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Harmony by Avoidance: An Emergent Account of Ikoma Tongue Root Harmony

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Abstract
Ikoma, a Bantu language of Tanzania, exhibits a tongue root harmony system where a salient property of the system is to avoid potentially disharmonic sequences by removing the problematic vowels from the domain of harmony: Since the strictest part of the harmony system involves non-high vowels, potentially disharmonic mid vowels raise to high in prefixes. The harmonic system shows various intricacies when root properties, prefix properties and suffix properties are given a unified analysis. Our proposal for Ikoma is couched within an Emergent Phonology model, where grammatical generalizations are established by a data-driven consideration of co-occurrence patterns that hold between phonological sequences and between morphological items and the phonological sequences adjacent to them.

1 Introduction

Ikoma (Bantu, E.45; Tanzania) is generally considered to be part of a dialect cluster with Nata and Isenye (Lewis et al. 2015). The impetus for the present study of tongue root harmony is twofold. First, while sequences of mid vowels typically agree in tongue root values, Ikoma (Higgins 2011) exhibits an intriguing "avoidance strategy" for achieving forms that do not violate tongue root harmony. In many cases where the tongue root value of one morpheme might conflict with the tongue root value of an adjacent morpheme, Ikoma achieves harmony not through matching tongue root values but by using a vowel that is outside the domain of harmony, due to its height value, thereby avoiding a disharmonic sequence. Second, a detailed consideration of the patterns shows Ikoma to have a system that is quite different from that of the closely related Nata, despite there also being striking similarities (Johannes [Gambarage] 2007, Gambarage2013, Gambarage & Pulleyblank 2017 on Nata). The Ikoma pattern warrants an independent treatment.

The avoidance strategy pattern is illustrated in 1. Roots with advanced vowels appear with a mid advanced prefix while roots with mid retracted vowels appear with a high advanced prefix, thereby avoiding a disharmonic advanced-retracted sequence of mid vowels.¹

¹ The C# designation indicates noun class membership. Square brackets indicate the morphological stem. An acute accent indicates high tone; the absence of an accentual mark indicates low tone.

1. Avoiding disharmony by height alternations (Higgins 2011:p.140)

advanced root		retracted root	
o-mo-[sino]	'widow' (C1)	o-mu-[sɛsɛ]	'slave' (C1)
o-ro-[réme]	'tongue' (C11)	o-ru-[yɔhɛ]	'eyebrow' (C11)

Where the noun stem begins with an advanced vowel, the class prefix is mid advanced; where the noun stem begins with a retracted vowel, the class prefix is high (advanced). Of interest, a rule or constraint model that results in a mid retracted prefix vowel with a mid retracted root (*o-mo-[sɛsɛ], *o-ro-[yɔhɛ]) might be considered preferable to one that results in the attested forms, yet in Ikoma (and Nata), the prefix vowel appears as high, effectively removing it from the phonological domain of harmony between mid vowels.

In this paper, we examine the disharmony avoidance strategy along with a number of other patterns that come together to form the complex system that Ikoma exhibits. We present our analysis in terms of a bottom-up, "emergent" approach to phonological patterns as presented in Archangeli & Pulleyblank (2013, 2015, 2016, 2018); see also Archangeli et al. (2012). The central hypothesis of Emergent phonology is that an innate "Universal Grammar" plays a minimal role in formulating a phonological analysis. Rather, in a highly bottom-up endeavor, learners observe language forms, identify similarities, track frequencies, and generalize (see works cited above). Lexical representations consist of sets corresponding to surface forms of morphs, not of abstract, single representations. This necessitates a mechanism to select among the various morphs for a given concatenation; in this paper, we show that much of the selection is driven by conditions that hold of roots as well as of concatenations, conspiring to avoid sequences that combine retracted mid vowels with advanced vowels. We turn first to relevant background information before exploring the disharmony avoidance patterns.

2 Background

The patterns we consider in this paper involve the co-occurrence patterns of vowel height and tongue root position in roots, stems, and words. Thus, there are two general properties of Ikoma that are useful for our purposes here: the morphological structure of words and the vowel inventory.

Nouns and verbs both have a "prefix-stem" structure. This is shown throughout with square brackets around the stem. Nouns have an additional "pre-prefix", which we refer to as a 'determiner' (DET), following Gambarage

(in prep).² Within the stem, verbs have one or more suffixes. One type augments the meaning of the verb (e.g. CAUSATIVE, AGENTIVE). Additionally, Ikoma shares the ubiquitous Bantu "final vowel", the verbal marker [a]. These structures are shown in 2.

2. Ikoma noun & verb morphology

- a. nouns: determiner [class prefix [stem root]]]
 b. verbs: [prefix [stem root - (suffix*) - (a)]]

The noun structure, with class prefixes, is illustrated in 3. For simplicity, we show only stem brackets (and not word brackets) in our data figures.

3. Ikoma noun prefixes

High advanced prefix, any stem vowel		Low prefix, any stem vowel	
e-ri-[yíha]	'cooking stone' (C5)	a-ma-[yíha]	'cooking stones' (C6)
e-ri-[fere]	'hoe' (C5)	a-ma-[fere]	'hoes' (C6)
e-ri-[βɛɣa]	'shoulder' (C5)	a-ma-[βɛɣa]	'shoulders' (C6)
e-ri-[fáakɔ]	'skin' (C5)	a-ma-[fáakɔ]	'skins' (C6)
e-ri-[tɔ́ŋgɔ]	'tribe' (C5)	a-ma-[tɔ́ŋgɔ]	'tribes' (C6)
e-ri-[yóri]	'price' (C5)	a-ma-[yóri]	'prices' (C6)
e-ri-[túre]	'steer' (C5)	a-ma-[túre]	'steers' (C6)

In terms of its inventory, Ikoma has seven vowels, all of which are oral.

4. Ikoma vowel inventory

i	U	high advanced
e	O	mid advanced
ɛ	ɔ	mid retracted
a		low retracted

As seen in 4, the high vowels are systematically advanced, the low vowel is systematically retracted, and the mid vowels may be either advanced or retracted.³ Higgins (2011) argues for the appropriateness of these feature values based on acoustic investigation.

²This morpheme, the properties of which are not crucial here, is referred to by various names in the literature, including 'augment', 'pre-prefix' and 'initial vowel' (Meeussen 1967, Katamba 2003).

³Consistent with our emergentist model, the features referred to, such as "retracted tongue root" and "high", are themselves emergent. We adhere to familiar names, but do not subscribe to the universalist hypothesis for distinctive innate features. See Mielke (2015, 2008), Archangeli & Pulleyblank (2018).

With this background, we are in position to set the stage for our discussion of harmony by avoidance. We begin with the co-occurrence patterns of vowels within roots, especially tongue root values in mid vowel sequences.

3 Root-internal restrictions

There are restrictions on the distribution of vowels within roots (Higgins 2011, p. 122). Retracted mid vowels do not occur with advanced vowels, illustrated by the examples in 5 and shown schematically in 6.

