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Reconsidering Linearity: Evidence from CV Metathesis[1]
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1 Introduction

- I present both formal and empirical reasons to develop an alternative to the faithfulness constraint regulating metathesis (LINEARITY), and suggest one based on the notion of *contiguity* (McCarthy and Prince 1995).
- The empirical reasons are drawn exclusively from Kwara'ae[2] (Austronesian). Kwara'ae makes a good case study because of its especially robust process of CV metathesis (see below).

2 Formal Considerations

- LINEARITY is defined as follows (McCarthy and Prince 1995, p. 123):

(1) S_1 is consistent with the precedence structure of S_2, and vice versa (No Metathesis).

Let $x, y \in S_1$ and $x', y' \in S_2$. If $x \Re x'$ and $y \Re y'$,

then x precedes ($<$) y iff x' precedes ($<$) y'.

- In other words, if a segment precedes another in the input, that precedence relation should be preserved by the corresponding segments in the output.[3]
- **How many such relations exist in a word?**
- For a word of length n, there are $(n^2 - n)/2$ pairs of segments with this precedence relation.
- **Example:** The underlying form of hypothetical *salofidu* /salofidu/ has eight segments, and 28 precedence relations.

[1]I would like to thank Sophie Streeter, Kie Zuraw, Donca Steriade, Bruce Hayes, Colin Wilson, Pat Keating, Greg Kobele, Lauren Varner, Andy Martin, and members of the UCLA Phonology Seminar for their assistance in this research.

[2]All the Kwara'ae data in this handout comes from Sophie Streeter, a native speaker of Kwara'ae to whom I am indebted for her time and commitment to the study of her language.

[3]In this sense, LINEARITY is essentially is a MAX constraint, applied to precedence relations, which are ordered pairs. We could equally well talk about a DEP version of Linearity, which is violated for every new precedence relation introduced in S_2. Domain internal segment-adjacent metathesis would violate each of these constraints equally.

(2)

s	a	l	o	f	i	d	u
s < a	a < l	l < o	o < f	f < i	i < d	d < u	
s < l	a < o	l < f	o < i	f < d	i < u		
s < o	a < f	l < i	o < d	f < u			
s < f	a < i	l < d	o < u				
s < i	a < d	l < u					
s < d	a < u						
s < u							
+7	+6	+5	+4	+3	+2	+1	+0

- Thus, LINEARITY is gradient; the farther a segment moves, the fewer precedence relations are preserved (Hume 2001).

(3)

/salofidu/		LINEARITY
a.	salofiud	(d < u)
b.	saloufid	(f < u) (i < u) (d < u)

- However, all of the precedence relations are potentially violable; the candidate which reverses the string [udifolas] preserves none of these relations, and thus violates LINEARITY 28 times.
- In other words, LINEARITY belongs to a particular class of gradient constraints that are *quadratic*, in the sense of Eisner (1997). Such constraints are problematic because:
  - Constraints of this type have been shown to make anomalous predictions like tone-centering (Eisner 1997) and a range of other predictions that McCarthy (2003) discusses.
  - They are categorically more powerful than the vast majority of other constraints that phonologists employ in their analyses.
  - They are formally too complex to compute optimization over, with any of the current proposals for so doing in the literature.

3 Empirical Considerations and Contiguity

- **The Problem**
  - When LINEARITY is ranked below some markedness constraint then by the Optimality-theoretic principle of strict domination, a candidate which has massive LINEARITY violations but which does not violate the markedness constraint is still more harmonic than candidates which violate the markedness constraint.

(4)

input		MARKEDNESS	LINEARITY
☞	cand1		*****
	cand2	*!	*

  - cand1 $\succ$ cand2.
  - Generally, the gradient nature of LINEARITY encourages local solutions to markedness (Hume 2001), but sometimes non-local solutions are in fact optimal.
  - **In other words, if metathesis is allowed to satisfy some markedness constraint, then any amount (and any kind) of re-ordering is allowed to avoid violating the markedness constraint.**

- Two alternatives: restrict GEN or introduce other constraints. I adopt the latter approach.
- This problem is illustrated with three classes of words in Kwara'ae.

