ↓ [⊢⊣]	*[−h])⊣	*(.V$^{Ⓢ}_{-h}$.)⊣	[−l] ↓ [⊣]	Max ↓ ⊢⊣
☞ a. [⊣] ʔʌːw ʌt			*	*		
b. [⊣] ʔʌːw [⊢] ʌt		*!				
c. [⊣] ʔʌːw At	*!					

4. Mayak stem-level harmony

Whereas Andersen claims that VR is a 'grammatical process', i.e., triggered morphologically by arbitrary affixes, I will show here that it derives from general phonological harmony processes which only differ from the word-level phonology described in the last section by constraint ranking. In fact there are good reasons to analyze VR as the result of vowel harmony, which becomes obvious if we turn our attention away from the verbal cases of VR, where the affixes inducing it are systematically deleted under hiatus with more peripheral word-level affixes, and turn to the nominal domain, where VR is virtually always accompanied by overt affixes.[2]

Consider first the plural affix -**it** which according to Andersen exhibits VR (24). Raising of [−ATR] stem vowels to [+ATR] in all of these forms is a straightforward case of regressive [+ATR] spreading. See Trommer (2011) for discussion of vowel shortening in the data in (24). Note also that Andersen does not cite any examples of -**it** with mid-vowel stems.

[2] Andersen discusses only three examples in passim where nouns without overt affixes are accompanied by VR. See Trommer (2011) for discussion.

(24) *A [–ATR] Stem-level affix: PL -**it** (Andersen 2000:38)*

	SG	PL	
a.	maːc	mʌj-it̪	'fire'
b.	pʌːm	pʌm-it̪	'mountain'
c.	mɪːŋ	miŋ-it̪	'deaf person'
d.	kɪːn	kin-it̪	'mat'

To be sure, the type of [ATR]-harmony triggered by -**it** slightly differs from the one we have diagnosed for word-level [ATR]-harmony, but if -**it** is taken to be a stem-level affix, the divergence between -**it** and comparable word-level affixes such as the past marker -**u** (cf. (11)) can be derived simply from different constraint rankings at word and stem level. Crucially, not only -**it**, but all overt Mayak affixes which trigger VR are [+ATR] – at least in the contexts where they actually trigger [ATR]-raising – as can be easily verified by checking through (25), (26) and (27), a fact which is purely accidental if VR is interpreted as a morphological process, but could not be otherwise if it is due to V-harmony.

Let us now have a look at another nominal number affix for which Andersen gives data instantiating the [–high –low] ⇒ [+high –low] component of VR, the suffix -**uk**/-**ʊk** (25):

(25) *A [–ATR] + floating [+ATR] stem-level affix: PL -**uk**/-**ʊk** (Andersen 2000:37)*

	SG	PL	
a.	mɛːk	mɪɣ-ʊk	'spider'
b.	jaːŋ	jʌŋ-uk	'crocodile'
c.	naːc	nʌj-uk	'calf'
d.	gɔːc	gʊj-ʊk	'bowl'
e.	d̪ir	d̪ir-uk	'shield'
f.	mʌːl	mʌl-uk	'leg of calf'
g.	bul	bul-uk	'stomach'
h.	puːl	pul-uk	'well,pool'
i.	cɪːma	cim-uk	'knife'
j.	bart̪a	bort̪-uk	'slave, servant'
k.	pura	pur-uk	'cloth'
l.	wʊrʊt	wʊr-ʊk	'hare'

Raising of stem vowels in the context of **-uk/-ʊk** can be understood as a standard case of height harmony: Mid vowels ([ɛ] and [ɔ]) are raised to high ([ɪ] and [ʊ]) in the context of other high vowels.[3] Again, this analysis cannot be rebutted by adducing word-level affixes such as **-u** which do not trigger height harmony on root vowels if height harmony is assigned to the stem level.

