Non-myopia in Sanskrit retroflex harmony

Abstract

Drawing on a two-million-word corpus of Sanskrit, two previously unrecognized generalizations are documented and analyzed concerning the morpho-prosodic conditioning of retroflex spreading (*nati*). Both reveal prefixes to be weak triggers in the sense that while prefixes trigger harmony, their access to targets is more restricted than that of non-prefix triggers, as analyzed here through the ‘ganging up’ of phonotactics and **CrispEdge** in classical HG. A (classical or serial) OT analysis using constraint conjunction, for its part, falters on the locality facts. Beyond the proposed classical HG analysis, a serial HG analysis is also possible, but only with a new type of non-local dependency constraint (cf. Mullin 2011, Walker 2014), effectively serving as memory that **CrispEdge** was breached earlier in the derivation.

Sanskrit exhibits a consonant harmony process called *nati* by which retroflexion spreads progressively and at any distance from a retroflex continuant trigger to a coronal nasal target (e.g. 1a–b), assuming that no consonantal coronal intervenes to block it (1c). A trigger can occupy any morphological position, including a prefix (1d).

(1) 
(a) √āṅg̣āu-eːna → [āṅg̣āu-eːṇa]  
(b) √ṅg-na → [ṅg-ṇa]  
(c) √ṭat̄-eːna → [ṭat̄-eːṇa]  
(d) p̣a-√fii-noː-ti → [p̣a-fii-ṇoː-ti]

*nati* has drawn the attention of linguists for nearly three thousand years. Among generative phonologists, it has played roles in treatments of harmony, (non-)iterativity, feature geometry, autosegmentalism, and prosodic phonology (§1), and continues to inform new developments. Recently, for instance, Jardine (2014) identified *nati* as one of only two known segmental (as opposed to tonal) processes in the world’s languages with the potential — judging by previous descriptions — to be ‘unbounded circumambient,’ that is, sensitive to unbounded contexts on both sides (due caution is expressed on this point, however, and indeed, as §4 will show, the right-side conditioning is bounded). Hansson (2010: 189–91) identifies several respects in which *nati* is unusual among consonant harmony systems, including the non-overlap between triggers and target, the coronal blocking of a coronal harmony, the progressive directionality, and the (occasional) phrasal domain. To these, one might add that prefixes rarely initiate harmony cross-linguistically (Baković 2000).

The present article has two goals. First, it simplifies previous analyses of the core facts of *nati*, primarily through incorporating into the analysis a phonetic property of retroflex stops, namely, ‘flapping out’ (i.e. releasing in a more anterior position; e.g. Boersma and Hamann 2005). Sanskrit is argued to be normal typologically in that its retroflex stops flap out, while its retroflex continuants do not. This constraint explains a number of at
first glance disparate properties of \textit{nati}, including its trigger set, non-iterativity, progressive directionality, and blocking by retroflexes of retroflex spreading.

Second, drawing on a two-million-word corpus of Vedic and Epic Sanskrit, this article revisits the primary data, identifying and analyzing two previously unrecognized (including by the grammars) morpho-prosodic conditions on \textit{nati}. Both independently reveal prefixes to be weak triggers in the sense that a prefix trigger has access to a proper subset of the targets accessible to a non-prefix trigger. Specifically, prefix triggers almost never access targets in immediately post-plosive position (§3) or immediately preceding a retroflex interval (i.e. VC\textsubscript{0}) (§4), while post-prefix triggers almost always do.

Both cases are analyzed in Harmonic Grammar (HG) through the ‘ganging up’ of the relevant independently motivated markedness constraint (*T\textsubscript{I} or OCP) with CrispEdge, which in this case penalizes spreading across the left edge of a root. A simplified illustration follows, using ‘\textit{nati}’ as a placeholder for the harmony-inducing constraint (see §2.2). In (2), harmony spreads from a root to an immediately post-plosive target. In (3), harmony spreads from a prefix to a target in the root-suffix complex. In (4), however, in which both the target is post-plosive and a root boundary must be breached, *T\textsubscript{I} and CrispEdge collectively outweigh \textit{nati}, and harmony fails.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
 & & nati & T\textsubscript{I} & CrispEdge \\
\hline
\hline
\sqrt{\text{mu}-\text{na}} & \mathcal{H} & 3 & 2 & 2 \\
\hline
a. \textbf{EF} & \sqrt{\text{mu}-\text{na}} & -2 & -1 & -1 \\
b. \sqrt{\text{mu}-\text{na}} & -3 & -1 & -1 \\
\hline
\hline
p\text{\textsubscript{4a}}-\sqrt{\text{ii}-\text{no}\text{-}\text{ti}} & \mathcal{H} & 3 & 2 & 2 \\
\hline
a. \textbf{EF} & p\text{\textsubscript{4a}}-\sqrt{\text{ii}-\text{no}\text{-}\text{ti}(-2) & -1 \\
b. p\text{\textsubscript{4a}}-\sqrt{\text{ii}-\text{no}\text{-}\text{ti}} & -3 & -1 \\
\hline
\hline
p\text{\textsubscript{4a}}-\sqrt{\text{a}p-\text{no}\text{-}\text{ti}} & \mathcal{H} & 3 & 2 & 2 \\
\hline
a. \textbf{EF} & p\text{\textsubscript{4a}}-\sqrt{\text{a}p-\text{no}\text{-}\text{ti}} & -4 & -1 & -1 \\
b. p\text{\textsubscript{4a}}-\sqrt{\text{a}p-\text{no}\text{-}\text{ti}} & -3 & -1 \\
\hline
\end{tabular}
\caption{Optimality Theory analysis of \textit{nati} harmony.}
\end{table}

An Optimality Theory (OT) analysis of these facts would require a conjoined (or similarly multi-predicate) constraint, which entails both a loss of generalization and certain empirical problems concerning locality (§4.3). An analysis set in serial OT has the same issues (§5.1). A classical serial HG analysis is also untenable. The issue, in brief, is that the critical violations of the two constraints needed for the gang effect come from separate steps in the derivation. In particular, the domain of harmony first spreads across the root boundary unaware of the plosive-target cluster lying in its path. In a later step, when the domain
reaches the target, all of the candidates available violate CrispEdge, so the grammar has no choice but to harmonize, as it would if harmony were root-initiated.

That said, serial HG augmented by non-local dependency constraints can handle the gang effect properly. Here, a proposal by Mullin (2011), namely, *DEPENDENT-HEAD(W), is extended to morphological or junctural structure for this purpose. This constraint effectively allows the serial HG grammar to refer back to the origin (head) of harmony at every step to determine whether it is prefix-initiated. Empowering serial HG with such non-myopia, however, introduces certain pathologies (and classical HG is also highly pathological; §5.3). The purpose of this article, then, is not to advocate for a particular harmony constraint, but rather to bring to light new locality problems concerning a well-known harmony system and to argue for an analysis of them in terms of the ganging up of independently motivated markedness constraints against harmony, whatever its mechanism.

1 The language and corpus

The basic facts surrounding nati ([nɔʈi]; English pronunciation ['nətɪ]) have been recounted numerous times since antiquity. Pāṇini (c. 500–350 BCE) treats them in a set of 39 rules in the last chapter of the last book of his grammar, the Asāḍhāyī (§8.4.1–39; see Böhtlingk 1887: 461–72, Vasu 1898: 1651–70). Nati is also discussed in the Prātiśākhya, ancient treatises on Vedic pronunciation (for primary references, see Wackernagel 1896: 188 and Allen 1951: 940).

The term nati, literally ‘bending, curvature’ (Allen 1953: 66), was not used by Pāṇini, but rather appears in the Prātiśākhya (Rk-Prātiśākhya 5.61, Vājasaneyi-Prātiśākhya 1.42). It refers to tongue retroflexion as an articulatory process. To refer to the retroflexes as a class, the ancient phoneticians used a different term, mūrdhanya ‘cerebral’, from mūrdhán, the relevant passive articulator. Nati is often erroneously spelled with an initial retroflex in phonological publications, but is properly dental-initial (as in the Prātiśākhya), coming from a zero-grade nominalization (< *n̥m-tī) of the root √nam ‘bend’, the same root found in ‘namaste’ (nam-as=te), literally ‘[a] bow [to] thee’. It does not, as the spelling *ṇati would suggest, mean something like ‘ṇ-ification’. While nati can in principle refer to any process of retroflexion, it is used in this article, as elsewhere, to refer specifically to retroflex harmony affecting nasals.


The language names used in this article, while standard, deserve comment, since different authors employ them with different degrees of specificity. First, ‘Sanskrit’ here refers to all of Old Indic (also known as Old Indo-Aryan). It is not used here to refer only to Classical Sanskrit, as it sometimes is elsewhere. Sanskrit in this broad sense can in turn be divided into two periods, the older ‘Vedic’ (c. 1500–600 BCE) and the younger ‘Classical’ (c. 600–BCE), the latter more closely conforming to Pāṇini’s rules (Masica 1993: 50–5). ‘Classical’ thus construed subsumes the two Sanskrit epics, though many authors prefer to put Epic Sanskrit in its own category separate from Classical.

When this article cites corpus counts, they derive from the texts enumerated in Figure 1, all downloaded from the Göttingen Register of Electronic Texts in Indian Languages. The texts, arranged roughly by chronology (the Rg-Veda being the oldest extant Sanskrit text), are labeled according to period and genre. Abbreviations are given in parentheses. For example, ‘10v 1b 5e’ would mean that the form is attested sixteen times total in the corpus, ten of which occur in the Vedas, one in the Brāhmaṇas, and five in the epics. The corpus includes over two million words in total, roughly one third Vedic and two thirds Epic. Since the corpus is not exhaustive, additional forms from dictionaries, grammars, and other texts are also cited freely when relevant, though not included in corpus statistics.

The consonant and vowel inventories of Sanskrit are shown in Figures 2 and 3, respectively (e.g. Cardona 2003). While this article employs the IPA for citing data (though not for names of texts, technical terms, etc.), the IPA can be easily converted back to the standard romanization using these tables. IPA transcriptions below depart from these tables only in giving the short low vowel as [a], as it is normally transcribed, despite its schwa-like quality. For the handful of vowels for which the Vedic and Classical values differ, the Classical values are always assumed, as is standard practice. Finally, the letter anusvāra, transcribed m and usually said to be a kind of placeless but moraic nasal coda (cf. Japanese), is omitted from Figure 2, and also does not happen to come up in any of the data cited below.

The rhotic, a retroflex continuant and by far the most common trigger of nati, is transcribed, with its syllabic variants, as [t] here, though it may have varied with tapped or trilled [t]. Whitney (1889: §24, §52), for one, insists that it was untrilled, noting, among other things, that “[n]o authority hints at a vibration as belonging to it,” as might be ex-

1 gretil.sub.uni-goettingen.de, accessed May 2014.
Period | Genre | Text | Word Count
--- | --- | --- | ---
Vedic | Vedas | Ṛg-Veda | 164,767
| | Sāma-Veda | 19,019
| | Atharva-Veda | 85,021
Brāhmaṇas | (b) | (Madhyamādīnā) Śatapatha | 127,255
| | Pañcaviṃśa | 42,700
| | Gopatha | 31,267
| | (Bāṣkala) Kauśitaki | 39,060
Early Upaniṣads | (u) | Brhadāranyaka | 16,502
| | Chāndogya | 13,968
Epic | (e) | Mahābhārata | 1,258,457
| | Rāmāyaṇa | 213,773
Total: 2,011,789

Figure 1: Sources and abbreviations covered in the corpus reports below. Each is given with its period, genre, and orthographic word count.

<table>
<thead>
<tr>
<th>Labial</th>
<th>Dental</th>
<th>Retroflex</th>
<th>Palatal</th>
<th>Velar</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>p</td>
<td>t</td>
<td>t̪</td>
<td>c</td>
<td>k</td>
<td>ǩ</td>
</tr>
<tr>
<td>ph</td>
<td>th</td>
<td>th̪</td>
<td>ch</td>
<td>kh</td>
<td>ǩ</td>
</tr>
<tr>
<td>b</td>
<td>d</td>
<td>d̪</td>
<td>j</td>
<td>g</td>
<td>ǧ</td>
</tr>
<tr>
<td>bh</td>
<td>dh</td>
<td>dh̪</td>
<td>jh</td>
<td>gh</td>
<td>ǧ</td>
</tr>
</tbody>
</table>

Figure 2: Sanskrit consonant inventory, with standard Indologists’ transcription in italics followed by IPA. Asterisked phones are specifically Vedic, [פק] and [ס] being variant pronunciations of [ח]. The chart includes phones usually assumed to be allophonic, viz., [n], [ŋ], [h], [פק], [ס], [l], and [ľ].