3.1 Basic Facts

- Metathesis in Kwara'ae may occur more than once per word[4]

(5)

	Citation	Normal	
a.	ˈŋe.la	ˈŋe̯al	'child'
b.	li.ˌma.ku	ˈli.ˌma̯uk	'my hand'
c.	ˈke.ta.ˌla.ku	ˈke̯at.ˌla̯uk	'my height'
d.	da.ˈro.ʔa.ˌni.da	ˈda̯or.ʔa.ˌni̯ɛd	'to share them'
e.	ˈra.ʔe.ˌra.ʔe.ˌna.ʔa	ˈra̯eʔ.ˌra̯eʔ.ˌnaˑʔ	'incline, slope'

- In the Normal form, almost every stressed syllable is heavy, and surface CVCV sequences are very rare.
- These phonotactics have been analyzed with the Stress to Weight Principle (Norquest 2001, Heinz 2004).[5]

(6) The Stress To Weight Principle: Stressed syllables should be heavy (Prince 1992, Kager 1999).

(7) **SWP** incurs a violation for each stressed light syllable in the output.

(8)

	/ketalaku/	SWP	LINEARITY
☞	a. ˈke̯at.ˌla̯uk		**
	b. ˈke.ta.ˌla̯uk	*!	*
	c. ˈke̯at.ˌla.ku	*!	*
	d. ˈke.ta.ˌla.ku	**!	

3.2 Case One

- Underlying forms like /$CV_1CV_2V_3CV_4$/.

(9)

	Citation	Normal	
a.	ˈfi.ku.ˌa.ʔa	ˈhi.ˌku̯aˑʔ	'gathering of them together'[6]
b.	ˈho.ni.ˌa.ra	ˈho.ˌni̯aˑr	'Honiara' (capital city of the Solomon Islands)
c.	ˈka.li.ˌo.ko	ˈka.ˌli̯oˑk	'clothes'

- These forms are surprising since there is a stressed light syllable on the surface.
- However notice that *[ˈhi̯**a**$_2$.ˌku̯a$_1$ʔ] ≻ [ˈhi.ˌku̯a$_1$ˑʔ].

[4] Appendix A describes legal Normal form vowel clusters.
[5] Plausible alternatives to the SWP are discussed in appendix B.
[6] Citation [f] is regularly realized as Normal [h].

– I assume the faithful candidate is eliminated because it violates the phonotactic that words do not end in a heavy syllable followed by a light syllable. Following Prince (1983), I attribute this to an undominated constraint banning weak moras of heavy syllables from bearing stress. (Kwara'ae Normal form regularly stresses the penultimate mora).

(10) *WeakMora=X1 incurs a violation whenever the weak mora of a heavy syllable bears stress.

(11)

	/fikua$_1$ʔa$_2$/	*WeakMora=X1	SWP	Linearity
☮	a. ˈhia$_2$.ˌkua$_1$ʔ			****
☹	b. ˈhi.ˌkua$_1$a$_2$ʔ		*!	*
	c. ˈhi.ˌkua$_1$.ʔa$_2$	*!	*	

- As a result, *[ˈCV$_1$V$_4$.ˌCV$_2$V$_3$C] is more harmonic than winning [ˈCV$_1$.ˌCV$_2$V$_3$V$_4$C].
- The problem extends to all words /CV(CVV)^{n}CV/.
- Idea: The order of the vowels in the input must be the same in the output.

(12)

	/fikua$_1$ʔa$_2$/	Preserve V Order	SWP	Linearity
	a. ˈhia$_2$.ˌkua$_1$ʔ	(u < a$_2$)! (a$_1$ < a$_2$)		****
☞	b. ˈhi.ˌkua$_1$a$_2$ʔ		*	*

3.3 Solution to Case One

3.3.1 Contiguity

- Proposal:

(13) Linearity **can be replaced by a richer family of** Contiguity **constraints.**

- I define the *contiguity* relation (→) as *immediate precedence.*
- Therefore, Contiguity constraints are linear; that is, the potential number of violations is limited by a linear function of the length of the word.

(14)

s	a$_1$	l	o	f	i	d	a$_2$
s→a$_1$	a$_1$→l	l→o	o→f	f→i	i→d	d→a$_2$	
+1	+1	+1	+1	+1	+1	+1	+0

- These Contiguity constraints come in two types Max and Dep (McCarthy and Prince 1993).

(15) Max-Contiguity:

Let $x, y \in S_1$ and $x', y' \in S_2$. If $x \Re x'$ and $y \Re y'$ then

if x immediately precedes $(\rightarrow) y$ then x' immediately precedes $(\rightarrow) y'$.

(No deletion of contiguity relations)

(16) DEP-CONTIGUITY:

Let $x, y \in S_1$ and $x', y' \in S_2$. If $x \Re x'$ and $y \Re y'$ then

if x' immediately precedes $(\rightarrow) y'$ then x immediately precedes $(\rightarrow) y$.

