On feature geometry of coronal articulations

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More place distinctions are recognized within the class of coronal articulations than in any other articulator class such as labial or dorsal. As a result, it has often been assumed that there are more features associated with the coronal articulator than with other articulators and that the internal structure of the coronal node in feature geometry is more complex than other nodes. In this paper, I argue that this is not necessarily the case. I present an analysis of coronal articulations in which marked coronals are the result of combining primary coronal articulations with secondary dorsal articulations. As a result, the coronal node consists of no more features or levels of structure than any other node. The proposed analysis is motivated by evidence from natural phonological classes, degrees of markedness within coronal classes and the interaction of coronal consonants with neighbouring vowels.

1. Introduction

Coronal articulations are those produced with the tip and/or blade of the tongue. Almost half of the places of articulation recognized by the IPA qualify as coronal. These include dental, alveolar, post-alveolar (i.e., palato-alveolar), alveolo-palatal, and retroflex.\(^1\) Since there are more place distinctions within the coronal class than there are within other articulator classes, it has often been assumed that there are more features associated with the coronal articulator than with other articulators, and that the internal structure of the coronal node in feature geometry is more complex than other nodes. In this paper, I argue that this is not necessarily the case. I present an analysis of coronal articulations in which marked coronals are the result of combining primary coronal articulations with secondary dorsal articulations. As a result, the coronal node consists of no more features or levels of structure than any other node. The proposed analysis is motivated by evidence from natural phonological classes, degrees of markedness within coronal classes, and the interaction of coronal consonants with neighbouring vowels.

The paper is organized as follows: Section 2 introduces some theoretical

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\(^1\) The status of palatal articulations is controversial. Some researchers classify them as coronal while others classify them as dorsal. I take true palatals to be primarily dorsal, but palato-alveolar and alveolo-palatal articulations to be coronal. The remaining non-coronal articulations recognized by the IPA are bilabial, labiodental, velar, uvular, pharyngeal, and glottal.
assumptions regarding the articulatory basis of phonological features. Section 3 outlines some generalizations concerning coronal articulations that should be accounted for by a model of feature geometry. Section 4 provides a brief survey of coronal features and feature geometries that have been proposed in the literature and evaluates them in light of the generalizations outlined in section 3. In section 5 I discuss an outstanding problem with the features [laminal] and [apical] as they are traditionally defined. In their place, I adopt an alternative set of features, [convex] and [concave], defined in terms of general tongue shapes, and argue that these avoid the problem associated with the former features and are more compatible with an articulatory model of feature geometry. In sections 6 and 7 I present a model for coronal articulations. The proposed model seeks to account for the full range of coronal articulations and the generalizations of section 3 without introducing additional features or levels of structure under the coronal node. Finally, in section 8 I comment on the default completion of underspecified nodes before offering some concluding remarks in section 9.

2. Theoretical background

From the earliest days of distinctive feature theory, phonological features were taken to be abstract primitives that serve to mediate between articulatory gestures on the one hand and acoustic/perceptual cues on the other. This approach is evident in Jakobson, Fant, and Halle’s (1952) seminal work on phonological features where each of the proposed features is defined in terms of both acoustic and articulatory correlates. Since that time there has been a trend toward a more articulator-based approach to features. For example, Chomsky and Halle’s (1968) work, The Sound Patterns of English (SPE), defines most of the proposed features in purely articulatory terms.

Reflecting on this trend, Halle (2002) observes that “whenever acoustically defined features were replaced by features based on articulation, this resulted in significant improvements in the formulation of the rules and a deeper understanding of the phenomena under discussion” (2002: 7). As a result, he reports: “I now believe that there is a direct connection only between features in memory and the articulatory actions to which they give rise, and that the acoustic aspects of features play a secondary role in phonology” (2002: 7). For Halle, features serve two functions: representational and articulatory. Words and morphemes are represented in memory in the form of feature structures and these feature structures also serve as instructions for articulatory actions.

Recently, Avery & Idsardi (2001) have proposed a strong articulatory model of feature geometry; one in which terminal features are interpreted as motor instructions to articulators. Following Halle (2002), I assume that a strong articulatory approach to phonological features is desirable. The analysis I propose for coronal articulations makes use of a slightly modified version of Avery & Idsardi’s (2001) feature geometry. This approach should not be taken to mean that acoustic/perceptual cues are not associated with phonological features in any way, or that they play no role in phonological processes. Rather, it assumes only that the inventory of phonological features, their definition, and their organization in feature geometry, should be motivated primarily by articulatory considerations.
3. Some generalizations concerning coronals

In order to gain insight into coronal features and their organization, linguists have often looked to languages with crowded coronal inventories for evidence. In particular, the languages of Australia and South Asia have been of interest since many of them distinguish up to three or four coronal stops. Some representative stop inventories from these languages are listed in (1) and (2).

