When Opacified Allophony Creates Variable Derived Environment Effects: Velar-Palatal Alternations in Sanskrit

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1. Sanskrit Palatal-Velar Alternations

1. Vedic Sanskrit possesses contrastive velar and (alveo-)palatal obstruents, which (partially) neutralize with each other and retroflex obstruents in various phonological contexts.
   Aspirated/breathy-voice obstruents of these series are not shown here.
2. Root- or stem-final velars and palatals generally show the following patterns (cf. Macdonell 1910: 24–35):

(1) Phonologically conditioned velar∼palatal alternations

	/___[+son]	/___ [−son, −cont]	/___[s]	/___]ω
/k/	[k] ([c])	[k/g]	[k]	[k]
/g/	[g] ([j])	[k/g]	[k]	[k]
/c/	[c] ([k])	[k/g]	[k]	[k]
/j₁/	[j] ([g])	[k/g]	[k]	[k]
/ś/	[ś]	[ṣ/∅/ḍ]	[k]	[ṭ]
/j₂/	[j] ([g])	[ṣ/∅/ḍ]	[k]	[ṭ]

2. Velar-Palatal Variation

1. Precisely in the non-neutralizing context preceding sonorants, variation between velars and palatals at the right edge of a root is attested preceding derivational suffixes.
2. Even segmentally identical suffixes may occur with distinct root allomorphs: *rók-a-*/*rok-á-* 'light' vs. *roc-á-* 'shining'.

(2) Velar–Palatal allomorphy across word-formation suffixes

		Word-formation Suffixes					
Root	Gloss	[-ə-]	[-ənə-]	[-mə-]	[-mən-]	[-rə-]	Other
1. *śak*	'be able'	[ɕákə-]	—	[ɕəgmá-]	[ɕákmən-]	[ɕəkrá-]	[ɕác-iː-]
2. *ruc*	'shine'	[róːkə-]	[roːcənáː-]	[rukmá-]	—	—	[ruc-aː-]
3. *arc*	'shine'	[ṛcə-]/[ərkáː-]	[ərcənə-]	—	—	—	[ṛk-vá-]
4. *vij*	'tremble'	[véːga-]	[veːjənə-]	—	—	[vigrá-]	[veːɟ-əkə-]
5. *vaj*	'be strong'	[vəɟə-]	[vəɟənə-]	—	[oːɟmán-]	[ugrá-]	[óːɟ-əs-]
6. *aj*	'drive'	[əɟáː-]	[əɟənə-]	[əɟmá-]	[áɟmən-]	[áɟrə-]/[ágrə-]	[əɟ-vin-]

3. Historical Origin

1. The contrastive velar (/k, g/) and palatal (/c, j₁) stops of Sanskrit originate from Proto-Indo-Iranian (PIIr.) */k, g/ via secondary split.
2. Velar stops underwent palatalization preceding [+front] vowels and glides (*/e(ː), i(ː), j/); this process was subsequently counterbled on environment by the merger of [−high] vowels as [ə]/[aː].
   See *i. a.* Wackernagel 1896, Kobayashi 2004, and Lubotsky 2018.

(3) Historical derivation of contrastive palatal and velar stops

*[réwko-]	*[rewkenó-]	*[=ke]	*[kós]	Early PIIr.
—	*[rawkʲenó-]	*[=kʲe]	—	Palatalization
*[rəwko-]	*[rəwkʲənáː-]	*[=kʲə]	*[kás]	Vowel Merger
róka-	*rocaná-*	*=ca*	*kás*	Sanskrit
'light'	'radiant'	'and'	'who:NOM.SG'	Gloss

3. The fricative /ś/ and plosive /j₂/, meanwhile, directly continue PIIr. alveo-palatal affricates from Proto-Indo-European */k̂, ĝ/.

4. Research Questions and Claims

Questions:

1. How should velar∼palatal variation in pre-sonorant contexts and alternation generally be synchronically treated?
2. What inferences does the synchronic treatment imply about the restructuring and reanalysis of the sound changes in **3.**?

Claims:

1. Statistical predominance of palatal outcomes ⇒ word-final velars were almost universally restructured as palatals.
2. Stem allomorphs with root-final velars may be productively generated, and are mainly conditioned by lexical properties of derivational suffixes.