(No insertion of contiguity relations)

- **Example:**

(17)

/salofidu/	MAX-CONTIG	DEP-CONTIG
a. salofiud	(i→d) (d→u)	(i→u) (u→d)
b. saloufid	(o→f) (d→u)	(o→u) (u→f)

- These constraints lack the property that long-distance metathesis costs more! C.f. McCarthy (2003).
- MAX-CONTIGUITY and DEP-CONTIGUITY have the same properties of I-CONTIG and O-CONTIG (McCarthy and Prince 1995) that make deletion and epenthesis at edges cheaper than domain internally.[7]
- In Kwara'ae Normal form, both of these constraints must be ranked below SWP.

3.3.2 V-Tier Contiguity

- The above empirical problem is solved by recognizing that CV metathesis never allows the vowels themselves to change order, which has the effect of prohibiting long distance CV metathesis.

(18) V-TIER MAX-CONTIGUITY: if V_1 immediately precedes V_2 in the vowel tier of the input, then the correspondent of V_1 must immediately precede the correspondent of V_2 in the vowel tier of the output.

- Thus the input /fikua$_1$ʔa$_2$/ also has a set of contiguity relations on the vocalic tier: (i→u), (u→a$_1$), and (a$_1$→a$_2$).

(19)

/fikua$_1$ʔa$_2$/	*WEAK MORA=X1	V-TIER MAX CONTIG	SWP	MAX CONTIG	DEP CONTIG
a. ˈhia$_2$.ˌkua$_1$ʔ		(u→a$_1$)! (a$_1$→a$_2$)		(i→k) (ʔ→a$_2$)	(i→a$_2$) (a$_2$→k)
☞ b. ˈhi.ˌkua$_1$a$_2$ʔ			∗!	(a$_1$→ʔ) (ʔ→a$_2$)	(a$_1$→a$_2$) (a$_2$→ʔ)
c. ˈhi.ˌkua$_1$.ʔa$_2$	∗!		∗		

[7] The input-output pair (xyz, xz) violates I-CONTIG once, MAX-CONTIG twice, and DEP-CONTIG once. The input-output pair (xyz, xy) violates I-CONTIG zero times, MAX-CONTIG once, and DEP-CONTIG zero times. The input-output pair (xz, xyz) violates O-CONTIG once, DEP-CONTIG twice, and MAX-CONTIG once. The input-output pair (xy, xyz) violates O-CONTIG zero times, DEP-CONTIG once, and MAX-CONTIG zero times.

3.4 Case Two

- The second class, exemplified below in (20), are those with longer underlying forms like /$CV_1CV_2V_3CV_4CV_5$/.

(20)

	Citation	Normal	
a.	li.ˈmau̯.ˌmu.lu	ˈli.mau̯.ˌmul	‘your (pl) hands’
b.	a.ˈŋi.a.ˌŋi.la	ˈa.ŋi̯ɛ.ˌŋi̯ɛl	‘tearful’
c.	ʔa.ˈʔai̯.ˌki.na	ˈʔa.ʔai̯.ˌki̯ɛn	‘aunts (collective)’
d.	i.ˈli.a.ˌla.na	ˈi.li̯ɛ.ˌlaˑn	‘his trying’

- Ranking Linearity below SWP predicts that the diphthong should be broken up to make the first syllable heavy.

(21)

	/limaumu$_1$lu$_2$/		SWP	Linearity
☮	a.	ˈli̯a.mu.ˌmu$_1$u$_2$l		**
☹	b.	ˈli.mau̯.mu$_1$u$_2$l	*!	*
	c.	ˈli.mau̯.ˌmu$_1$.lu$_2$	**!	*

- V-Tier-Max-Contig cannot help since the order of the vowels has not changed.

3.5 Solution to Case Two

- Proposal: CV metathesis may create new vowel clusters on the surface, but it cannot destroy ones that exist in the underlying form.

(22) V-V Max-Contiguity if V_1 immediately precedes V_2 in the input, then the correspondent of V_1 must immediately precede the correspondent of V_2 in the skeletal tier of the output.

(23)

	/limaumu$_1$lu$_2$/		V-V Max Contig	SWP	Max Contig	Dep Contig
	a.	ˈli̯a.mu.ˌmu$_1$u$_2$l	(a→u)!		**	**
☞	b.	ˈli.mau̯.mu$_1$u$_2$l		*	**	**
	c.	ˈli.mau̯.ˌmu$_1$.lu$_2$		**!		

- Note the violations of this constraints are always a subset of the violations of the general Max-Contiguity constraint. Whenever this constraint is violated, so is Max-Contiguity.

3.6 Case Three

- The third class of words, exemplified in (24), are underlying forms of the kind /CVCVCV/.

