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, Ni 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

<table>
<thead>
<tr>
<th></th>
<th>Labial</th>
<th>Labiodental</th>
<th>Alveolar</th>
<th>Post-alveolar</th>
<th>Palatal</th>
<th>Velar</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plosive</td>
<td>p</td>
<td>t</td>
<td>d</td>
<td>c</td>
<td>j</td>
<td>k</td>
<td>g</td>
</tr>
<tr>
<td>Nasal</td>
<td>m</td>
<td>n</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fricative</td>
<td>β</td>
<td>f</td>
<td>v</td>
<td>s</td>
<td>z</td>
<td>ž</td>
<td>ɣ</td>
</tr>
<tr>
<td>Affricate</td>
<td>gf</td>
<td>ts</td>
<td>Ø</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approximant</td>
<td>w</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>j</td>
</tr>
</tbody>
</table>


• 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.
Kinyarwanda’s coronal harmony

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

3. Acoustic data

3.1 Experimental data

(8) **Retroflex [t] is neutral (neither triggers nor blocks)**

```
-togosez + i-e → [togoɾezε] ~ [togoɾezε]  ‘make boil for / at’ (perf.)
-seɾuzi-e → [seɾuzε] ~ [seɾuzε]  ‘provoke, irritate’ (perf.)
-zit-a → [ziɾa]  ‘be forbidden (taboo)’
```

9. Affricates do not participate in coronal harmony

a. [ts] does not undergo harmony, i.e. it acts like a stop.
   -tsii²baɾaζ + i-e → [tsii²baraz]  ‘cause to be obsolete’ (perf.)
   -tsiʃi соврем - i-e → [tsiʃi соʃiʃa]  ‘make drink slowly’ (perf.)

b. [ts] 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 [ɾ] does not trigger harmony. [ts] does not undergo harmony.
d. [ɾ] 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)


- 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 [gaaζɛ] and [gaaςa] appear to be relatively lower than those for [aa] in [gaaςa] and [gaaςa], 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).
Spectrograms of [s z g z] (male native speaker)

- Post-alveolar fricatives display characteristics of retroflex sounds.

3.2 Kinematic data

Questions

i. What is the geometry of the tongue tip-blade during sibilants?

ii. Is there a difference in geometry of the tip-blade for [t] in the following contexts:
   - blocking (preceding a retroflex fricative)
   - harmony (flanked by syllables that contain a retroflex fricative)
   - non-harmony (preceding a retroflex fricative, preceded by an alveolar fric.)

iii. 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)

3.2.1 Method

Subject: Male, adult native speaker of Kinyarwanda.

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.

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.)

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>Transcription</th>
<th>Gloss</th>
<th>Tokens</th>
</tr>
</thead>
<tbody>
<tr>
<td>soma basataze gusa</td>
<td>[basatazɛ]</td>
<td>NONCE</td>
<td>7</td>
</tr>
<tr>
<td>soma bashata gusa</td>
<td>[baʃata]</td>
<td>NONCE</td>
<td>7</td>
</tr>
<tr>
<td>soma bazaata gusa</td>
<td>[bazaata]</td>
<td>‘they will throw’</td>
<td>5</td>
</tr>
<tr>
<td>soma bajaata gusa</td>
<td>[baʒaata]</td>
<td>NONCE</td>
<td>9</td>
</tr>
<tr>
<td>soma basataje gusa</td>
<td>[basatajɛ]</td>
<td>NONCE</td>
<td>6</td>
</tr>
<tr>
<td>soma bashamáaje gusa</td>
<td>[basamáajɛ]</td>
<td>‘who are attractive’</td>
<td>7</td>
</tr>
<tr>
<td>soma basamáaze gusa</td>
<td>[basamáajɛ]</td>
<td>‘who are attractive’</td>
<td>7</td>
</tr>
<tr>
<td>soma bashakáaje gusa</td>
<td>[baʃakáajɛ]</td>
<td>‘who have covered (the roof) with’</td>
<td>7</td>
</tr>
<tr>
<td>soma basakáaje gusa</td>
<td>[baʃakáajɛ]</td>
<td>‘who have covered (the roof) with’</td>
<td>7</td>
</tr>
<tr>
<td>soma basakáaze gusa</td>
<td>[baʃakáajɛ]</td>
<td>‘let them cover (the roof) with’</td>
<td>7</td>
</tr>
</tbody>
</table>
Data analysis