(1) Representative Australian coronal stop inventories

<table>
<thead>
<tr>
<th></th>
<th>Dental</th>
<th>Alveolar</th>
<th>Retroflex</th>
<th>Palatal</th>
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<tbody>
<tr>
<td>Kayardild</td>
<td>t</td>
<td>t</td>
<td>t</td>
<td>t</td>
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<tr>
<td>Warlpiri</td>
<td>t</td>
<td>t</td>
<td>t</td>
<td>t</td>
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<tr>
<td>Ngiyambaa</td>
<td>t</td>
<td>t</td>
<td>t</td>
<td>t</td>
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<tr>
<td>Dyirbal</td>
<td>t</td>
<td>t</td>
<td>t</td>
<td>t</td>
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</table>

(2) Representative South Asian coronal stop inventories

<table>
<thead>
<tr>
<th></th>
<th>Dental</th>
<th>Alveolar</th>
<th>Retroflex</th>
<th>Palatal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malayalam (Dravidian)</td>
<td>t</td>
<td>t</td>
<td>t</td>
<td>t</td>
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<tr>
<td>Telugu (Dravidian)</td>
<td>t</td>
<td>t</td>
<td>t</td>
<td>t</td>
</tr>
<tr>
<td>Hindi (Indo-Aryan)</td>
<td>t</td>
<td>t</td>
<td>t</td>
<td>t</td>
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</tbody>
</table>

There are at least three kinds of information that we can glean from these (and other) languages that are relevant for a model of coronal feature geometry. They are: (a) information regarding the natural classes of coronal segments; (b) information about degrees of markedness within these classes; and (c) information about the interaction of coronals with neighbouring vowels. In the remainder of this section I will draw generalizations concerning these three issues based primarily on data from Australian and South Asian languages.

3.1. Word accent

Cross-linguistically, dental and palatal stops tend to be laminal in their articulation (i.e., articulated with the tongue blade), while alveolar and retroflex stops tend to be apical (i.e., articulated with the tongue tip). Languages with large coronal inventories show a strong sensitivity to the apical/laminal distinction. Thus, lamino-dentals and lamino-palatales tend to form a natural class distinct from apico-alveolars and retroflexes. The evidence for these natural classes in Australian languages is “enormous” (Evans 1995: 727). It can be found in historical changes, synchronic and morphophonemic variation, and phonotactics. According to Dixon (1980, 2002), Proto-Australian had two

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2 The class of sounds referred to here as ‘palatal’ are typically laminal post-alveolars, and not true palatales. In South Asian languages they are often pronounced with an affricated release. Throughout this paper I follow the South Asian tradition in using the term ‘palatal’ as a cover term for any articulation that is laminal and either alveolar or post-alveolar (i.e., palato-alveolar or alveolo-palatal) whenever a more fine-grained distinction is not required. This practice also seems common in Australian descriptions. Also, I follow Ladefoged and Maddieson (1996) in representing this class with the symbol /t/. Other common transcription conventions include /c/, /č/, /ts/, and /tʃ/. There are some South Asian languages that distinguish up to two articulations within this category. I discuss these in section 7.
coronal stops: one laminal and one apical. The laminal stop developed lamino-palatal allophones before high, front vowels and the apical stop developed retroflex allophones in the context of back vowels and/or rhotics. The complementary distribution of these stops eventually led to a phonemic split in some languages, with the result that the modern Australian languages typically have three or four coronal stops, as exemplified in (1).

The laminal and apical classes are still evident in synchronic variation and phonotactic patterns in most Australian languages. In many languages, the lamino-dental and lamino-palatal stops are in complementary distribution, while in others the apico-alveolar and retroflex stops are in complementary distribution. Thus, while some languages maintain a four-way contrast among coronals, those that maintain only three do so by collapsing either the apicals or the laminals into a single phonemic category. Moreover, even languages that maintain the full four-way contrast tend to neutralize distinctions within classes in certain positions. Thus, most languages neutralize the alveolar vs. retroflex distinction word-initially, or ban apicals altogether from that position. Similarly, some languages also neutralize the dental vs. palatal distinction word-finally (Evans 1995, Hamilton 1996, Dixon 2002).

Evidence of laminal and apical classes can also be found in Dravidian and other South Asian languages. For example, Dravidian shows a dis-preference for apicals word-initially, similar to the dis-preference for word-initial apicals found in Australian languages. Proto-Dravidian had a full four-way contrast among coronals, but had a phonotactic constraint against word-initial apicals, both alveolar and retroflex. Only laminals (dental and palatal) occurred in that position. Most modern Dravidian languages have lost the alveolar series, but still maintain a ban on word-initial retroflexes (at least in native vocabulary) (Krishnamurti 2003).

Further evidence of an apical/laminal class distinction is found in patterns of loanword adaptation in South Asian languages. Dravidian languages that distinguish two apicals (alveolar and retroflex) adapt the apico-alveolar stops of English as alveolar (e.g., Kanniyakumari dialect of Tamil, Christdas 1988) or as alveolar in some contexts and retroflex in others (e.g., Malayalam, Asher & Kumari 1997). Those that lack an alveolar stop consistently adapt English alveolars as retroflex, never as dental. This is true not only of Dravidian languages such as Telugu (Jagannath 1981), but also of Indo-Aryan languages such as Hindi (Ohala 1978). Moreover, these same languages adapt the lamino-dental stops of Portuguese loanwords, and the interdental fricatives of English loans as dental stops. Some examples from Telugu are listed in (3) and (4). I take these data as another instantiation of the laminal/apical class distinction.

<table>
<thead>
<tr>
<th>(3)</th>
<th>English</th>
<th>Telugu</th>
<th>English</th>
<th>Telugu</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ</td>
<td>→ ṭ</td>
<td>thick</td>
<td>[tikku]</td>
<td></td>
</tr>
<tr>
<td>δ</td>
<td>→ ᵇ</td>
<td>leather</td>
<td>[lædrəru]</td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>→ ṭ</td>
<td>ticket</td>
<td>[tikətu]</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>→ ᵇ</td>
<td>doctor</td>
<td>[daːktəru]</td>
<td></td>
</tr>
</tbody>
</table>

3 This implies that the interdental fricatives of English are laminal, a conclusion that is consistent with the definition of laminal articulations as convex that I adopt in section 5.
3.2. Markedness among coronals

Marked articulations are more complex and, therefore, less common cross-linguistically. Their presence in a phonemic system tends to imply the presence of another (unmarked) articulation. Unmarked articulations are simpler and often function as defaults with respect to phonological alternations and rules. They are more common than marked articulations and their presence in a phonemic system implies nothing about the presence of other (marked) articulations. The question of markedness is relevant in feature geometry since marked features are generally equated with either positive feature values (in models that make use of binary features) or with the presence (as opposed to absence) of a monovalent feature. In other words, the relative complexity of an articulation is modeled as relative complexity of feature structure. According to this approach, markedness is the presence of some feature and/or structure, while unmarkedness is taken to be the absence of features and/or structures (e.g., Rice & Avery 2004).