5. Ikoma root/stem vowels – examples

i...i	a.	o-ro-[ríyí]	'wickerwork'	o...e	q.	o-ro-[βohe]	'grinding stone'
i...e	b.	o-mo-[símbe]	'prostitute'	o...o	r.	o-yo-[yoro]	'leg'
i...o	c.	a-ha-[yíro]	'place'	o...a	s.	e-ke-[βónda]	'tobacco pipe'
i...a	d.	o-mo-[yíha]	'tendon'	ε...ε	t.	o-ru-[hémbε]	'horn'
u...i	e.	e-ye-[kúndi]	'fist'	ε...ɔ	u.	e-yi-[séntɔ]	'cup'
u...u	f.	aŋ-[yúβu]	'hippo'	ε...a	v.	e-ri-[βεya]	'shoulder'
u...e	g.	o-yo-[túmbe]	'large chair'	ɔ...ε	w.	o-ru-[yɔhe]	'eyebrow'
u...o	h.	a-[túyo]	'herd'	ɔ...ɔ	x.	a-[kóro]	'heart'
u...a	i.	a-[suná]	'mosquito'	ɔ...a	y.	a-n-[tʃóka]	'snake'
e...i	j.	o-mo-[remi]	'farmer'	a...i	z.	e-yi-[táti]	'eyelid'
e...u	k.	e-ri-[yeyu]	'molar tooth'	a...u	aa.	e-ki-[hamú]	'chin'
e...e	l.	a-ma-[fere]	'hoes'	a...e	bb.	e-yi-[saré]	'twin'
e...o	m.	e-ke-[mero]	'throat'	a...o	cc.	e-kj-[áro]	'village'
e...a	n.	e-ri-[tema]	'liver'	a...ε	dd.	a-ma-[sáahε]	'blood' (long V)
o...i	o.	a-[moni]	'pupil'	a...ɔ	ee.	a-[sakó]	'basket'
o...u	p.	o-mu-[βóhu]	'prisoner'	a...a	ff.	e-ri-[ráka]	'larynx'

6. Ikoma root-internal vowel sequences

V1\V2	i	u	E	O	ε	ɔ	a
I	a	-	B	C	-	-	d
U	e	f	G	H	-	-	i
E	j	k	L	M	-	-	n
O	o	p	q	R	-	-	s
ε	-	-	-	-	t	u	v
ɔ	-	-	-	-	w	x	y
A	z	aa	bb	Cc	dd	ee	ff

Higgins (2011) points out that the patterns given in 6 are somewhat different when long vowels are taken into consideration. Although short retracted

vowels [ε, ɔ] do not appear before high advanced vowels, as indicated in 6, long retracted vowels may occur in this context, 7.

7. Long retracted mid vowels before high vowels

- ku-[hɔrɛɛri] 'appease'
- ki-[ɪɔɔhu] 'smooth'
- o-βu-[róti] 'prophecy'
- e-ri-[yɔɔti] 'tax'

Although the examples appear to be highly limited, it seems that long retracted vowels may also appear after high vowels.

8. Long retracted mid vowels after high vowels

- kw-[ihɛɛβa] 'think'
- am-[iihɛɛβɔ] 'plans'

Overall, three types of conditions explain the gaps in 6. First, there is an absence of mid-mid vowel sequences where the mid vowels have different tongue root values. Both advanced-retracted and retracted-advanced sequences are prohibited.

9. *[ATR, mid] C₀[RTR, mid] (abbreviated: *e/o...ε/ɔ)

Penalize a sequence with an advanced mid vowel followed immediately or in the next syllable by a retracted mid vowel.

10. *[RTR, mid] C₀[ATR, mid] (abbreviated: *ε/ɔ...e/o)

Penalize a sequence with a retracted mid vowel followed immediately or in the next syllable by an advanced mid vowel. These conditions hold of both short and long vowels. Second, we have an absence of mid retracted vowels adjacent to high vowels.

11. *[RTR, mid] C₀[high] (abbreviated: *ε/ɔ...i/u)

Penalize a sequence with a short retracted mid vowel followed immediately or in the next syllable by a high vowel.

12. *[high] C₀[RTR, mid] (abbreviated: *i/u...ε/ɔ)

Penalize a sequence with a high vowel followed immediately or in the next syllable by a short retracted mid vowel. These conditions involving high vowels govern only short mid vowels. Finally, we have a more limited condition governing the absence of a sequence where a high front vowel is followed by a high back vowel.

13. *[high, front] C₀[high, round] (abbreviated: *i...u)

Penalize a sequence with a high front vowel followed immediately or in the next syllable by a high back vowel.

Taken together, these conditions account for the pattern of gaps seen in root-internal vowel sequences. Of particular interest, these conditions play a major role in explaining various patterns of alternations that occur with stem-level and word-level affixation, shown in the next sections.

4 Harmony by avoidance in prefixes

In this section, we consider cases where prefixes have two surface forms, one mid and the other high. Identifying two forms for a single set of morphosyntactic features motivates the learner to determine when to use which form. In Ikoma, the distribution is in part governed by purely phonological phonotactic conditions, and in part governed by conditions that involve the morphology, either morphotactic conditions combining reference to both phonology and morphology or default conditions governing unconditioned choice of a particular form of a morpheme. We begin our discussion by examining prefix patterns with nouns, before turning to verbs, whose prefixes behave much like the noun prefixes, but where suffix interactions also give evidence of disharmony avoidance.

4.1 Nouns

There are both non-alternating and alternating prefixes in Ikoma. Non-alternating prefixes, either high or low, are illustrated above in 3. On the other hand, prefixes involving mid vowels present two variants, one mid and the other high, illustrated in 14. The mid variant patterns with advanced root vowels and the high variant patterns with retracted root vowels.

14. Alternating prefix examples (Higgins 2011, p. 140)

Mid advanced prefix Advanced stem vowel		High (advanced) prefix Retracted stem vowel	
o-mo-[sino]	'widow' (C1)	o-mu-[sɛsɛ]	'slave' (C1)
o-mo-[remi]	'farmer' (C1)	o-mu-[ɣaβo]	'medicine man' (C1)
o-ro-[réme]	'tongue' (C11)	o-ru-[ɣɔhɛ]	'eyebrow' (C11)
e-me-[ɣóndo]	'farms' (C4)	e-mi-[tʃaré]	'rice' (C4)
e-ye-[túmbe]	'chair' (C7)	e-ki-[βára]	'grassland' (C7)

The observed pattern of alternation is consistent and widespread in the language: prefixes with a mid advanced vowel have a counterpart with a

high advanced vowel: {mo, mu}_{CL.1}, {me, mi}_{CL.4}.⁴ This lexical redundancy defines a set of 'morphs' (a 'morph set') which serves to represent the relevant 'morpheme'. For example, either member of the morph set of {mo, mu} represents noun class 1, just as either of {me, mi} represents noun class 4. The lexical redundancy governing this set of surface morphs is given in 15.

15. Morph Set Relation: MSR-mid-implies-high

$\exists M_i, M_i = \text{a class prefix}, M_i \ni \text{mid}_i \# \rightarrow \exists M_j, M_j \ni \text{high}_i \#$

If a class prefix morph set includes a morph ending in a mid vowel then it also includes a morph ending in an otherwise identical high vowel.

example {mo}_{CL.1} → {mo, mu}_{CL.1}

A Morph Set Relation such as MSR-mid-implies-high explicitly expresses multi-member morph sets as a productive pattern in the language; when a new mid prefix is encountered, a high counterpart is automatically generated.

Phonotactics and disharmony avoidance. Consider now the cases seen in 14, where a class prefix occurs before a stem beginning in a retracted vowel, such as {sɛsɛ}_{SLAVE}. Because SLAVE belongs to noun class 1, and there are two CLASS.1 prefix morphs, {mo, mu}_{CL.1}, creating the prefixed form gives two possibilities, the attested o-mu-[sɛsɛ]_{SLAVE} (C1) and the unattested *o-mo-[sɛsɛ]. Just as the condition *e/o...ɛ/ɔ, (9, *[ATR, mid] C₀ [RTR, mid]) rules out sequences of root vowels that put an advanced mid vowel before a retracted mid vowel, so does it rule out such a sequence involving a prefix. We show this via an assessment table.⁵

16. Assessment of {o}_{DET}-{mo, mu}_{CL.1}-{sɛsɛ}_{SLAVE}

	DET-CL.1-SLAVE	*e/o...ɛ/ɔ
→ a.	o-mu-[sɛsɛ]	
b.	o-mo-[sɛsɛ]	*!

⁴Recall from 3 that this relation is not reciprocal. For example, the high vowel prefix {ri}_{CL.3} in 3 does not have a mid vowel counterpart.

⁵The assessment table bears an intended resemblance to Optimality Theory tableaux (Prince & Smolensky 1993) as well as the somewhat different approach taken under harmonic serialism (McCarthy 2010). Differences include: (i) the top left cell is occupied by the morphosyntactic features to be realized; (ii) the top row shows conditions that are motivated by surface forms in the language (there is no universal constraint set); (iii) the lefthand column shows all and only the combinations produced by the morph sets being combined. Note that there is not an infinite set of candidates -- the total number of candidates is the product of the number of morphs found in each component morph set.