☞ Sanskrit shows evidence for a **variable process of palatal velarization in derived pre-sonorant contexts.**

GitHub

Data, code, and references available here:

10a. /j₁/ vs. /j₂/

1. Segments /j₁/ and /j₂/ exhibit significantly different behaviors, in line with their historical origins.
2. One of these must be an abstract segment: /j₂/ = /z/ (in parallel to /ɕ/)?
3. A model operating with selection of root allomorphs can avoid any potential abstractness.

5. Data Collection

1. **Source:** Whitney 1885 — index of Sanskrit roots, verbal stems, and nominal and adjectival derivatives based on principles of the Sanskrit grammatical tradition (cf. Werba 1997).
2. Roots included: all roots with a final palatal or velar stop (*k*(*h*), *g*(*h*), *c*(*h*), *j*(*h*)) that attest velar-palatal allomorphy (N = 86).
3. From these roots, all nominal and adjectival derivatives in which the root-final consonant precedes a [+sonorant] segment were collected (N = 697).

(4) Sample of Palatal-Velar Alternation Database

Form	Gloss	**Outcome**	**Root**	**Suffix**	**Fin. Rt. Seg.**
róka-	'light'	Velar	*ruc*	√*á-a-*	/c/
bhajana-	'sharing (N)'	Palatal	*bhaj*	*-ana-*	/j₁/
-sargin-	'releasing (A)'	Velar	*sṛj*	*-in-*	/j₂/
mūrchā-	'stupor'	Palatal	*mūrch*	*-ā-*	/ch/

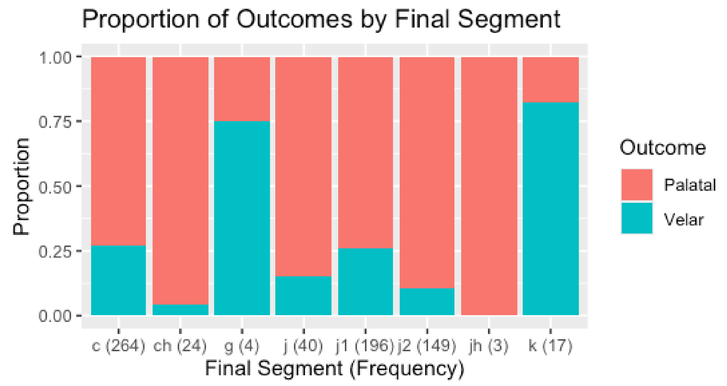
4. See Mayrhofer 1986–2001 and Rix and Kümmel 2001 for root reconstructions.

8. Modeling I

- Four independent variables to predict palatal vs. velar outcome in word-formation (two phonological, two morphological): Rt-Fin-Seg, Suff-Init-Seg, Root, Suffix.
- Problem: collinearity of phonological and morphological predictors (Suffix-Initial-Segment mostly or entirely overlaps with a single Suffix).
- Four single-predictor and four multiple predictor binomial Bayesian logistic regression models fitted using `bayesglm()` (Gelman et al. 2009, Gelman et al. 2013) in R.

6. Role of Final Segment

- 83.7% of roots and of roots and 93.1% (649/697) of word types word-types contain root-final /c/, /j₁/ or /j₂/ .
- 76.6% (534/697) of word types exhibit a root-final palatal, with differently distributed outcomes by root-final segment.



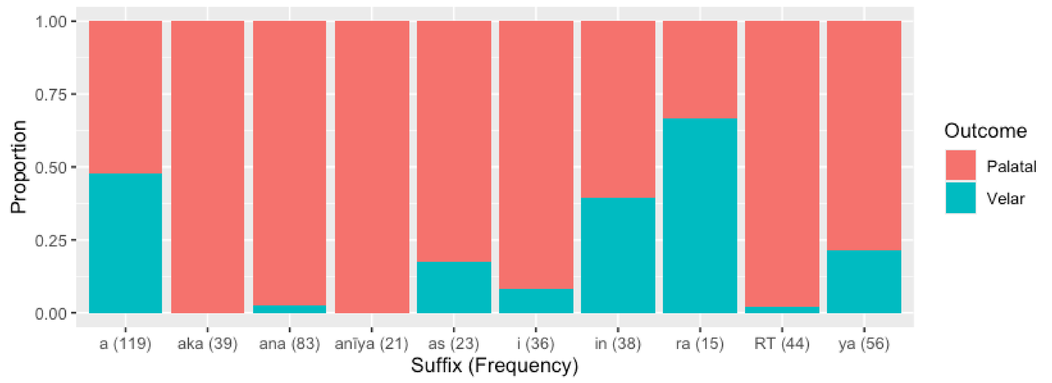
(5) Distribution /c, j₁/ vs. /j₂/

	Final Velar	Final Palatal	**SUM**
/c, j₁/	123	337	460
/j₂/	16	133	149
SUM	139	470	609

