The violability of backness in retroflex consonants

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Abstract

This paper addresses remarks made by Flemming (2003) to the effect that his analysis of the interaction between retroflexion and vowel backness is superior to that of Hamann (2003b). While Hamann maintained that retroflex articulations are always back, Flemming adduces phonological as well as phonetic evidence to prove that retroflex consonants can be non-back and even front (i.e. palatalised). The present paper, however, shows that the phonetic evidence fails under closer scrutiny. A closer consideration of the phonological evidence shows, by making a principled distinction between articulatory and perceptual drives, that a reanalysis of Flemming's data in terms of unviolated retroflex backness is not only possible but also simpler with respect to the number of language-specific stipulations.

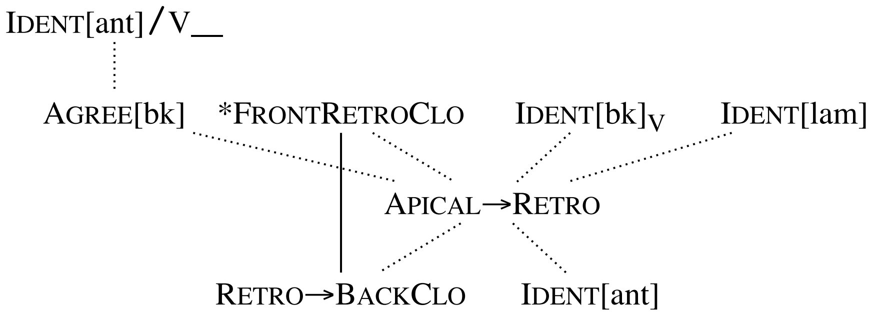
1 Introduction

This paper is a reply to Flemming's article "The relationship between coronal place and vowel backness" in *Phonology* **20.3** (2003). In a footnote (p. 342), Flemming states that "a key difference from the present proposal is that Hamann (2003b) employs inviolable articulatory constraints, whereas it is a central thesis of this paper that the constraints relating coronal place to tongue-body backness are violable". The only such constraint that is violable for Flemming but inviolable for Hamann is the constraint that requires retroflex coronals to be articulated with a back tongue body. Flemming expresses this as the violable constraint RETRO→BACK, or RETRO→BACKCLO if it only requires that the closing phase of a retroflex consonant be articulated with a back tongue body. One of the main points made by Hamann (2003b), by contrast, is that tongue-body retraction is a necessary concomitant of apico-postalveolar and apico-palatal articulations; Hamann implements this necessity as a restriction enforced by GEN, i.e. articulatory candidates that combine a retroflex tongue tip with a non-back tongue body do not appear in tableaus. The 'key difference' between Hamann's and Flemming's approaches can indeed be simplified as the difference between regarding RETRO→BACK(CLO) as violable or as inviolable constraints. Flemming adduces two kinds of evidence for the violability of RETRO→BACK and even RETRO→BACKCLO: linguistic and phonetic. The linguistic evidence consists of his analyses of several languages where the release phase of retroflex consonants is not back (i.e. RETRO→BACK is violated), and of his analyses of Walmatjari and Koḍagu, where he proposes tableaus in which even RETRO→BACKCLO is violated in a winning candidate. The phonetic evidence consists of claims in a footnote (p. 339) about palatalised retroflexes in Russian, fronted postvocalic retroflexes in Gujarati and palatalised retroflex trills in Toda. The present paper shows (in §2 and §3) that the linguistic evidence can be reanalysed with an unviolated RETRO→BACKCLO, largely within Flemming's own formalisation, and (in §4) that the phonetic evidence that Flemming himself refers to does not support his claims. We finally show (in §5) that making a principled distinction between articulatory and phonological representations leads to analyses where RETRO→BACKCLO is superfluous and RETRO→BACK is unviolated even during the release phase of retroflex consonants.

