

Harmony in Optimality Theory

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Consonant Harmony and Feature Extension: Coronal Harmony in Kinyarwanda

Topic:

- **Local “consonant” harmony**
 - Harmony that operates only between segments that are articulatorily adjacent.
 - Case study of coronal harmony in Kinyarwanda.
 - Typological differences that distinguish from non-local consonant harmony.

1. Introduction

(1) Coronal harmony

Many patterns are amenable to two types of analysis:

i. Agreement by Correspondence (ABC)

- (Overtly) interacting segments are highly similar, i.e. a subset of a language’s coronal consonants (Hansson 2001, Rose & Walker 2004).
- Most patterns show no blocking, only transparency.
- Some patterns show a palatal bias effect, which suggests a grounding in language production mechanisms (Hansson 2001).
- Close examination of certain patterns supports an ABC(-type) approach (e.g. Baztan Basque, Clements 2001; Chumash, McCarthy to appear).

ii. Feature Extension

- The feature involved in coronal harmony can carry without perceptible effect through transparent segments: non-coronal Cs, vowels, coronal Cs for which the feature is not contrastive (Flemming 1995a, Gafos 1996, Ní Chiosáin & Padgett 1997).
- Some patterns show opacity, which, along with other properties of the system, supports a feature extension analysis (Sanskrit, Hansson 2001, Rose & Walker 2004; Kinyarwanda, Walker & Mpiranya to appear, cf. Hansson 2005).

(2) What Kinyarwanda’s coronal harmony brings to the picture:

- Strong theoretical and empirical evidence that coronal harmonies exist that involve feature extension.
- Kinyarwanda involves retroflex harmony, rather than an (alveo-)palatal harmony as previously characterized; thus, it is not a case involving a palatal bias.
- A case of opacity in coronal harmony. The only reported instance in a living language.
- Kinematic (EMA) data indicate that a tongue tip-blade angle associated with retroflexion carries through transparent consonants.

Collaborators on this research: on phonological description and analysis of Kinyarwanda, Fidèle Mpiranya (CNRS Sorbonne Nouvelle/University of Chicago); on EMA study, Dani Byrd, Sungbok Lee, Celeste DeFreitas (USC), Fidèle Mpiranya (CNRS Sorbonne Nouvelle/University of Chicago).

2. Kinyarwanda Data

Kinyarwanda is a Bantu language spoken in Rwanda, and neighboring areas of Uganda, Congo-Kinshasa, and Burundi.

(3) Consonant inventory

| | Labial | Labiodental | Alveolar | Post-alveolar Retroflex | Palatal | Velar | Glottal |
|-------------|--------|-------------|----------|-------------------------|---------|-------|---------|
| Plosive | p | | t d | | c ɟ | k g | |
| Nasal | m | | n | | ɲ | | |
| Fricative | β | f v | s z | ʂ ʐ | ç | | h |
| Affricate | pf | | ts | tʂ | | | |
| Flap | | | | ɽ | | | |
| Approximant | w | | | | j | | |

- Nasal plus obstruent sequences: [ᵐb, ᵐf, ᵐv, ᵐs, ᵐz, ᵐʂ, ᵐz, ᵐd, ᵐc, ᵐj, ᵐg], treated here as NCs (prenasal or cluster) syllabified into an onset (after Sibomana 1974, Kimenyi 1979, Coupez 1980, Jouannet 1983, Mpiranya 1998, cf. Myers 2005).
- Additional consonant variants occur in sequences underlyingly composed of a consonant plus /j w/.

(4) Vowel inventory:

Five vowels [i e a o u], which each present a length contrast. Four tones: high, low, falling and rising. Contour tones occur only on long vowels (Myers 2003). The high tone is marked with an acute accent; the low tone is not marked.

(5) **Kinyarwanda's coronal harmony**

- Triggers: [ʃ z].
- Operates regressively in the stem (root plus suffixes).
- (Audible) targets: [s z].
- Intervening vowels and consonants are perceived as unaffected.

| | | |
|----------------------------|-------------------------|--------------------------------|
| zi- + sáaz- + i-e | → [ʃááze] | 'become old' (Class 10, perf.) |
| -úuz- + i-e | → [úúze] | 'fill' (perf.) |
| -sas- + i-e | → [ʃaʃe] | 'make the bed' (perf.) |
| -soo ⁿ z- + i-e | → [ʃoo ⁿ ze] | 'be hungry' (perf.) |
| -baaz- + iĩʃ- | → [baazʃiʃa] | 'plane (woodwork)' (caus.) |
| cf. -ʃit- + i-e | → [ʃise] | 'penetrated' |

The perfective suffix /-i-e/ causes a stem-final alveolar fricative to become retroflex (see also the agentive suffix /-i/, below).

(6) **Proximity effects**

- a. Harmony is obligatory in adjacent syllables.
- | | | |
|--------------------------|-------------------------|---------------------|
| -soo ⁿ z- + i | → [ʃoo ⁿ zi] | 'victim of famine' |
| -sas- + i | → [ʃaʃi] | 'bed maker' |
| -siiz- + i-e | → [ʃiize] | 'level off' (perf.) |
- b. Harmony is optional in non-adjacent syllables.
- | | | |
|-----------------|---------------------------|---|
| -zímagiz- + i-e | → [zímagize] ~ [zímagize] | 'mislead' (perf.) |
| -ásamuz- + i-e | → [ásamuze] ~ [áʃamuze] | 'make open largely one's mouth' (perf.) |
| -sákuz- + i-e | → [sákuze] ~ [ʃákuze] | 'shout' (perf.) |
| -sakaaz + i-e | → [sakaaze] ~ [ʃakaaze] | 'cover (the roof) with' (perf.)' |