χ^2 = 15.462, p < 0.001, OR = 3.029, V = 0.0253 (weak)

7. Role of Word-Formation Suffix

- Data was coded for 102 distinct suffix types. Suffix *-a-* divided into 11 groups.
- Of the 59 suffixes occurring at least twice, 27 types (45.7%) occur exclusively with root-final palatal segments. 23 suffix types (38.9%) show a velar outcome in at least 15% of word types (median = 0!).
- If all stress/ablaut variants of *-a-* are treated as a single suffix, the ten most common suffixes make up 68% (474/697) of word types.



9. Modeling II: Results

- Model selection based on the Akaike Information Criterion indicates that a model using Rt-Fin-Seg (phonological) and Suffix (morphological) performs best (Model G).

(6) AIC of 8 Bayesian Logistic Regression Models

Model	A	B	C	D	E	F	**G**	H
Predictors	Rt-Fin-Seg	Suff-Init-Seg	Root	Suffix	Full	Full – B	**A + D**	C + D
AIC	715	668	771	649	726	710	618	699

☞ Velar-palatal variation is best predicted by a root's final segment plus lexical propensities of suffixes.

10. Phonological Analysis

1. **What are the underlying segments?**
   - Models with Root as a predictor find few roots with a statistically significant propensity for final palatals (2 in Model H), rather more with a significant velar preference (6 in Model H).
   - Excepting two roots considered to have /k/ or /g/, the palatal allomorph is predominant in nearly all cases.

   ☞ Analytical efficiency: posit underlying palatals that surface as such by default in pre-sonorant contexts (as per the Indian grammatical tradition).
2. **Productive velars or (mere) allomorph selection?**
   - For roots in /-c/ and /-j₁/, the availability of inherited root allomorphs containing a velar is plausible (e.g., *roká-* < [rewkó-]).
   - But: weak performance of the predictor Root suggests that velars are generated from underlying palatals, not chosen in the phonology from listed allomorphs (cf. Booij and van der Veer 2015).
   - In addition: at least 8 roots with /j₂/ (< PIE */ĝ/) show derived forms with historically unexpected velars.
3. **Suffix-conditioned velarization:** as with Slovenian palatalization (Jurgec 2016), much type-level variation is conditioned by suffixes.
   - Reducibility to local phonological effects is partly possible: [−syllabic] and [+back] segments significantly prefer velars.
   - Reducibility to cyclic effects also partly possible: "secondary" (stem-attaching) suffixes like *-in-* and *-ya-* are likely velar-preferring because they are mainly derived to stems in velarizing *-a-*.

11. Phonological Change

1. **Restructuring:** roots with final velars */k, g/ in Proto-Indo-Iranian were overwhelmingly subject to restructuring as palatal-final.
   - Preceding inflectional affixes, velars in a pre-sonorant context are rare archaisms (e.g., 1SG.NPST *vivákmi* to *vac-* vs. *vacmi*).
   - In the data, excepting two roots considered to have /k/ or /g/ (*śak-* and *iṅg-*), the palatal allomorph is predominant in nearly all cases.
   - Open question: what factors favored palatal allomorphs?
2. **Suffix propensities < historical origin**
   - Differences in the behavior of /ə/-initial suffixes are attributable to origin in earlier palatalizing */e/ vs. non-palatalizing */o/ (see **3.**).
   - Among suffixes with a velarizing propensity in Model G (see **9.**), 91% thereof (31/34) can unproblematically be reconstructed as furnishing a non-palatalizing environment.
3. **Derived-environment effects and rule inversion**
   - Proto-Indo-Iranian Palatalization could apply when both trigger ([+front] vocoid) and target (velar) were contained within the same morph (e.g., *=ca* 'and').
   - Alternations between velars and palatals at the left edge of the root conditioned by root ablaut are unknown in Sanskrit (though still found in the related Avestan: 3SG.SUBJ *caraṯ* to *kar-* 'make').
   - Restructuring in favor of palatals means the generation of velar allomorphs constitutes a species of **rule inversion** (Vennemann 1972).
   - The limitation of velarization to the root + suffix boundary makes velarization is a **derived-environment effect** (Kiparsky 1973).

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