Expected for a trill, given the general level of articulatory detail commanded by the ancient phoneticians. Other possible but not strong hints at the smoothness of the rhotic include its frequent glide-like alternations in syllabicity (not unlike English) as well as its frequent confusions with the lateral (ibid. §53). Furthermore, as elaborated in §2.2, the fact that the rhotic initiates a domain of progressive retroflex spreading indicates that it does not ‘flap out’ into a more anterior position on its release. Since retroflex stops and flaps typically flap out, while retroflex fricatives do not, this diagnostic also points to a smooth rhotic.
As the caption to Figure 2 implies, dental /n/ vs. retroflex /ŋ/ is a phonemic contrast in Sanskrit (cf. e.g. [paṇa] ‘drinking’ vs. [paṇa] ‘stake in a game’). Nevertheless, its functional load is low, the vast majority (over 80%) of tokens of [ŋ] being due to \textit{nati}.²

<table>
<thead>
<tr>
<th></th>
<th>Front</th>
<th>Central</th>
<th>Back</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>i [i]</td>
<td></td>
<td>u [u]</td>
</tr>
<tr>
<td></td>
<td>ĭ [iː]</td>
<td></td>
<td>ā [uː]</td>
</tr>
<tr>
<td>Mid</td>
<td>e [ɛ] ([ai]*)</td>
<td>a [ə]</td>
<td>o [ɔ] ([au]*)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>ai [ai] ([aːi]*)</td>
<td>aː [aː]</td>
<td></td>
</tr>
<tr>
<td>Diphthong</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3: Sanskrit vowel and syllabic consonant inventory. As before, asterisked transcriptions are the Vedic pronunciations (as reconstructed in this case, not as in contemporary recitation). All items can be considered phonemic.

This article uses final hyphens in citing words only when they would be hyphenated in standard romanization. The lack of a hyphen does not imply that the word could stand alone as such. For example, the word \textit{nati} itself could never occur as \textit{nati} without an ending (e.g. nominative singular [nati-h]), but is normally cited as \textit{nati}, not \textit{nati-} or \textit{natih}. Internal hyphens, which are often problematic, are supplied freely when convenient, but always when the morphology is relevant to the application of \textit{nati}, in ways to be explicated. As is also common practice in citing Sanskrit words, pitch accent is marked when convenient (generally when a word is being quoted from a text in which accent is marked), though lack of a marked accent does not imply that the word lacks an accent or that its location is unknown.

2 Triggers, targets, blockers, and the importance of flapping out in their analysis

2.1 Preliminary data

\textit{Nati} is a progressive (left-to-right) consonant harmony. Its triggers are all and only the non-lateral retroflex continuants, \{l ŋ l̆ \} (on the status of \{l l̆\} as (non-)triggers, which has not previously been discussed, see §2.3.1). Its lone target is the dental nasal /n/, which

²The present corpus includes 122,680 tokens of [ŋ]. Of these, 82.4% occur in a \textit{nati} context, though this figure includes occasional false positives in which underlying /n/ happens to occur in \textit{nati} context and excludes occasional false negatives in which \textit{nati} obtains across a word boundary.
becomes retroflex [n]. Harmony obtains across an arbitrarily long string of segments so long as no blocker intervenes. Blockers (also called opaque segments, though opacity is an otherwise laden term in phonology) comprise the consonantal (i.e. excluding [j]) coronals. These properties are summarized in (5). The domain is typically the word (though sometimes larger in Vedic and smaller in Classical). For the most part (though see §3), harmony is blind to morphology. For example, a rhotic in a prefix will target a visible nasal in a root, suffix, infix, or other prefix, a rhotic in a suffix will target subsequent suffixes, and so forth. Syllabic position is also irrelevant. \textit{Nati} applies only if the target immediately precedes a vowel, glide, or nasal; on this restriction, see §2.3.2. 

\begin{itemize}
\item Directionality: progressive 
\item Triggers: \textipa{\textipa{õ} \textipa{õ} \textipa{õ} \textipa{õ} \textipa{õ}}
\item Target: \textipa{n}
\item Outcome: \textipa{ï}
\item Blockers: consonantal coronals, i.e.
\begin{itemize}
\item dentals \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʱ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʱ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʱ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʱ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʱ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʱ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʱ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʱ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʱ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʱ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʱ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{d返回搜狐\textipa{n} n* \textipa{h} \textipa{h} \textipa{j} \textipa{jʱ} \textipa{b} \textipa{bʱ} \textipa{c} \textipa{cʱ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʱ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{dʱ} \textipa{n} \textipa{s} \textipa{l} \textipa{lʰ} \textipa{t} \textipa{tʰ} \textipa{d} \textipa{d返回搜狐\textipa{n} \*Unattested or ambiguous as blockers; see text.
\end{itemize}
\end{itemize}

As an illustration, consider the instrumental singular suffix \textipa{-ena} (see also e.g. Hansson 2010:179ff for a different presentation of the basic data). When attached to a stem lacking a trigger, it surfaces as such, as in (6). (The \textit{vs. 0} addendum to a corpus citation makes it explicit that no counterexample is found in the corpus; in general, however, patterns suggested by example sets are entirely regular unless otherwise noted.) When the stem contains an (unblocked) trigger, the suffix undergoes \textit{nati}, as shown in (7).

\begin{enumerate}
\item[(6)] \item[(a)] \textipa{[ká:m-ena]} 'by desire' \quad (v10 b3 e37 vs. 0) \item[(b)] \textipa{[pad-éna]} 'by step' \quad (v2 b5 vs. 0) \item[(c)] \textipa{[ba:n-ena]} 'by arrow' \quad (e66 vs. 0) \item[(d)] \textipa{[mu:n-ena]} 'by the stupid (one)' \quad (e6 vs. 0) \item[(e)] \textipa{[ga:j-ena]} 'by elephant' \quad (v10 b3 e37 vs. 0) \item[(f)] \textipa{[jo:j-ena]} 'by means' \quad (e37 vs. 0) \item[(g)] \textipa{[j-éna]} 'by which/whom' \quad (v212 b62 u6 e769 vs. 0) \item[(h)] \textipa{[gu:fi-ena]} 'by cave' \quad (e6 vs. 0) \item[(7)] \item[(a)] \textipa{[na:j-ena]} 'by man' \quad (e18 vs. 0) \item[(b)] \textipa{[manusj-ena]} 'by human' \quad (e20 vs. 0) \item[(c)] \textipa{[dʱá:ám-ena]} 'by dharma' \quad (b1 u1 e295 vs. 0) \item[(d)] \textipa{[cúg-ena]} 'by horn' \quad (e4 vs. 0) \item[(e)] \textipa{[rú:g-hav-ena]} 'by the Rāghava' \quad (e28 vs. 0) \item[(f)] \textipa{[vi:šambʱ-ena]} 'by span' \quad (e3 vs. 0) \item[(g)] \textipa{[tú:jaŋ-ena]} 'by tripartite' \quad (e1 vs. 0) \item[(h)] \textipa{[puːpaugʱ-ena]} 'by the heap of flowers' \quad (e1 vs. 0)
\end{enumerate}
As mentioned, harmony is blocked by an intervening coronal. This subsumes the dental, retroflex, and palatal series, with the one exception of the palatal glide /j/, which is always transparent (as in (7-b, g) above). Some blockers are exemplified in (8). Items (e–f) also reinforce that retroflex stops do not serve as triggers (see also (6) (c–d) above).

(8) (a) [t̥atʰ-ena] ‘by chariot’ (v63 b11 e111 vs. 0)  
(b) [paːçat-ena] ‘by the antelope’ (e18 vs. 0)  
(c) [fiːdaj-ena] ‘by heart’ (v2 b6 u3 e30 vs. 0)  
(d) [uːsal-ena] ‘by the wicked man’ (e1 vs. 0)  
(e) [uiːːt-ena] ‘by Virāṭa’ (e14 vs. 0)  
(f) [gaːud-ena] ‘by Garuḍa’ (e5 vs. 0)  
(g) [iːːj-ena] ‘by royal’ (e34 vs. 0)  
(h) [maːːiːc-ena] ‘by the Mārica’ (e4 vs. 0)

Certain coronals, while possible to analyze as blockers, cannot be illustrated in blocking position. First, /l/ and /ʃ/, while expected to block, are rare and unattested in diagnostic positions in the corpus. Lacking evidence to the contrary, they are assumed to behave like /l/ and /ʃ/. The situation is similar for the palatal nasal, which is only attested adjacent to a palatal stop in the corpus, and therefore cannot be isolated as a blocker, though it is presumed to be one. Second, as previously observed (Gafoṣ 1999:213, Arsenault 2012:147), the triggers — all coronal — are ambiguous in their status as blockers, since they could be either transparent to the previous trigger or blocking with re-triggering; see (9). The status of these segments as blockers is therefore free to follow from theory-internal considerations.

(9) (a) [ksiːːt-énə] ‘by milk’ (v1 e8 vs. 0)  
(b) [cáːːiːt-énə] ‘by the body’ (v1 b1 e33 vs. 0)

Finally, the dental nasal cannot occur in blocking position because it itself undergoes harmony, becoming [n]. In such cases (as with underlying /ŋ/, which is not a trigger), harmony does not spread beyond the undergoing /n/ to the following /n/; see (11). Thus, it is also possible, though not necessary, to consider dental and retroflex nasals to be blockers.

(10) (a) [piːm-énə] ‘by breath’ (v15 b57 u17 e11 vs. 0)  
(b) [kʃan-ena] ‘by an instant’ (b1 e108 vs. 0)  
(c) [fiːːŋj-ena] ‘by gold’ (v2 b3 e4 vs. 0)  
(d) [piːːjaŋŋj-ena] ‘by introductory’ (b11 vs. 0)

2.2 Core analysis

The facts introduced to this point are now analyzed before turning to additional complications. A key and often overlooked component of their explanation, it is maintained here, concerns ‘flapping out’ (Ladefoged 1964), a property of retroflex stops (including nasals) by which the tongue tip moves forward during the closure phase of the segment, releasing into a more anterior position (ibid., Bhat 1973:47, Dave 1977, Simonsen et al. 2000, Dart 1991, Shalev et al. 1993, Butcher 1995, Krull et al. 1995, Steriade 1995:5f, Spajić et al. 1996, Dart
and Nihalani 1999, Flemming 2003, Hamann 2003, Boersma and Hamann 2005, Arsenault 2012). As such, retroflex stops are contour segments, so to speak, and could be narrowly transcribed as such, e.g. narrow [ṭt] for broad [ṭ] (Boersma and Hamann 2005:21ff). The narrower transcription does not imply that the release of a retroflex stop is homophonous with that of a dental stop; it indicates only that the release enters an anterior (e.g. alveolar) configuration (Steriade 1995: 6).

The acoustic consequence of flapping out is that the F3 depression associated with retroflexion is realized more prominently in the VC than CV transition. Flapping out has been documented palatographically for retroflex stops of Australia, Scandinavia, and South Asia (including daughters of Sanskrit such as Hindi and Gujarati; op. cit.), and is further supported by their phonological behavior, particularly their better cueing by left-hand context (e.g. Steriade 1995, Hamann 2003). But flapping out does not apply to all retroflexes. As Boersma and Hamann (2005: 18) clarify, while it is a typical, perhaps universal, property of retroflex stops, it is undocumented in studies of retroflex fricatives and affricates. The absence of flapping out among fricatives is likewise corroborated by their phonology, particularly their frequent interactions with following vowels (ibid.).

It is therefore assumed on both typological and internal grounds that the Sanskrit retroflex stops flap out, while the retroflex fricative does not. Internal grounds include the behavior of stops vs. fricatives in nati, as explained presently, as well as their licensing requirements: Retroflexion is contrastive for stops only in post-vocalic position (with marginal exception due to onomatopoeia and dialect borrowing), while the retroflex fricative is more broadly distributed (e.g. [sάt] ‘six’ vs. [sάt] ‘being’). Thus, [s] is narrowly [s], not [s̪s̪].

While the typology is less clear for retroflex rhotics, internal grounds support treating Sanskrit [ɭ] like [s] in terms of flapping out. Aside from its comparably broad licensing (e.g. it occurs word-initially, where it retains its retroflex character, as confirmed by nati), the fact that both [ɭ] and [s] serve as triggers for progressive retroflexion is itself prima facie evidence of their lack of flapping out, given that the consensus holds nati to be a spreading-driven harmony (e.g. Flemming 1995b, Gafos 1999, Ní Chiosáin and Padgett 2001, Rose and Walker 2004, Hansson 2010, Jurgec 2011). That the mechanism of nati is strictly local spreading (i.e. gestural extension) as opposed to feature agreement across non-undergoing interveners is supported by the existence of blockers, progressive directionality, disjoint triggers and target, and the (occasional) phrasal domain (op. cit., especially Hansson 2010: 189ff). In order to initiate a progressive domain of retroflex spreading, the retroflex continuants cannot flap out. This asymmetry between stops and continuants is summarized in (11).³ In what follows, retroflex stops will continue to be given their broad transcriptions, with the understanding that they flap out.