2 The linguistic evidence: Walmatjari

The first evidence that Flemming adduces for the violability of RETRO→BACKCLO comes from his analysis of Walmatjari, a Pama-Nyungan language where apical consonants assimilate their place to the preceding vowel (across a word boundary), i.e. anterior apicals occur after front vowels and retroflexes after back vowels. The ranking Flemming proposes for Walmatjari (p. 356) is reproduced as the dotted lines in (1). The solid line is a ranking that Flemming considers universal.

(1) *Flemming's grammar of Walmatjari*



We see indeed that RETRO→BACKCLO is ranked very low. In fact, it is ranked at the very bottom of the hierarchy, with three strata of constraints crucially ranked above it. Had Flemming included RETRO→BACK in the hierachy, it would have been ranked even lower, because it is more restrictive than RETRO→BACKCLO. If grammar (1) were correct, Hamann's claim of the inviolability of RETRO→BACK would be contradicted to a dramatical extent. Below, however, we discuss in detail how Flemming arrives at grammar (1) and give a much simpler alternative analysis that has RETRO→BACKCLO ranked at the top rather than at the bottom. The difference between RETRO→BACK and RETRO→BACKCLO is discussed in §5, where we show that a general replacement of RETRO→BACKCLO by RETRO→BACK yields the same empirical results.

2.1 Flemming's analysis of Walmatjari with bottom-ranked retroflex backness

Figure (1) shows the Walmatjari rankings of RETRO→BACKCLO below APICAL→RETRO and of APICAL→RETRO below *FRONTRETROCLO. Flemming establishes these two rankings in his tableau (32), which we reproduce here as (2).

(2) *Flemming's account of postvocalic place assimilation of apicals*

		*FRRETROCLO	APICAL→RETRO	RETRO→BACKCLO	IDENT[ant]
a.	iʈ				
	i. i$^{\text{i}}$ʈ	*!		*	
	☞ ii. i$^{\text{i}}$t̺		*		*
b.	at̺				
	☞ i. a$^{\text{ɨ}}$ʈ			*	*
	ii. a$^{\text{ɨ}}$t̺		*!		
c.	ut̺				
	☞ i. u$^{\text{ɯ}}$ʈ				*
	ii. u$^{\text{ɯ}}$t̺		*!		

Flemming's notation of output candidates has to be understood as follows. The tongue-body positions of both the closing phase and the release phase of coronals are transcribed as superscripts: $^{\text{i}}$ for front, $^{\text{ɨ}}$ for central and $^{\text{ɯ}}$ for back. Thus, [u$^{\text{ɯ}}$ʈ$^{\text{ɨ}}$i] stands for a retroflex plosive with a back closing phase and a central release, sandwiched between a rounded back vowel and an unrounded front vowel. With this detailed notation for overt phonetic forms, Flemming follows Steriade (1993) in assigning phonological relevance to the closing and release phases of consonants. In (2), we only see instances of the closing phase, because apical consonants assimilate their place only to the preceding vowel in Walmatjari. Two of Flemming's constraints refer to this closing phase only. The constraint *FRONTRETROCLO militates against retroflex consonants that have a closing phase with a front tongue body position, and is therefore violated in [$^{\text{i}}$ʈ]. The constraint RETRO→BACKCLO militates against retroflex consonants that have a closing phase with a non-back tongue-body position, and is therefore violated in [$^{\text{i}}$ʈ] as well as in [$^{\text{ɨ}}$ʈ]. These two constraints have an obvious universal ranking of *FRONTRETROCLO >> RETRO→BACKCLO. Flemming's constraint APICAL→RETRO states that "contrastively [apical] coronals must be [–anterior]" (p. 354), and is therefore violated by every occurrence of the apical alveolar [t̺] in a language where coronals contrast for apicality, as Walmatjari is. Finally, IDENT[ant] expresses input-output faithfulness of the feature [anterior], and is therefore violated if an underlying retroflex (i.e. [apical, –anterior]) is realised as an apical alveolar (i.e. [apical, +anterior]), or the reverse. The low ranking of IDENT[ant] causes the neutralisation of place for all apicals: alveolar after [i], retroflex after [a] and [u].