Within the apical class, retroflexes are generally considered more marked than alveolars, at least from an articulatory point of view. A retroflex articulation requires a greater displacement of the tongue tip from its neutral position. Further evidence of the markedness of retroflexes comes from the fact that they are cross-linguistically rare. Only 11.4% (36 out of 317) of languages surveyed by Maddieson (1984: 32) have retroflex stops. This makes them even less common than other notoriously marked articulations such as uvulars, which are found in 14.8% (47 out of 317) of the languages in Maddieson’s survey. Moreover, retroflexes occur only in languages with large consonant inventories that have at least one other coronal (Hamann 2003, 2005). There are no languages in which retroflex stops are the only coronal series. There are, however, languages in which the only coronal series is alveolar (Maddieson 1984).

When it comes to laminal articulations, the question of markedness is not as clear. Based on evidence from Australian languages, many researchers have taken palatals to be less marked than dentals (e.g., Dixon 1980, Hamilton 1993, Gnanadesikan 1994, Harvey & Baker 2005). Australian languages with a single laminal phoneme tend to have palatals, not dentals (e.g., Warlpiri and Dyirbal in (1)). If palatals and dentals occur in free variation, then the palatal is still the major, more frequent allophone. There are no Australian languages with a single laminal that is consistently dental. Thus, the overall preference for palatal articulations in Australian languages, with or without dentals, is taken as evidence that they are the unmarked laminals.

The reasoning behind this approach is questionable. It is true that the presence of a marked articulation within a system generally implies the presence of the unmarked, and not vice versa. However, I suggest that a language may still show preference for a marked articulation when it needs to maintain a maximal distinction with other

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4 Retroflexes are not necessarily marked from a perceptual point of view, at least not in VC contexts where their formant transitions are quite salient (Ohala 1978, Hamann 2003, Steriade 2001).
articulations in a crowded inventory. Consider the case of Dravidian. There is little doubt that retroflexes are more marked than alveolars within the apical class. Nevertheless, those Dravidian languages with a single apical series (e.g., Telugu in (2)) consistently maintain the marked retroflexes over the unmarked alveolars. The same is true of Indo-Aryan languages such as Hindi. Although there are no other apicals that need to be distinguished there are still other coronals in the system. Thus, retroflexion may function as a kind of enhancement that keeps the single apical maximally distinct from other coronals. Similarly, I suggest that the preference for palatals in Australian languages should not be taken as evidence of their unmarked status. Rather, they could be preferred in order to enhance their distinction from other (i.e., apical) coronals in those languages.

There are other kinds of evidence that point to dentals as the unmarked laminal. For example, in those languages where dentals and palatals are in complementary distribution, it is the palatals that occur in the more restricted environment; namely, in the context of front and/or high vowels. This would suggest that the palatals are assimilating some extra feature(s) from their environment and that they are, therefore, more marked (at least in terms of features and feature structure). Moreover, as in the case of retroflexes, palatals only occur in languages with larger inventories including at least one other coronal (Maddieson 1984). There are no languages in which palatals are the only coronal stops, but there are languages in which dentals are the only coronal (e.g., French and other Romance languages). Thus, I take dentals to be the unmarked laminal series.

3.2. Interaction between coronals and vowels

The interaction of palatal consonants with high and/or front vowels is well attested cross-linguistically. For example, in many Australian languages lamino-dental stops become palatal in the context of high, front vowels. Similarly, an affinity is found cross-linguistically between retroflexes and back and/or low vowels (Gnanadesikan 1994; Hamann 2002, 2003; Flemming 2003; Boersma & Hamann 2005). In a cross-linguistic study of the phonetics and phonology of retroflexion, Hamann (2003) catalogues a wide variety of processes involving retroflex consonants and neighbouring vowels. Her list includes the following:6

(5) Phonological processes involving retroflex consonants and vowels (Hamann 2003)

a. /ut/ → [ut] retroflexion in a back vowel context
b. /it/ → [it] de-retroflexion in a front vowel context
c. /it/ → [ït] or [u[t] vowel retraction in the context of a retroflex

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5 According to Maddieson’s (1984) survey, 99.7% of languages have dental or alveolar stops while only 18.6% have palatal or palato-alveolars. Unfortunately, Maddieson does not distinguish between dentals and alveolars on account of the fact that they are not always reliably distinguished in his sources, and because contrast between the two is rare. Thus, it is difficult to say whether palatals (broadly defined) are more or less common than dentals. What is clear and important for the point at hand, however, is that palatals only occur in languages with another coronal, whereas dentals are not restricted in this way.

6 Hamann’s (2003: 94) list also includes rounding of a front vowel in the context of a retroflex consonant (i.e., /it/ → [ït]). Unlike the other processes, this one is not articulatorily motivated. Citing work by Flemming, Hamann suggests that it involves “a reduction of the retroflex gesture with concomitant rounding of the vowel in order to preserve the perception of a low F3 typical for a retroflex” (2003: 104).
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d. /æt/ → [æt] vowel lowering in the context of a retroflex

e. /iət/ → [iət] vowel diphthongization in the context of a retroflex

All of these alternations show an articulatory affinity between retroflex consonants and low/back vowels, and a dis-preference for combinations of retroflex consonants with high/front vowels. This affinity is further corroborated by phonetic studies such as that of Dixit and Flege (1991) which found that the degree of retroflexion in Hindi retroflex stops decreases systematically depending on the vowel context, moving from /a/ to /u/ to /i/.