In fact there is independent evidence that the affixes triggering VR also differ in other respects from word-level affixes. First, they typically trigger shortening of stem vowels (cf. the examples in (25a–c, f, h, i)), a process which is apparently never found with word-level affixes. Second, the AP in Mayak which is cited by Andersen as the typical case for a morphological exponent of VR in the verbal domain, also exhibits stem-level properties in its effects on stem consonants (cf. Trommer 2011: chapter 7). Third, whereas word-level affixes such as plural **-ni** may attach to nouns of any length (26) (recall that verb roots in Mayak are strictly monosyllabic whereas noun stems may contain up to 4 syllables), the combination of a stem-level number affix and its base is always maximally bisyllabic.[4]

(26) *A word-level affix attaching to polysyllabic stems: PL* ***-ni*** *(Andersen 2000:39)*

	SG	PL	
a.	girint̪i	girint̪i-ni	'hippopotamus'
b.	almaːlaga	almaːlaga-ni	'spoon'
c.	rʊːɗ-a	rʊːɗ-a-ni	'my grandfather'
d.	baːb-a	baːb-a-ni	'my father'

The bisyllabicity restriction on stem-level affixes is especially striking for the only VR-triggering affix which actually attaches to bisyllabic bases, the infix **-u-**,**-ʊ-**, which adheres to bisyllabicity by overwriting the second stem vowel (27):

[3] That low vowels are opaque to vowel height harmony is a phenomenon found in many languages, see e.g. Beckman (1997) on Shona.

[4] Combinations of verb stems and stem-level affixes are always bisyllabic because verb stems in Mayak are always monosyllabic, and stem-level affixes subsyllabic or monosyllabic.

(27) *A [–ATR] + floating [+ATR] stem-level affix: PL* ***-u-/-ʊ-*** *(Andersen 2000:39)*

	SG	PL	
a.	kɪlkat̪	kilkut̪	‘broom’
b.	mɛlɣat̪	mɪlɣʊt̪	‘shelf’
c.	rɛːkat̪	rɪkʊt̪	‘pot type’
d.	kamal	komul	‘girl’
e.	nanaːn	nʌnun	‘snake’
f.	kawɪl	kowul	‘sheep’
g.	d̪ʌld̪ʌːk	d̪ʌld̪uk	‘fox’
h.	mɔrcɔŋ	mʊrcʊŋ	‘horse’
i.	d̪ɔŋɔl	d̪ʊŋʊl	‘cock’
j.	gʊɗɔn	gʊɗʊn	‘bull’
k.	kut̪ɛr	kut̪ur	‘pig’

The analysis of Mayak V-harmony processes in the following is tentative simply because Andersen provides very few examples for most affixes. I depart from the observation that the affixes inducing VR differ in interesting detail. Thus, plural **-d̪in/-d̪ɪn** (28) apparently differs from plural **-it** in two respects: It occurs in a [+ATR] and a [–ATR] variant according to the [ATR] specification of the stem vowel ((28a) vs (28e)), and it does not induce [+ATR] raising (28c). This dissociation of [+high]-raising and [+ATR]-raising further supports the assumption that VR must be decomposed into different phonological harmony processes.

(28) *A [–ATR] stem-level affix:* ***-d̪in/-d̪ɪn*** *(Andersen 2000:38)*

	SG	PL	
a.	d̪ɔːl	d̪ʊːl-d̪ɪn	‘anus’
b.	gɛːl	gɪl-d̪ɪn	‘lion’
c.	ʔɪːr	ʔɪr-d̪ɪn	‘thief’
d.	jɔːm	jʊm-d̪ɪn	‘monkey species’
e.	run	run-d̪in	‘year’

I assume that the vowel of **-d̪in** is underlyingly [˫] and undergoes [ATR] harmony similarly to the one we have observed for word-level affixes, whereas plural **-it** is specified [+ATR], which accounts for the fact that it never surfaces as **-ɪt**. Finally there seems to be a third class of stem-level affixes, instantiated by plural **-uk/-ʊk** and **-u-/-ʊ-** which surface sometimes as [+ATR] and sometimes as [−ATR] according to the context, but nonetheless trigger [+ATR]-raising on low and high vowels. I analyze these affixes as containing [−ATR] vowels accompanied by exponents consisting of a floating [+ATR]. The table in (29) summarizes the representations and effects of all three affix types:

(29) *Stem-level affix types in Mayak*

		Context Dependent [ATR]	**[high] raising [ɛ] ⇒ [ɪ]**	**[ATR] raising [a] ⇒ [ʌ]**
a. -d̪in/-d̪ɪn	[⊢] – ɪ – [+h] [–l]	+	+	–
b. -it	[⊣] – i – [+h] [–l]	–	+	+
c. -uk/-ʊk -u-/-ʊ-	[⊣] [⊢] – ʊ – [+h] [–l]	+	+	+

The analysis uses the constraints in (30) which were already used for Mayak word-level harmony and are extended here to range over F (i.e., [ATR] and [h]). Thus Dep F abbreviates Dep [⊢⊣], Dep [h]. Dep F which is again undominated will not be explicitly shown in the following tableaux.