In constraint-based models, harmony is often treated as the consequence of either a requirement that segments agree for a feature feature (Baković 2000) or a prohibition against opposite values for the same feature (Pulleyblank 2002), the latter being the strategy followed here.⁶ Such constraints typically result in sequences with similar feature values, e.g. sequences of mid retracted or mid advanced vowels. This is not the case in Ikoma. Rather, once the mid advanced prefix is eliminated by the harmony condition, as shown in 16b, harmony itself is no longer a factor because only a high prefix morph remains, o-mu-[sɛsɛ] 'slave', 16a. The core sequences for harmony involve mid vowels, so by choosing a high vowel prefix form, the prefix is in essence exempted from harmony. Thus, harmony is achieved by shrinking the relevant domain, avoiding sequences of mid vowels that could potentially be disharmonic.

This case illustrates an important difference between the bottom-up approach taken here and the top-down approach of OT. According to the classical version of 'Gen' (Prince & Smolensky 1993) as well as the somewhat different approach taken under harmonic serialism (McCarthy 2010), candidate outputs are generated for an underlying form and assessed for optimality. Given an input like /o-mo-[sɛsɛ]/, candidates such as ...mu-[sɛsɛ] (changing the single feature [high]) and ...mo-[sɛsɛ] (changing the single feature [ATR]) would both be generated. The problem therefore becomes how to guarantee the optimality of the former (involving [high]) rather than the latter (involving [ATR]).⁷ The optimality-based approach is top-down in the sense that a postulated abstract underlying form gives rise to a set of postulated outputs from which the actual output is chosen. Under the emergentist assumptions we explore here, only actually occurring morph-forms are considered. In this case, there are two attested surface forms for the relevant class prefix, [mo] and [mu]; a form like ...mɔ-[sɛsɛ] is therefore not considered at all because {mɔ} is not part of the class prefix morph set. The overgeneration of forms by Gen is prevented under Emergence by requiring that productively 'generated' forms are the result strictly of combining the morphs found in morph sets and morph sets only contain morphs directly corresponding to surfaced forms. Patterns within morph sets are characterized by morph set relations (like MSR-mid-implies-high, 15). The prohibition on mid advanced followed by mid retracted is therefore sufficient for selecting the correct form because *...[mɔ-sɛsɛ] is not an option when combining occurring morphs.

⁶See Sasa (2009) for a review of approaches to harmony in Optimality Theory.

⁷See Higgins (2011) for details, and Gambarage & Pulleyblank (2017) for discussion of this approach in both Ikoma and the closely related Nata.

Low vowel roots and a restricted phonotactic. In one class of cases, the analysis we have begun to sketch here fails in its current form. In cases where a stem begins with a low vowel, the *e/o...ɛ/ɔ condition is irrelevant since the key sequence does not involve a sequence of two mid vowels. As such, we would expect surface forms such as *e-me-[tʃarɛ] 'rice' and *e-ke-[βara] 'grassland' (14) rather than the actually attested forms e-mi-[tʃarɛ] and e-ki-[βara]. That is, there is nothing in the *e/o...ɛ/ɔ phonotactic that motivates the presence of a high vowel in the prefix when the following noun has a low vowel in the first syllable. While it is possible that the phonotactic could be altered in a purely phonological way, an altered phonotactic is not clearly warranted. For example, as seen in 5 and 6, low vowels can freely co-occur with advanced mid vowels in noun roots, both in a mid-low sequence (e.g. e-ri-[téma] 'liver') and in a low-mid sequence (e.g., e-ʔi-[sarɛ] 'twin'). Similarly in verbs, low vowels may occur with advanced vowels. The canonical verbal suffix -a for example, follows both retracted and advanced vowels in verb roots, for example ʔu-[ʔɛʔ-a] 'carry' and ko-[reh-a] 'pay'.⁸

It seems therefore that we need a phonological condition prohibiting the appearance of a mid vowel prefix specifically when preceding a root containing an initial low vowel. (See Gambarage & Pulleyblank 2017 for relevant discussion in Nata).

17. *[mid] [ROOT C₀[low] (abbreviated: *e/o [a])

Penalize a sequence with a mid vowel prefix followed immediately or in the following syllable by a low vowel.

18. Assessment of {e}_{DET}-{me, mi}_{CL.4}-{βara}_{GRASSLAND}

	DET-GRASSLAND-CL.4	*e/o...ɛ/ɔ	*e/o [a]
→	a. e-mi-[βara]		
	b. e-me-[βara]		*!

The role of default. Where the root is advanced (mid or high), neither the mid vowel phonotactic nor the mid-low phonotactic is relevant, yet the two prefix morphs do not appear in free variation. We propose that in such cases, the default form of the morph is selected (Mascaró 2007, Bonet et al

⁸The alternation between [ʔ] and [k] in the infinitive prefix reflects the Ikoma version of 'Dahl's Law', Davy & Nurse 1982, a prohibition on voiceless velars before voiced obstruents; see Higgins 2011, p. 57-62 on Dahl's Law in Ikoma. Further examples are seen elsewhere, for example in 21, 22. Under the Emergent model sketched here, the infinitive would have four morphs: {ʔu, ʔo, ku, ko} INFINITIVE. For our purposes here, we simplify figures by ignoring the Dahl's Law effects.

2013). For Ikoma prefixes, the default is the mid advanced form, assigned by a morph set relation because it is a general property of prefixes. The condition Default (Def) penalizes non-default morphs. It must be ranked below both phonotactics, otherwise the default morph is erroneously selected for all verb roots regardless of vowels. We indicate the default morph in a morph set via underlining: {mo, mu}_{CL.1}, etc.

19. Default (Def) Penalize a non-default morph.

20. Assessment of {o}_{DET}-{mo, mu}_{CL.1}-{sino}_{WIDOW}

	WIDOW-CL.1	*e/o...ε/ɔ	*e/o [a	Def
a.	o-mu-[sino]			*!
→ b.	o-mo-[sino]			

From noun patterns to verb patterns. Prefixes in verbs behave much the same way as in nouns, with surface forms resulting from the options made available by morph set relations, and the choice between morphs governed by phonotactics and default considerations. For example, the infinitive prefix has both high and advanced mid prefixes and the prefix pattern is fully comparable to that seen for nouns. Verbs, however, introduce a new complication that we now turn to: certain verb roots have multiple morphs. So a means of selecting not only the correct prefix morph but also the correct root morph is required. This selection is determined by the following suffix.

4.2 Prefixes in verbs with alternating roots

Perhaps the first thing to note when considering alternations in verb roots is that most roots do *not* alternate. Indeed, the only root vowel that alternates is the front mid vowel in verbs. The alternation is illustrated by comparing the form of the verb root 'carry' in the infinitive and in the agentive and passive:

21. Alternations in verb roots

gloss	Infinitive	Agentive	passive
'carry'	ɣu-[ɣεɣ-a]	o-mu-[ɣεɣ-i]	ɣu-[ɣεɣ-u]

The observed alternation is found only in verbs with a front mid retracted vowel. All other vowels, including the back mid retracted vowel, show no verb root vowel alternations, as can be seen in a full paradigm of cases.