Interestingly, the context in which palatals are preferred (i.e., high/front vowels) is precisely the context in which retroflexes are dis-preferred. Not surprisingly, therefore, Hamman (2003) argues that palatalization and retroflexion are mutually incompatible. Thus, there is a cross-linguistic correlation between palatals (i.e., marked laminals) and high/front vowels on the one hand, and between retroflexes (i.e., marked apicals) and low/back vowels on the other; and these two correlations are complementary. To the extent that these complementary correlations are articulatorily motivated, they should be reflected in an articulatory model of feature geometry.

4. A brief survey of coronal features

In this section I provide a brief survey and evaluation of phonological features and feature geometries that have been proposed for coronal articulations, beginning with the feature specifications of Chomsky & Halle (1968) in (6). This feature system distinguishes all four coronal stops with only two binary features: [±distributed] and [±anterior]. Chomsky & Halle’s definition of these features is given in (7).

<table>
<thead>
<tr>
<th></th>
<th>Dental</th>
<th>Alveolar</th>
<th>Retroflex</th>
<th>Palatal</th>
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</thead>
<tbody>
<tr>
<td>[coronal]</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>[distributed]</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>[anterior]</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

(7) a. **Anterior – Nonanterior:** “Anterior sounds are produced with an obstruction that is located in front of the palato-alveolar region of the mouth; nonanterior sounds are produced without such an obstruction.” (1968: 304)

b. **Distributed – Nondistributed:** “Distributed sounds are produced with a constriction that extends for a considerable distance along the direction of the air flow; nondistributed sounds are produced with a constriction that extends only for a short distance in this direction.” (1968: 312)

Chomsky & Halle’s feature system served as the standard approach in generative phonology for many years. The features in (6) are assumed in most generative accounts of South Asian and Australian languages (e.g., Nash 1980 (Warlpiri); Mohanan & Mohanan 1984 (Malayalam); Christdas 1988 (Tamil)). Early attempts to constrain feature
theory via feature geometry simply reproduced Chomsky and Halle’s features in tree format, as in (8).

(8) Sagey (1986)

```
place
  |labial
dorsal
  |round
coronal
  |high low back
  |anterior
distributed
```

(9) Coronal articulations based on Sagey (1986)

```
Dental	Alveolar	Retroflex	Palatal
	[t]
  |coronal
[+dist] [+ant] [−dist] [+ant] [−dist] [−ant] [+dist] [−ant]
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Despite its dependence on Chomsky & Halle (1968), Sagey’s (1986) geometry does represent at least two significant developments. First, in keeping with the trend toward articulator-based feature systems, it introduced organizing nodes representing the major articulators: labial, coronal, and dorsal. Secondly, whereas in Chomsky and Halle (1968) the feature [±distributed] was not bound to any articulator, in Sagey’s model it is a dependant of coronal. Ultimately, this paved the way for a reinterpretation of this feature in terms of the apical/laminal distinction of traditional phonetics (e.g., Keating 1991). Many subsequent works replaced [±distributed] with the monovalent features [laminal] and [apical], defined as ‘tongue blade’ and ‘tongue tip’ articulations, respectively (e.g., Hamilton 1993; Gnanadesikan 1994).

Subsequent research has also questioned the validity of the feature [anterior] and its monovalent complement [posterior]. First and foremost, it has been argued that features such as [anterior] and [posterior] do not capture natural phonological classes in any language. The use of these features predicts that retroflexes [t] and palatals [t] should form a natural class (i.e., [posterior]), as should lamino-dentals [t] and apico-alveolars [t] (i.e., [anterior]). This is clearly not the case, as argued in section 3 and in greater detail by Gnanadesikan (1994). Secondly, these features represent passive targets, not active articulatory gestures. As such, they are not consistent with other features in an articulator-based model. To this we might add that the actual place of articulation for many coronal stops varies considerably outside of the range defined by such features. For example, phonetic studies have shown that retroflexes, while tending to be post-alveolar, may vary from alveolar ([anterior]) to post-alveolar and/or palatal (both [posterior]) (e.g., Ladefoged & Maddieson 1996, Hamann 2003).
In light of these developments, recent proposals have favored the features [apical] and [laminal] over [±distributed]. However, these features alone are not sufficient to distinguish all coronal stops and there has been no consensus on what features should replace [anterior] and [posterior]. Most proposals treat [apical] and [laminal] as the primary dependants of [coronal], and introduce additional dependants under these. For example, Hamilton (1993) introduces the features [dental] and [retroflex] in (10) along with the feature specifications in (11).

(10) Hamilton (1993)

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CORONAL
   \---\---
   |     |
LAMINAL APICAL
   [dental] [retroflex]
```

(11) Coronal articulations according to Hamilton (1993)

<table>
<thead>
<tr>
<th></th>
<th>Dental</th>
<th>Alveolar</th>
<th>Retroflex</th>
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<tr>
<td></td>
<td>t</td>
<td>t</td>
<td>t</td>
<td>t</td>
</tr>
<tr>
<td>CORONAL</td>
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<tr>
<td>LAMINAL</td>
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<td></td>
</tr>
<tr>
<td>[dental]</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[retroflex]</td>
<td></td>
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</tbody>
</table>

One problem with Hamilton’s (1993) proposal is that it makes dental stops more marked than palatals. While certain facts in Australian languages suggest this possibility, they are best interpreted differently in light of cross-linguistic evidence, as I argued in section 3. Moreover, the features [dental] and [retroflex] each serve a single function in the geometry: that of distinguishing dentals from other laminals and retroflexes from other apicals, respectively. They do not capture natural classes or account for the interaction of the various coronals with neighbouring vowels.