<table>
<thead>
<tr>
<th>Mean Angle: Articulatory variable under focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Defined as mean angle for receivers attached to tongue tip and blade over the consonant constriction interval.</td>
</tr>
<tr>
<td>• 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).</td>
</tr>
<tr>
<td>• 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).</td>
</tr>
<tr>
<td>• 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).</td>
</tr>
</tbody>
</table>

3.2.2 Results

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 [s 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 [s z].)

Mean angle for sibilants in contexts independent of coronal harmony.

(One token of [Bazuta] excluded because it was an outlier.)

<table>
<thead>
<tr>
<th>Mean Angle</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>[s] in [bsataze]</td>
<td>32.61</td>
<td>2.38</td>
<td>30.02</td>
<td>37.35</td>
</tr>
<tr>
<td>[z] in [Bazuta]</td>
<td>31.51</td>
<td>2.68</td>
<td>29.37</td>
<td>35.09</td>
</tr>
<tr>
<td>[s] in [Bazata]</td>
<td>19.98</td>
<td>3.00</td>
<td>17.03</td>
<td>23.89</td>
</tr>
<tr>
<td>[z] in [Bazjuta]</td>
<td>20.66</td>
<td>2.65</td>
<td>16.31</td>
<td>24.29</td>
</tr>
</tbody>
</table>

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.

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

<table>
<thead>
<tr>
<th>Mean Angle</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocking: [basataze]</td>
<td>39.56</td>
<td>6.08</td>
<td>31.62</td>
<td>48.77</td>
</tr>
<tr>
<td>Non-harmony: [basataze]</td>
<td>38.16</td>
<td>3.55</td>
<td>33.64</td>
<td>43.78</td>
</tr>
</tbody>
</table>

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.

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

<table>
<thead>
<tr>
<th>Mean Angle</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harmony: [basamáâze]</td>
<td>22.23</td>
<td>1.12</td>
<td>20.19</td>
<td>23.93</td>
</tr>
<tr>
<td>Failed harmony: [basamáâze]</td>
<td>28.18</td>
<td>1.51</td>
<td>26.21</td>
<td>31.07</td>
</tr>
<tr>
<td>Non-harmony: [basamáâze]</td>
<td>27.94</td>
<td>2.42</td>
<td>23.63</td>
<td>30.33</td>
</tr>
<tr>
<td>Harmony: [basakáâze]</td>
<td>38.72</td>
<td>4.50</td>
<td>33.88</td>
<td>45.36</td>
</tr>
<tr>
<td>Failed harmony: [basakáâze]</td>
<td>43.31</td>
<td>4.49</td>
<td>35.09</td>
<td>48.23</td>
</tr>
<tr>
<td>Non-harmony: [basakáâze]</td>
<td>42.61</td>
<td>2.17</td>
<td>39.06</td>
<td>45.74</td>
</tr>
</tbody>
</table>
(24) Follow up test

- One-way ANOVA tested for a difference in mean angle for [m] in harmony context ([i|aamämäget]) vs. mean angle for [s] and [z] (pooled) ([i|aamätaa]). 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 [s 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].

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

<table>
<thead>
<tr>
<th>$sa ku z e$</th>
<th>Perceived: [šakuqe]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[retroflex]</td>
<td></td>
</tr>
</tbody>
</table>

(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.).

(29) Agreement by Correspondence Approach

<table>
<thead>
<tr>
<th>$sa ku z e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>[retroflex] [retroflex]</td>
</tr>
</tbody>
</table>

(30) Points of departure

a. 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: articular compatibility, contrast.

b. Agreement by Correspondence
- True transparency: Intervening, non-corresponding segments do not participate in harmony.
- Intervening, non-corresponding segments will not show blocking effects, because they do not participate in harmony.

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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.

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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.