(7) **Opacity of palatals and coronal stops**

- a. Retroflex [ʎd] blocks harmony and does not trigger harmony itself.
- | | | |
|--------------------------------|----------------------------|------------------------|
| -sáa ⁿ qaaaz- + i-e | → [sáa ⁿ qaaze] | 'make explode' (perf.) |
|--------------------------------|----------------------------|------------------------|
- b. Alveolar stops [t d n] and palatals block harmony.
- | | | |
|------------------|---------------------------|------------------------------|
| -sítaaz- + i-e | → [sítaaze] | 'make stub' (perf.) |
| -sódoók-i- + ize | → [sódookeze] | 'make move slowly' (perf.) |
| -súnuúk-i- + ize | → [súnuukize] | 'show furtively' (perf.) |
| -zíg-an-i- + ize | → [zíganiize] (n+i → [ŋ]) | 'economize' (perf.) |
| -zújaaz- + i-e | → [zújaaze] | 'become warm (liq.)' (perf.) |

Note: In some contexts with an underlying suffix /-i-/, the perfective is expressed with the allomorph [-ize].

(8) **Retroflex /ɽ/ is neutral (neither triggers nor blocks)**

| | | |
|------------------|-------------------------------|------------------------------|
| -togoseɽez + i-e | → [togoseɽeɽe] ~ [togoʃeɽeɽe] | 'make boil for / at' (perf.) |
| -seɽuz- i-e | → [seɽuze] ~ [ʃeɽuze] | 'provoke, irritate' (perf.) |
| -ziɽ-a | → [ziɽa] | 'be forbidden (taboo)' |

(9) **Affricates do not participate in coronal harmony**

- a. [ts] does not undergo harmony, i.e. it acts like a stop.
- | | | |
|---------------------------------|------------------------------|---------------------------------|
| -tsii ^m baɽaz- + i-e | → [tsii ^m baɽaze] | 'cause to be obstinate' (perf.) |
| -tsitsimuz- + i-e | → [tsitsimuze] | 'make drink slowly' (perf.) |
- b. [tʃ] is absent in triggering contexts (rare in post-initial position).

(10) **Summary**

- a. Kinyarwanda's coronal harmony operates regressively among sibilants in the stem.
- b. Intervening vowels and non-sibilant consonants are not perceptibly affected.
- c. Palatal consonants are opaque, as are alveolar and retroflex stops. Retroflex [ʎd] does not trigger harmony. [ts] does not undergo harmony.
- d. [ɽ] is neutral.
- e. Harmony in adjacent syllables is obligatory.
- f. Harmony extending to non-adjacent syllables is optional.

3. Experimental data

3.1 Acoustic data

(11) **Observations** (see spectrograms below)

- a. F2 and F3 for [aa] in [gaaze] and [gaaʃa] show convergence.

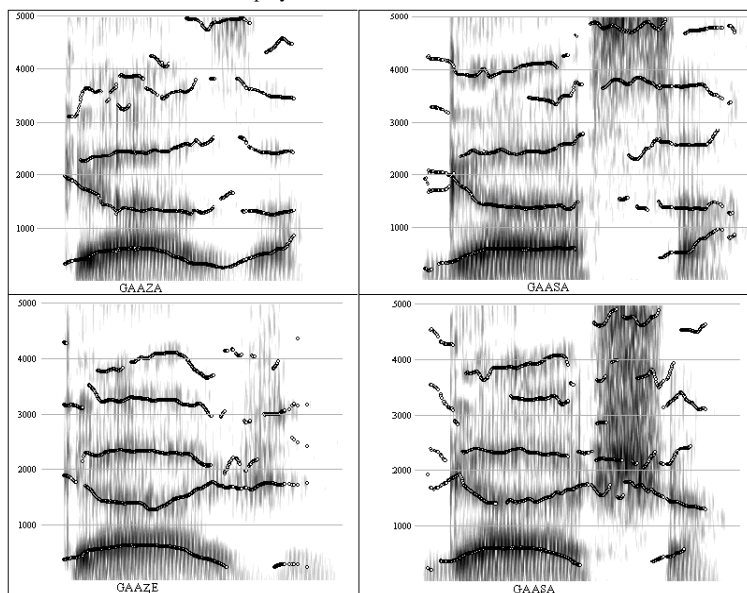
- Transitions from vowels into consonants for retroflexes show some distinct lowering of F3, and mid to high F2 depending on vowel context (Hamann 2003).
- A lowered trajectory for F3 is generally identified as most distinctive acoustic characteristic of retroflexion (Hamilton 1996 on Australian Aboriginal languages; Ohala & Ohala 2001 on Hindi retroflex stops; see Hamann 2003 for an overview).

- b. F3 and F4 for [aa] in [gaaza] and [gaaʃa] appear to be relatively lower than those for [aa] in [gaasa] and [gaaza], which show a rising trajectory.

Additional studies on lowering of high formants in retroflex Cs and/or their clustering include Fant (1968), Stevens & Blumstein (1975), Flemming (1995b), Steriade (1995a), Ladefoged & Maddieson (1996), Narayanan et al. (1999).

(12) Spectrograms of [s z ʒ z̥] (male native speaker)

- Post-alveolar fricatives display characteristics of retroflex sounds.