Another more recent proposal is that of Harvey & Baker (2005) who use the features [tip up] for dentals and [sublaminal] for retroflexes, as illustrated in (12) and (13). Retroflexes are known to have dynamic articulations involving what Hamann (2003) calls a ‘flapping out’ gesture. Harvey & Baker attempt to capture this dynamic articulation by assigning the feature [sublaminal] only to the initial portion of a retroflex stop. Thus, retroflexes are predicted to have sublaminal VC transitions, but apical CV transitions.
(12) Harvey & Baker (2005)

\[
\begin{array}{c}
\text{CORONAL} \\
\text{[laminal]} & \text{[apical]} \\
\text{[tip up]} & \text{[sublaminal]}
\end{array}
\]

(13) Coronal articulations according to Harvey & Baker (2005)

\[
\begin{array}{cccc}
\text{Dental} & \text{Alveolar} & \text{Retroflex} & \text{Palatal} \\
\text{\texttt{t}} & \text{\texttt{t}} & \text{\texttt{t}} & \text{\texttt{t}} \\
\text{CORONAL} & \text{CORONAL} & \text{CORONAL} & \text{CORONAL} \\
\text{[laminal]} & \text{[apical]} & \text{[apical]} & \text{[apical]} & \text{[laminal]} \\
\text{[tip up]} & \text{[sublaminal]}
\end{array}
\]

Like Hamilton’s proposal, Harvey & Baker’s geometry makes dentals the marked laminal; a prediction that is difficult to maintain cross-linguistically. Although their analysis predicts some interaction between laminals and front vowels (by treating front vowels as [laminal]), it makes no predictions about the interaction of retroflexes with back/low vowels. Moreover, it predicts that retroflexes are necessarily [sublaminal], whereas it is well established that retroflexes are predominantly apical in most Indo-Aryan languages (Ladefoged & Maddieson 1996), and that they vary between apical and subapical articulations in others (e.g., Malayalam, Dart & Nihalani 1999).

5. Redefining apical and laminal

There is another problem with models like those of Hamilton (1993) and Harvey & Baker (2005). While the features [laminal] and [apical] have proven effective in capturing natural phonological classes, the definition of these features in terms of tongue blade and tongue tip is difficult to maintain in light of the full range of variation found in phonetic implementation. For example, Dart (1998) investigated the general claim that English coronal stops are apico-alveolar while those of French are lamino-dental. Based on palatographic and linguagraphic evidence she concluded that these generalizations are true, but only as statistical trends. In actual implementation, she found that there was a great deal of individual variation, both in terms of place (dental vs. alveolar) and in terms of the point of constriction on the tongue (apical vs. laminal). This kind of variation is difficult to explain if features such as [apical] and [laminal] are defined in terms of tongue ‘tip’ and ‘blade’, especially since reliable definitions of tip and blade are elusive. Definitions of the tongue blade range from as little as 10-15mm behind the tip to as much as 3-4 cm (Keating 1991). Even more problematic is defining the boundary between ‘tip’ and ‘blade’. At what point along the surface of the tongue does one become the other?
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Dart’s study of English and French not only highlights the problem for traditional definitions of [apical] and [laminal] but also points to a possible solution. Both the palatographic data of the original (1998) study, and a subsequent analysis of the acoustic data from that study (2004), clearly suggest that French stops are articulated with a higher tongue body position behind the obstruction when compared to English stops. On the basis of this evidence, Dart suggests that French stops are articulated with a convex tongue shape involving a higher, more fronted tongue body configuration while English stops are articulated with a concave tongue shape involving a lower, more backed tongue body.

If the features [apical] and [laminal] are redefined in terms of relative tongue shapes, and re-named [concave] and [convex] respectively, then they can account for the statistical trend toward apico-alveolar articulations in English and lamino-dental articulations in French while still allowing for individual variation. A concave tongue shape like that in (14b) will most likely yield an apical articulation involving contact between the tongue tip and the alveolar region on account of the fact that the tip is slightly turned up and drawn back. Similarly, a convex tongue shape like that in (14a) is expected to produce a laminal articulation involving contact between the tongue blade and the denti-alveolar region since the tip is neither turned up nor drawn back. Moreover, if it is the overall tongue shape that is important, and not the specific point of contact between the active and passive articulators, then some degree of variation from this norm is expected and irrelevant.

(14)   a.   b.

[convex] ‘laminal’       [concave] ‘apical’

A re-definition of the traditional apical/laminal distinction in terms of the features [concave] and [convex] is also more in keeping with a model based on articulatory features. Rather than referring to a point of constriction on the surface of the tongue, the convex and concave definitions are more directly related to articulatory, muscular gestures involving the curl of the tongue. This approach bears a resemblance to that of Avery & Idsardi (2001). They propose an articulatory model of feature geometry in which terminal features are interpreted as motor instructions to articulators. Their model explicitly recognizes the fact that muscle groups form antagonistic pairs and formalizes this fact by organizing antagonistic pairs of features under special nodes called dimensions. For example, Avery & Idsardi organize coronal features under two dimensions, Tongue Groove and Tongue Curl, as in (15).
(15) Avery & Idsardi (2001)

Articulator

Coronal

Dimension

Tongue Groove

Tongue Curl

Gesture

[groove]

[lateral]

[down]

[retroflex]

The antagonistic relationship between features within dimensions is captured by subjecting all dimension nodes to a non-branching constraint. Thus, a given segment cannot be simultaneously tongue tip [down] and [retroflex]. Presumably, Avery & Idsardi’s [down] feature would be used to distinguish palatals in which the tongue tip is often down behind the lower teeth. Similarly, the feature [retroflex] would distinguish retroflexed coronals. However, it is not clear what would distinguish lamino-dentals from apico-alveolars in this model.