The remaining constraints in (1) are needed for handling some cases not included in (2). The constraint IDENT[lam] is needed to outrule a third candidate in (2a), namely [i$^{\text{i}}$t̠], with a laminal postalveolar plosive. The high ranking of the constraint IDENT$[\text{bk}]_{\text{V}}$ makes sure that underlying vowel backness always surfaces faithfully, outruling such candidates as [ɯ$^{\text{ɯ}}$ʈ] in (2a) or [i$^{\text{i}}$t̺] in (2c). The constraint AGREE[bk] expresses the idea that the tongue-body position of a vowel has to be identical to that of the neighbouring closing or release phase, thus ruling out candidates like [i^{ɯ}ʈ] in (2a) and [a^{ɯ}ʈ] in (2b). The high ranking of the constraint Ident[ant]/V__ makes sure that place neutralisation of apicals only occurs across word boundaries, i.e. that underlying word-internal sequences like |iʈ| and |ut̪|[1] are realised faithfully as /iʈ/ and /ut̪/.[2] In the next sections we simplify the analysis of Walmatjari in three steps.

2.2 Reanalysis of Walmatjari with top-ranked backness of retroflexes

The low ranking of Retro→BackClo is established by Flemming on the basis of (2b). If Retro→BackClo were top-ranked (as claimed by Hamann), the winner would be [a^{i}t̪], with the wrong apical. But some relevant candidates are missing from these tableaus. In the case of (2b), the missing candidate is [a^{ɯ}ʈ]. This candidate violates none of the three markedness constraints in (2) and would therefore win if added to tableau (2b). Flemming is aware of this (p. 355): "These tableaux only include candidates that satisfy Agree[backness] since this constraint is undominated, and consequently omitted from the tableaux" (sic). Candidate [a^{ɯ}ʈ] violates Agree[bk] because [a] has a central tongue-body position whereas the closing phase [^{ɯ}] involves a back tongue-body position. The auditory result, presumably, is that of a vowel [a] that receives a back colouring when it approaches the stop phase of the consonant. Flemming does not explain why Agree[bk] cannot be violated. In general, this constraint is violable, as can be seen from the winning candidate in Flemming's tableau (25), where an underlying |tu| is realised as [t^{i}u]. In the specific case of Walmatjari, Flemming gives no evidence to the effect that the pronunciation is [a^{i}ʈ] rather than [a^{ɯ}ʈ]. We thus feel free to reanalyse (2b) with an undominated Retro→BackClo (and, a forteriori, an undominated *FrontRetroClo) and a dominated Agree[bk], as we do in tableau (3).

(3) *Flemming's constraints, but with undominated backness of retroflexes: a-case*

at̪	Retro→BackClo	Apical→Retro	Agree[bk]	Ident[ant]
a. a^{i}ʈ	*!			*
b. a^{i}t̪		*!		
☞ c. a^{ɯ}ʈ			*	*

However, we also have to add two analogous candidates in (2a), and this would require a different ranking of Flemming's constraints, as shown in (4).

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[1] In the present article, the underlying representation is given in pipes |x|, the phonological surface form in slashes /x/ and the overt phonetic form in square brackets [x].

[2] The ranking in (1) is ambiguous with respect to the actual pronunciation of word-internal |iʈ|: if Agree[bk] outranks *FrontRetroClo, its pronunciation will be [i^{i}ʈ], otherwise [i^{ɯ}ʈ].

(4) *Flemming's constraints, but with undominated backness of retroflexes: i-case*

iʈ	Retro→BackClo	Agree[bk]	Apical→Retro	Ident[ant]
a. i^{i}ʈ	*!			
☞ b. i^{i}t̺			*	*
c. i^{ɨ}ʈ	*!	*		
d. i^{ɯ}ʈ		*!		