22. Roots with low- and high-vowel suffixes

	gloss	infinitive	agentive	passive
nonalternating	'weed'	ɣo-[tʃiβ-a]	o-mo-[tʃiβ-i]	ɣo-[tʃiβ-u]
	'dig'	ɣo-[tuk-a]	o-mo-[tuk-i]	ɣo-[tuk-u]
advanced	'pay'	ko-[reh-a]	o-mo-[reh-i]	ko-[reh-u]
	'weave'	ko-[rok-a]	o-mo-[rok-i]	ko-[rok-u]
nonalternating	'inherit'	ɣu-[ɣaβ-a]	o-mu-[ɣaβ-i]	ɣu-[ɣaβ-u]
retracted	'do'	ɣu-[kɔɾ-a]	o-mu-[kɔɾ-i]	ɣu-[kɔɾ-u]
alternating	'carry'	ɣu-[ɣεɣ-a]	o-mu-[ɣεɣ-i]	ɣu-[ɣεɣ-u]

Three points are important. First, an explanation is needed for why there is alternation at all. Second, an explanation is needed for why some front vowels alternate but retracted back vowels do not (o-mu-[kɔɾ-i], *o-mu-[kɔɾ-i]). Third, an explanation is needed for the height of the prefix immediately preceding the mid advanced root variant. In nonalternating instances of a mid advanced root vowel (e.g. {reh}_{PAY}), the prefix vowel is mid advanced (e.g. o-mo-[reh-i]); in need of an explanation therefore is why the prefix vowel is high when the root is alternating (e.g. o-mu-[ɣεɣ-i], *o-mo-[ɣεɣ-i]).

Our account of these points involves the establishment of a multi-member morph set, a phonotactic constraint already referred to, a root-determined selection property, and, when all else fails, an appeal to Default. We consider these four points in turn.

Alternation: Morph sets with multiple members. As seen in 15, a morph set relation represents a systematic relation between multiple members of a morph set, thereby characterizing alternation within the Emergence model. Observing that Ikoma has two closely related morphs when a verb root contains a mid front retracted vowel, a crucial aspect of the analysis is to establish the relevant MSR: Any verb root morph set containing a mid front retracted vowel also contains a morph with a mid front advanced vowel.

23. Morph Set Relation: MSR-CεC-implies-CεC ***preliminary*** (cf. 25)

$\exists M_i, M_i = \text{Verb}, M_i \ni \dots \epsilon_i C \# \rightarrow \exists M_j, M_j \ni \dots \epsilon_j C \#$

If the morph set of a verb includes a morph whose final vowel is mid front retracted [ε] then it also includes an otherwise identical morph whose final vowel is advanced [e].

example {ɣεɣ}_{V; CARRY} → {ɣεɣ, ɣeɣ}_{V; CARRY}

As with the previously examined morph set relation, we assume that such redundancies reflect the learner's generalization from a potentially small set of cases involving morph set pairs to predict the existence of an

advanced form for a verb where only the retracted form has been encountered. This enables the learner to predict and use novel forms.

No alternation: noMSR. The MSR-C&C-implies-CeC accounts for the alternation with front mid vowel roots. That this MSR is not generalized to include retracted back vowels captures the absence of alternations with back mid vowel roots (see assessments in 33, 44). Such roots have only one morph, e.g. {kɔr}_{po}. Consequently, there is no "alternative choice"; there is simply no verb root alternation.

Note that this account covers the facts but does not explain the existence of the front-back asymmetry. Higgins (2011, p. 223) notes that "Front-back asymmetries are quite common in Bantu vowel height harmony in verbal extensions. Though ... the Ikoma pattern ... [is] perhaps difficult to explain..., the fact that such patterns exist should not come as too much of a surprise." We have no additional insight to add on this point. The crucial point in terms of the model is that unless there is an MSR to generate a second morph, alternative morphs will only be posited if they are actually encountered by the learner. We do not assume the kind of OT-style "Gen" (Prince & Smolensky 1993) that automatically creates candidates such as [...kor...] for an underlying form /...kɔr.../; as a result, there is no need for conditions to eliminate sequences containing the putative morph * [...kor...].

Assessing alternatives: Phonotactics. Given a verb root with two morphs, the learner must determine when to use each one. We consider the agentive first, where the advanced verb root morph appears before the advanced high suffix vowel.

Recall that when considering vowel distribution in roots (see 5, 6), we observed a systematic absence of vowel sequences involving a retracted mid vowel preceding a high vowel, encoded as the condition in 11, *ε/ɔ...i/u. This same condition plays a role in assessing morph combinations. In 24, we provide the relevant assessment table, showing the key role of *ε/ɔ...i/u in eliminating options 24a,c. (Anticipating our discussion of 29, we treat the retracted verb morph as the default.)

24. Assessment of {mu, mo}_{CL.1}-{yεy, yeɣ}_{CARRY}-{i}_{AGENTIVE}

CARRY-AGENTIVE-CL.1		*ε/ɔ...i/u	*e/o...ε/ɔ	*e/o [a]	Def
a.	o-mu-[yεy-i]	*!			*
(→) b.	o-mu-[yeɣ-i]				**!
c.	o-mo-[yεy-i]	*!	*!		
d.	o-mo-[yeɣ-i]				*

As can be seen from 24, this analysis successfully accounts for the advanced form of the root when preceding a high vowel suffix. As is also clear, however, some further condition is required to identify the correct form of the prefix, so that 24b will be selected over 24d, despite Default.

Idiosyncratic yet systematic patterns: Morphotactic selection. As shown in the assessment table in 24, *ε/ɔ...i/u eliminates the retracted root morphs in 24a, c when an advanced high suffix follows. However, we also see that the advanced root morph occurs with a high prefix, despite the default preference for a mid vowel prefix morph 24d. That is, the advanced mid verb root morph in the poly-morph sets idiosyncratically -- yet systematically -- prefers a preceding high vowel. Since this is general, it can be assigned by a slight modification of MSR-C&C-implies-CeC (23).

25. Morph Set Relation: MSR-C&C-implies-CeC ****final**** (cf. 23)

∃ M_i, M_iVerb, M_iε...ε_iC \# → ∃ M_j, M_jε...ε_jC \#, M_jεHIGH-V____
If the morph set of a verb includes a morph whose final vowel is mid front retracted [ε] then it also includes an otherwise identical morph (i) whose final vowel is advanced [e], and (ii) that selects for a preceding high vowel.

example {yεy}_{V; CARRY} → {yεy, yeɣ_{HL}}_V; CARRY

Once this selection preference is in place, the correct surface form is identified.

26. High Selection (*abbreviated*: Hi Sel)

Penalize a sequence where a designated morph is preceded by a nonhigh vowel. Selection in general is the means by which Emergence formalizes idiosyncratic behavior of specific morphs or morph sets. In many cases (such as this one), the selection requirements themselves are phonological in nature, but because these requirements attach to specific morphs or morph sets we refer to them as *morphotactics*.

27. Assessment of {mu, mo}_{CL.1}-{ye_Y, ye_{YHI}}_CARRY-{i}_AGENTIVE

CARRY-AGENTIVE-CL.1	*ε/ɔ...i/u	*e/o...ε/ɔ	*e/o [a]	Hi Sel	Def
A o-mu-[ye _Y -i]	*!				*
→ B o-mu-[ye _{YHI} -i]					**
C o-mo-[ye _Y -i]	*!	*!			
D o-mo-[ye _{YHI} -i]				*!	*

Interestingly, Ikoma has other contexts in which roots idiosyncratically prefer the high prefix over the mid advanced alternative, 28. Some monosyllabic noun roots with the vowel [u] require a high vowel in the prefix, 28a, while other such roots appear with the expected mid vowel prefix, 28b.

28. Idiosyncratic high prefixes

a. high prefix

o-mu-[kú]	'son-in-law'
o-mu-[tú]	'head (sg)'
e-mi-[tú]	'head (pl)'
o-βu-[ku]	'be engaged'

b. mid prefix

o-mo-[nu]	'mouth'
o-γo-[tú]	'ear'
o-βo-[tu]	'flour'
o-ro-[ku]	'firewood'

(from [ko-rwatseru oβu-ku])

For the roots in 28b, nothing special needs to be said; the mid-advanced version of the class prefix is the expected form. For the monosyllabic u-roots, Hi Selection is a property of this idiosyncratic set of roots which are themselves phonologically characterized.

When all else fails: Default. We now turn to evidence for treating the retracted morph as the default morph in such verb roots. As shown in 29, the infinitive pattern supports this analysis.