$\begin{array}{|l|c|l|c|}
\hline
\text{onset (V-to-C)} & \text{offset (C-to-V)} & \text{broad} & \text{narrow} \\
\hline
\text{retroflex continuants} & \text{posterior} & \text{posterior} & [s] & [s] \\
\text{retroflex stops} & \text{posterior} & \text{anterior} & [n] & [n̪] \\
\text{dentals} & \text{anterior} & \text{anterior} & [n] & [n] \\
\hline
\end{array}$

³As mentioned, the status of retroflex laterals as triggers is treated in §2.3.1.
The constraint enforcing flapping out in stops is here called FlapOut. Loosely speaking, this constraint requires every retroflex coronal stop to have an anterior offset. Coronal is specified because non-coronal stops can link to [retroflex] on this analysis (as when retroflexion spreads through them), and non-coronal retroflexes such as [k] do not flap out. In terms of gestural/autosegmental spans, the constraint demands that every retroflex coronal stop coincide with the right edge of its span of retroflexion, as in (12). One other caveat is that only released retroflex stops flap out. A cluster such as /ïú/, for instance, is presumably realized as [ï>út], not [>ïn>út]. The latter, which contains a dental stop between two retroflex stops, can be ruled out by other constraints (much as, say, [kqk] would be). But GEN also produces candidates in which such clusters share their [retroflexion] feature. In such candidates, NoGap (footnote 4) and the no-line-crossing convention guarantee that the first part does not flap out. As suggested by Hamann (2003) and Boersma and Hamann (2005), a constraint along the lines of FlapOut is potentially hardwired in GEN and unnecessary to include in CON. Here it is treated as an undominated constraint for expository purposes.

(12) FlapOut: Penalize every retroflex coronal stop that is non-final in its span of retroflexion.

Next, a constraint is required to motivate the harmony, whose mechanism appears to be strictly local spreading as opposed to long-distance agreement with intervening non-undergoers (op. cit.). Several constraint-based approaches to spreading can be found in the literature (e.g. ALIGN, SPREAD, SPECIFY, *A-Span, Agree, Share). It is beyond the present scope to evaluate all of them in the context of nati, though see §5 for further discussion. Here, ∀-Harmony(F/C, V) is employed, following Walker (2014: 511): “For every feature F in context C in a word, a violation is assigned to every vowel to which F is not associated.” For nati, generalization to all segments, not just vowels, is appropriate, and no context C requires specification. Given these generalizations, the constraint in (13) is akin to SPREAD. Pathologies of this general approach to harmony are addressed in §5.3. As also emphasized there, the core arguments of this article do not hinge on the selection of this particular constraint, or even this genre of constraint, as a harmony driver.

(13) ∀-Harmony([retro], segment) (abbreviated ∀-Harmony): For every [retroflexion] token, penalize every segment to which it is not associated.

Given the autosegmental setting, the spreading feature is often taken to be privative, as with [retroflexion] here, agreeing with recent analyses of Sanskrit (e.g. Ní Chiosáin and Padgett 2001) and of other languages (e.g. McCarthy 2009, 2011, Walker 2014). This assumption is not crucial here; if binary [anterior] or [TTCO] (Tongue Tip Constriction Orientation; Gafos 1999) were instead employed, the constraint definitions could be recalibrated. A competing faithfulness constraint, Ident(retro) (14), penalizes changing a segment’s input value for retroflexion. (MAX and Dep referring to association lines, as in Myers 1997 and Jurgec

4Highly ranked or GEN-encoded NoGap (e.g. Kiparsky 1981, Archangeli and Pulleyblank 1994, Walker 2014), not shown in the tableaux, rules out candidates in which retroflex spans skip over segments.
Ident (retro) as defined is never violated by a stop that flaps out because such a stop is both retroflex and anterior. For example, candidate (a) in (16) has three, not four, violations of Ident (retro), since the span-final nasal is more narrowly [ɾn]. Candidate (d), however, receives a violation of Ident (retro) for its retroflex nasal, since the nasal does not flap out in that case, being medial in its span.

(14) Ident (retro): Penalize a segment that is retroflex in the input but not in the output or anterior in the input but not in the output.

Relatedly, directional Ident$_{I \rightarrow O}$ (retro) proscribes specifically de-retroflexion (15). This must outrank bidirectional Ident (retro) in order to prevent triggers such as /ɭ/ and /ʃ/ from undergoing de-retroflexion as a solution to ∀-Harmony (on directional Ident, see Pater 1999, Rose and Walker 2004, 2011, Walker 2014; cf. also MAX referring to autosegments). While [ɾ] is not part of the inventory, [s] is, and therefore cannot be ruled out merely by inventory restrictions.

(15) Ident$_{I \rightarrow O}$ (retro): Penalize a segment that is retroflex in the input but not in the output.

The simple ranking FlapOut $\gg$ ∀-Harmony, while not yet the full story, already captures several core features of nati. First, it captures the stop/continuant asymmetry in triggering without specifying it in the harmony apparatus, as shown in (16) and (17). Because retroflex stops flap out (not only in Sanskrit, but perhaps universally), they cannot trigger. In the tableaux, spans of retroflexion (i.e. strings in which every segment is linked to the same token of [retroflex]) are parenthesized. Retroflexion is redundantly marked on every segment within the span, using an underdot if the IPA lacks a symbol. As (16) and (17) also illustrate, this analysis predicts regressive retroflexion insofar as no blocker interferes (blocking is treated below). No harm comes from this prediction, for two reasons. First, if it were incorrect, one could add a constraint preventing leftward spreading such as Initial (feat) (McCarthy 2009: 9; also McCarthy 2004 on headed spans). But the prediction is not incorrect, at least not on language-internal grounds. Sanskrit orthography distinguishes retroflexion only in coronals. It follows that retroflexion in non-coronals is effectively hidden structure (granting also the impossibility of instrumental study) and free to follow from analytical and typological considerations (Allen 1951: 940ff, Steriade 1995: 51).

(16)

<table>
<thead>
<tr>
<th>kaɾ∢ɛna</th>
<th>FlapOut</th>
<th>Ident$_{I \rightarrow O}$ (retro)</th>
<th>∀-Harmony</th>
<th>Ident (retro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. kaɾ∢ɛna</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>b. kaɾ∢ɛna</td>
<td>3 W</td>
<td>1 L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. kaɾ∢ɛna</td>
<td>5 W</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. (kaɾ∢ɛna)</td>
<td>1 W</td>
<td>L</td>
<td>5 W</td>
<td></td>
</tr>
<tr>
<td>e. kaɾ∢ɛna</td>
<td>1 W</td>
<td>L</td>
<td>1 L</td>
<td></td>
</tr>
</tbody>
</table>
Second, the analysis predicts the directionality of nati without specifying it in the harmony apparatus. Consider /vəːnaːãa/ in (18). Retroflexion spreads onto the vowels surrounding /ã/, but cannot affect the preceding /n/, given that [ŋ] continued by retroflexion would violate FlapOut. Thus, the system embodies the prediction that retroflex spreading harmony targeting stops could only possibly be progressive, as in Sanskrit. Regressive retroflex spreading harmony is attested, as in Kinyarwanda (Walker and Mpiranya 2005, Walker et al. 2008), but its targets are continuants, not stops, consistent with this proposal.

Third, the analysis captures the fact that harmony terminates when it reaches a target nasal, rather than propagating through that nasal to yet another target; see (19). In other words, the so-called non-iterativity of harmony is derived from an independently motivated property of the language rather than implemented as an ad hoc parameter or constraint.5

5A common refrain of rule-based analyses of nati purports to derive its non-iterativity from the fact that a retroflex nasal, the outcome, does not otherwise serve as a trigger, without relating it to any phonetic property (cf. e.g. Johnson 1972, Howard 1973, Anderson 1974, Ringen 1976, Kiparsky 1985). On the present analysis, it is no coincidence that the retroflex nasal neither triggers nor propagates, as both are motivated by FlapOut. But the present analysis does not relate the (non)iterativity of a harmonic process to whether or not its trigger(s) and target(s) overlap. It predicts a harmony to be possible in which a segment undergoes and propagates the harmony without triggering it. Indeed, if nati is analyzed as strictly local spreading (op. cit.), then this prediction is borne out even by nati: A segment such as [k] undergoes and propagates without being a trigger.
Fourth, harmony is asymmetric in the sense that an anterior continuant does not cause an unblocked retroflex nasal to become anterior (cf. /sa-gaïa/ → [sa-gaŋa], *[sa-gana]). This follows from the statement of ∀-Harmony, which favors the spreading of retroflexion, but not of anteriority. While the present ranking predicts *[sa-gaŋa] for this input, the prevention of segments such as /s/ from undergoing harmony is treated immediately below in (22). The point here is that anterior continuants are not triggers like retroflex ones.

Fifth and finally, the ranking so far captures blocking by retroflex stops (e.g. [uïa]:ena]), which retroflexion cannot spread through without violating FlapOut. Retroflex continuants (e.g. /kši:t-ena/ → [kši:t-ena]) are also handled appropriately, since the retroflex span is free to spread to /n/ regardless of the multiplicity of triggers. This leaves only blocking by palatals (except /j/) and dentals. The former can be motivated biokinematically (and hence potentially by GEN), in that a palatal articulation is incompatible (in Sanskrit, if not universally) with tongue tip retroflexion (Gafos 1999:213f, 223f; cf. Hamann 2003, Flemming 2003, Boersma and Hamann 2005). As Gafos (1999: 214) also emphasizes, this articulatory incompatibility naturally fails to extend to the palatal vocoid, which involves less arching of the tongue body.

At this point, then, FlapOut ≫ ∀-Harmony remains incomplete concerning the core data only in that (a) it fails to restrict the targets to /n/ as opposed to the other anteriors, viz. /t tʰ d dʰ s l l/, and (b), relatedly, it fails to capture blocking by anterior, which are thus far predicted to undergo en route to a target just like non-coronals. For example, the correct output for /qas-ena/ is [qas-ena], in which /s/ both blocks and fails to undergo retroflexion. But the ranking so far generates *[qas-ena], in which /s/ is both transparent to and undergoes retroflexion. Following Ní Chiosáin and Padgett (1997: 36; also Ohala and Ohala 1993, Padgett 1995, Gafos 1999, Steriade 1995, 2009a), place is generally less faithful for nasals than for other consonants, particularly obstruents. For one, nasals are more likely to undergo assimilation, all else being equal. Moreover, diachronically, a contrast between dental and retroflex is less robust for nasals than for plosives, as suggested by the daughters of Sanskrit that lost the /n ∼ ñ/ contrast while preserving phonemic retroflexion in the plosives (e.g. Bengali, Nepali, Hindi dialects; Masica 1993).

A solution, then, is to rank ∀-Harmony below a faithfulness constraint that prevents retroflexion from spreading onto oral coronals, e.g. Ident_{OrCor}(retro) in (20) (once again, an arboreal constraint such as DepLink_{OrCor}(retro) would have the same effect). This constraint must penalize spreading retroflexion onto even oral coronals that flap out, as oral coronals must be prevented from undergoing as targets. This general strategy of Faith[specific] ≫ Harmony ≫ Faith[general] is not new here but employed by all constraint-based analyses of nati (see below) to implement the asymmetry between /n/ and other dentals.
IdentOrCor(retro): Penalize an oral coronal that is retroflex in the output but not in the input.

In essence, while this approach assumes that [retroflex] can link to any segment (except perhaps the palatals), its interaction with coronals, especially oral coronals, is afforded special faithfulness due to its greater perceptibility on them. Tongue tip orientation during non-coronals is less tightly regulated. Gafos (1999: 222) employs FAITH(Tongue Tip Constriction Orientation, Obstruent) to this end, but this constraint fails to account for blocking by /l/ and for the transparency of non-coronal obstruents. The analysis of Ni Chiosáin and Padgett (1997: 36) is dispersion/contrast-based, evaluating paradigms as candidates (cf. Flemming 1995a). The approach here is more classical, and predicts blocking to be independent of the contrastive status of retroflexion in coronals. In Sanskrit, after all, all coronals block, but retroflexion is contrastive for only a subset of them. In particular, there is no anteriority contrast in the laterals in any period, but laterals block in all periods (as do the palatals, for which retroflexion is moot). While one could still maintain that laterals block because retroflexion is contrastive for some coronals in Sanskrit, or because retroflexion is a possible contrast for laterals typologically, invoking contrast at all is unnecessary. The greater perceptibility of retroflexion differences in coronals, especially oral coronals, can be projected onto faithfulness constraints (cf. Steriade 2009a). While this explanation still invokes dispersion in some sense, it does not require evaluating paradigms as candidates.

Tableau (21) illustrates both blocking of harmony by an oral coronal and failure of the same oral coronal to undergo harmony. Tableau (22) shows that anticipatory harmony to a coronal continuant (for which FLAPOUT is no help) is also properly ruled out.