3.2 Kinematic data

(13) *Questions*

- What is the geometry of the tongue tip-blade during sibilants?
- Is there a difference in geometry of the tip-blade for [t] in the following contexts:
 - blocking (preceding a retroflex fricative)
 - non-harmony (preceding an alveolar fricative)
- Is there a difference in geometry of the tongue tip-blade for [m] and [k] in the following contexts:
 - harmony (flanked by syllables that contain a retroflex fricative)
 - failed harmony (preceding a retroflex fricative, preceded by an alveolar fric.)
 - non-harmony (preceding an alveolar fricative)

The following provides only a sketch of the study, for fuller details, see Walker et al. (in prep.) Note that the discussion below reports on a subset of the variables analyzed for the above consonants. Data were also collected to examine [t] and [ʔ], but they are not discussed here.

3.2.1 Method

- (14) **Subject:** Male, adult native speaker of Kinyarwanda.
- (15) **Procedure**
- Data collected using EMA magnetometer system
 - Receivers placed on subject, centered in the midsagittal section:
 - on the nose, between the eyes
 - on the maxilla
 - on tongue tip, 7 mm behind the apex
 - on tongue blade, 7 mm behind the receiver on the tongue tip
 - Audio recording made simultaneous with collection of articulatory data
 - Experiment designed to record seven repetitions of each stimulus. Stimuli order randomized in seven separate blocks.
 - Words spoken in Kinyarwanda carrier phrase “soma ‘X’ gusa” ‘read X only.’
 - Words presented to the subject in “scientific” orthography. Same as Kinyarwanda’s standard orthography but also indicates long Vs and high tones.
 - In contexts where harmony is optional, occurrence or non-occurrence of harmony was indicated by the word’s spelling.
- (16) **Stimuli**
- Left column: stimuli as presented to subject to speak aloud.
 - Center columns: transcription of the target word and its English gloss (not presented as stimuli).
 - Right column: number of viable tokens recorded for each target word. (A recording error in the third block resulted in extra repetitions of some words and a missed repetition for some others. Some tokens were excluded because of a problem with the recorded material. One token was mispronounced.

| Stimuli | Transcription | Gloss | Tokens |
|----------------------|---------------|------------------------------------|--------|
| soma basataze gusa | [basataze] | NONCE | 7 |
| soma bashata gusa | [baʒata] | NONCE | 7 |
| soma bazaata gusa | [bazaata] | ‘they will throw’ | 5 |
| soma bajaata gusa | [baʒaata] | NONCE | 9 |
| soma basataje gusa | [basataʒe] | NONCE | 6 |
| soma bashamáaje gusa | [baʒamáaze] | ‘who are attractive’ | 6 |
| soma basamáaje gusa | [basamáaze] | ‘who are attractive’ | 7 |
| soma basamáaze gusa | [baʒamáaze] | ‘let them be attractive’ | 8 |
| soma bashakáaje gusa | [baʒakáaze] | ‘who have covered (the roof) with’ | 7 |
| soma basakáaje gusa | [basakáaze] | ‘who have covered (the roof) with’ | 7 |
| soma basakáaze gusa | [basakáaze] | ‘let them cover (the roof) with’ | 7 |

(17) **Data analysis**

Mean Angle: Articulatory variable under focus

- Defined as mean angle for receivers attached to tongue tip and blade over the consonant constriction interval.
- A positive angle characterizes an orientation in which tongue tip is lower than tongue blade with greater angle corresponding to a lower tongue tip relative to blade (zero places both receivers at the same height, and negative corresponds to tongue tip receiver higher than tongue blade).
- Constriction interval was determined by algorithmically identified timepoints for coronal consonants' beginning and end (on basis of movement trajectory of tongue tip receiver in the vertical dimension, using MAVIS).
- Constriction interval was determined by acoustically identified timepoints for bilabial and velar consonants' beginning and end (because trajectory of tongue tip and blade did not provide sufficient information to consistently identify these landmarks).

3.2.2 Results

(18) **Articulation of sibilants (independent of coronal harmony)**

- Mean angle reliably and robustly distinguished alveolar and retroflex fricatives.
- All sibilants show positive mean tongue tip-blade angles.
- Post-alveolar fricatives show lower mean angles, indicating that tongue tip is higher relative to tongue blade than in alveolars.
- Ladefoged & Maddieson (1996) draw a distinction between strongly retroflex articulations vs. lesser retroflexion like that in Kinyarwanda [ʒ z], where tongue tip is nevertheless raised so there is a space below. (Other fricatives that show this lesser degree of retroflexion occur in Mandarin and Polish. Ladefoged & Maddieson (1996) transcribe such sounds using [ʒ z].)

(19) Mean angle for sibilants in contexts independent of coronal harmony.
(One token of [ʒaʒaata] excluded because it was an outlier.)

| Mean Angle | Mean | Std. Dev. | Minimum | Maximum |
|-------------------|-------|-----------|---------|---------|
| [s] in [ʒasataze] | 32.61 | 2.38 | 30.02 | 37.35 |
| [z] [ʒazaata] | 31.15 | 2.68 | 29.37 | 35.09 |
| [ʒ] in [ʒaʒata] | 19.98 | 3.00 | 17.03 | 23.89 |
| [z] in [ʒazaata] | 20.66 | 2.65 | 16.31 | 24.29 |

(20) **Opaque [t]**

- Mean angle measured in [t] in blocking context and non-harmony context.
- One-way ANOVA (Statview 5.0.1 by SAS) tested factor of context (levels: blocking, non-harmony) on mean angle in [t]. No significant difference found ($F(1, 11) = .27, p = .62$).
- Results confirm that [t] does **not** participate in coronal harmony.