29. Assessment of {γo, γu}_{INFINITIVE}-{ye_Y, ye_Y}_CARRY-{a}_FINAL.VOWEL

INFINITIVE-CARRY-FV	*ε/ɔ...i/u	*e/o...ε/ɔ	*e/o [a]	Hi Sel	Def
→ a. γu-[ye _Y -a]					*
b. γo-[ye _Y -a]		*!			**
c. γu-[ye _{YHI} -a]				*!	*
d. γo-[ye _{YHI} -a]					

A sequence like 29b is ruled out because the mid vowel sequence is disharmonic; a sequence like 29d is ruled out because it violates the Hi

Sel morphotactic condition. This leaves two possibilities, both of which have a high vowel prefix (resulting minimally in one Default violation): γu-[ye_Y-a] (29a), γo-[ye_{YHI}-a] (29c). Since all phonotactic and morphotactic conditions are satisfied by both, the choice must be due to Default. Default in verb roots is completely general. Consequently, this too can be assigned by MSR rather than learned for each individual verb.

30. Morph Set Relation-Verb root default

∃ M-set_i, M-set_i=Verb, M-set_i∩M-set_j, M-set_i∩...ε... → M_j

If the morph set of a verb includes a morph with a mid front retracted vowel [ε] then that morph is the default morph.

Example {ye_Y, ye_{YHI}}_V; CARRY → {ye_Y, ye_{YHI}}_V; CARRY

Summary: The analysis presented here accounts for the distribution of alternating prefix morphs and the alternating verb root morphs shown in 22. We appeal to morph set relations to express regular alternations; phonotactics then determine, in large part, which morph to use in a given context. In certain cases, an anomalous form is systematically used; this is characterized by morphotactic selection. When both phonotactics and morphotactics fail to make a selection, the default form is employed. While these principles account for much of the Ikoma patterns, the discussion is not complete without considering the patterns that arise when verbs are followed by multiple suffixes.

5. Harmony by avoidance in suffixes

Suffixes with mid vowels alternate, as shown in 31. They may occur in final position, as in the subjunctive, or followed by a final vowel, as with the applicative and applicative-causative. We consider final alternating vowels of the subjunctive first.

31. Alternating and non-alternating roots and suffixes

final vowel	Subjunctive	applicative	appl-caus	gloss
[a]	{e, ε}	{εr, er}	{εr, er}-[i]	
I γo-[tʃiβ-a]	to-[tʃiβ-e]	γo-[tʃiβ-εr-a]	γo-[tʃiβ-er-i]	'weed'
U γo-[tuk-a]	to-[tuk-e]	γo-[tuk-εr-a]	γo-[tuk-er-i]	'dig'
E ko-[reh-a]	to-[reh-e]	ko-[reh-εr-a]	ko-[reh-er-i]	'pay'
O ko-[rok-a]	to-[rok-e]	ko-[rok-εr-a]	ko-[rok-er-i]	'weave'
A γu-[γaβ-a]	to-[γaβ-e]	γu-[γaβ-εr-a]	γu-[γaβ-er-i]	'inherit'
ɔ γu-[kɔr-a]	tu-[kɔr-ε]	γu-[kɔr-εr-a]	γu-[kɔr-er-i]	'do'
ε γu-[ye _Y -a]	to-[ye _Y -e]	γu-[ye _Y -εr-a]	γu-[ye _Y -er-i]	'carry'

5.1 Final alternating mid vowel suffix

There are three properties to explain about the final {e, ε}_{SUBJUNCTIVE} paradigm. First, the suffix is typically advanced; it is retracted only following roots with mid retracted [ɔ]. Second, the prefix appears with its mid vowel morph whenever the suffix itself is advanced. Finally, the mid front alternating root appears with its advanced morph, not its retracted morph.

Default and morph choice. We account for the first two properties by identifying the more common morph as the default, {e, ε}_{SUBJUNCTIVE}, coupled with the phonotactic conditions on the distribution of retracted mid vowels. With this assumption, Default is sufficient to make the suffix selection with advanced roots, shown with the high-vowel root {tuk}_{DIG} in 34. (Anticipating our analysis slightly, we include the ranking of *e/o...ε/ɔ and *ε/ɔ...i/u above *ε/ɔ...e/o).

32. Assessment of {γo, γu}_{INFINITIVE}-{tuk}_{DIG}-{e, ε}_{SUBJUNCTIVE}

INF-DIG-SBJTV	*ε/ɔ...i/u	*e/o...ε/ɔ	*ε/ɔ...e/o	*e/o [a	Hi Sel	Def
- a. o-[tuk-e].						
B γo-[tuk-ε]						*!
C γu-[tuk-e]						*!
D γu-[tuk-ε]						**!

In contrast, the prohibition against mixing tongue root values in sequences of mid vowels results in selecting a form with maximal Default violations when the root has a retracted back mid vowel, 33d.

33. Assessment of {γo, γu}_{INFINITIVE}-{kɔr}_{DO}-{e, ε}_{SUBJUNCTIVE} **preliminary** (cf. 38)

INF-DO-SBJTV	*ε/ɔ...i/u	*e/o...ε/ɔ	*ε/ɔ...e/o	*e/o [a	Hi Sel	Def
A γo-[kɔr-e]		*!	*			*
B γo-[kɔr-ε]		*!				*
C γu-[kɔr-e]			*!			**
→ d γu-[kɔr-ε]						

Mid Selection and the distribution of the advanced prefix morph. When the root has a low vowel, we discover the need for a further Selection condition. The conditions thus far erroneously predict *γu-[γaβ-e], 34c, instead of the attested γo-[γaβ-e], 34a.

34. Assessment of {γo, γu}_{INFINITIVE}-{γaβ}_{INHERIT}-{e, ε}_{SUBJUNCTIVE} **preliminary** (cf. 36)

INF-INHERIT-SBJTV	*ε/ɔ...i/u	*e/o...ε/ɔ	*ε/ɔ...e/o	*e/o [a	Hi Sel	Def
(→) a. γo-[γaβ-e]				*!		
b. γo-[γaβ-ε]				*!		*
← c. γu-[γaβ-e]						*
d. γu-[γaβ-ε]						**!

The special property of the SUBJUNCTIVE is that (except with a back mid retracted root) it occurs with a mid vowel prefix -- even when the phonotactics would be expected to select a high vowel prefix. We characterize this with a selection restriction on the suffix, {e, ε}_{MID__SUBJUNCTIVE}, and a corresponding condition, Mid Selection.

35. Mid Selection (abbreviated: Mid Sel)

Penalize a sequence where a SUBJUNCTIVE stem is preceded by a high vowel. The pattern with low roots shows that Mid Selection must outrank both *e/o [a and High Selection.

36. Assessment of {γo, γu}_{INFINITIVE}-{γaβ}_{INHERIT}-{e, ε}_{MID__SUBJUNCTIVE}

INF-INHERIT-SUBJUNCTIVE	*ε/ɔ...i/u	*e/o...ε/ɔ	Mid Sel	*ε/ɔ...e/o	*e/o [a	Hi Sel	Default
→ a. γo-[γaβ _{HI} -e _{MID}]					*	*	
b. γo-[γaβ _{HI} -ε _{MID}]						*	*
c. γu-[γaβ _{HI} -e _{MID}]				*!			
d. γu-[γaβ _{HI} -ε _{MID}]				*!			

We expect the advanced morph in alternating roots. Consider now the poly-morph verb roots. As 37 demonstrates, the conditions motivated above serve to account for this more complex case as well. All forms except for the attested γo-[γeγ-e] are eliminated by the combination of Mid Selection and *e/o...ε/ɔ: because the SUBJUNCTIVE selects for a mid vowel, any cases with a high prefix vowel are ruled out; because the only mid vowel option is advanced, this forces the advanced root morph. This again shows that Mid Selection must outrank High Selection; compare 37d, e.