(30) *Constraints on [h] and [⊢⊣]*

a. DEP F — Assign ∗ to every F which is in M but not in P

b. *[-h])$_F$ — Assign ∗ to every non-unary F span whose right-most vowel is [–h] in I

c. MAX$^{\bullet}_{\downarrow F}$ — Assign ∗ to every morphological association line between a segmental root node and a feature node which is not phonetic

The constraints in (31) trigger and further constrain [ATR]-harmony; they are all crucially undominated at the stem level. V → [⊣], an extended version of [–l] → [⊣], (31a) triggers [⊢⊣]-spreading and accounts for the fact that regressive [⊣] spreading at the word level also affects the low vowel [a]. *E$_{⊣}$ (31b) implements the ban on [+ATR] mid vowels already observed in section 3. It has two crucial effects: First, in the output of the stem level there are no phonetic mid-vowels which accounts for the fact that Mayak does not have such segments apart from those which are derived by regressive [ATR]-harmony triggered by word-level affixes. Second, Vs which are [–h–l] in the input to the stem level will not become [+ATR] at this stratum even if they finish as high vowels ([ɛ] may become [ɪ], but not [e] or [i]). This holds because *E$_{⊣}$ is an I-Structure constraint. The constraint DE$^{\bullet}_{\uparrow ⊣}$ (31c) is a DERIVED ENVIRONMENT constraint blocking association in monomorphemic contexts generalizing the constraint ALTERNATION proposed by van Oostendorp (2007) (see Trommer 2011 for general discussion of this constraint type). In the analysis here, it has the effect that a floating affix [⊣] can only associate to the affix vowel if it also associates to a stem V.

(31) *Additional constraints on [⊢⊣]*

a. V ↓ [⊣] — Assign ∗ to every V which does not dominate a [⊣] in I

b. *E$_{⊣}$: — Assign ∗ to every • which dominates [–h], [–l] and [⊣] in I

c. DE$^{\bullet}_{\uparrow ⊣}$ — Assign ∗ to every [ATR] node which is dominated through an epenthetic | by a tautomorphemic • but not by a heteromorphemic •

Finally, there are two constraints which specifically refer to [h]. Constraint

(32a) triggers [h]-harmony on mid-vowels, and the undominated constraint in (32b) blocks rightward spreading of [+h]:

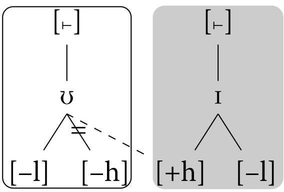
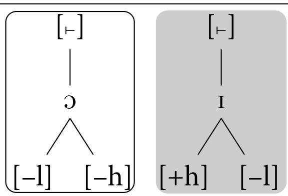
(32) *Additional constraints on [h]*

a. [–l] ↓ [+h] — Assign * to every V which dominates [–l] but not [+h] in I

b. Max$^{\bullet\downarrow}_{h}$] — Assign * to every vowel which is right-peripheral on its tier and dominates F in M, but not in P

I will start the discussion of single cases with -**d̪in/dɪn**. With a mid-vowel stem, the [+h] of the affix vowel spreads to the base vowel to satisfy [–l] → [+h]. No [+ATR]-raising takes place since -**d̪in** is specified [⊢], and Dep F (not shown in the tableau) is undominated:

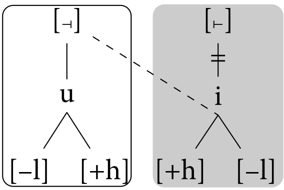
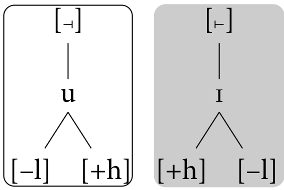
(33) *[High]-raising: left-spreading of [+h] (jɔm-d̪ɪn ⇒ jʊm-d̪ɪn)*