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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; 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.)
Obligatory harmony in adjacent syllables

- Ex. [sasif], *[sasi] ‘bed maker.’

(34) **SPREAD-L-ADJ(−retroflex)**

Any [retroflex] feature associated to a [−son, +cont] segment $S_i$ is also associated to any [−son, +cont] segment $S_i$ in an adjacent syllable that precedes $S_j$ in the stem.

$\Rightarrow$ 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.

- 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 $\alpha$ be a segment in the input and $\beta$ be any correspondent segment of $\alpha$ in the output. If $\beta$ is [retroflex], then $\alpha$ is [retroflex].

$\Rightarrow$ Prohibits segments that gain a [retroflex] feature. (IDENT-OI(−) after Pater 1999.)

Constraint ranking

(36) **SPREAD-L-ADJ(−retroflex) >> IDENT-OI(−retroflex)**

- Accomplishes **obligatory** harmony in adjacent syllables.

(37) **Obligatory harmony in adjacent syllables:**

<table>
<thead>
<tr>
<th>[sāaaj+e]</th>
<th>SPREAD-L-ADJ(−retroflex)</th>
<th>IDENT-OI(−retroflex)</th>
</tr>
</thead>
<tbody>
<tr>
<td># a. sāaaze</td>
<td>#</td>
<td>***</td>
</tr>
<tr>
<td>b. sāaaze</td>
<td>#1</td>
<td>#</td>
</tr>
</tbody>
</table>

Optional harmony extending to non-adjacent syllables

- Ex. [āimagi] – *[āimagi] ‘mislead’ (perf.)

(38) **SPREAD-L-STEM(−retroflex)**

Any [retroflex] feature associated to a [−son, +cont] segment $S_i$ 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
   • 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)

<table>
<thead>
<tr>
<th>Language</th>
<th>Constraint</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>/sákuz+i-e/</td>
<td>SPREAD-L-STEM-(retro)</td>
<td>IDENT-OI(retro)</td>
</tr>
<tr>
<td>a. sákuzge</td>
<td>*!</td>
<td>*****</td>
</tr>
<tr>
<td>b. sákuzge</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

(42) Absence of harmony extending to non-adjacent syllables:
   IDENT-OI(retro) >> SPREAD-L-STEM-(retro)

<table>
<thead>
<tr>
<th>Language</th>
<th>Constraint</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>/sákuz+i-e/</td>
<td>IDENT-OI(retro)</td>
<td>SPREAD-L-STEM-(retro)</td>
</tr>
<tr>
<td>a. sákuzge</td>
<td>*!</td>
<td>**</td>
</tr>
<tr>
<td>b. sákuzge</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

(43) Opacity
   • Ex. [sítaaaze], *[sítaaaze] ‘make stub’ (perf.)

(44) Retroflex harmony ranking
   *![retro]/CORSTOP, *![retro]/PAL
   SPREAD-L-ADJ-(retro), (SPREAD-L-STEM-(retro))
   IDENT-OI(retro)
   (SPREAD-L-STEM-(retro))

(45) Blocking by a coronal stop

<table>
<thead>
<tr>
<th>Language</th>
<th>Constraint</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>/sítaaaz+i-e/</td>
<td>*![retro]/CORSTOP</td>
<td>SPREAD-L-STEM-(retro)</td>
</tr>
<tr>
<td>a. sítaazge</td>
<td>*!</td>
<td>*****</td>
</tr>
<tr>
<td>b. sítaazge</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

(46) Remaining issue: Blocking by [*d]
   • Cannot be attributed to contrast maintenance (cf. Ni Chiosáin & Padgett 1997 on
     Sanskrit).
   • Kinematic data still under analysis but thus far points to greater retroflexion in [*d]
     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
   a. Kinyarwanda’s coronal harmony is accomplished via feature extension.
   b. The extended [retroflex] feature carries through intervening vowels and
      consonants but is not perceived on segments described as “transparent.”
   c. [s z] trigger harmony but not [*d], because retroflexion is contrastive only in
      fricatives post-initially.
   d. A regressive spreading constraint requiring harmony in adjacent syllables drives
      obligatory harmony in this context.
   e. A spreading constraint operating in the stem domain is variably ranked with
      IDENT-OI(retro) to produce optional harmony over longer distances.
   f. 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