37. Assessment of $\{\gamma o, \gamma u\}_{\text{INFINITIVE}} - \{\gamma e \gamma, \gamma e \gamma\}_{\text{CARRY}} - \{e_{\text{MID}}, \epsilon\}_{\text{MID}} - \{\epsilon\}_{\text{SUBJUNCTIVE}}$

		* $\epsilon/\gamma \dots i/u$	* $e/o \dots \epsilon/\gamma$	Mid Sel	* $\epsilon/\gamma \dots e/o$	* $e/o [a$	Hi Sel	Default
INF-CARRY-SUBJUNCTIVE								
a.	$\gamma o - [\gamma e \gamma - e_{\text{MID}}]$		*!		*			*
b.	$\gamma o - [\gamma e \gamma - \epsilon_{\text{MID}}]$		*!		*			*
c.	$\gamma u - [\gamma e \gamma - e_{\text{MID}}]$			*!				**
d.	$\gamma u - [\gamma e \gamma - \epsilon_{\text{MID}}]$			*!				**
→ e.	$\gamma o - [\gamma e \gamma_{\text{HI}} - e_{\text{MID}}]$						*	*
f.	$\gamma o - [\gamma e \gamma_{\text{HI}} - \epsilon_{\text{MID}}]$		*!				*	**
g.	$\gamma u - [\gamma e \gamma_{\text{HI}} - e_{\text{MID}}]$			*!				**
h.	$\gamma u - [\gamma e \gamma_{\text{HI}} - \epsilon_{\text{MID}}]$		*!	*!				***

We must now ask why the mid prefix vowel does not surface when the root has a retracted back mid vowel, as in $\{k\gamma r\}_{\text{DO}}$. In this case, the $o \dots \gamma$ sequence is prohibited by $*e/o \dots \epsilon/\gamma$ and the high prefix is prohibited by Mid Selection. The lower ranked $*\epsilon/\gamma \dots e/o$ decides in favor of $\gamma u - [k\gamma r - \epsilon]$. This shows that Mid Selection is subordinate to $*e/o \dots \epsilon/\gamma$.

38. Assessment of $\{\gamma o, \gamma u\}_{\text{INFINITIVE}} - \{k\gamma r\}_{\text{DO}} - \{e, \epsilon\}_{\text{SUBJUNCTIVE}}$ ****final**** (cf. 33)

		* $\epsilon/\gamma \dots i/u$	* $e/o \dots \epsilon/\gamma$	Mid Sel	* $\epsilon/\gamma \dots e/o$	* $e/o [a$	Hi Sel	Default
INF-DO-SUBJUNCTIVE								
a.	$\gamma o - [k\gamma r - e_{\text{MID}}]$		*!		*			*
b.	$\gamma o - [k\gamma r - \epsilon_{\text{MID}}]$		*!					*
c.	$\gamma u - [k\gamma r - e_{\text{MID}}]$			*	*!			**
→ d.	$\gamma u - [k\gamma r - \epsilon_{\text{MID}}]$			*				**

A quick review of the assessments in 36 and 37 show that this added ranking does not affect the outcome in those cases. Confirmation of the analysis presented thus far is found with alternating mid vowel suffixes which are followed by either low or high vowels, the topic of the next section.

5.2 Alternating nonfinal suffixes

We turn now to the applicative and applicative-causative paradigms, illustrated in 31. These paradigms are interesting since, as we have already seen, alternating vowels behave differently when followed by low and high vowels. The low final vowel appears with the simple applicative; in contrast, the causative itself is a high vowel, [i], so the applicative-causative ends with a high vowel.

When the low final vowel follows the applicative, the applicative surfaces as advanced only when following an advanced mid vowel root (e.g. 43 below). With a high vowel root, none of the phonotactics are relevant when the following vowel is [a] (nor are the morphotactics). Default therefore decides between the various possibilities in favor of the default retracted suffix morph. (Note that were the advanced suffix morph the default, it would be selected, counter to the evidence). This is shown in 39.

Low vowel roots, as seen in 40, are comparable as far as the suffixes are concerned, but behave differently in their prefixes. With the low vowel root in 40, $*e/o [a$ forces the prefix vowel to be high. This contrasts with the high vowel root in 39, where there is no pressure for a prefix vowel to be other than default (mid advanced).

39. Assessment of $\{\gamma o, \gamma u\}_{\text{INFINITIVE}} - \{tuk\}_{\text{DIG}} - \{\epsilon r, er\}_{\text{APPLICATIVE}} - \{a\}_{\text{FINAL.VOWEL}}$

		* $\epsilon/\gamma \dots i/u$	* $e/o \dots \epsilon/\gamma$	Mid Sel	* $\epsilon/\gamma \dots e/o$	* $e/o [a$	Hi Sel	Default
INF-DIG-APPLIC-FV								
→ a.	$\gamma o - [tuk - \epsilon r - a]$							
b.	$\gamma o - [tuk - er - a]$							*!
c.	$\gamma u - [tuk - \epsilon r - a]$							*!
d.	$\gamma u - [tuk - er - a]$							*!*

40. Assessment of { γo , γu }_{INFINITIVE}–{ $\gamma\text{a}\beta$ }_{INHERIT}–{ er , er }_{APPLICATIVE}–{ a }_{FINAL.VOWEL}

	* $\text{e}/\text{ɔ}...\text{i}/\text{u}$	* $\text{e}/\text{o}...\text{e}/\text{ɔ}$	Mid Sel	* $\text{e}/\text{ɔ}...\text{e}/\text{o}$	* $\text{e}/\text{o} [\text{a}]$	Hi Sel	Default
INF-INHERIT-APPLIC-FV							
a. $\gamma\text{o}-[\gamma\text{a}\beta-\text{er}-\text{a}]$					*!		
b. $\gamma\text{o}-[\gamma\text{a}\beta-\text{er}-\text{a}]$					*!		*
→ c. $\gamma\text{u}-[\gamma\text{a}\beta-\text{er}-\text{a}]$							*
d. $\gamma\text{u}-[\gamma\text{a}\beta-\text{er}-\text{a}]$							**!

With the (nonalternating) back retracted root vowel, the requirements that mid vowels do not disagree in tongue root values (* $\text{e}/\text{o}...\text{e}/\text{ɔ}$, * $\text{e}/\text{ɔ}...\text{e}/\text{o}$) force the prefix to be high and the applicative suffix to be retracted.

41. Assessment of { γo , γu }_{INFINITIVE}–{ $\text{k}\text{ɔ}\text{r}$ }_{DO}–{ er , er }_{APPLICATIVE}–{ a }_{FINAL.VOWEL}

	* $\text{e}/\text{ɔ}...\text{i}/\text{u}$	* $\text{e}/\text{o}...\text{e}/\text{ɔ}$	Mid Sel	* $\text{e}/\text{ɔ}...\text{e}/\text{o}$	* $\text{e}/\text{o} [\text{a}]$	Hi Sel	Default
INF-DO-APPLIC-FV							
a. $\gamma\text{o}-[\text{k}\text{ɔ}\text{r}-\text{er}-\text{a}]$		*!		*			*
b. $\gamma\text{o}-[\text{k}\text{ɔ}\text{r}-\text{er}-\text{a}]$		*!					*
c. $\gamma\text{u}-[\text{k}\text{ɔ}\text{r}-\text{er}-\text{a}]$				*!			*
→ d. $\gamma\text{u}-[\text{k}\text{ɔ}\text{r}-\text{er}-\text{a}]$							*

With the front mid vowel roots, which have both advanced and retracted morphs, the same requirements prohibiting disagreement in tongue root values eliminate most of the possible morph combinations. For the three combinations that respect the mid vowel phonotactics (42c,f,h), consideration of Default values selects 42c.