(21)

<table>
<thead>
<tr>
<th>FlapOut</th>
<th>IDENT_{I→O}(retro)</th>
<th>IDENT_{OrCor}(retro)</th>
<th>∀-HARMONY</th>
</tr>
</thead>
<tbody>
<tr>
<td>as-ena</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>a. (ə)</td>
<td>(ə)asena</td>
<td></td>
<td>5 W</td>
</tr>
<tr>
<td>b.</td>
<td>(ə)asena</td>
<td></td>
<td>3 W 1 L</td>
</tr>
<tr>
<td>c.</td>
<td>(əas)ena</td>
<td></td>
<td>1 W 1 L</td>
</tr>
<tr>
<td>d.</td>
<td>(əas;e)na</td>
<td></td>
<td>1 W 1 L</td>
</tr>
<tr>
<td>e.</td>
<td>əas:ena</td>
<td></td>
<td>L</td>
</tr>
</tbody>
</table>

(22)

<table>
<thead>
<tr>
<th>FlapOut</th>
<th>IDENT_{I→O}(retro)</th>
<th>IDENT_{OrCor}(retro)</th>
<th>∀-HARMONY</th>
</tr>
</thead>
<tbody>
<tr>
<td>sa-gana</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>a. ə</td>
<td>s(aga)na</td>
<td></td>
<td>1 L 5 W</td>
</tr>
<tr>
<td>b.</td>
<td>(əaga)na</td>
<td></td>
<td>1 L</td>
</tr>
<tr>
<td>c.</td>
<td>sagan(ə)na</td>
<td></td>
<td>5 W</td>
</tr>
<tr>
<td>d.</td>
<td>s(aga)na</td>
<td></td>
<td>1 L</td>
</tr>
<tr>
<td>e.</td>
<td>sagana</td>
<td></td>
<td>L</td>
</tr>
</tbody>
</table>

To summarize thus far, the ranking for basic nati, including its trigger and target sets, directionality, non-iterativity, retroflex-anterior asymmetry, and transparent vs. blocking
segments, is depicted as a Hasse diagram in (23). As mentioned above, FlapOut might be part of Gen, and if so omitted here.

\[
\text{FlapOut} \quad \text{Ident}_{I\rightarrow O}(\text{retro}) \quad \text{Ident}_{OrCor}(\text{retro}) \quad \forall\text{-Harmony}(\text{retro, segment}) \quad \text{Ident}(\text{retro})
\]

(23)

This analysis improves upon previous constraint-based analyses of nati (full OT analyses being offered in Ní Chiosáin and Padgett 1997, 2001 and Gafos 1999; cf. also sketches in Steriade 1995 and Jurgec 2011). First, the proposed pro-harmony constraint is the simplest, merely stating the feature that spreads. The constraint says nothing about the set of triggers, targets, or directionality; all of these properties fall out from interaction with other relatively simple and independently motivated constraints. Compare the pro-harmony constraints in (24)–(27), all of which include one or more features of the triggers and/or target (viz. continuancy and/or coronality), as well as directionality.

(24) **Tip Position**: ‘A nasal apical maintains the same tip position, raised or lowered, as a preceding continuant apical’ (Steriade 1995: 51)

(25) **Align-R([retroflex], C)**: ‘Align any [retroflex] feature contained in a [+continuant] segment \(S_m\) to a consonant \(S_n\), where \(n > m\)’ (Ní Chiosáin and Padgett 1997: 36)

(26) **Harmony**([TTCO = [retroflex], trigger = [+continuant]]) [in which TTCO refers to Tongue Tip Constriction Orientation and Harmony is defined essentially as **Align-R**] (Gafos 1999: 218–23)

(27) **Align-R**(p-phrase, [-anterior], [+coronal]) (Jurgec 2011: 23)

In the present analysis, the interaction of \(\forall\text{-Harmony}\) and FlapOut (which, again, is well-motivated independently to the extent that it might be part of Gen) captures several at first glance disparate properties of nati, including the restriction of triggers to continuants, the progressive directionality (given that the target is a stop), the blocking by retroflex stops, and the non-iterativity of spreading, in the sense that harmony cannot spread through the first eligible target to any following target.

The celebrated non-iterativity of nati (see e.g. Kiparsky 1985:113, Gafos 1999:213, Kaplan 2008:21, Hansson 2010:190) is here an artifact of the target being a stop. In other constraint-based analyses, non-iterativity is stipulated or left unanalyzed (see also footnote 5 on a common rule-based approach). It is stipulated through a dedicated, rankable constraint in Jurgec (2011: 23) and through alignment directly to the target (as opposed to a domain edge)
in Ñi Chiosán and Padgett (1997: 36). As explained by Hansson (2010: 186–8), the analysis of Gafos (1999) fails to account for non-iterativity, and alignment-to-target analyses fail to properly handle blocking, at least given the vague formulation of target selection in (25). The present analysis not only covers non-iterativity, but requires it of retroflex harmonies targeting stops. A hypothetical version of Sanskrit with otherwise the same phonetics but iterative nati, or nati feeding another progressive retroflexion, could not exist. At the same time, if the target of retroflexion is a continuant, non-termination and feeding are predicted. Indeed, this prediction is borne out by Sanskrit: Consider ruki, another rule of progressive retroflexion, by which a rhotic, velar, or non-low vowel causes immediately following /s/ to become retroflex (Selkirk 1980, Beguš 2012). Ruki, as predicted, invariably feeds nati, as in /vís-ana/ → [vís-aña] ‘sprinkling’, in which the rhotic first triggers retroflexion in the sibilant, which in turn triggers retroflexion in the nasal (recall that [s] would otherwise block nati). This is possible because the target of ruki retroflexion is a continuant, unlike the target of nati retroflexion.

This analysis, like the previous ones just cited, is couched in non-serial constraint-based grammar and employs a pro-harmony constraint that is part of a family of constraints implementing harmony by alignment or spreading that is known to exhibit certain pathologies. This issue, and particularly the viability of a serial analysis of nati, is addressed in §5. While this section has treated the basic properties of nati, including its triggers, targets, blockers, directionality, and non-iterativity, all of which are known in the phonological literature, some additional complications are documented and analyzed in the following sections.

2.3 Addenda concerning the basic rule

2.3.1 The status of retroflex laterals as triggers

The triggers for nati are usually reported to be the retroflex continuants, which include \{õ õ:õ\}. But the Vedic inventory, as Figure 2 suggests, also includes laterals [í] and [íH], presumably also retroflex continuants. They appear exclusively as allophones of /ã/ and /ãH/ in intervocalic position in certain Vedic texts. Judging by 45 diagnostic tokens in the present corpus, retroflex laterals never trigger nati.

Possible causes for this failure include the following. First, it could be synchronic opacity, with lateralization counterfeeding nati. Second, it could be that the apparent opacity is not synchronic but a historical artifact. Under this scenario, at the time of composition, the stops would have been pronounced as stops. At some later point in the transmission of the text, lateralization would occur, but without retriggering nati, either because nati had lost productivity, or because the nasals’ anteriority was orthoepically fixed. Finally, it is possible that the class of triggers was synchronically not the retroflex continuants, but the central retroflex continuants, potentially with phonetic motivation. Given the laterals’ shallow origin in stops, for instance, perhaps they continued to flap out in articulation, in which case they could not trigger. In any case, given the rarity of these allophones and the irrelevance of this issue to the remainder of this article, these questions are left open.
2.3.2 Restrictions on the right-hand context

*Nati* is usually reported to apply only if the target immediately precedes a vowel, glide, or nasal (i.e. a non-liquid sonorant). As Schein and Steriade (1986: 720–2) motivate (see also Hansson 2010: 183), failure before a word boundary, liquid, or fricative follows from general phonotactics independent of *nati*, such as word-final neutralization. Only non-application before a plosive (e.g. /caʔ-a-n-ti/ → [caʔ-a-n-ti] ‘wander (3pl)’) requires further comment, as retroflex nasal-plosive clusters are otherwise permitted (e.g. /pʰan-ta/ → [pʰan-ta] ‘spring (pass. part.)’). On the present analysis, failure in [caʔanti] is already handled by Ident\textsubscript{OrCor}(retro), which preserves [t] as such, outranking the imperative to spread (other run-of-the-mill constraints, such as CODA\textsubscript{COND}, proscribe heterorganic *[ŋt]*). Meanwhile, [pʰanʔa] is ensured by Ident\textsubscript{I→O}(retro) ≫ Ident\textsubscript{OrCor}(retro), which requires preserving underlying /ŋ/ at the expense of /t/.

3 Weak prefixes I: immediately post-plosive targets

3.1 Data and HG analysis

One aspect of *nati* often omitted from generative discussions is that while velars and labials are normally transparent, as illustrated in (7) above, they often block when immediately preceding the target nasal. For example, consider the verb stem [pʰa:p-] ‘attain’ (from preverb [pʰa] + root [a:p]). *Nati* applies without exception whenever the target nasal is post-vocalic, as in (28) (and numerous similar examples). But when the nasal immediately follows the final [p] of the stem, as in (29), *nati* always fails. This failure is not, moreover, a function of the [nu]/[noː] suffix (class five present stem formative), as (30) illustrates using the same preverb and suffix but vowel-final root.

(28) (a) [pʰa:p-aŋa] ‘attaining’ (b1 e5 vs. 0)
   (b) [pʰa:p-aŋi:ja] ‘to be attained’ (e2 vs. 0)

(29) (a) [pʰa:p-noc-ti] ‘attains (3s)’ (v1 b21 u1 e183 vs. 0)
   (b) [pʰa:p-nu-jáːh] ‘should attain (2s optative)’ (u1 e14 vs. 0)

(30) (a) [pʰa-fiː-noc-ti] ‘incites (3s)’ (b2 e1 vs. 0)
   (b) [pʰa-fiː-nu-jáːh] ‘should incite (2s optative)’ (e1 vs. 0)

The post-plosive blocking of *nati* in (29) no doubt reflects a more general perceptually driven phonotactic of Sanskrit. While /n/ and /ŋ/ generally contrast (§1), the contrast is virtually confined to tautomorphemic post-vocalic (occasionally post-sonorant) position (Steriade 1995). Retroflex nasals can be found in post-plosive position, but only due to assimilation. Putting aside *nati* contexts, if the plosive is coronal, the following coronal nasal must agree in place (e.g. [ʔaːnta] ‘gift’, [aŋaːtā] (proper name), [jaːmā] ‘sacrifice’); otherwise, the coronal nasal must be dental (e.g. [suːpna] ‘sleep’, [aŋi] ‘fire’). No isolated lexemes like *[suapŋa]* or *[aŋŋi]* are found.
The analysis from §2.2 can be easily amended by adding a highly ranked constraint forbidding post-plosive retroflexes, e.g. *Tï in (31). While this constraint could likely be generalized further, e.g. to palatal and velar (but not labial) nasals, these details of formulation are unimportant here. Retroflex plosive-nasal clusters (e.g. [a[tñas:]), can be motivated by assimilatory constraints dominating *Tï, not shown. In order to prevent harmony in e.g. [pA-a:p-ño:-ti], *Tï must be ranked above ∀-Harmony, as in (32).

(31) *Tï: Penalize every retroflex nasal immediately following a plosive.

<table>
<thead>
<tr>
<th>pû-a:p-ño:-ti</th>
<th>*Tï</th>
<th>∀-Harmony</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (pû-a:p) -</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. (pû-a:p-ñ)</td>
<td>1 W</td>
<td>3 L</td>
</tr>
</tbody>
</table>

Ranking (32) is an oversimplification, however, since nati does regularly target a post-plosive nasal target in some forms. The data in (33) cover all such forms in the corpus (see §1), sorted by descending frequency. Irrelevant affixation and compounding is now factored out in the entries, such that only the relevant root and affix, if any, are shown. For example, (d) [jékñtas] includes counts for [jékñtas] in various case forms as well as prefixed [su-][jékñt-] and suffixed [jékñtas-vati:]. The ‘vs. 0’ annotation indicates that the lexeme never occurs as *[jékñtas] in any genre, period, or morphological context.

(33) (a) [qûbío-ñV-] ‘grasp (pres. stem)’ (v33 b15 vs. 0)
     (b) [ûug-ñå] ‘break (pass. part.)’ (v2 e40 vs. 0)
     (c) [ûuk-ñå] ‘cut off (pass. part.)’ (v4 b7 u7 e2 vs. 0)
     (d) [jékñtas] ‘inheritance’ (v14 vs. 0)
     (e) [îô-ñV-] ‘be satisfied (pres. stem)’ (v7 vs. v1 [AV 20.136.5])
     (f) [iûsk-ñå] ‘sharp (cf. [iûsk-ñå], id.)’ (e5 vs. 0)
     (g) [pûg-ñå] ‘unite (pass. part.)’ (v1 vs. 0)
     (h) [jêk-ñå] ‘wound (pass. part.)’ (b1 vs. 0)

By contrast, all of the forms in the corpus in which an otherwise eligible post-plosive /n/ fails to undergo nati are given in (34). When the trigger is not explicitly shown, as in (c), assume that the ‘X-’ portion contains a visible trigger. For example, (c) [X-gñà] ‘X-killer’ subsumes [nû-gñà] ‘man-killer’, [ûtûa-gñà] ‘Vtura-killer’, and so forth, generalizing over irrelevant affixation and compounding as before. Similarly, when ‘preverb-’ is indicated in the gloss, all applicable trigger-containing preverbs (e.g. [pûa-]) are included.
The difference between (33), in which nati applies to post-plosive targets, and (34), in which it does not, is that in all of the cases in (33), no root boundary intervenes between trigger and target, whereas in almost all of the cases in (34) (with a handful of exceptions to be addressed in §3.2), a root boundary intervenes. This root boundary criterion separates tokens into the two categories with almost perfect accuracy (100% hits and no misses for the first set; >99% hits and <1% misses for the second). Furthermore, it holds across genres and periods. On its lack of recognition in the previous literature, see §3.2.

To be sure, some of the nati failures in (34) could be attributed to compounds failing to undergo nati by virtue of being compounds. In Classical Sanskrit, nati rarely applies across compound boundaries. In Vedic, it often does so, but — importantly for the present purposes — never when the target is post-plosive. The compound cases are unproblematic here, since nati failure is simply overdetermined in them. In any case, compound blocking is not the whole story. Even preverbs that otherwise normally trigger nati in their stems never affect a post-plosive target. This was already demonstrated in (28) through (30); some additional examples involving /põa-/ are given in (35) and (36). Other trigger-containing prefixes (e.g. [paõi-], [duù-]) behave the same.