I prefer to replace Avery & Idsardi’s Tongue Curl features [down] and [retroflex] with the features [convex] and [concave], respectively. Under these conditions, both dentals and palatals are [convex], while alveolars and retrofлексes are [concave].

(16) Proposed coronal feature geometry

Articulator

Coronal

Dimension

Groove

Curl

Gesture

[grooved]

[lateral]

[convex]

[concave]

‘laminal’

‘apical’

This move has several advantages. It predicts the desired natural classes (in keeping with Hamilton 1993, Gnanadesikan 1994, etc.) while at the same time maintaining a strong articulatory definition of the features (in keeping with Avery & Idsardi 2001). Moreover, it predicts a certain amount of variation in the contact between active and passive articulators. The question now becomes: How are retroflexes distinguished from alveolars, and palatals from dentals?

6. Apical articulations

In her cross-linguistic study of the phonetics and phonology of retroflexion, Hamann (2003) identifies four articulatory properties of retroflexion: apicality, posteriority, sublingual cavity, and retraction (17). Hamann notes that these four properties are interrelated. The presence of a given property, or combination of properties, may entail the presence of other properties. She provides the list of entailments in (18).

---

7 Some of the entailments in (18) are questionable. For example, posteriority does not necessarily entail a sublingual cavity as suggested in (18a). A laminal post-alveolar articulation would be posterior by most definitions but may not have a sublingual cavity if the tongue tip is down behind the lower teeth as it sometimes is in such articulations (c.f., Keating 1991: 43).
Articulatory properties of retroflexion (Hamann 2003)

a. apicality: articulated with the tip or underside of the tongue
b. posteriority: articulated behind the alveolar ridge
c. sublingual cavity: a cavity beneath the tongue
d. retraction: displacement of the tongue back towards the pharynx

We have already seen that posteriority represents a static target and is problematic when used as a phonological feature. Not surprisingly, Hamann suggests that posteriority is the only property which might not be a necessary property of retroflexion, on the grounds that retroflexes exhibit some variation in their place of articulation. Thus, it seems that posteriority should be a derived, statistical tendency for retroflexes, and not a necessary articulatory specification.

Of the three remaining properties proposed by Hamann, only two are potential articulatory features in the sense that they might represent motor instructions to articulators. These are apicality (when defined as a concave tongue gesture) and retraction. Moreover, there is an entailment relationship between these two properties and all the others. A concave tongue shape combined with a retracted tongue body will yield a large sublingual cavity, and most likely, a posterior place of articulation. Strangely, this entailment is overlooked by Hamann. I offer it in (19).

apicality & retraction → sublingual cavity & posteriority

If this is so, then we have a solution to the question at hand. Both apico-alveolars and retroflexes share the articulatory feature [concave], but retroflexes are distinguished from alveolars by an additional articulatory gesture: a retracted tongue body.

The question now becomes: How do we represent retraction in terms of articulatory features within the geometry proposed in (16)? We might entertain the possibility of re-deploying the features [anterior] and [posterior] and redefining them, not in terms of static targets, but in terms of general tongue body positions. According to this option, [anterior] would be defined as a fronted tongue gesture, while [posterior] would represent a retracted tongue gesture. However, this move is both unnecessary and undesirable given that we already have features for this purpose within most models of feature geometry; namely, the dorsal features [front] and [back].

The idea that retroflexes might be specified for a dorsal feature such as [back] is not new. Similar proposals have been made by others on phonetic/articulatory grounds and on the grounds that retroflexes interact phonologically with back vowels (e.g., Gnanadesikan 1994; Hamann 2002, 2003; Flemming 2003; Boersma & Hamann 2005).
For example, Gnanadesikan (1994) proposes that retroflexes are apical coronals with a secondary dorsal node, as in (20) and (21).

(20) Gnanadesikan (1994)

```
Coronal
│
Laminal     Apical
│
[dental]    Dorsal
```

(21) Coronal articulations according to Gnanadesikan (1994)

```
Dental       Alveolar       Retroflex       Palatal
│        │              │              │
Coronal     Coronal       Coronal       Coronal
│        │    │            │
Laminal     Apical       Apical       Laminal
│        │              │
[dental]    Dorsal
```

Unfortunately, there are problems with Gnanadesikan’s geometry. First, she makes the dorsal articulator a dependant of the feature [apical] on the grounds that assimilatory processes involving the spread of retroflexion spread the coronal features along with the dorsal feature [back]. However, this dependency relationship implies that all vowels and all dorsal consonants are necessarily coronal and apical. This is clearly an undesirable prediction. Secondly, like other geometries reviewed above (e.g., Hamilton 1993, Harvey & Baker 2005) it makes dentals the marked laminal.

Avery and Idsardi’s (2001) articulator-based model organizes antagonistic dorsal features into two dimensions: Tongue Height and Tongue Thrust. Following their lead, I assume the geometry in (22) and propose the feature specifications for apicals in (23).