(21) Mean tongue tip-blade angle for [t] in blocking and non-harmony contexts.

| Mean Angle [t] | Mean | Std. Dev. | Minimum | Maximum |
|--------------------------------|-------|-----------|---------|---------|
| Blocking: [ʒasataze] | 39.56 | 6.08 | 31.62 | 48.77 |
| Non-harmony: [ʒasataze] | 38.16 | 3.55 | 33.64 | 43.78 |

(22) **Transparent [m] and [k]**

- Mean angle measured in contexts: harmony, failed harmony, and non-harmony.
- Differences in mean angle tested using two-factor ANOVA. Factors were context (levels: harmony, failed harmony, non-harmony) and consonant (levels: [m], [k]).
- Main effect for factor of mean angle was found ($F(2, 36) = 13.09, p < .0001$).
- As expected, consonant factor was also significant ($F(1, 36) = 286.18, p < .0001$). No interaction between factors of context and consonant ($F(2, 36) = .35, p = .71$).
- Post-hoc tests using Fisher's PLSD found that mean angle in harmony context was significantly different from failed harmony context ($p < .0001$) and non-harmony context ($p < .0001$). No significant difference for mean angle in failed harmony context and non-harmony context ($p = .39$).
- These results indicate that angle associated with retroflexion carries through "transparent" [m] and [k]. Lack of difference for mean angle in failed harmony and non-harmony contexts suggests that different mean angle in harmony contexts is not simply a result of coarticulation.

(23) Mean tongue tip-blade angle for [m] and [k] in three contexts.

| Mean Angle [m], [k] | Mean | Std. Dev. | Minimum | Maximum |
|-------------------------------------|-------|-----------|---------|---------|
| Harmony: [ʒaʒamaaze] | 22.23 | 1.12 | 20.19 | 23.93 |
| Failed harmony: [ʒasamaaze] | 28.18 | 1.51 | 26.21 | 31.07 |
| Non-harmony: [ʒasamaaze] | 27.94 | 2.42 | 23.63 | 30.33 |
| Harmony: [ʒaʒakaaaze] | 38.72 | 4.50 | 33.88 | 45.36 |
| Failed harmony: [ʒasakaaaze] | 43.31 | 4.49 | 35.09 | 48.23 |
| Non-harmony: [ʒasakaaaze] | 42.61 | 2.17 | 39.06 | 45.74 |

(24) Follow up test

- One-way ANOVA tested for a difference in mean angle for [m] in harmony context ([βaʃamáaze]) vs. mean angle for [ʃ] and [z] (pooled) ([βaʃata], [βaʃaata]). No significant difference found ($F(1, 21) = 3, p = .1$).
- These results indicates that mean angle does not show a significant change from that of [ʃ z] during “transparent” [m]. Findings suggest that tongue tip-blade angle conducts strongly and systematically over the interval that contains harmonizing fricatives, even though it is not perceived on intervening [m].¹

4. Analysis

4.1 Diagnosing the assimilation structure

(25) **The [retroflex] feature**

- *Assumption:* The assimilation involves the privative feature **[retroflex]** (after Ní Chiosáin & Padgett 1997; note also Gafos 1996).
- [Retroflex] is phonetically realized as a tongue-tip/blade orientation.

For previous work on retroflexion feature(s) in the context of coronal harmony, see, e.g., Sagey 1986, Schein & Steriade 1986, Steriade 1986, Gafos 1996, Clements 2001, Hamann 2003.

Two approaches to coronal harmony systems

- Feature extension
- Agreement by Correspondence

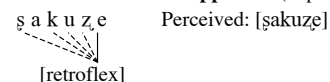
(26) **Feature Extension**

- Coronal harmony results from feature (or gesture) extension so that the feature carries through articulatorily adjacent segments.
- The extended feature carries through all segments intervening between trigger and target, but it is not perceived by speakers on segments described as “transparent.” (Flemming 1995a, Gafos 1996, Ní Chiosáin & Padgett 1997;² also Hansson 2001 and Rose & Walker 2004 on Sanskrit coronal harmony. See also Wiltshire & Goldstein 1998, Hamann 2003 and cited work therein positing that retroflexion posture is held across intervening segments.)

¹ For experimental examination of related issues surrounding transparency in vowel harmony systems, see Gafos & Benus (2003) and Gick et al. (2005).

² Ní Chiosáin & Padgett (1997) allow the possibility that although phonological spreading is strictly local, the spreading feature might not be phonetically implemented on transparent segments.

(27) **Feature Extension Approach** (depicted here in autosegmental representation)

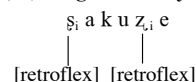


(28) **Agreement by Correspondence**

- Coronal harmony results from feature matching in segments that stand in a correspondence relation which is established between *similar* segments.
- Intervening segments do not participate in the process—they are unaffected in both perceptual and articulatory terms.
- Other consonant harmonies are also posited to arise via ABC (e.g. for laryngeal features, [nasal], dorsal harmony, etc.).

(Hansson 2001, Rose & Walker 2004, note also Clements 2001, McCarthy to appear.)

(29) **Agreement by Correspondence Approach**



(30) **Points of departure**

- Feature Extension
 - Perceptual transparency: Intervening segments are participants in the process but not perceived as such.
 - Potential for blocking. Harmony is blocked by segments that cannot undergo spreading. Factors: articulatory compatibility, contrast.
- Agreement by Correspondence
 - True transparency: Intervening, non-corresponding segments do not participate in harmony.
 - Intervening, non-corresponding³ segments will not show blocking effects, because they do not participate in harmony.