Input: = b.		*[-h])$_F$	Max$^{\bullet\downarrow}_{h}$]	*E$_⊣$	DE$^{\bullet\uparrow}_{⊣}$	[–l] ↓ [+h]	V ↓ [⊣]	Max$^{\bullet\downarrow}_{F}$
☞ a.							*	*
b.						*!	*	

The affix -**d̪in** does not trigger any changes in other stem-Vs. [+ATR]-raising is excluded since the affix does not contain an underlying [⊣], and low vowels do not undergo [+h]-raising because they vacuously fulfill [–l] → [⊣], thus the constraint does not induce a violation of Max$^{\bullet\downarrow}_{F}$. However, the vowel of -**d̪in** itself becomes [+ATR] after [+ATR] vowels to satisfy V → [⊣]:[5]

[5] Andersen does not provide data where -**d̪in** becomes [+ATR] after the low [+ATR] vowel ʌ,

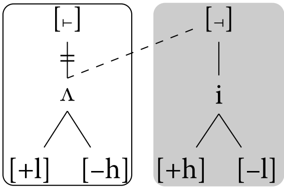
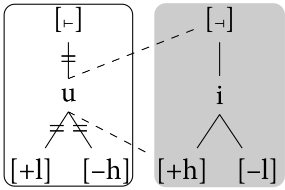
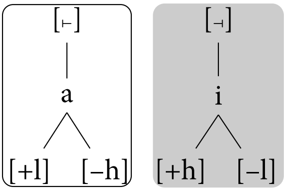
(34) *Context-dependent [ATR]-realization: right-spreading of [⊣]*
(run-d̪ɪn ⇒ run-d̪in)

Input: = b.	*[-h])$_F$	MAX$_h$	]*E̲	DE	[–l] ↓ [+h]	V ↓ [⊣]	MAX$_F$
☞ a. 							*
b. 						*!	

Let us turn now to the behavior of **-it**, which is underlyingly specified as [⊣]. If preceded by a low (or high) [⊢] stem, the [⊣] of the affix spreads to the stem-V, resulting in [+ATR]-raising triggered by V → [⊣]. Candidate (35b) illustrates the fact that [+h]-raising never affects low vowels because the MAX$_F$ -violation for [h] (and the concomitant violation for [-l] to avoid a [+l+h] vowel) is not justified by a higher-ranked markedness constraint:

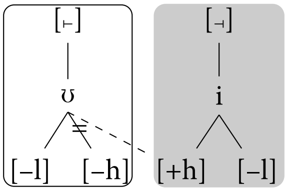
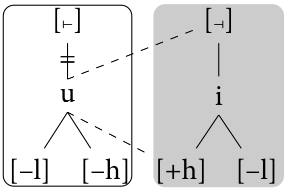
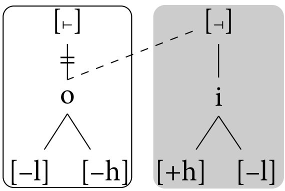
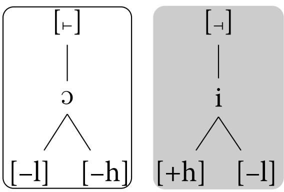
but since -**uk** and -**u**- do so, I assume that this behavior extends to -**d̪in**. There are no input [+ATR] mid vowels in stems because *E̲ is undominated at the exponent level.

(35) *Leftwards spreading of [⊣] (maac-it ⇒ mʌc-it)*

Input: = c.		$^*E_{⊣}$	DE$^{\bullet}_{↑⊣}$	[−l] ↓ [+h]	V ↓ [⊣]	Max$^{\bullet}_{↓F}$
☞ a.						*
b.						**!*
c.					*!	

Andersen does not provide an example where **-it** attaches to a mid-V stem. However, the prediction made by the analysis here is that the stem-vowel raises to high as with other VR affixes. This is shown for the hypothetical noun root ***ʔɔt** in (36):