(22) Proposed coronal and dorsal features

```
Oral Place
│
Coronal     Dorsal
│
Groove     Curl     Height     Thrust
│     │       │       │
[groove] [lateral] [convex] [concave] [high] [low] [front] [back]
```
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(23) Proposed feature geometry for apical articulations

<table>
<thead>
<tr>
<th>Alveolar</th>
<th>Retroflex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral Place</td>
<td>Oral Place</td>
</tr>
<tr>
<td>Coronal</td>
<td>Coronal</td>
</tr>
<tr>
<td>Curl</td>
<td>Curl</td>
</tr>
<tr>
<td>[concave]</td>
<td>[concave]</td>
</tr>
<tr>
<td></td>
<td>[back]</td>
</tr>
</tbody>
</table>

The proposed analysis has the desirable effect of making both sub-lingual cavity and posteriority derived properties of retroflexion. Retroflexes have been shown to vary from apical alveolar or post-alveolar to subapical palatal in articulation (Ladefoged & Maddieson 1996, Dart 1999, Hamann 2003). This variation is entirely expected under the proposed model in which the place of articulation and point of contact on the articulator are not specified. Rather, retroflexes are specified only for a concave tongue shape and a retracted tongue body. With the tongue in a concave position, retraction will result in a ‘bunching’ of the tongue; i.e., in a more concave shape with a greater degree of tongue curl. Moreover, the farther back the contact happens to be made, the more subapical the articulation will be, given the extreme concave shape of the tongue and the angle of the roof of the mouth behind the alveolar ridge.

(24) a. apical post-alveolar retroflex [concave] + [back]  
   b. sub-apical palatal retroflex [concave] + [back] (+ [low]?)

Speculating a little, I suggest that the more extreme variety of sub-apical, palatal retroflexion might be the result of combining two dorsal features: [back] and [low]. This would be consistent with the observation of Dixit and Flege (1991) that the retroflex stops of Hindi are maximally retroflex in the context of low, back /a/, and somewhat less retroflex in the context of /u/. I sketch this possibility in (25). Note, however, that no language is known to contrast two degrees of retroflexion (Ladefoged & Maddieson 1996). Thus, it is doubtful that any language would need to use both dorsal features, [low] and [back], contrastively. Under these conditions [low] may only function as a default or enhancement feature on marked apicals. I leave this as an open question for further research (see also section 8).
The proposed analysis preserves the insight of Gnanadesikan (1993) that retroflex segments are essentially apical coronals with a secondary dorsal articulation. However, it avoids the undesirable implications of making the dorsal articulator a dependant of the coronal node.\(^8\) This analysis also has potential to account for the affinity of retroflexion with low, back vowels, and the incompatibility of retroflexion with high, front vowels and palatalization.

7. Laminal articulations

Granted that dentals and palatals are both [convex], how are they distinguished? Once again we might entertain the idea of using features such as [anterior] for dentals and [posterior] for palatals, as is done in so many other accounts. Again, however, we find that the so-called palatals are not consistently posterior as this approach assumes. For example, in Telugu they have both alveolar ([anterior]) and post-alveolar ([posterior]) allophones (Krishnamurti 1998). Using palatographic and linguagraphic evidence, Dart & Nihilani (1999) demonstrate that the so-called palatal of Malayalam are overwhelmingly alveolar and never post-alveolar for their subjects. Moreover, for one of the subjects in their study these segments were denti-alveolar; a surprising fact if they are taken to be distinctively [posterior].

If laminal articulations are not distinguished on the basis of anteriority or posteriority, then how are they distinguished? Once again, the acoustic data from Dart & Nihilani’s (1999) study provides some clues. Since the palatales are in fact alveolar, Dart & Nihilani suggest that they are distinguished from the apico-alveolars solely on the basis of being laminal. Their acoustic analysis also suggests that the laminal alveolar is produced with a higher tongue body behind the constriction compared to the apico-alveolar. This much is fully consistent with the proposed analysis in which laminals have a convex tongue shape; but it does not indicate how laminal alveolars might be distinguished from lamino-dentals. However, Dart & Nihilani note an interesting pattern that is unique to the laminal alveolars (i.e., the so-called palato-alveolars): their formant transitions are characterized by a raising of F2 and lowering of F3 that is reminiscent of the ‘velar pinch’.

\(^8\) I assume that the spreading of retroflexion involves, not the spreading of the coronal node, but of a higher node such as Oral Place. In this way, both the primary coronal and secondary dorsal features are spread together.
The raising of F2 and lowering of F3 seen in the preconsonantal formant transitions leading to the *palatoalveolars*... was typical of most speakers. This convergence of F2 and F3, usually associated with velars, is perhaps an indication that the back of the tongue is raised as well as the front during these articulations. (Dart & Nihilani 1999: 138)

In light of this data, I propose an analysis of palatals parallel to the one proposed for retroflexes. Just as retroflexes were analyzed as apicals with a secondary dorsal articulation, I suggest that palatals are laminals with a secondary dorsal articulation; in this case [high].

(26) Proposed feature geometry for laminal articulations


dental | palatal
---|---
oral place | oral place
| coronal | coronal | dorsal
| curl | curl | height
[convex] | [convex] | [high]

With the tongue in a convex position, raising the tongue body will result in a more extreme convex shape; one in which the tip is much lower than the body. This is turn will tend to produce a contact pattern in which the tongue tip fails to make contact at all (unlike dentals) and the blade makes contact in the alveolar region (and not the denti-alveolar region).