³ An operative word in (30b) is “non-corresponding.” See Hansson (2005) on a scenario in which an intervening segment that is in correspondence with trigger and target could produce blocking, given a local evaluation of correspondence within sequences of corresponding segments. Hansson speculates on an ABC account for Kinyarwanda which would rely on blocking consonants standing in correspondence with harmonizing sibilants. The scenario necessitates widening the set of Cs that stand in correspondence with [ʃ z] to include not just targets [s z] but also blocking segments. However, as Hansson points out, the neutrality of [ʃ] rests on it being excluded from correspondence with [ʃ z]. This is problematic, because it would require that retroflex [ʃ z] be more similar to palatal [ɲ j] than retroflex [ʃ].

- (31) *Kinyarwanda's coronal harmony*
- Transparency*
 - Experimental evidence that a retroflex gesture is strongly sustained during “transparent” consonants.
 - Blocking*
 - Coronal stops and palatals block harmony
 - [ɽ], which is more similar to triggers and targets than blocking Cs, is neutral in the harmony system.
- Kinyarwanda’s “transparency” and opacity phenomena therefore diagnose it as a **Feature Extension** harmony.

4.2 An Extension-based Account of Kinyarwanda’s Coronal Harmony

The spreading constraint

- Operates within specified domains.
 - Adapted with some changes from Ní Chiosáin & Padgett (1997) on Sanskrit.
- (32) **SPREAD-L-DOMAIN-(retroflex)**
Any [retroflex] feature associated to a [–sonorant, +continuant] segment S_j is also associated to any [–sonorant, +continuant] segment S_i that precedes S_j in a given domain.
- Issue: the “too-many solutions” problem. Problematic predictions arise under “traditional” formulations of constraints involved in the analysis of feature extension. For discussion and proposals, see Bakovic (2000), Bakovic & Wilson (2000) Wilson (2003), McCarthy (2004). (Note also Blumenfeld to appear on prosody-sensitive assimilations.) This is an important matter for any analysis of assimilation in OT. Nevertheless, as it is not focus of the present topic(s), the spreading constraint will be assumed here for ease of exposition.

(33) Trigger asymmetry:

Retroflex fricatives /ʂ z/ trigger harmony but not /t/ or [ʈd].

- Fricatives alone trigger harmony because only /ʂ z/ are contrastively retroflex.
- Related findings:
- Round harmony systems serve to make distinctive feature specifications more easily perceptible (Kaun 1995).
 - Certain Romance raising harmonies uniquely promote contrastive [+high] specifications (Dyck 1995, Walker 2005, Campos 2006).

Obligatory harmony in adjacent syllables

- Ex. [ʂaʂi], *[saʂi] ‘bed maker.’
- (34) **SPREAD-L-ADJσ-(retroflex)**
Any [retroflex] feature associated to a [–son, +cont] segment S_j is also associated to any [–son, +cont] segment S_i in an adjacent syllable that precedes S_j in the stem.
- Version of SPREAD-L requiring that [retroflex] spread to an adjacent syllable.

Processes limited to adjacent syllables or consonants separated by no more than a vowel in other work:

- Syllable-adjacent nasal agreement in Lamba, Ndonga, and certain other Bantu languages (Odden 1994, Piggott 1996, Hansson 2001, Rose & Walker 2004).
- OCP effects characterized as restricted to segments separated by only a mora (“syllable adjacency”) (e.g. Yimas, Dahl’s Law in Bantu, Meeussen’s rule in Bantu; Odden 1994, Suzuki 1998) or only a vowel (“consonant adjacency”) (Tigre, Tigrinya; Rose 2000).

Whether adjacent syllables constitute a “domain” requires further investigation. Nevertheless, a window of adjacent syllables is evidenced in proximity effects in various languages.

- (35) **IDENT-OI(retroflex)**
Let α be a segment in the input and β be any correspondent segment of α in the output. If β is [retroflex], then α is [retroflex].
- Prohibits segments that gain a [retroflex] feature. (IDENT-OI(F) after Pater 1999.)

Constraint ranking

- (36) SPREAD-L-ADJσ-(retroflex) >> IDENT-OI(retroflex)
- Accomplishes *obligatory* harmony in adjacent syllables.
- (37) Obligatory harmony in adjacent syllables:

| /sáaz+i-e/ | SPREAD-L-ADJσ-(retro) | IDENT-OI(retro) |
|--------------|-----------------------|-----------------|
| ᵛᵃᵃ a. sáazɛ | | *** |
| b. sáazɛ | *! | * |

Optional harmony extending to non-adjacent syllables

- Ex. [zímagiʂɛ] ~ [zɿmagiʂɛ] ‘mislead’ (perf.)
- (38) **SPREAD-L-STEM-(retroflex)**
Any [retroflex] feature associated to a [–son, +cont] segment S_j is also associated to any [–son, +cont] segment S_i that precedes S_j in the stem.

- (39) SPREAD-L-STEM-(retro) and IDENT-OI(retro) are variably ranked
- Accomplishes *optional* harmony that extends across multiple syllables.

(40) **Variable ranking**

- Captured by constraints that are probabilistically ranked according to assigned ranking values (Boersma 1998, Hayes & MacEachern 1998, Zuraw 2000, Boersma & Hayes 2001; cf. Antilla 1997, Ringen & Heinämäki 1999 on unranked constraints).
- A constraint with a much higher ranking value than another will effectively always dominate, e.g. in obligatory harmony in adjacent syllables.
- Two constraints with close ranking values will vary in their ranking. This is the case for SPREAD-L-STEM-(retro) and IDENT-OI(retro).