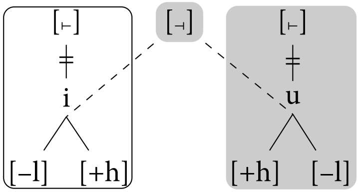
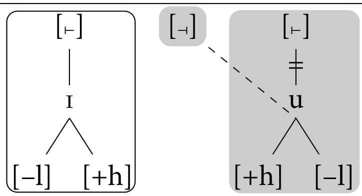
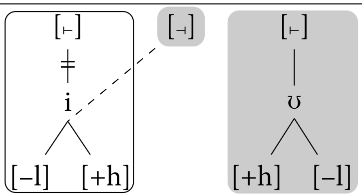
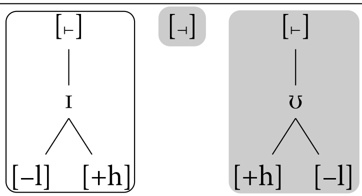
(36) *L-spreading of +h/No L-spreading of [⊣] (*ʔɔt-it ⇒ *ʔʊt-it)*

Input: = d.		*E$_{⊣}$	DE$^{•}_{↑⊣}$	[–l] ↓ [+h]	V ↓ [⊣]	MAX$^{•}_{↓F}$
☞ a.					*	*
b.		*!				*
c.		*!		*		*
d.				*!	*	

The output of (36) would actually undergo regressive [+ATR]-spreading at the word level resulting in **ʔu t-it**. This is also the prediction which results from Andersen's description of the empirical generalizations.

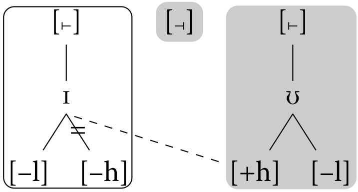
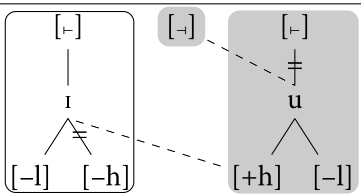
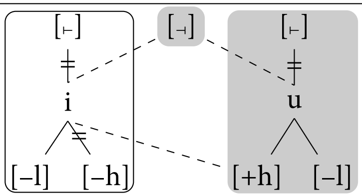
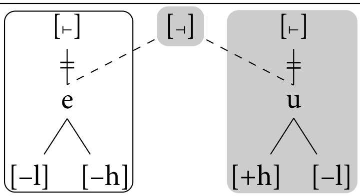
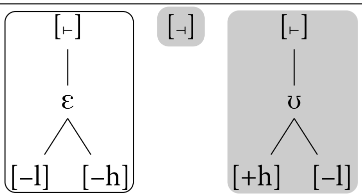
Affixes with a floating [⊣] induce [+ATR]-raising on both affix and peripheral (non-mid) stem vowels by association of the floating feature to satisfy V → [⊣]:

(37) *Association of floating [⊣] (cɪɪm-⊣-ʊk ⇒ cim-uk)*

Input: = d.		DEP F	DE$\dot{\uparrow}_{\dashv}$	[–l] ↓ [+h]	V ↓ [⊣]	MAX$\dot{\downarrow}_{F}$
☞ a.						**
b.			*!		*	*
c.					*!	*
d.					*!*	

Importantly with mid-vowel stems, we get [+h]-raising, but not [+ATR]-raising. The crucial candidate is (38c) which exhibits both processes, but is blocked since the stem vowel non-withstanding the phonetic deassociation is still associated to [–h], [–l], and [⊣], and hence violates $*\underset{\dashv}{E}$. The essential role of DE$\dot{\uparrow}_{\dashv}$ becomes obvious in (38b), where it blocks association of the floating [⊣] to the affix vowel only:

(38) *L-Spreading of [+h]/non-association of floating [⊣]*
(mɛk-⊣-ʊk ⇒ mɪɣ-ʊk)

Input: = e.		*E⊣	DE↑⊣	[–l] ↓ [+h]	V ↓ [⊣]	Max↓F
☞ a.					**	*
b.			*!		*	*
c.		*!				*
d.		*!		*!		*
e.				*!	**	

5. Conclusion

In this paper, I have shown that the apparent challenge posed by vowel raising in Mayak can be captured by two formal devices, generalized markedness constraints in a containment-based approach to phonological opacity (Trommer 2011), and the stratal organization of the morphology-phonology interface (Kiparsky 2003, Bermúdez-Otero 2013). Since both mechanisms are amply supported by empirical and conceptual evidence, this reduces the vowel raising problem to independently motivated primitives of grammatical organization. The added value of the phonological analysis for Mayak is that it allows for capturing succinctly apparent additional small-scale differences in the behavior of different affixes triggering vowel raising. The question whether these differences are fully general for the language is an important challenge for future empirical investigation.

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