(27) a. [convex] lamino-dental  b. [convex] + [high] lamino-alveolar

In light of this analysis a new question arises. Some languages have both lamino-alveolar [t$\text{s}$] and lamino-post-alveolar [t$\text{ʃ}$], either as allophones in complementary distribution (e.g., Telugu) or as phonemes (e.g., Kashmiri). How are these articulations distinguished? Evidence from complementary distribution in languages such as Telugu provides a clue. In these languages, the post-alveolars occur before front vowels (28). I take this as evidence that post-alveolar [t$\text{ʃ}$] is distinguished from alveolar [t$\text{s}$] by having a fronted tongue body position. Thus, post-alveolar [t$\text{ʃ}$] is characterized by the feature
[front] in addition to [high], as illustrated in (29).


<table>
<thead>
<tr>
<th>Telugu</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>[tsalì]</td>
<td>‘cold’</td>
</tr>
<tr>
<td>[tʃilakà]</td>
<td>‘parrot’</td>
</tr>
<tr>
<td>[tsàpa]</td>
<td>‘mat’</td>
</tr>
<tr>
<td>[tʃìpurù]</td>
<td>‘broom’</td>
</tr>
<tr>
<td>[tsukka]</td>
<td>‘droplet’</td>
</tr>
<tr>
<td>[tʃètì]</td>
<td>‘tree’</td>
</tr>
<tr>
<td>[tsúpú]</td>
<td>‘sight’</td>
</tr>
<tr>
<td>[tʃèrù]</td>
<td>‘open palm’</td>
</tr>
<tr>
<td>[tsoːtu]</td>
<td>‘shirt’</td>
</tr>
</tbody>
</table>

(29) Proposed feature geometry for lamino-alveolars and lamino-post-alveolars

At first glance, it might seem odd that a fronted tongue body would result in a more posterior place of articulation. However, within the model proposed here this makes perfect sense. Fronting of a tongue that has a convex shape and a raised body will cause the raised portion of the tongue body to make contact with the slope of the palate behind the alveolar ridge, as illustrated in (30b).

The proposed analysis makes dentals the least marked of the laminal stops. The so-called palatals (both alveolar [ts] and post-alveolar [tʃ]) are distinguished by secondary dorsal articulations involving the features [high] and [front]. This analysis not only captures generalizations concerning the natural class of laminals and the markedness of palatals within that class, but also accounts for the affinity of palatals with high/front vowels.
8. Default completion of underspecified dimensions

The model of feature geometry adopted here is essentially that of Avery & Idsardi (2001) with only minor modifications to the Tongue Curl dimension. In Avery & Idsardi’s model, secondary articulations are only specified up to the dimension node. In other words, they are always underspecified. However, terminal features are required for phonetic implementation. Thus, underspecified dimensions must be completed via the filling in of default features. Default features are assumed to be universal, although they might be context sensitive.

The representations for coronal articulations sketched above are fully specified in terms of both primary and secondary articulators. Assuming Avery & Idsardi’s constraint on secondary articulations, the representation of retroflex and palatal stops would involve (potentially) fully-specified coronal nodes, but underspecified Tongue Thrust and/or Tongue Height dimensions under the dorsal node. Speculating a little, I suggest that the default completion of dorsal features may be dependant on the features under the primary coronal node. Thus, the default completion for [concave] segments (i.e., apicals) would be [back] for the Tongue Thrust dimension and [low] for Tongue Height. Similarly, the default completion for [convex] segments (i.e., laminals) would be [high] for Tongue Height and [front] for Tongue Thrust. This possibility is sketched in (31) and (32) with default features in brackets.

(31) Default completion of apicals with secondary dorsal dimensions

Retroflex (apical post-alveolar)          Retroflex (subapical palatal)
  \[ \begin{array}{c}
  \text{Oral Place} \\
  \text{Coronal} \\
  \text{Curl} \\
  [\text{concave}] \\
  \text{Thrust} \end{array} \]          \[ \begin{array}{c}
  \text{Oral Place} \\
  \text{Coronal} \\
  \text{Curl} \\
  [\text{concave}] \\
  \text{Height} \\
  \text{Thrust} \end{array} \]

(32) Default completion of laminals with secondary dorsal dimensions

Palatal (lamino-alveolar)          Palatal (lamino-post-alveolar)
  \[ \begin{array}{c}
  \text{Oral Place} \\
  \text{Coronal} \\
  \text{Curl} \\
  [\text{convex}] \\
  \text{Height} \end{array} \]          \[ \begin{array}{c}
  \text{Oral Place} \\
  \text{Coronal} \\
  \text{Curl} \\
  [\text{convex}] \\
  \text{Height} \\
  \text{Thrust} \end{array} \]
Recall that there is a cross-linguistic correlation between marked laminals (palatals) and high/front vowels, and between marked apicals (retroflexes) and low/back vowels. The fact that the two correlations are complementary is a reflection of the fact that they are associated with two antagonistic coronal features, [convex] and [concave], involving complementary tongue gestures, each with its own default completion for secondary dorsal dimensions.

9. Conclusion

Most models of feature geometry account for the multiplicity of coronal articulations by positing additional features and levels of structure within the coronal node. In the analysis sketched here, the coronal node has no more features or levels of structure than any other node. Rather, the multiplicity of coronal articulations results from the fact that the tongue tip and blade ride on the tongue body. Thus, by superimposing secondary tongue body gestures on primary coronal gestures a wider range of coronal articulations is achieved. The features employed here, and their definitions, maintain a strong articulatory basis while at the same time accounting for the full range of variation in contact patterns between active and passive articulators exhibited in phonetic implementation.

The proposed analysis is based on broad cross-linguistic generalizations. It has potential to provide an insightful account of natural phonological classes, degrees of markedness within coronal classes, and interactions of coronal consonants with neighbouring vowels. It remains to be seen whether it can stand the test of more detailed analyses of individual languages. I leave this for future research.

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