- (41) Harmony extending to non-adjacent syllables:

SPREAD-L-STEM-(retro) >> IDENT-OI(retro)

| /sákuz+i-e/ | SPREAD-L-STEM-(retro) | IDENT-OI(retro) |
|---------------|-----------------------|-----------------|
| ᵛᵃᵃ a. šákuᶑe | | ***** |
| b. sákuzᶑe | *! | * |

- (42) Absence of harmony extending to non-adjacent syllables:

IDENT-OI(retro) >> SPREAD-L-STEM-(retro)

| /sákuz+i-e/ | IDENT-OI(retro) | SPREAD-L-STEM-(retro) |
|----------------|-----------------|-----------------------|
| a. šákuᶑe | ***!*** | |
| ᵛᵃᵃ b. sákuzᶑe | * | * |

Opacity

- Ex. [sítáaᶑe], *[šítáaᶑe] ‘make stub’ (perf.)

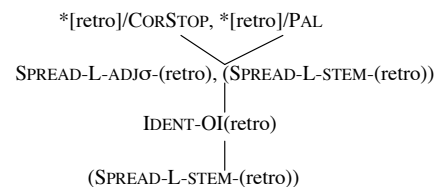
(43) **Markedness constraints**

- *[retro]/CORSTOP: No retroflex coronal stops.
- *[retro]/PAL: No retroflex palatals.
(On the incompatibility of retroflex and palatal articulations, see Gafos 1996, Clements 2001, Hamann 2003, Boersma & Hamann 2005; note also Flemming 2003.)

Constraint ranking

- Coronal stops and palatals never undergo harmony; hence markedness constraints in (43) dominate [retroflex] spreading constraints.
- The above markedness constraints will also function in the grammar to enforce the lack of contrastive retroflex coronal stops and palatals.

(44) **Retroflex harmony ranking**



- (45) Blocking by a coronal stop

| /sítáaz+i-e/ | *[retro]/CORSTOP | SPREAD-L-STEM-(retro) | IDENT-OI(retro) |
|----------------|------------------|-----------------------|-----------------|
| ᵛᵃᵃ a. sítáaᶑe | | * | * |
| b. šítáaᶑe | *! | | ***** |

(46) **Remaining issue: Blocking by [ʰd]**

- Cannot be attributed to contrast maintenance (cf. Ní Chiosáin & Padgett 1997 on Sanskrit).
- Kinematic data still under analysis but thus far points to greater retroflexion in [ʰd] than in fricatives. Possible prohibition on a shared retroflexion gesture across fricatives and obstruent stops, due to qualitative differences. (See Kaun 1995 for a related observation involving a prohibition on [Round] shared across different vowel heights.)
- Alternative possible basis in diachrony.

(47) **Summary – Analysis**

- Kinyarwanda’s coronal harmony is accomplished via feature extension.
- The extended [retroflex] feature carries through intervening vowels and consonants but is not perceived on segments described as “transparent.”
- [š z] trigger harmony but not [ʰd], because retroflexion is contrastive only in fricatives post-initially.
- A regressive spreading constraint requiring harmony in adjacent syllables drives obligatory harmony in this context.
- A spreading constraint operating in the stem domain is variably ranked with IDENT-OI(retro) to produce optional harmony over longer distances.
- Blocking by alveolar stops and palatals results from markedness constraints that prohibit retroflex coronal stops and palatals.

5. Sanskrit: A Second Coronal Harmony System with Blocking

(48) Coronal and palatal consonants in Sanskrit (after Gafos 1996)

Dental: /t t^h d d^h s n l/

Retroflex: /ʈ ʈ^h ɖ ɖ^h ʂ ʂ r r/

Palatals: /ç ç^h ǰ ǰ^h ʃ ʃ/

(49) Sanskrit's retroflex harmony (Nati)

Alternations observed in nominal and adjectival suffix *-ana* (Whitney 1889).

- Triggers are [ʃ r ʈ].
- (Perceptible) target is /n/.
- Intervening vowels and consonants are not (perceptibly) affected.

| | | |
|----|----------|--------------|
| a. | rakṣaṇa | ‘protection’ |
| | kṛpaṇa | ‘miserable’ |
| | ākramaṇa | ‘striding’ |
| | kṣajaṇa | ‘habitable’ |

- Opaque segments are all coronal and palatal consonants (except /j/).

| | | |
|----|-----------------------|-------------|
| b. | vard ^h ana | ‘increase’ |
| | rocana | ‘shining’ |
| | vṛjana | ‘enclosure’ |
| | ceṣṭana | ‘stirring’ |

- Operates progressively only.
- | | | |
|----|-----------------------|-----------|
| c. | -niṣṭ ^h a- | ‘eminent’ |
| | -nrmṇa- | ‘manhood’ |

Previous work on Sanskrit's Nati harmony includes Allen 1951, Selkirk 1980, Schein & Steriade 1986, Steriade 1986, 1995a, Shaw 1991, Clements & Hume 1995, Flemming 1995a, Gafos 1996, Ní Chiosáin & Padgett 1997, Hansson 2001, Hamann 2003, Rose & Walker 2004. See this work for discussion of further complexities in the system.

(50) Analytical highlights

- Sanskrit's retroflex harmony involves *feature extension*, not ABC (Flemming 1995a, Gafos 1998, Ní Chiosáin & Padgett 1997, Hansson 2001, Rose & Walker 2004).
- Extended feature continues through intervening segments, but its production is not perceived on transparent consonants and vowels.
- Intervening dentals are opaque because their participation in harmony would neutralize a contrast. Palatals (except /j/) block because they are incompatible with [retroflex] (e.g. Gafos 1996, Ní Chiosáin & Padgett 1997).

(51) Trigger and targets

- Continuants alone trigger retroflex harmony, because retroflexion is more acoustically salient in them vs. stops (Ní Chiosáin & Padgett 1997, Gafos 1996).
- Nasals alone are targeted, because they are more susceptible to place / retroflexion assimilation (Gafos 1996, Ní Chiosáin & Padgett 1997).