(35) Some illustrations of /põa-/ triggering nati in its base:
(a) [põ-a:ki-nti] ‘incited (3s)’ (e82 vs. 0)
(b) [põa-mi:n-ti] ‘frustrates (3s)’ (b5 vs. 0)
(c) [põa-ja:nta] ‘setting out’ (v5 b1 e21 vs. 0)

(36) Some illustrations of /põa-/ failing to trigger nati in its base:
(a) [põ-a:p-nV-] ‘attain (pres. stem)’ (v2 b62 u4 e510 vs. 0)
(b) [X-agni] ‘X-fire/Agni’ (v161 b195 u2 e104 vs. 0)
(c) [X-gña] ‘X-killer’ (v27 b38 e379 vs. 0)
(d) [X-bðag-na] ‘preverb-break (pass. part.)’ (b1 e90 vs. 0)
(e) [d(a)uù-(ù)V´ apn-ja] ‘bad sleep’ (v35 b1 e12 vs. 0)
(f) [X-gña] ‘preverb-kill (3pl forms)’ (v3 b14 vs. 0)
(g) [fiaqi-knika] ‘bay-colored’ (v2 vs. 0)
(h) [paõj-akna] ‘?’ (b2 vs. 0)
(i) [niõ-vigna] ‘?’ (e1 vs. 0)
(j) [bðagña] ‘?’ (v2 vs. 0)
(k) [vi-shak-na] ‘fix (pass. part.)’ (v1 vs. 0)
(l) [tõ-p-nV-] ‘be satisfied (pres. stem)’ (v1 vs. v7; see (33))
the specified boundary. Here, the relevant specification is CrispEdge([retroflex], √), as in (37). This constraint is violated by (...√...), i.e., a span of retroflexion containing the left edge of a root. The typological asymmetry between prefixes and suffixes to the effect that prefixes tend to be more separate phonologically is well-documented cross-linguistically (e.g. Greenberg 1957:86–94, Nespor and Vogel 1986, Hawkins and Cutler 1988, Bybee et al. 1990, van Oostendorp 1999, Cysouw 2009, and many others), as is root privilege (e.g. Alderete 1999). Moreover, prefixes rarely trigger harmony cross-linguistically (Hall and Hall 1980, Baković 2000). Sanskrit prefixes (etymologically separate words that underwent univerbation in the case of preverbs), as established here, do trigger, but do so more weakly than roots, as this analysis will motivate. In Vedic, in which compounds such as [indõa:gn´ı:] ‘the Indra-Agni pair’ never undergo nati despite nati otherwise frequently applying across compound members and sometimes even clitic groups, it is evident that √ has a comparable status within compounds and phrases, as this analysis already predicts without further stipulation.

(37) CrispEdge([retroflex], √) (abbreviated CrispEdge):
Penalize a span of retroflexion that contains the left edge of a root.

A more complex case of attenuation of harmony across morphological boundaries has been documented and analyzed by McPherson and Hayes (2012). They show that in Tommo So, the likelihood of a suffix’s undergoing harmony is correlated with how many abstract boundaries (or levels, so to speak) intervene between it and the root, regardless of phonological distance. The present case is more straightforward, in that only a single prominent boundary, the prefix-root juncture, is invoked as a harmony attenuator.

Descriptively, then, the new generalization can be summarized as in (38). As the presentation implies, nati failure in (c) can be analyzed by the ‘ganging up’ (e.g. Jäger and Rosenbach 2006, Pater 2009b: 1008ff) of the two markedness constraints implied by (a) and (b) against the pro-harmony constraint. That is to say, while neither a violation of (a) alone nor (b) alone is enough to prevent nati, when both (a) and (b) are simultaneously violated, nati fails in just this ‘worst-of-the-worst’ case scenario.

(38) (a) When the trigger and target straddle a prefix-root juncture, nati generally applies.
(b) When the target immediately follows a plosive, nati generally applies.
(c) When the trigger and target straddle a prefix-root juncture and the target immediately follows a plosive, nati fails.

Formally, ganging up can be analyzed using weighted constraints, as in Harmonic Grammar (HG; Legendre et al. 1990, Smolensky and Legendre 2006, Pater 2009b, Potts et al. 2010) or regression modeling more generally. In HG, each candidate’s harmony is the sum of its weighted violations, and the candidate with the greatest harmony (H) is (in classical HG) the winner. Constraint weights are nonnegative and violations are nonpositive. To save space in tableaux, the undominated constraints in §2.2, namely, FlapOut, IDENT₁→O(retro), and IDENT₉₉₉₉₉ₑ(retro), and candidates violating them, are not shown; they can be given arbitrarily high weights. Tableau (39) shows a prefix triggering nati when *TH₁ is not at stake.
Because ∀-HARMONY outweighs CRISPEDGE, harmonizing across √ is optimal.

(39)

<table>
<thead>
<tr>
<th></th>
<th>∀-HARMONY</th>
<th>IDENT(retro)</th>
<th>Tη</th>
<th>CRISPEDGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>(p₄a-√fi-n)ο-ti</td>
<td>-23</td>
<td>-3</td>
<td>-4</td>
</tr>
<tr>
<td>b.</td>
<td>p(μa-√fi-n)ο- ti</td>
<td>-23</td>
<td>-4</td>
<td>-3</td>
</tr>
<tr>
<td>c.</td>
<td>p(μ)a-√fi-no- ti</td>
<td>-24</td>
<td>-8</td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>(p₄a)-√fi-no- ti</td>
<td>-24</td>
<td>-6</td>
<td>-2</td>
</tr>
<tr>
<td>e.</td>
<td>(p₄a-√fi)n- no- ti</td>
<td>-26</td>
<td>-5</td>
<td>-3</td>
</tr>
<tr>
<td>f.</td>
<td>(p₄a-√fi)i-no- ti</td>
<td>-26</td>
<td>-4</td>
<td>-4</td>
</tr>
</tbody>
</table>

Weights were assigned in (39) based on running all of the tableaux in this article (and others not shown) through OT-Help 2.0 (Staubs et al. 2010), which solves HG systems using linear programming (Potts et al. 2010). In other words, they anticipate the full analysis, as summarized in §4.4. That said, however, they also work for the partial analyses illustrated in each section taken independently. Thus, if the weights from the full analysis (and here) are transferred back to the tableaux in §2.2, the analysis there works, in the sense that no winner has incorrect overt structure (hidden structure need not be treated identically). In (39), because ∀-HARMONY and IDENT(retro) have the same weight, certain hidden structure (namely, whether [p] undergoes) is optional. If this is felt to be infelicitous, ∀-HARMONY can be given a slightly higher weight of 3 + ϵ, such that only (a) wins, as in §2.2.

Crucially, in any case, /[n]/ in the suffix — whose retroflexion is overt — must undergo in this system. Recall that a flapped out [ñ] does not violate IDENT(retro) as defined in (14), entailing that it gains the benefit of harmonizing without the penalty of losing its anteriority.6 This system therefore allows harmony to spread at no cost through any number of transparent interveners until a target is reached, at which point a benefit accrues to the candidate, given that it saves a violation of ∀-HARMONY at no cost from IDENT(retro). Tableau (40), showing the same input as (30) does in §2.2, is another example of freely variable hidden, but not overt, structure in this scheme.

6If IDENT(retro) were not evaluated this way, harmony could still be achieved by giving more weight to ∀-HARMONY to compensate. Constraints militating against flapping out, such as *Contour(retro), are assumed to have arbitrarily low weights.
Returning to the argument for ganging up, this set of weights properly handles the violability of \(*T\ï\) when harmony is not prefix-initiated, as shown in (41). In (41) and (42), irrelevant rules of debuccalization and vowel elision, respectively, are assumed by fiat. In (41), \(\forall\text-HARMONY\) outweights \(*T\ï\), making harmony the greater imperative.

When harmony would violate both \(*T\ï\) and CrispEdge, as in (42), it fails, since \(w(*T\ï) + w(\text{CrispEdge}) > w(\forall\text-HARMONY)\). With these weights, in fact, harmony does not spread beyond the prefix at all. Partial harmony towards target /n/ beyond the prefix confers no advantage, given its penalty from CrispEdge. With these weights, then, Sanskrit exhibits ‘sour grapes spreading’ (Padgett 1995, Wilson 2006, Walker 2010) in the sense that spreading only enters the post-prefix domain if it is ultimately rewarded by reaching a nasal target (for an example of a different type of sour grapes spreading, see Walker 2010). If harmony cannot be achieved fully, nothing compels it to extend all of the way up to the pre-target segment and then terminate.

Such a gang effect cannot be implemented in (classical) Optimality Theory (OT; Prince and Smolensky 1993/2004). In short, \([p\eta-i\text{-in}:ti]\) entails \(\forall\text-HARMONY \gg \text{CrispEdge}\)
and [ɕːkŋɑ̃] entails ∀-HARMONY ≫ *T₁. But the composite ranking ∀-HARMONY ≫ CRISPEDGE, *T₁ then incorrectly generates *[p̥t-aːpŋoːti]. One possible response in OT would be to fuse CRISPEDGE ∧ *T₁ into a single hybrid constraint local to the word. For arguments against constraint conjunction, see Pater (2009a). In the present case, for instance, the conjoined constraint would be violated (erroneously) even if the violations of CRISPEDGE and *T₁ came from two independent domains of harmony (see §4.3).

Given the weights here, the phonological distance between the trigger and target is irrelevant. If the roots in tableaux (39)–(42) were a thousand segments long, the winners would be the same, thanks to the trading off of violations between ∀-HARMONY and IDENT(retro) discussed above. Nevertheless, HG with the present CON but different weights could produce pathological distance effects. This issue is considered further in §5.3.

3.2 Philological addenda

This section will now conclude with some remarks on exceptions and on the lack of previous recognition of the rule described here. As a representative passage from an (anglophone) grammar, Whitney (1889: §195a) says only the following about post-plosive targets (Wackernagel 1896 says somewhat more, but the outlook for the present point is the same):

"The immediate combination of n with a preceding guttural or labial seems in some cases to hinder the conversion to ŋ: thus, vr.traghná etc., kšubhnáti, tr.pnoti (but in Veda tr.pn.u), kšepnú, sušumná."

This description implies that post-plosive targets vary freely, as indeed phonologists mentioning this caveat have taken it (Steriade 1995: 52f, Hansson 2010: 182). It is the nature of grammars, after all, to list exceptions without tempering them with clear indications as to the statistical robustness of the rule. To address Whitney’s examples, [√v̩t̩a-√ɡh̩ná:] follows the rule proposed here. [√kšu̩b̩-nV-] does not, but is sufficiently rare to be entirely absent (with either [n] or [ŋ]) from the present two-million-word corpus. [√t̩p-NV-] (N ∈ {n, ŋ}) occurs eight times and breaks the rule only once. In other words, Whitney foregrounds the exception, not the rule. [√kšep-nV-] occurs once and is a genuine exception. [su-√sum-nV-], for its part, is not included in the lists above, which consider only post-plosive targets. Its counts here are ‘v5’ for [n] and ‘v1 b1 e7’ for [ŋ].

[su-√sum-nV-] and two similar forms from the list of non-undergoers in (34), namely [vi-√skab̩-na] and [d(a)uš-√(s)uápn-ja], require further comment. In all three, the trigger [s] ostensibly occupies the root (ambiguously so in the case of [dušuápnja] from /dus-suápn-ja/), and none exhibits nati of a post-plosive target. While at first glance exceptions to the proposed rule, they arguably already follow from it, strictly construed. In these cases, the trigger acquires its retroflexion from the prefix via ruki (§2.2). Thus, they can all be analyzed as violating CRISPEDGE (assuming an amenable analysis of ruki), which, together with the post-plosive target, properly suppresses nati (but not ruki).

Putting aside these three forms with ruki as explained, then, the rule, as stated above, is a near-perfect generalization. All 138 tokens with post-plosive nati have a domain of
retroflexion that is root-initiated, and 1,648 of 1,652 (99.8%) of tokens with a failure of post-plosive nati have a domain of retroflexion that is pre-root-initiated. The only robust exceptions in this corpus are one token of [√kṣep-nV-], one of [√tṛp-nV-] (against seven of [√tṛp-ṇV-]), and possibly two of [bhṛg̥ta] in the Śāma-Veda, whose meaning could not be secured. At any rate, to the extent that any variation does occur, including highly skewed preferences, HG can accommodate it (e.g. Hayes and Wilson 2008, Pater 2009b).

4 Weak prefixes II: clashing spans of retroflexion

4.1 Data and HG analysis

As a further complication, nati also fails under certain predictable circumstances when a retroflex follows the target (within a certain proximity). As with post-plosive blocking in §3, this failure is by every indication systematic and productive. For example, consider once again the preverb [põa-], now with the root √nac- ‘vanish’ (or ‘reach’). As §3 demonstrated, [põa-] triggers nati in a root or suffix. /põa-nac-/ is no exception, as (43) reinforces.