42. Assessment of { γo , γu }_{INFINITIVE}–{ $\gamma\text{e}\gamma$, $\gamma\text{e}\gamma$ }_{CARRY}–{ er , er }_{APPLICATIVE}–{ a }_{FINAL.VOWEL}

	* $\text{e}/\text{ɔ}...\text{i}/\text{u}$	* $\text{e}/\text{o}...\text{e}/\text{ɔ}$	Mid Sel	* $\text{e}/\text{ɔ}...\text{e}/\text{o}$	* $\text{e}/\text{o} [\text{a}]$	Hi Sel	Default
INF-CARRY-APPLIC-FV							
a. $\gamma\text{o}-[\gamma\text{e}\gamma-\text{er}-\text{a}]$		*!					
b. $\gamma\text{o}-[\gamma\text{e}\gamma-\text{er}-\text{a}]$		*!		*			*
→ c. $\gamma\text{u}-[\gamma\text{e}\gamma-\text{er}-\text{a}]$							*
d. $\gamma\text{u}-[\gamma\text{e}\gamma-\text{er}-\text{a}]$				*!			**
e. $\gamma\text{o}-[\gamma\text{e}\gamma_{\text{HI}}-\text{er}-\text{a}]$		*!					*
f. $\gamma\text{o}-[\gamma\text{e}\gamma_{\text{HI}}-\text{er}-\text{a}]$							**!
g. $\gamma\text{u}-[\gamma\text{e}\gamma_{\text{HI}}-\text{er}-\text{a}]$		*!					**
h. $\gamma\text{u}-[\gamma\text{e}\gamma_{\text{HI}}-\text{er}-\text{a}]$				**!			

The advanced suffix morph is selected only with advanced mid roots. As in the cases just seen, the prohibition on mid advanced vowels preceding mid retracted vowels rules out any option that has a retracted suffix morph. Default then selects between the final two possibilities, 43b, d.

43. Assessment of { γo , γu }_{INFINITIVE}–{ rok }_{WEAVE}–{ er , er }_{APPLICATIVE}–{ a }_{FINAL.VOWEL}

	* $\text{e}/\text{ɔ}...\text{i}/\text{u}$	* $\text{e}/\text{o}...\text{e}/\text{ɔ}$	Mid Sel	* $\text{e}/\text{ɔ}...\text{e}/\text{o}$	* $\text{e}/\text{o} [\text{a}]$	Hi Sel	Default
INF-WEAVE-APPLIC-FV							
a. $\gamma\text{o}-[\text{rok}-\text{er}-\text{a}]$							
→ b. $\gamma\text{o}-[\text{rok}-\text{er}-\text{a}]$							*
c. $\gamma\text{u}-[\text{rok}-\text{er}-\text{a}]$		*!					*
d. $\gamma\text{u}-[\text{rok}-\text{er}-\text{a}]$							**!

In the case where the applicative combines with the causative, the final causative suffix being a high advanced vowel, the pattern changes. In all cases, the high vowel prevents a preceding retracted morph, due to the high-ranked * $\text{e}/\text{ɔ}...\text{i}/\text{u}$. With the nonalternating roots, this leads to harmony when the root is mid advanced (ko-[reh-er-i], ko-[rok-er-i]) and to harmony by vacuous avoidance when the root is high or low ($\gamma\text{o}-[\text{t}\text{ɕ}\text{i}\beta-\text{er}-\text{i}]$, $\gamma\text{o}-[\text{t}\text{u}\text{k}-\text{er}-\text{i}]$, $\gamma\text{u}-[\gamma\text{a}\beta-\text{er}-\text{i}]$). In the case of the front mid vowel alternating root, since the applicative suffix must be advanced, the advanced root morph is

chosen for reasons of harmony (γu -[$\gamma e \gamma$ -er-i]). Of particular interest, however, is the pattern that results with a back mid retracted root, γu -[$k\alpha r$ -er-i], a root with no advanced alternant.

44. Assessment of $\{\gamma o, \gamma u\}_{\text{INFINITIVE}} - \{k\alpha r\}_{\text{DO}} - \{\epsilon r, e r\}_{\text{APPLICATIVE}} - \{i\}_{\text{CAUSATIVE}}$

DO-APPLIC-CAUS		* $\epsilon/\alpha...i/u$	* $e/o...i/\alpha$	Mid Sel	* $\epsilon/\alpha...e/o$	* e/o [a]	HiSel	Def
a.	γo -[$k\alpha r$ - ϵr -i]	*!	*!					
b.	γo -[$k\alpha r$ -er-i]		*!		*			*
c.	γu -[$k\alpha r$ - ϵr -i]	*!						*
→ d.	γu -[$k\alpha r$ -er-i]				*			**

As seen in 44, there is no fully harmonic way to satisfy the conflicting requirements on a mid vowel imposed by the high vowel to its right (advancement) and the retracted root vowel to its left (retraction). The result is a disharmonic form with a retracted mid vowel preceding an advanced mid vowel, in order to best satisfy the conditions given the options available.

5.3 The inersive: a 3-way alternation

There is a class of non-productive suffixes discussed in Higgins (2011), the inersive. The inersive has six morphs, three possible vowels ([o, α , u]) and two possible consonants ([r, k]). The vowel choice is systematic; the consonant choice is not. The inersives are illustrated in 45; there are no clear cases involving a verb root with the front mid [ϵ , e] alternation.

45. Inversive vs. Inversive-causative

	Inversive	gloss	Invers-caus	Gloss
i, e, o	{-or, -ok, -ur, -uk, - αr , - αk }-[a]		{-or, -ok, -ur, -uk, - αr , - αk }-[i]	
	γw -[itf-or-a]	'be full'	γw -[itf-or-i]	'fill'
	γo -[se β -ok-a]	'sprout'	γo -[se β -ok-i]	'cause to sprout'
	ko-[hor-or-a]	'come from'	γo -[so β -or-i]	'husk'
u, a	ko-[hup-ur-a]	'uncover'	γo -[hup-ur-i]	'cause to uncover'
	γu -[$\gamma a r$ -uk-a]	'return'	γu -[$\gamma a r$ -ok-i]	'return (s.t.)'
α	γu -[$\gamma \alpha r \alpha r$ - αk -a]	'be straight'	γu -[$\gamma \alpha r \alpha r$ -ok-i]	'straighten'

We suggest that the preferred default vowel is [u] given its appearance after [a] and [u] roots. However, after [i] roots we find [o], not [u]. This is consistent with the prohibition against root-internal [i...u] sequences, discussed in 13. When [u] is not available, the next best suffix vowel is [o], and this is what appears after [i] roots. A prohibition of mid vowels followed by [u] -- presumably related to the common pattern of Bantu height harmony (Hyman 1999) -- leaves the selection of [o] or [α] after mid roots to the tongue root sequence prohibitions. Interestingly, in the case of an inersive-causative with an [α] root, the high ranking of * $\epsilon/\alpha...i/u$ prefers the advanced form of the suffix, resulting in the disharmonic sequence found in words like γu -[$\gamma \alpha r \alpha r$ -ok-i] 'straighten', already seen in the APPLICATIVE-CAUSATIVE in 44.

5.4 Summary

In this section, we have explored the vowel distribution patterns in polymorphemic forms. In these cases, we observed the interplay of default with phonotactics and morphotactic selection. For the most part, the necessary phonotactics also serve to characterize well-formed roots in Ikoma. Harmony is achieved between roots and alternating mid vowel suffixes by the requirements on mid vowel sequences; we see harmony-by-avoidance with the prefixes only, due to the nature of the two prefix morphs (one high and one mid advanced). In only one set of forms does a disharmonic sequence arise, when a non-alternating [α] root is followed by both an alternating suffix and a terminal high vowel suffix. The high ranking of * $\epsilon/\alpha...i/u$ requires the advanced suffix morph, while the lack of an advanced root morph means there is no harmonic choice to be had.

6 Distribution of determiners in Ikoma and Nata

We conclude here by raising one final example that is interesting for comparative and historical reasons, one of the cases where Ikoma is interestingly different than the closely related Nata. It is this kind of example that demonstrated the need to examine Ikoma independently of Nata. The example involves selection of the determiner morph preceding class prefixes, in the combination DETERMINER-CLASS-noun.

In Ikoma, class prefixes may be either invariant (3) or variable (14). We know from patterns of root-internal co-occurrence (6) that $i...e$ sequences are disfavored. For example, the presence of a condition like * $i/u...e/\alpha$ (12) has no effect on a prefix-stem sequence because neither the noun nor the class prefix has an alternative form, e.g., e-ri-[$\beta e \gamma a$] 'shoulder' (C5). On the other hand, as examined in some detail above, many noun class prefixes

exhibit mid and high variants, where the choice depends on the tongue root value of the initial stem vowel: o-mo-[sino] 'widow' vs. o-mu-[sɛsɛ] 'slave', both nouns of class 1. These were the core cases of harmony by avoidance. But what about the properties of the determiner, the morph that precedes the class prefix?