(52) Why Sanskrit retroflex harmony involves feature extension, not ABC

(Evidence discussed by Hansson 2001; cf. also Rose & Walker 2004)

- **Shows opacity.** This is not seen in any other pattern of consonant assimilation across an unaffected vowel (or across vowels and consonants).
- **Does not show a similarity effect.** Patterns of consonant assimilation across an unaffected vowel (at minimum) always target sounds most similar to the triggers. Inclusion of additional targets implies inclusion of any sounds that are more similar to the trigger.
- **Shows progressive directionality.** Patterns of consonant assimilation across an unaffected vowel (at minimum) show (a strong tendency for) regressive directionality (excluding root-controlled assimilations).
- **Potentially applies at the phrasal level, across word boundaries.** Patterns of consonant assimilation across an unaffected vowel (at minimum) apply within the word or a smaller morphological domain.

Points of comparison: Sanskrit and Kinyarwanda retroflex harmony

(53) Similarities

- Assimilating feature.* Both involve retroflexion assimilation.
- Triggers.* Retroflex fricatives trigger harmony (but in Sanskrit, /r/ does too).
- Opacity.* Dental/alveolar consonants and (most) palatals block harmony.

(54) Differences

- Triggers.* Triggers in Sanskrit are continuants [ʃ r], but triggers in Kinyarwanda are only the fricatives [ʃ z] (/t/ is neutral).
- Targets.* Target of Sanskrit's harmony is /n/, which is relatively dissimilar from the triggers. Targets in Kinyarwanda's harmony are fricatives, which are highly similar to the triggers.
- Opaque segments.*
 - Opaque dentals in Sanskrit contrast with a retroflex series. In Kinyarwanda, most blocking alveolars do not contrast with retroflex sounds.
 - The palatal glide /j/ is opaque in Kinyarwanda and transparent in Sanskrit.

- d. *Direction*. Sanskrit's harmony is progressive, Kinyarwanda's is regressive.
- e. *Domain*. Sanskrit harmony can operate across words, in Kinyarwanda it is limited to the stem.

6. Conclusion and further issues

(55) Kinyarwanda's coronal harmony: typological / theoretical issues

- **Triggers**. Triggers for retroflex harmony may be restricted to those for which the feature is contrastive.
- **Targets**. A coronal harmony resulting from feature extension that shows an apparent "similarity effect."
- **Transparency**. Experimental evidence indicates that retroflexion actually carries through "transparent" consonants.
- **Opacity**. Coronal opacity may result from incompatibility alone, independent of contrast.

(56) Further issues: Feature Extension vs. ABC

- a. *An apparent similarity effect*
- Kinyarwanda's coronal harmony shows an apparent "similarity effect" in the sense that it is (audibly) restricted to only fricatives.
 - This suggests certain diagnostics of coronal harmony produced by ABC vs. feature extension are not as straightforward as previously conceived.
 - Unlike correspondence-based harmonies, Kinyarwanda's similarity effect might result from a confluence of factors in the language including aspects of its contrast system, markedness constraints, and its particular harmony system.
- b. *Assimilation within adjacent syllables*
- Adjacent syllable domain that restricts spreading is reminiscent of proximity effects in correspondence-based assimilation (Hansson 2001, Rose & Walker 2004).
 - The special status of neighboring syllables, its formal characterization, and why it cross-cuts extension-based and agreement-based assimilations, as well as OCP effects, merits further investigation.

Appendix: Patterns involving the long causative formative [-iiṣ-(i)-]

Data: Coronal harmony in Kinyarwanda causative forms

- The retroflex fricative in the causative suffix [-iiṣ-(i)-] triggers harmony only in sibilants that occur in a preceding *adjacent* syllable.⁴

(57) Harmony from [ʃ] in the causative affecting an adjacent syllable.

- mes+iiṣ-(i)- → [meṣeeṣa] 'wash (cloth)' (caus.)
 -sáaz+iiṣ-(i)- → [sáazziṣa] 'make become old' (caus.)
 -sas+iiṣ-(i)- → [saṣiiṣa] 'make the bed' (caus.)
 -soo^oz+iiṣ-(i)- → [soo^ozeeṣa] 'be hungry' (caus.)

In several of the above forms, fricatives affected by coronal harmony in the syllable preceding [ʃ] in the causative themselves trigger harmony in preceding fricatives.

(58) No harmony from [ʃ] in the causative affecting a non-adjacent syllable.

- som+iiṣ-(i)- → [someeṣa] 'drink' (caus.)
 -soṭ+iiṣ-(i)- → [soṭeeṣa] 'pay tax' (caus.)
 -ásam+iiṣ-(i)- → [ásamiiṣa] 'open one's mouth' (caus.)
 -aⁿzik+iiṣ-(i)- → [aⁿzikiṣa] 'make someone to begin (grinding)'

Suffixal /i/ is realized as [e] after a mid root vowel.

- The long causative [-iiṣ-(i)-] blocks harmony from a following trigger.

(59) Blocking by causative [-iiṣ-(i)-].

- som+iiṣ-(i)- + iṣe → [someeṣeṣe] 'drink' (caus., perf.)
 -soṭ+iiṣ-(i)- + iṣe → [soṭeeṣeṣe] 'pay tax' (caus., perf.)
 -ásam+iiṣ-(i)- + iṣe → [ásamiiṣiṣe] 'open one's mouth' (caus., perf.)
 -aⁿzik+iiṣ-(i)- + iṣe → [aⁿzikiṣiṣe] 'begin (grinding)' (caus., perf.)