(43) Nati applies before non-retroflex interval.
(a) [põa-ṇac-ja-ti] ‘vanishes (3s)’ (e53 vs. 0)
(b) [põa-ṇac-ja-n-ti] ‘vanish (3pl)’ (b2 e3 vs. 0)
(c) [põa-ṇac-in-i:] ‘destroyer (fem.)’ (e5 vs. 0)
(d) [põá-ṇak] ‘reach (aorist)’ (v4 b1 u1 vs. 0)
(e) [põa-ṇac-aj-e:] ‘destroy (3s caus. opt.)’ (e2 vs. 0)
(f) [põa-ṇac-a] ‘disappearance’ (e17 vs. 0)

But when the final consonant of √nac- is realized as retroflex (owing to irrelevant morphophonology), as seen most frequently in the participial stem [põa-ṇas-ṭa-] ‘vanished’, nati fails in the vast majority of instances, as shown in (44). Forms (c) and (d) do not appear in the present corpus, but are cited as such in the sources given (‘MW’ abbreviating Monier-Williams 1899).

(44) Nati fails before a retroflex interval.
(a) [põa-ṇas-ṭa-] ‘vanished (past pass. part.)’ (e80 vs. e9)
(b) [vi-põa-ṇas-ṭa-] ‘vanished (past pass. part.)’ (e11 vs. 0)
(c) [põa-ṇas-tum] ‘to vanish (inf.)’ (0 vs. 0; MW: 659)
(d) [põa-na-ṇ-k-ṣ-ja-ti] ‘will vanish (3s fut.)’ (0 vs. 0; Allen 1951: 946)

In sum, the corpus contains a total of 320 instances of /põa-nac-/. Of them, 218 have a non-retroflex ending, and nati applies in 100% of those cases. The remaining 102 have a retroflex ending, and nati fails in 91% of those cases. Moreover, the pattern suggested by this paradigm is general. Regardless of the prefix and root involved, nati fails to penetrate the root domain when a retroflex follows the target within the first interval (Steriade 2009b), i.e., VC₀ (also provided that no blocker intervenes, as in [nāṭa]). Some other examples are given in (45). Diagnostic forms are infrequent because the requisite set-up is quite specific,
being a trigger-containing prefix on a stem with a visible dental nasal followed by a visible retroflex, which in Sanskrit is unlikely to be provided by a suffix. But insofar as forms meeting these criteria are found, the generalization is well-supported.

\[(45)\]

(a) \([\text{põa-\text{nõt-}}]\) ‘dance forth’ (v1 e32 vs. 0)
(b) \([\text{paõi-\text{nõt-}}]\) ‘dance around’ (v3 e1 vs. 0)
(c) \([\text{põa-\text{nãd-}}]\) ‘roar’ (e1 vs. 0)
(d) \([\text{põa-\text{nakš-}}]\) ‘approach’ (0 vs. 0; MW: 681)
(e) \([\text{paõi-\text{nakš-}}]\) ‘encompass’ (0 vs. 0; Macdonell 1910: §47)

Aside from the nine exceptional (against 91 regular) tokens of \([\text{põa-\text{nåt-}}]\) mentioned in (44), the only other cases in the corpus in which a prefix triggers nati in a root domain in which the following interval is retroflex are given in (46).\(^7\) Note that all five tokens in (46) involve a long vowel intervening between target and potential suppressor, unlike all of the cases in (44) and (45); this detail is revisited in §4.2.

\[(46)\]

(a) \([\text{põa-\text{ne-\text{s-ja-}}}]\) ‘lead forth (fut.)’ (b1 e2 vs. 0)
(b) \([\text{põa-\text{ne-\text{s-at}}}]\) ‘lead forth (3s subj.)’ (v1 vs. 0)
(c) \([\text{põa-\text{na/-\text{ja-}}}]\) ‘waterway’ (e1 vs. 0)

That nati is suppressed by a following retroflex is already well-established in the literature (Macdonell 1910: §47, Allen 1951: 945f, Hansson 2010: 184), though to my knowledge no formal analysis of it has been put forth. Hansson (2010: 184) suggests that it might arise from misperception, specifically, the hypocorrective misattribution of the source of the cues for retroflexion on the nasal to the surrounding retroflexes. But given the data to be presented in (47), this explanation can hardly be correct: In other contexts, Sanskrit orthoepy/orthography consistently records retroflexion on nasals in inter-retroflex position.

Previous discussions do not make explicit the fact that suppression by a following retroflex happens in only a very limited context that is both morphologically and phonologically determined. Hansson (2010), for one, implies that the blocking is unbounded, reporting only that “when there is also an /s/ or /r/ later in the word, retroflexion fails to apply” (184; original emphasis).\(^8\) Indeed, Macdonell (1910), whom he cites, leaves this interpretation open. Graf (2010) and Jardine (2014) also take the suppression domain to be potentially unbounded, with appropriate caution. Allen (1951) rightly specifies that the suppressing retroflex can be at most one vowel away, but omits any mention of morphological conditioning.

In particular, suppression by a following retroflex occurs only when the trigger-target span crosses \(\sqrt{\text{√}}\), the left edge of a root. Within the root-suffix complex, nati applies regardless of

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\(^7\)Though it is not a verbal form, the Vedic compound \([\text{sV` aõ-ïaõa}]\) ‘sky-man’ (v17 b4 e4 vs. 0) is also an exception to the analysis proposed in this section. Other compounds, such as \([\text{cikùa:-naõa}]\) ‘trainer, facilitator’ (v3 vs. 0), follow the generalization. Either the adjacency of the trigger and target is relevant for \([\text{sV` aõ-ïaõa}]\), or perhaps there is simply some lexical variation in compounds.

\(^8\)The restriction of the following suppressor to retroflex continuants as opposed to retroflex consonants in general is also unmotivated and not adopted here. The single token in (46-c) is not decisive, since the long vowel in that case might be blamed for attenuating the suppressive influence of the following [d].
whether the following interval contains a retroflex, as the examples in (47) (among numerous others) illustrate. In fact, such cases of non-suppression within the root-suffix complex vastly outnumber the cases of cross-√ suppression considered above.

(47) (a) [√bõa:ñiañ-é-š-śu] ‘Brahmins (loc. pl.)’ (v2 b1 e67 vs. 0)  
(b) [√põa:ñi-é-šu] ‘breaths (loc. pl.)’ (v1 b16 u7 e7 vs. 0)  
(c) [√gũi-ñi-ś-śu] ‘grasp (2s imp.)’ (e15 vs. 0)  
(d) [√k̩-ñu-ś-śu] ‘do/make (2s imp.)’ (v26 b1 vs. 0)  
(e) [√põ-ñ-ka-ś-śi] ‘unite (2s)’ (v8 b2 vs. 0)  
(f) [√põa:ñ-i-ś-śu] ‘breathers (loc. pl.)’ (e7 vs. 0)  
(g) [√põa:ň-√4ši] ‘ancient rishi’ (e6 vs. 0)  
(h) [√iān-t-i-ś-ta] ‘rejoice (2pl aorist)’ (v1 vs. 0)  
(i) [a-√4a:ñ-i-ś-uh] ‘rejoice (3pl aorist)’ (v1 vs. 0)

Descriptively, then, the new generalization can be summarized as in (48), whose structure mirrors (38) in §3.

(48) (a) When the trigger and target straddle a prefix-root juncture, nati generally applies.  
(b) When the target immediately precedes an unblocked retroflex interval, nati generally applies.  
(c) When the trigger and trigger straddle a prefix-root juncture and the target immediately precedes an unblocked retroflex interval, nati fails.

As (48) implies, a gang effect with CrispEdge is once again in evidence. What remains to be treated is nature of the markedness constraint implied by (b). Here, it is proposed that the failure of harmony in such cases reflects the OCP (Obligatory Contour Principle; Leben 1973, McCarthy 1986, Myers 1997) or a similar proximity principle. OCP(retro) in (49) penalizes every instance in which two spans of retroflexion come into contact.

(49) OCP(retro): Penalize adjacent domains of retroflexion.

On this approach, [põa-√4n-ś-ś-], for instance, fails to undergo nati because doing so would give *(põa-√n-ś-t-), which violates both OCP(retro) and CrispEdge (other constraints, namely, FlapOut and IdentI→O(retro) in §2.2, prevent fusing or deleting the autosegments). Nevertheless, this approach falls short, given forms such as [põa-√ň-ś-ś-] in which a vowel intervenes between target and suppressor. Candidate *(põa-√n-ś-t-ś-) is not penalized by OCP(retro).

But *(põa-√n-ś-t-ś-) runs afoul of other articulatory and perceptual desiderata. Articulatorily, it requires a rapid excursion in tongue tip position. The tip, having just flapped out from [ň], must immediately flap back up for [ś], all in the course of a short vowel. Rapid excursions are often avoided in autosegmental systems. In tonology, *HLH is sometimes invoked to handle such cases (e.g. by McPherson 2014 as “Penalize two H tones separated by a single L association line” (19); also Cahill 2007, Hyman 2010; cf. *TROUGH in Yip 2002).
Moreover, perceptually, the cues for retroflexion manifest more on a preceding than following vowel (§2.2). Accordingly, many languages license retroflex contrasts only post-vocically (though this is less of an imperative for fricatives, which have better internal cues and do not flap out, as discussed in §2.2). A sequence V(C...) is particularly marked in that the vowel actively conflicts in anteriority with the following consonant. Its markedness can be captured by LICENSE(retro) in (50) (cf. RETRO/V_ in Steriade 1995; the present formulation only clarifies that the preceding vowel must actually be able to manifest the cues of retroflexion in order to confer any perceptual benefit to the following retroflex consonant). This formulation penalizes word-initial retroflexes, but DEP and IDENT_I→O(retro) are highly weighted, so they stand. Managing additional phonotactics, such as the differing distributions of retroflex fricatives and stops, would take us too far afield here.

(50) LICENSE(retro): Penalize a retroflex coronal that is not licensed by a preceding vowel (where ‘licensed’ means it shares a domain of retroflexion).

Given these constraints, the analysis runs as follows. First, the fact that a prefix such as [põa-] normally triggers harmony across √ continues to hold, as (51) illustrates. (Adding LICENSE removes one of the hidden-structure options in (40) in §3, but there is no harm in doing so.) In the following three tableaux, irrelevant sandhi operations (final neutralization, ruki, and retroflexion of a cluster, respectively) are assumed by fiat.

(51)

<table>
<thead>
<tr>
<th>põa-√nac</th>
<th>H</th>
<th>√-HARMONY</th>
<th>IDENT</th>
<th>LICENSE</th>
<th>OCP</th>
<th>CrispEdge</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (põa-√n)ak</td>
<td>-17</td>
<td>-2</td>
<td>-2</td>
<td>-1</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>b. p(õa-√n)ak</td>
<td>-17</td>
<td>-3</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>c. p(õ)a-√nak</td>
<td>-18</td>
<td>-5</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>d. (põ)a-√nak</td>
<td>-18</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>-1</td>
<td></td>
</tr>
</tbody>
</table>

Second, when no √ intervenes, an OCP violation is tolerated, as in (52). Once again, candidates with fusion and deletion are ruled out by other constraints in §2.2.

(52)

<table>
<thead>
<tr>
<th>√ian-i-s-</th>
<th>H</th>
<th>√-HARMONY</th>
<th>IDENT</th>
<th>LICENSE</th>
<th>OCP</th>
<th>CrispEdge</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. √(qan)(iš)-</td>
<td>-29</td>
<td>-5</td>
<td>-3</td>
<td>-1</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>b. √(q)ani(s)-</td>
<td>-33</td>
<td>-8</td>
<td>-1</td>
<td>-2</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>c. √(q)ni(s)-</td>
<td>-33</td>
<td>-7</td>
<td>-2</td>
<td>-2</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>d. √(qan)i(s)-</td>
<td>-30</td>
<td>-6</td>
<td>-2</td>
<td>-2</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>e. √(q)an(iš)-</td>
<td>-30</td>
<td>-7</td>
<td>-2</td>
<td>-1</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>f. √(q)n(iš)-</td>
<td>-30</td>
<td>-6</td>
<td>-3</td>
<td>-1</td>
<td>-1</td>
<td></td>
</tr>
</tbody>
</table>
Finally, when √ would interrupt harmony in (53), harmony fails, thanks to the collective weight of OCP and CrispEdge: \( w(\text{OCP}) + w(\text{CrispEdge}) > w(∀-\text{HARMONY}) \). LICENSE > CrispEdge ensures that the second span cannot retreat across the vowel to save the OCP violation, as candidate (b) demonstrates.

Beyond harmony, the activity of OCP(retro) and License(retro) is corroborated by reduplication in Sanskrit. Consider the desiderative, which comprises both a CV reduplicant prefix in which V is high and a sibilant suffix /-s/. If the root is /s/-initial and no retroflex follows, the root undergoes ruki retroflexion conditioned by the prefix, as in [si-√sa:s-] ‘wish to gain’ (for √sa:) and [su-√su:s-] ‘wish to sleep’ (for √suap). But if the following interval contains an unblocked retroflex, ruki is usually (though not always) suppressed, as in [si-√saŋk-ś-] ‘wish to hang’ (for √sañé) and [si-si:õ-ś-] ‘wish to flow’ (for √sõ).

### 4.2 Philological addenda

This proposal agrees with the previous research (Macdonell 1910: §47, Allen 1951: 945f, Hansson 2010: 184) concerning the existence of a blocking effect of a following retroflex. Nevertheless, a few of the forms cited by these other researchers in favor of blocking, namely, those in (54), are not covered by the analysis here as it stands. Corpus counts are based on the present corpus, ‘=’ indicates a compound boundary, and ‘X’ subsumes all attested first members of the compound containing a visible trigger.