For determiners, both height and backness are predictable: the determiner is low before a low vowel, front before a front vowel and back before a back vowel. In Ikoma, the determiner is also invariably nonhigh.⁹ Interestingly, there can never be pressure for a nonlow determiner to be other than mid advanced -- class prefixes are advanced, whether high or mid, and since a determiner precedes a class prefix we expect the determiner's mid vowel to be advanced preceding an advanced vowel. Consequently, the determiner is realized as [o-] or [e-] for both advanced and retracted nonlow roots. The examples considered here have all involved consonant-initial noun stems; we turn now to nouns that are vowel-initial, schematically, V+CV+[VCV...]. If there are no V/∅ alternations (to resolve the V+V sequence), we expect unremarkable harmony patterns. However, in Ikoma, we find that the class prefix morph has a C^G alternative, the 'G' indicating a glide, which is selected to avoid the V+V sequence. This gives rise to a word in which the determiner occurs in a syllable immediately preceding the root vowel. Consider relevant examples in Ikoma involving labialized and palatalized class prefixes.

46. Class prefixes involving labialization or palatalization: Ikoma

Labialized

- a. o-mw-[ʃho] 'nephew' (C1)
b. o-mw-[átani] 'neighbor' (C1)

Palatalized

- c. e-kj-[ónde] 'genet' (C7)
d. e-kj-[áro] 'village' (C7)

These sequences are unproblematic for advanced roots (46a,c). However, we see the juxtaposition of advanced prefix and retracted root vowels in (46b, d), counter to the general prohibition on advanced mid vowels adjacent to retracted vowels. In a theory that views harmony as the result of a rule that changes surface forms, we might expect the determiner to be automatically subject to harmonic restrictions with the root vowel. In contrast, in a theory that views all patterns of alternation to be determined by the composition of morph sets, there would be no a priori expectation for change in the determiner.

As seen in these examples, where class prefixes exhibit the harmony by avoidance strategy (cf. e-me-[yóndo] 'farms' (C4) vs. e-mi-[tsaré] 'rice' (C4), e-ye-[túmbe] 'chair' (C7) vs. e-ki-[βára] 'grassland' (C7), in example 14) the

⁹For discussion of the similar, though not completely identical, pattern in Nata, see Johannes (2007).

determiner in Ikoma is invariant. This is unproblematic in our account: the morph set for the determiner simply includes {e} while the morph sets for the class prefixes include both mid and high vowels.

Such a pattern, however, is not tension-free: there is bottom-up pressure for MSRs and phonotactics consistent with the observable data and top-down pressure for learned items to conform to phonotactics. The result of glide formation is a series of derived disharmonic sequences, cases where mid advanced vowels precede retracted vowels, a non-conforming sequence given phonotactics that hold elsewhere. The possibility arises, then, of learning a more general form of the MSR-mid-implies-high (15) to include all prefixes (such as determiners), not just class prefixes. This more general MSR is exactly what we observe in the closely related Nata. The determiner is mid (advanced) when the root is advanced (47a, c), but avoids disharmony by surfacing as high when the root vowel is retracted (47b,d). Hence Nata resolves the tension of potentially disharmonic sequences through a more general prefix morph set relation. Selecting the appropriate determiner morph follows from the same sort of phonotactic considerations as seen in Ikoma.

47. Class prefixes involving labialization or palatalization: Nata

Labialized

- a. o-mw-[iiká] 'pressure/gas' (C3)
b. u-mw-[ɛɛrí] 'month/moon' (C3)

Palatalized

- c. e-kj-[uumbá] 'room' (C7)
d. i-kj-[ɔ́ɔ́ndɛ] 'honey badger' (C7)

Ikoma, however, shows evidence of additional sub-generalization. Because the secondarily articulated consonants of the noun class prefixes are systematically preceded by advanced mid vowels, without regard for the following vowel's tongue root value and as a result of there not being a high determiner, a subpattern is observable whereby the sequence [e/o Cⁱw...] is possible, to the exclusion of *[i/u Cⁱw...]. Where the labialized or palatalized consonant is at the left edge of a root, we indeed find a mid advanced prefix, even when the root vowel is retracted.

48. Roots beginning with labialization or palatalization: Ikoma

o-mo-[ɣje] 'town'

o-mo-[βjémi] 'hunter'

As noted by Higgins (2011), such roots take advanced mid noun class prefixes, even when the result is disharmonic with respect to the nonhigh vowel sequence. Such cases suggest that the minor morphologically-conditioned regularity, following from the determiner in Ikoma having no high alternant, has worked its way into the phonological grammar, with the prohibition on high vowels before secondarily articulated consonants outranking the general phonotactic. That is, *[i/u Cⁱw...] >> *e/o...ɛ/ɔ.

7 Conclusion

The leading idea behind the analysis of Ikoma vowel distribution that we have presented is that complex patterns of alternation can be understood by the combination of two data-driven strategies.

First, the identification of skewed patterns in phonological strings can give rise to phonotactic constraints. These phonotactic constraints are taken by the learner to govern word shapes and to govern choices between competing morph possibilities. In Ikoma, we saw that constraints corresponding to skewings in root vowel co-occurrence patterns play a role in determining alternations in the vocalic properties of both prefixes and suffixes, in 9-13. These phonotactics also contribute a top-down pressure during acquisition for new lexical items to conform to the patterns of the language (Martinet al. 2013), which can in turn lead to language change (Blevins 2004). We sketched a small part of the comparison between Ikoma and Nata, suggesting how such change might come about.

Second, as words and sub-word constituents are identified by the learner, they too are assessed for skewings in their combinatorial possibilities. When morphs are concatenated, there are several possible types of patterns, each of which is illustrated in Ikoma.

- a. *Phonotactics are observed.* The morph sets contain sufficient appropriate morphs that it is possible to select a sequence of morphs that satisfies all phonotactics.

Example: $\gamma u - [k\alpha r - \epsilon r - a]_{\text{INFINITIVE-DO-APPLICATIVE-FINAL VOWEL}}$ (41).

- b. *Phonotactics are not observed due to morph set limitations.* Where the morph sets contain a single morph, or a very limited set of morphs, the result may be that every possible combination of morphs violates some phonotactic.

Example: $\gamma u - [k\alpha r - u]_{\text{INFINITIVE-DO-PASSIVE}}$ (see 22) is the only possible root-suffix combination, despite $*\epsilon/\alpha \dots i/u$ (11).

- c. *Phonotactics are not observed due to ranking with other phonotactics.* Where there are sufficient combinations of morphs, there may be competing phonotactics; selection of any one form necessarily entails violation of some phonotactic.

Example: $\gamma u - [k\alpha r - \epsilon r - i]_{\text{INFINITIVE-DO-APPLICATIVE-CAUSATIVE}}$ violates $*\epsilon/\alpha \dots e/o$ yet is the best choice (see 44: every other combination violates a higher-ranked phonotactic)

- d. *Phonotactics are not observed due to a higher ranking morphotactic.* For some morphs, there are skewings in the distribution of adjacent sounds. These sub-patterns are phonological but not generalizable; they are instead specific to particular morphs or morph sets.

Example: $\gamma o - [\gamma e \gamma_{\text{HL}} - \epsilon_{\text{MID}}]_{\text{INFINITIVE-CARRY-SUBJUNCTIVE}}$ appears with the mid vowel prefix because it is a subjunctive form, formalized as Mid Selection and illustrated in 37. (A high prefix generally appears with this root).

As shown here, by tracking frequency distributions between vowels of different types, formalising skewed distributions as cooccurrence restrictions, making explicit relations between corresponding sets of surface morphs, and governing the choice of alternating morphs by cooccurrence restrictions, a grammar can go a very long way in accounting for the sorts of patterns observed in occurring harmony systems, whether those patterns are general or restricted.

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