(24)

	Citation	Normal	
a.	li.ˈma.ku	ˈli.ˌmau̯k	‘my hands’
b.	fi.ˈku.da	ˈhi.ˌku̯ad	‘to gather them together’
c.	ma.ˈda.mo	ˈma.ˌdao̯m	‘moon, month’

- In this case, the ranking SWP ≫ LINEARITY predicts, for example, that *[ˈhik.ˌdu̯a], where the [u] has moved rightward, is more harmonic than [ˈhi.ˌku̯ad], where the [a] has moved leftward [8].

(25)

/fikuda/		SWP	LINEARITY
☮	a. ˈhik.ˌdu̯a		*
☹	b. ˈhi.ˌku̯ad	*!	*
	c. ˈhi.ˌku.da	*!*	

3.7 Solution to Case Three

- When you consider the contiguity relations that have been destroyed and the new ones that have been created, we see the following.

(26)

/fikuda/		SWP	MAX-CONTIG	DEP-CONTIG
☮	a. ˈhik.ˌdu̯a		(k→u)(u→d)(d→a)	(k→d)**(d→u)**(u→a)
☹	b. ˈhi.ˌku̯ad	*!	(u→d)(d→a)	(u→a)(a→d)

- The key is to recognize that CV metathesis in Kwara'ae never creates CV transitions.[9]

(27) C-V DEP-CONTIGUITY If C immediately precedes V in the skeletal tier of the output, then the correspondent of C must immediately precede the correspondent of V in the input.

(28)

/fikuda/		C-V DEP CONTIG	SWP	MAX CONTIG	DEP CONTIG
	a. ˈhik.ˌdu̯a	(d→u)!		***	***
☞	b. ˈhi.ˌku̯ad		*	**	**
	c. ˈhi.ˌku.da		*!*		

3.8 Summary

- Generally, there are no stressed light syllables in Kwara'ae.
- There are a few classes of words that are exceptions to this phonotactic.
- Such exceptions are not predicted to exist under the standard faithfulness constraint regulating linear order (LINEARITY).
- These exceptions are accounted for by replacing LINEARITY with a family of CONTIGUITY constraints. In addition to the basic MAX/DEP-CONTIGUITY, I have suggested the following constraints to account some generalizations.

[8] There is evidence that CVC syllables should be treated as heavy syllables (see Heinz (2004) for details).

[9] Directionality of CV metathesis appears to depend on the stress pattern of the language (Blevins and Garrett 1998, 2004). However, since the Normal and Citation forms have different stress patterns (Heinz 2004), and since the stress pattern of the Normal form is predictable, it is not clear how to encode this hypothesis in OT in the case of Kwara'ae. In the system presented here, the stress pattern would have to be linked to the ranking C-V DEP-CONTIGUITY≫ SWP.

(29) –V-Tier-Max-Contiguity – CV metathesis does not change the order of the vowels with respect to each other.

–V-V-Max-Contiguity – CV metathesis requires underlying contiguous vowels to be contiguous on the surface.

–C-V-Dep-Contiguity – CV metathesis does not introduce new CV transitions.

4 Where to go from here

4.1 The Contiguity Family

- This suggests a family of Contiguity constraints with the following constraints operating on the skeletal tier...
  - Max/Dep-Contiguity
  - V-V-Max/Dep-Contiguity
  - C-V-Max/Dep-Contiguity
  - V-C-Max/Dep-Contiguity
  - C-C-Max/Dep-Contiguity
- ...and with constraints operating on V (and C) tiers:
  - V-Tier-Max/Dep-Contiguity
  - C-Tier-Max/Dep-Contiguity

4.2 Phonetic Groundedness

- It has been observed that vowels are coarticulatory even with intervening consonants (Öhman 1966) (see (Keating 1988) for an overview), which may justify a constraint like V-Tier-Max-Contig.
- However, it is more difficult to justify the other members of the constraint family.
- Is there any advantage to restating the Contiguity constraints in finer detail, say in the terms of gestural scores (Browman and Goldstein 1992, Gafos 2002)?

4.3 Typology

- The family of constraints above is sufficient to enlarge the typology to include languages like Kwara'ae.
- Without adopting specific fixed rankings, it is not sufficient to rule out unusual and unattested patterns, e.g. Kwara'ae′ which ranks V-Tier-Max-Contig below SWP.
- What are the necessary rankings?

5 Conclusions

- LINEARITY is formally too powerful a constraint, and its realization as an OT constraint makes incorrect empirical predictions in Kwara'ae.
- Both the formal and empirical problems are resolved by replacing LINEARITY with a richer family of CONTIGUITY constraints.
- This has led to identifying three relevant properties of CV metathesis, namely
  - The order of the vowels may not change.
  - Underlying contiguous vowels must be contiguous on the surface.
  - A prohibition on the introduction of CV transitions (in Kwara'ae)

A Normal Form Vowel Qualities

- The following table summarizes how the diphthong in the Normal form is predictably derived from two vowels from the set [i,u,e,o,a].