<table>
<thead>
<tr>
<th>(53)</th>
<th>põa-√naC-ta-</th>
<th>H</th>
<th>∀-HARMONY</th>
<th>IDENT</th>
<th>LICENSE</th>
<th>OCP</th>
<th>CrispEdge</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>(põa)-√n(aṣ-t)a-</td>
<td>-48</td>
<td>-10</td>
<td>-5</td>
<td>-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>(põa-√n)a(ś-ṭ)a-</td>
<td>-53</td>
<td>-10</td>
<td>-5</td>
<td>-3</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>(põa-√n)(aṣ-ṭ)a-</td>
<td>-49</td>
<td>-9</td>
<td>-5</td>
<td>-1</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>p(ṭ)a-√na(ś-ṭ)a-</td>
<td>-54</td>
<td>-13</td>
<td>-2</td>
<td>-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>(põa)-√na(ś-ṭ)a-</td>
<td>-54</td>
<td>-11</td>
<td>-4</td>
<td>-3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Forms (a–b) involve non-application across the boundary between two preverbs, which is not the left edge of a root, and therefore not predicted to be a context for suppression by this analysis. On the one hand, one could posit that the left edge of every preverb is also a √-level boundary, which would not be unusual typologically. On the other hand, there is an alternative possible explanation for these cases: In Epic Sanskrit, natī application across (at least certain) preverbs is unreliable in general. Tellingly, though the relevant examples are sparse, a few tokens of the same preverb [pāḷ-] before [ni-] or [nis-] (=niṭ-)] are attested without a following retroflex, and in all four examples (viz. [pāḷ-ni-√g₄nanta],...
Forms (c–d) are compounds in which the second member begins with a prefix. Once again, the left edge of a prefix is not the left edge of a root. Nevertheless, it would not be out of line typologically to assume that at least a $\sqrt{a}$-level boundary stands between the members of these compounds (cf. Kiparsky 2010). It is also the case, as with preverbs, that nati application is in general more variable across members of compounds (cf. §3 and footnote 7), though in this case a stronger argument can be made for blocking. The initial members of the compounds in (c–d) comprise [puŋi-], [sa-fi-qa-], [can-də-], and [va-ṣa-]. In every one of the 12 instances in the Rg-Veda in which one of these initials attaches to a /nV[retroflex]/ base, nati fails. By contrast, in every one of the eight instances in which one of these initials attaches to any other /n/-initial base, nati succeeds, a significant difference (Fisher’s exact test $p < .0001$). Thus, the expansion of $\sqrt{a}$ to compound boundaries is likely to be motivated, at least for Vedic.

Finally, the exceptions to retroflex suppression in (46), namely [põa-$\sqrt{a}$ie:-ù-] (v1 b1 e2) and [põa-$\sqrt{a}$a:i-ja-] (e1), still escape the current analysis. As noted, however, they all involve retroflex intervals with long vowels, unlike all of the cases exhibiting suppression. Since a long vowel is better able to host a retroflex contour, LICENSE(retro) in (50) could be amended to specify that only a single vocalic mora is required for retroflex licensing. Given the rarity of these exceptions, however, this potential refinement is not pursued here.

4.3 The failure of constraint conjunction

The outlook is the same as in §3. While prefixes generally trigger harmony, the phonological contexts that they access comprise a proper subset of those accessed by triggers originating in the root-suffix complex. This subset relation is here modeled as a gang effect in HG. As argued in §3, an OT account would require invoking conjoined constraints that, aside from their intrinsic complexity and more challenging learnability, are pathological empirically (Pater 2009a). For example, in the present case, OCP $\land$ CRISPEDGE local to word (it could not be local to a smaller constituent, such as the root) erroneously predicts that harmony will be blocked even when the violations of OCP and CRISPEDGE come from independent domains of harmony.

Consider, for example, the compound [põa-$\sqrt{a}$a:i-ja-$\sqrt{a}$a:i-ja:] (e1), in which a violation of CRISPEDGE comes from the first member and an unrelated violation of OCP comes from the juncture between the final two members. Harmony is never suppressed in such cases, as the HG analysis here properly captures, as in (55). Candidates (b–e) are merely bookkeeping showing which hidden structure is optimized given the weights. This optimal hidden structure appears in the winner (a) and in contenders (f–g), which contain the critical comparisons with (a) in terms of overt structure.

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9The preverb sequence [põa-] + [ni-], for its part, always undergoes nati (as [põa-ni-]), but there is no example of this sequence followed by a retroflex interval to reveal whether suppression would occur.
With a conjoined constraint, namely, OCP ∧ CrispEdge, an OT analysis can handle the simple cases. First, all else being equal, harmony crosses $\sqrt{}$, as in (56).

Second, all else being equal, harmony spreads up to a retroflex interval, as in (57).

Third, when the domain of harmony would have to cross $\sqrt{}$ and the potential target immediately precedes a retroflex interval, as in (58), harmony fails. This is once again the correct outcome.
The locality problem becomes apparent in more complex cases, such as the compound in tableau (55) above, which in (59) is now submitted to the OT grammar just established. Given the ranking(s) necessary to handle tableaux (56)–(58) properly, the wrong candidate inevitably wins in (59). Candidate (a), with nati applying at both potential loci, should win, as it did in the HG tableau in (55). But the conjoined constraint now eliminates it, oblivious to the independent origins of the violations of the OCP and CrispEdge. Whether (c) or (d) wins in this tableaux depends on whether OCP dominates CrispEdge, which is indeterminate in (56)–(58). Either way, however, the output is incorrect. OT-Help 2.0 (Staubs et al. 2010) was once again employed to check that no ranking works for all four OT tableaux in this section.

4.4 Final weights

The full set of weights for the classical HG analysis in this article is summarized in (60). Only three weight levels need be posited, namely, 2, 3, and ‘arbitrarily high,’ i.e., undominated. This is only one possible set of weights (as determined by OT-Help 2.0); other vectors would also be compatible with the data.
5 Analytical comparisons

5.1 Classical serial harmony

This section argues that a Harmonic Serialism (HS) analysis of the generalizations discussed in §3–4 is not viable, either in an OT or HG setting, without introducing constraints implementing non-local dependencies between triggers and targets (Mullin 2011, Walker 2014; see §5.2).

HS is like classical OT/HG in that each language comes with a fixed ranking or weight vector over constraints. Unlike classical OT/HG, however, only one operation (e.g. addition or deletion of an association line) is permitted per GEN/Eval cycle, and the output of each evaluation is recycled as an input to a new evaluation until no more changes are optimizing, at which point the derivation converges. On harmony in HS, as well as more general background on the theory, see McCarthy (2009, 2011) and references therein.

Following McCarthy (ibid.), SHARE, as defined in (61), is employed as a pro-harmony constraint in this section, though for the present purposes it is interchangeable with ∀-HARMONY. Indeed, when there is exactly one span of retroflexion in a candidate, their violation profiles are identical, and nothing here is affected by their subtle differences in other situations. All other constraints are defined as in previous sections.

(61) SHARE(retro): For every pair of adjacent segments, assign a penalty if they are not both linked to the same token of [retroflexion].

Consider the derivation of [(õe˙:k˙ï)ah] from /õe:knah/ in (62). Spreading to the target proceeds one segment at a time, eroding violations of SHARE along the way until the target is reached, at which point spreading any further violates FLAPOUT. The output in this last step is the same as the input, meaning that the derivation has converged.\(^{10}\)

\(^{10}\)As defined in §2.2, IDENT is not violated by flapping out in step 3, though this detail is irrelevant here.
Serial OT fails to capture the gang effect in §3.1 for the same reason that non-serial OT does. In particular, SHARE must dominate *\text{Tr}\_l as just demonstrated (step 3), and must also dominate CrispEdge to motivate spreading across \(\sqrt{\text{}}\) in the general case. But then SHARE \(\gg \) \{*\text{Tr}\_l, CrispEdge\} erroneously induces spreading across \(\sqrt{\text{}}\) to a post-plosive target. Just as in §3.2 and §4.3, a conjoined (or similarly multi-predicate) constraint could be invoked as a patch, but it comes with the same baggage as before, including both incorrect empirical coverage (§4.3) and analytical extravagance: The conjoined constraint, after all, does not replace the two constraints it combines, but rather adds to them a third that is both complex and not independently motivated. On the non-serial HG approach, the work of the conjoined constraint falls out from the interaction of the two simple and independently needed constraints.

More interesting, perhaps, is that serial HG (Pater 2012, Mullin 2011, Kimper 2011) also cannot capture the gang effect, given that the violations of *\text{Tr}\_l and CrispEdge do not arise in the same step. In (63), these two constraints are poised to gang, collectively outweighing SHARE. In step 2, because \(w(\text{SHARE}) > w(\text{CrispEdge}) + w(\text{IDENT})\), harmony crosses \(\sqrt{\text{}}\), oblivious to the post-plosive target lying in its path. When the domain reaches this target in step 4, the damage to CrispEdge is already done, in that all available candidates violate it. At that point, then, the grammar has no choice but to treat /pn/ in (63) like /kn/ in (62) and harmonize the nasal. Indeed, for this reason, no possible weighting of these constraints in serial HG can correctly handle as a suite all three cases exemplified by [\text{põa}\sqrt{\text{Hiïo:ti}}], [\sqrt{\text{õe:kïah}}, and [\text{põ}\sqrt{\text{a:pno:ti}}]. The convergence tableau (step 5) is omitted in (63) because FlapOut is not shown.
(63) Step 1.

\[
\begin{array}{|c|c|c|c|c|}
\hline
p(\eta)\sqrt{a:p-nor-ti} & \mathcal{H} & \text{SHARE} & *\text{T}_\text{R} & \text{CrispEdge} & \text{IDENT} \\
\hline
a. \not\in (p\eta)\sqrt{a:p-nor-ti} & -37 & -6 & 4 & 3 & 1 \\
b. p(\eta)\sqrt{a:p-nor-ti} & -42 & -7 & & & \\
c. p(\eta\sqrt{a:p-nor-ti} & -40 & -6 & -1 & -1 & \\
\hline
\end{array}
\]

Step 2.

\[
\begin{array}{|c|c|c|c|c|}
\hline
(p\eta)\sqrt{a:p-nor-ti} & \mathcal{H} & \text{SHARE} & *\text{T}_\text{R} & \text{CrispEdge} & \text{IDENT} \\
\hline
a. \not\in (p\eta\sqrt{a:p-nor-ti} & -34 & -5 & 4 & 3 & 1 \\
b. (p\eta)\sqrt{a:p-nor-ti} & -36 & -6 & & & \\
\hline
\end{array}
\]

Step 3.

\[
\begin{array}{|c|c|c|c|c|}
\hline
(p\eta\sqrt{a:p-nor-ti} & \mathcal{H} & \text{SHARE} & *\text{T}_\text{R} & \text{CrispEdge} & \text{IDENT} \\
\hline
a. \not\in (p\eta\sqrt{a:p-nor-ti} & -28 & -4 & 4 & 3 & 1 \\
b. (p\eta\sqrt{a:p-nor-ti} & -33 & -5 & & & \\
\hline
\end{array}
\]

Step 4.

\[
\begin{array}{|c|c|c|c|c|}
\hline
(p\eta\sqrt{a:p-nor-ti} & \mathcal{H} & \text{SHARE} & *\text{T}_\text{R} & \text{CrispEdge} & \text{IDENT} \\
\hline
a. \not\in (p\eta\sqrt{a:p-nor-ti} & -25 & -3 & 4 & 3 & 1 \\
b. (p\eta\sqrt{a:p-nor-ti} & -27 & -4 & & & \\
\hline
\end{array}
\]

5.2 Serial harmony with *DP-HEAD(W)

Mullin (2011: 10, 42) describes two cases of weak triggering in harmony that in some respects resemble the Sanskrit cases here, analyzing them in serial HG augmented with a new constraint family, *DEPENDENT-HEAD(W) (abbreviated *DP-HEAD(W)). In Cairene Arabic, for instance, the emphatic coronals \{tʰ, dʰ, sʰ, zʰ, rʰ\} trigger regressive emphasis harmony. But [rʰ] is weaker than the other triggers, in that a high front vocoid blocks spreading from [rʰ] but not from the other triggers (Watson 2002: 270–6). As in §5.1, harmony is driven by SHARE. Blocking can follow from a feature co-occurrence constraint, e.g. *[RTR, +hi, -back]. But a system with only these two constraints cannot distinguish strong from weak triggers. The crucial third ingredient is *DP-HEAD(W), as in (64), where W in this case characterizes [r]. Furthermore, headed spans are assumed, such that every domain of spreading is headed by a particular segment, normally the trigger (e.g. McCarthy 2004).

(64) *DP-HEAD(W): “Assign a violation for every dependent of a featural domain that is headed by a segment with feature set W” (Mullin 2011: 40).