Coronal and palatal consonants in Sanskrit (after Gafos 1996)
- Dental: \( t^h, d^h, s, n, l \)
- Retroflex: \( t^h, d^h, ʂ, n, r, f \)
- Palatal: \( c^h, ʃ, ʒ, ʃ, j \)

Sanskrit’s retroflex harmony (Nati)
Alternations observed in nominal and adjectival suffix –\( \text{āta} \) (Whitney 1889).
- Triggers are \( [ṣ, r] \).
- Opaque segments are all coronal and palatal consonants (except /j/).
- Operates progressively only.
- Opaque segments are all coronal and palatal consonants (except /j/).


Analytical highlights
- 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).

Points of comparison: Sanskrit and Kinyarwanda retroflex harmony

(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 / retroflex 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.

(53) **Similarities**
- Assimilating feature. Both involve retroflexion assimilation.
- Triggers. Retroflex fricatives trigger harmony (but in Sanskrit, /t/ does too).
- Opaqueness. Dental/alveolar consonants and (most) palatal segments block harmony.

(54) **Differences**
- Triggers. Triggers in Sanskrit are continuants [ṣ r], but triggers in Kinyarwanda are only the fricatives [ʃ j] (/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. Coronol 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 (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 [-i-iš-(i)-]

Data: Coronal harmony in Kinyarwanda causative forms

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

(57) Harmony from [s] in the causative affecting an adjacent syllable.
- mes+iš-(i)- → [mešeqa] ‘wash (cloth)’ (caus.)
- sāz+iš-(i)- → [sāzēša] ‘make become old’ (caus.)
- sas+iš-(i)- → [sashēša] ‘make the bed’ (caus.)
- so0o+z+iš-(i)- → [so0ožeqa] ‘be hungry’ (caus.)

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

(58) No harmony from [s] in the causative affecting a non-adjacent syllable.
- som+iš-(i)- → [someeqa] ‘drink’ (caus.)
- soř+iš-(i)- → [sořeqa] ‘pay tax’ (caus.)
- šam+iš-(i)- → [šameeqa] ‘open one’s mouth’ (caus.)
- a’zii+iš-(i)- → [a’ziišeqa] ‘make someone to begin (grinding)’

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

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

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

- som+iš-(i)- + izč → [somečešeqa] ‘drink’ (caus., perf.)
- soř+iš-(i)- + izč → [sořečešeqa] ‘pay tax’ (caus., perf.)
- šam+iš-(i)- + izč → [šamečešeqa] ‘open one’s mouth’ (caus., perf.)
- a’zii+iš-(i)- + izč → [a’ziišeqa] ‘begin (grinding)’ (caus., perf.)

(60) Summary – Coronal harmony and the causative suffix

a. [s] 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 [-i-iš-(i)-] blocks harmony from a following trigger.

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4 Coronal harmony triggered by -i-iš-(i)- is optional when the target sibilant occurs in the stem-initial syllable (–se+š-(i) → [šeqa] ‘mould’ (caus.)).
Analysis

(61) Morphology of causative formation

a. Two formatives: short -i- and long -ii-(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)- [sommees]a 'drink with (utensil)'; -som+i- [som'i]a '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, Manyu Rugero & Mukala 1987).
   • The long causative is reconstructed in Proto-Bantu as *-rti- (Guthrie 1967-1971, Hyman 1999, 2003).
d. Evidence for the long causative’s final -i(i)-:
   • Perfective form [-iiz] follows -iis-(i)-. Perfective allomorph [-iz] (vs. perf. allomorph -i-e) is realized only after stems ending in underlying -i/ii.
   • Short -i- and long -iis-(i)- both trigger spirantization from postposed -i- in reduplicative forms, e.g. -og-i- + -i- → -og-i-i- [goeez]a 'cleanse for / at;' -og+iis-(i)- + -i- → -og-eez-i-i- [goeezeta] 'wash with, for / at.'

(62) Proposal: A strong suffix

• 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 V C-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.