(30)

V_1V_2		V_2				
		i	u	e	o	a
V_1	i	iˈ	i͡u	⊘	i͡o	i͡ɛ
	u	u͡i	uˈ	u͡ɛ	⊘	u͡ʌ
	e	e͡i	e͡u	ɛˈ	e͡o	e͡a
	o	o͡i	o͡u	o͡e, u͡e	ɔˈ	o͡a
	a	a͡i, e͡i, eˈ	a͡u, oˈ	æ, a͡e	a͡o	aˈ
⊘ = *unattested*						
Nuclei following a ',' occur in faster speech						

- The quality of the second element of the diphthong is predictable given V_1 and V_2.
- Likewise, given any cell, V_2 is predictable.

B Alternatives to SWP

- **The problems above persist even if different markedness constraints are employed to motivate metathesis in Kwara'ae.**
- This is illustrated with the constraints in (31) with respect to Case One (§3.2).

(31) a. *UNSTRESSED SYLLABLE incurs a violation for each unstressed syllable in the output form.

b. *Struc incurs a violation for each syllable in the output (economy was the motivating factor for Kwara'ae metathesis in Sohn (1980)).

c. Final-C (at the foot level) incurs a violation for each foot which does not end in a consonant.

*Unstressed Syllable

- Consider underlying forms like /(C)V_1CV_2V_3(CV(C)V_n)^n/.

(32)

	Citation	Normal	
a.	li.ˈmau̯.ˌmu.lu	ˈli.mau̯.ˌmuˑl	'your (pl) hands'
b.	a.ˈŋi.a.ˌŋi.la	ˈa.ŋi̯ɛ.ŋi̯ɛl	'tearful'
c.	ʔa.ˈʔai̯.ˌki.na	ˈʔa.ʔai̯.ki̯ɛn	'aunts (collective)'
d.	i.ˈli.a.ˌla.na	ˈi.li̯ɛ.ˌlaˑn	'his trying'

- *[ˈli**u**.ˌmau̯.ˌmul] ≻ [ˈli.mau̯.ˌmuˑl] because the former has no unstressed syllables, whereas the actual winner has one.

(33)

	/limau$_1$mu$_2$lu$_3$/	*UnstressedSyl	Linearity
☮	a. ˈliu$_3$.ˌmau$_1$.ˌmu$_2$l		******
☹	b. ˈli.mau$_1$.ˌmu$_2$u$_3$l	*!	*

- In general, *[ˈ(C)V_1V_n.ˌCV_2V_3.(ˌCV(C)V_{n-1})$^{n-1}$CV(C)] is more harmonic than actual surface [ˈ(C)V_1.CV_2V_3.(ˌCVV_nC)^n].

*Struc

- Consider forms of the /CVVCVCVCV/ variety:

(34)

	Citation	Normal	
a.	ˈmau̯.ri.ˌla.ku	ˈmau̯.ri.ˌlau̯k	'my being alive'
b.	ˈfai̯.ri.ˌri.di	ˈfai̯.ri.ˌriˑd	'to slip'
c.	ˈsae̯.fi.ˌlo.da	ˈsai̯.hi.ˌlo̯ad	'to ask them'

- *Struc must be ranked below a constraint like *Triphthong[10].

(35)

	/fai$_1$ri$_2$ri$_3$i$_4$d/	*Triphthong	*Struc	Linearity
☞	a. ˈfai$_1$.ri$_2$.ˌri$_3$i$_4$d		**	**
	b. ˈfai$_1$i$_2$r.ˌri$_3$i$_4$d	*!	***	*

- As a result, in words like those in (9) (/CVCVVCV/), we have:

[10]In Normal form monosyllabic words like *fuamu* 'to you' Citation [fu.ˈa.mu] Normal [ˈfu̯au̯], metathesis occurs presumably to satisfy some other constraint such as the prohibition of stress on the weak mora of a heavy syllable (Prince 1983), or foot-alignment to the right.

(36)

/fikua$_1$?a$_2$/		*Triphthong	*Struc	Linearity
☮	a. ˈfia$_2$.ˌkua$_1$?		**	****
	b. ˈfi.ˌkua$_1$.?a$_2$?		***!	*
☹	c. ˈfi.ˌkua$_1$a$_2$?	*!	**	*

Final C

- The argument here closely follows the arguments with *Struc.

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