This approach works only in an HG setting, since *DP-HEAD(W) must gang up with *[RTR, +hi, -back] to overcome SHARE. If *DP-HEAD(W) dominated SHARE, the weak
trigger would never initiate harmony. If \([\text{RTR, } +hi, -back]\) dominated \(\text{SHARE}\), blockers would block strong and weak triggers alike. Finally, if the collective weight of \(*\text{DP-HEAD}(W)\) and \([\text{RTR, } +hi, -back]\) was less than that of \(\text{SHARE}\), blockers would fail to block strong and weak triggers alike. Note also that \(*\text{DP-HEAD}(W)\) requires gradient assessment, in the sense that it penalizes a weak span according to its size. For example, a weak span containing ten segments receives nine violations.

For this approach to transfer to Sanskrit, \(W\) cannot be a feature matrix, but must refer to morphological structure, either by specifying prefixhood (65) or the root boundary (66).

\begin{align*}
(65) \quad & *\text{DP-HEAD}(\text{prefix}): \text{Assign a violation for every dependent of a [retroflex] domain that is headed by a segment in a prefix.} \\
(66) \quad & *\text{DP-HEAD}(\sqrt{\_}): \text{Assign a violation for every dependent of a [retroflex] domain that contains } \sqrt{ }. \\
\end{align*}

These two formulations make different predictions, though Sanskrit data might not decide between them. \(*\text{DP-HEAD}(\text{prefix})\) entails that intra- or inter-prefix contexts are treated like cross-\(\sqrt{ }\) contexts, in that a post-plosive or pre-retroflex target within the prefix domain would fail to undergo. \(*\text{DP-HEAD}(\sqrt{ })\) is closer to the analysis above in that it is not prefixhood \textit{per se} that attenuates harmony, but the breach of \(\sqrt{ }\). Harmony is then expected to apply within the pre-\(\sqrt{ }\) domain exactly as it applies in the post-\(\sqrt{ }\) domain. This second formulation arguably possesses the advantage of explaining why prefixes are weak without merely stipulating them to be weak. More concretely, it links the weakness of prefixes to another testable aspect of the prosody: Prefixes as opposed to suffixes are weak triggers in Sanskrit because the greater juncture occurs at the prefix-root boundary. On the \(*\text{DP-HEAD}(\text{prefix})\) formulation, it is a stipulation that \(*\text{DP-HEAD}(\text{prefix})\) and not \(*\text{DP-HEAD}(\text{suffix})\) is the active constraint. Moreover, as discussed in §3, cross-linguistically, prefixes are less likely than suffixes to serve as triggers, just as they tend to be more separate prosodically. Only formulation (66) lends these generalizations to a potential synthesis.

At the same time, however, \(*\text{DP-HEAD}(\sqrt{ })\) is more of a departure from Mullin (2011), in that it specifies a property of the domain that does not inhere in its head. Thus, for illustrative purposes, \(*\text{DP-HEAD}(\text{prefix})\) is employed here, but with the caveats just mentioned. In derivation (67), it is assumed that /1/ is the head of the retroflex span at every step, though in a fuller analysis, this would have to be guaranteed through constraint weighting. IDENT is set at zero for simplicity, but could be given greater weight. \(*\text{DP-HEAD}(\text{prefix})\) essentially tempers the benefit of spreading when the head is weak; it is an anti-harmony constraint. Each segment added to the prefix-initiated domain gains 6 points on \(\text{SHARE}\) but loses 3 on \(*\text{DP-HEAD}(\text{prefix})\), such that the net benefit of adding one segment to a weak domain is 3. Because this net benefit is less than the weight of \(*\text{T}_{\text{NI}}\) when a weak span reaches /n/, upholding \(*\text{T}_{\text{NI}}\) is a greater imperative than spreading to one more segment. A strong domain, on the other hand, gets all of the benefit \(\text{SHARE}\) (6 points per segment) with none of the cost of \(*\text{DP-HEAD}(\text{prefix})\). Thus, a strong domain will induce violation of \(*\text{T}_{\text{NI}}\) whose strength is only 4.
The analysis succeeds, but at the price of introducing to serial HG a family of non-local dependency constraints which continue to look back to the origin of harmony, whatever its distance, with each new addition to the domain. In this sense, then, certain non-myopia can be couched in serial HG. The proposal of Mullin (2011) would also need to be extended to cover morpho-prosodic conditions, not just phonological features. Moreover, it remains to be seen whether it is sufficient for such non-local dependencies to refer only to heads of domains, or whether they must refer also to other properties of domains, such as boundary containment. As suggested above, pinning span weakness on prefixhood \textit{per se}, as opposed to √-crossing, could in principle be empirically wrong for Sanskrit, though diagnostic data are sparse. In the one-pass HG analysis in §3–4, the weakness of prefixes (but not suffixes) as triggers was derived from their greater prosodic separation from the root. But if *DP-HEAD(prefix) and *DP-HEAD(suffix) are both in CON, either could have been active in Sanskrit, regardless of whether prefixes or suffixes cohere more. Further research on other harmony systems could shed more light on these questions.

### 5.3 Pathologies of the HG approaches

As argued above, an OT approach, whether classical or serial, and even if augmented with conjoined constraints in either case, undergenerates the Sanskrit pattern. A straightforward
classical HG analysis is available. A serial HG analysis is also available if a certain type of non-local dependency constraint is admitted. That said, a drawback of both HG approaches, especially the classical one, is overgeneration. Reining in such too-many-solutions pathologies, as they are sometimes called, remains an area of perennial focus in constraint-based theory (cf. Wilson 2000, 2001, Blumenfeld 2006, Steriade 2009a).

∀-HARMONY is part of a family pro-spreading constraints (including SPREAD and ALIGN) known to exhibit certain pathologies (Wilson 2003, McCarthy 2004, 2009, 2011, Kimper 2011). For instance, since these constraints penalize unharmonized segments, they predict deletion of non-undergoers or blockers, an unattested pattern. Set in a classical HG framework, the situation is even worse, since a gradiently evaluated constraint such as ∀-HARMONY is subject to what might be called the cut-off-point pathology, as illustrated with constructed examples in (68) and (69). In this grammar, a blocker / tu / is deleted to permit retroflexion to spread further in service of ∀-HARMONY (already a pathology), but only if more than seven segments would otherwise remain unharmonized. The cut-off could not only be seven, of course, but any number, as determined by the ratio of \( w(\text{MAX}) \) to \( w(∀-\text{HARMONY}) \).

(68)

<table>
<thead>
<tr>
<th></th>
<th>Max</th>
<th>∀-Harmony</th>
</tr>
</thead>
<tbody>
<tr>
<td>(st)amamama</td>
<td>7.5</td>
<td>1</td>
</tr>
<tr>
<td>a. t° (st)amamama</td>
<td>-7</td>
<td>-7</td>
</tr>
<tr>
<td>b. (șamașama)</td>
<td>-7.5</td>
<td>-1</td>
</tr>
</tbody>
</table>

(69)

<table>
<thead>
<tr>
<th></th>
<th>Max</th>
<th>∀-Harmony</th>
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</thead>
<tbody>
<tr>
<td>(st)amamamam</td>
<td>7.5</td>
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<td>a. t° (st)amamam</td>
<td>-8</td>
<td>-8</td>
</tr>
<tr>
<td>b. t° (șamașama)</td>
<td>-7.5</td>
<td>-1</td>
</tr>
</tbody>
</table>

As mentioned in §2.2, the arguments in this article (e.g. for morpho-prosodic conditioning and ganging) do not depend on invoking ∀-HARMONY as opposed to some other harmony-inducing constraint. One possible solution to the cut-off-point pathology while remaining in HG would be the use of a non-gradiently evaluated pro-harmony constraint such as *A-Span in a headed spans framework (McCarthy 2004).\(^1\) For this approach to work for nati, however, the framework described by McCarthy (2004) would require substantial revision, which would have taken us too far afield in §2.2.

Consider a simple example of nati, such as /ãana/ → [aŋa]. Parenthesizing spans of retroflexion and anteriority, the output is [(aŋa)(a)]. In headed spans, harmony is motivated by *A-Span, which assigns a penalty for each span juncture, effectively promoting more inclusive spans. Given the discussions of FLAPOut and non-iterativity in §2.2, [(aŋa)(a)]

\(^{1}\)Another general line of defense against cut-off-point pathologies is learnability. For example, if the HG learner is Bayesian or maximum entropy-based, even if the theory permits formulation of a particular strict cut-off, the cut-off might be difficult to learn as such without a large amount of very specific evidence of the sort that is unlikely to obtain in a natural setting.
cannot be reduced to a single span. The question is then what makes it superior to contenders *[(õa˙)(na)] and *[(õ)(ana)], also with single violations of *A-Span, but without nati. McCarthy’s (2004) strategy of motivating blocking by making blockers head their own spans is not at first glance viable for Sanskrit, since the blocker /n/ also undergoes. Thus, a constraint such as CorHd, which requires a coronal to be the head of its span, is of no help. The should-be winner [(õa˙)(a)] is still harmonically bounded by *[(õa˙)(na)].

If the theory is revised such that spans can be subsegmental, there may be a way out. In particular, [n], as motivated in §2.2, is actually a contour segment [ñ]. Let us assume, then, that the two portions of this segment occupy different anteriority spans, as in [(õa˙n)(a)], with the understanding that [n](n) is not a consonant cluster. [(õa˙n)(na)] is still at this point harmonically bounded by *[(õa˙)(na)]. But the latter can be ruled out by adding a constraint, say, LICENSE(ant), that penalizes an anterior coronal unlicensed by a preceding anterior vowel (cf. LICENSE(retro) in §4.1). At last /qana/ can be analyzed, as in (70), in which heads of spans are underlined, SpHdL requires spans to be left-headed, and *Contour (unnecessary here) is violated by flapping out. But this is only the most basic case; it is left to future work to determine whether this approach, and particularly its extension to subsegmental spans, is viable for the other nati facts and for harmony in general.

![Table](70)

Serial HG augmented with *Dp-Head(W) has its own set of pathologies. *Dp-Head(W) is effectively an anti-harmony constraint which is rewarded by reducing the size of a harmonic span (a weak span, to be sure, but any head can be defined as weak given the constraint template). To do so, one strategy is deletion. Allowed to gang with other phonotactics, it can produce effects in which marked structure is deleted, or epenthesis forbidden, within harmonic spans, but not elsewhere. For example, if \(w(\text{Max}) = 3\), \(w(*\text{Dp-Head(W)}) = 2\), and \(w(*\text{Tn}) = 2\), \(\text{Tn}\) clusters are resolved by deletion within a harmonic span but left to stand elsewhere, e.g., schematically, \([\text{aṅkṣṇ}a]\text{kṣṇa} → [(\text{aṅ}aṅa)\text{kṣṇa}]\). This specific example might be answered if /k/ in HS cannot be deleted in one fell swoop, but must pass through gradual reductions (McCarthy 2008). However, even with gradual attrition, if the weakest pre-deletion stage, say, [?] or [h], is part of the relevant phonotactic, the pathology stands. For example, substituting NoCoda for *Tn and deploying whatever the weakest link is as codas, we get \([(\text{aṅ}aṅa)\text{ṅaṅa}] → [(\text{aṅ}aṅa)\text{ṅaṅa}]\). Furthermore, such deletion could be confined to the subset of harmonic spans whose triggers are defined as weak.

A similar pathology obtains for epenthesis, wherein epenthesis is permitted to resolve a cluster such as *Tn in strong domains but not in weak ones. A weight vector giving this pathology is <5, 2, 2, 1> for <Share, *Tn, *Dp-Head(W), Dep>. As confirmed in OT-
Help 2.0 (Staubs et al. 2010), for a strong span, harmony first spreads over the stop and nasal and then epenthesis occurs between them (because $w(*T\eta) > w(Dep)$). For a weak span, harmony once again spreads over T and $\eta$, but then the derivation converges without epenthesis (because $w(*T\eta) < w(*Dp\text{-}Head(W)) + w(Dep)$). The several tableaux involved are omitted here to save space. This pathology could perhaps be answered by restricting epenthesis into spans via GEN, but the details remain to be explored.

In short, every approach has pathologies, though some are more troubling than others, and this is an area of ongoing research (see also Walker 2014 for a recent discussion of ∀-HARMONY that does not overlap with the points in this section). It is not the goal of this article to argue for a particular pro-harmony constraint, though it is maintained that an OT setting (classical or serial) is insufficient. The primary purpose is to document new cases of non-myopia and to show how they can be analyzed through the interaction of independently motivated markedness constraints, whatever the pro-harmony apparatus.

6 Conclusion

Sanskrit retroflex spreading is attenuated by root boundaries, such that triggers in prefixes access fewer targets in the root-suffix complex than do triggers originating in the root-suffix complex. At least two independent processes demonstrate this attenuation. First, only a non-prefix-initiated trigger can access a post-plosive target (§3). Second, only a non-prefix-initiated trigger can access a target that immediately precedes a retroflex interval (§4). These restrictions reveal the activity of two markedness constraints, taken here to be $*T\eta$ (*vel sim.*) and the OCP, respectively. Permitted to gang with CrispEdge in HG, they implement the observed subset relation among triggers. On the other hand, an OT analysis, whether classical or serial, would require a conjoined constraint, which §4.3 argues is both a loss of generalization and empirically inviable. A serial HG analysis is possible, but only with a new type of non-local dependency constraint (extending Mullin 2011) that permits various non-myopic effects to be analyzed in that framework, and in so doing introduces certain pathologies which remain to be explored more fully in future research.

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