(60) Summary – Coronal harmony and the causative suffix

- a. [ʃ] in the causative suffix triggers harmony only in *adjacent* syllables, i.e. it is a weaker trigger than retroflex fricatives elsewhere in the stem.
- b. The causative [-iiṣ-(i)-] blocks harmony from a following trigger.

⁴ Coronal harmony triggered by -iiṣ-(i)- is *optional* when the target sibilant occurs in the stem-initial syllable (-se+iiṣ-(i)- → [seeṣa] ~ [seeṣa], 'mould' (caus.)).

Analysis

(61) Morphology of causative formation

- a. *Two formatives*: short *-i-* and long *-iis-(i)-*; same meaning.
- b. *Allomorph choice*:
 - Morpho-phonology: e.g. no *-i-* with stem-final sibilant or monosyllabic stem.
 - Semantics: e.g. instrumental vs. active: *-som+iis-(i)-* [-someeʃa] ‘drink with (utensil)’; *-som+i-* [som^hja] ‘make someone drink’ (Mpiranya 1998).
- c. *The long causative is morphologically complex*.
 - *-iis-(i)-* is composed of two morphological segments, i.e. as a discontinuous morpheme, because they can be separated in morphological processes. (On similar representations in other Bantu languages, see Hyman 1999, 2003, Bastin 1986, Munya Rugero & Mukala 1987).
 - The long causative is reconstructed in Proto-Bantu as **-itʃ-i-* (Guthrie 1967-1971, Hyman 1999, 2003).
- d. *Evidence for the long causative’s final -(i)-*.
 - Perfective form [-ize] follows *-iis-(i)-*. Perfective allomorph [-ize] (vs. perf. allomorph *-i-e*) is realized only after stems ending in underlying /i/.
 - Short *-i-* and long *-iis-(i)-* both trigger spirantization from postposed *-i-* in reduplicative forms, e.g. *-óg-i- + -iṭ-* → *-óg-iṭ-iṭ-i-* [ógeʒeza] ‘cleanse for / at.’; *-óg+iis-(i)- + -iṭ-* → *-óg-eeʃ-iṭ-iṭ-i-* [ógeeʃeʒeza] ‘wash with, for / at.’

(62) Proposal: A strong affix

- The long causative formative in Kinyarwanda involves a category that is stronger than other suffixes. It will be referred to here as a “strong-suffix.”
- It has a more robust morphological boundary that inhibits spreading into or out of its domain.

(63) Phonological evidence for strength of long causative [-iis-(i)-]

- a. *Phonological size*:
 - No other suffix in Kinyarwanda has an underlying long vowel. (Other suffixes with a long vowel are variants of *-VC-* forms and generally have emphatic connotation.)
- b. *Weak/absent participation in phonological processes in the stem*
 - *Coronal harmony*. (i) *-iis-(i)-* triggers harmony only in adjacent syllables, and (ii) it blocks harmony from following suffixes.
 - *Voicing dissimilation*. Dahl’s Law in Kinyarwanda causes dissimilation involving obstruents: *ku-ʃiim-* → [gu-ʃiim-a] ‘congratulate’; *-sót-uuk-* → [sódooka] ‘move slowly.’ But *-iis-(i)-* does not participate: *-haat-iis-(i)-* → [haatiiʃa] ‘shuck with’).

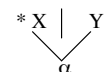
(64) Further research: Category of long causative

- In containing a long vowel, *-iis-* has a prosodic size resembling a root rather than an affix. Moreover, its phonological weight is suggestive that it holds the status of a head. (For related work, see Dresher & van der Hulst 1998, McCarthy & Prince 1995, 1999, Urbanczyk 1996, 1999, Downing in press, a.o.).
- It is conceivable that *-iis-(i)-* belongs to a category-type that stands between a suffix and a root. (For a review of work supporting word-formations intermediate between derivation and compounding, see Booij 2000. Note also Matthews 1974 on the notion of complex roots or stems.)

(65) The effect of boundary strength

- CRISP-EDGE[Cat] prohibits multiple linking of phonological structure across the boundary of a given type of linguistic category. (For formal definitions of CRISP-EDGE, see Itô & Mester 1999, Walker 2001b, Kawahara to appear.)

(66) CRISP-EDGE[strong-suffix]



where “|” represents the boundary of a strong-suffix morpheme

(67) Ranking

- SPREAD-L-ADJσ-(retro) >> CRISP-EDGE[strong-sfx] >> SPREAD-L-STEM-(retro)
- Accomplishes harmony from that occurs in adjacent syllables only.

Exemplification

- (68) Obligatory harmony from retroflex in long causative to adjacent syllable:
SPREAD-L-ADJσ-(retro) >> CRISP-EDGE[strong-suffix]

| /mes+iis-(i)-a/ | SPREAD-L-ADJσ-(retro) | CRISP-EDGE[strong-sfx] |
|-----------------|-----------------------|------------------------|
| ☞ a. meʃ-eeʃ-a | | * |
| b. mes-eeʃ-a | *! | |

- (69) No harmony to non-adjacent syllable, and long causative blocks harmony from a retroflex which follows it: CRISP-EDGE[strong-suffix] >> SPREAD-L-STEM-(retro)

| /ásam+iis-(i)-ize/ | SPREAD-L-ADJσ-(retro) | CRISP-EDGE[strong-sfx] | SPREAD-L-STEM-(retro) | IDENT-OI(retro) |
|--------------------|-----------------------|------------------------|-----------------------------|-----------------|
| ☞ a. ásam-iis-ize | | * | *(^h ʒ) **(z) | |
| b. áʃam-iis-ize | | *!* | | ***** |