One cannot have both (3) and (4) at the same time. As a first step toward solving the predicament, we have to look in detail into what the constraint Agree[bk] refers to. Flemming defines Agree[bk] both as an articulatory constraint that refers to the articulatory effort associated with a front-back tongue body movement and as a perceptually-oriented constraint that maximises the auditory constancy of a vowel (p. 346). Such a mixture of articulatory and perceptual drives is not really in the spirit of the remainder of Flemming's article. We will show in §2.4 that the two drives can indeed be separated, but to handle the workings of Agree[bk] in the above tableaus, it will suffice to regard this constraint solely as an articulatory constraint. This constraint, then, is formalised by Flemming as a binary constraint that assigns one violation mark if the tongue body is displaced and no violation mark if it is not; this binarity makes this constraint an instance of Steriade's (1995) Displace.

Now that we interpret Agree[bk] as a constraint against articulatory effort, the incompatibility of (3) and (4) can be solved by making the constraint non-binary. A non-binary formalisation of this constraint must more severely punish a tongue-body movement from front to back, as in [i^{ɯ}ʈ], than the smaller tongue-body movement from central to back, as in [a^{ɯ}ʈ]. This can be accomplished in either of two ways: Agree[bk] could be a *gradient* constraint that assigns more violation marks to [i^{ɯ}ʈ] than to [a^{ɯ}ʈ], in the spirit of Kirchner's (1998) Lazy, or it could be a fixed ranking of *categorical* constraints whereby [i^{ɯ}ʈ] violates a higher ranked constraint than [a^{ɯ}ʈ], in the spirit of Boersma's (1998) *Distance or Kirchner's (1998: 201ff) serialised version of Lazy. Only the categorical option works here (in support of McCarthy's 2003 proposal that *all* constraints should be categorical). In fact, Hamann (2003b: 180) proposes the fixed ranking *Distance(iR) >> *Distance(ɨR), where R stands for any retroflex segment. According to Boersma (1998: 150), *Distance constraints can be universally ranked if one of the two movements (in this case from front to back) completely encloses the other movement (in this case from central to back). Since Flemming uses the universal ranking by enclosure himself (namely in the fixed ranking *FrontRetroClo >> Retro→BackClo), the replacement of a single Agree[bk] with a constraint pair ranked by the degree of *dis*agreement between vowel and closing phase must be completely in the spirit of Flemming's account. With Flemming's notation of features, we have *Distance(front,back), violated by [i^{ɯ}], and *Distance(central,back), violated by [a^{ɯ}] and (a forteriori) by [i^{ɯ}]. The fixed ranking is *Distance(front,back) >> *Distance(central,back). We can now propose an account in terms of *Distance, as in tableau (5) (the analysis will be improved again in the next section).

(5) *Walmatjari with a hierarchy of tongue-body movement constraints*

		RETRO→ BACKCLO	*DISTANCE (front,back)	APICAL→ RETRO	*DISTANCE (central,back)	IDENT [ant]
a.	iʈ					
	i. iⁱʈ	*!				
	☞ ii. iⁱt̪			*		*
	iii. iᵚʈ		*!		*	
b.	at̪					
	i. aᶤʈ	*!				*
	ii. aᶤt̪			*!		
	☞ iii. aᵚʈ				*	*
c.	ut̪					
	☞ i. uᵚʈ					*
	ii. uᵚt̪			*!		

By using a fixed ranking of categorical constraints rather than a single binary constraint or a gradient constraint we thus derive all the phenomena of Walmatjari sentence-level place neutralisation of apicals without having to violate RETRO→BACKCLO in any winning candidate. As far as these facts are concerned, this constraint could well be included in GEN.

2.3 Simplifying the analysis by separating articulatory and perceptual drives

Flemming intended many of his constraints to have a solely articulatory interpretation (RETRO→BACK, RETRO→BACKCLO, *FRONTRETROCLO) or a solely perceptually-oriented interpretation (IDENT[bk], IDENT[lam], IDENT[ant]). In §2.2 we saw that the ambiguously formulated constraint AGREE[bk] could be regarded as articulatory. In this section we question Flemming's constraint APICAL→RETRO, which has the appearance of an articulatory constraint such as RETRO→BACKCLO but is actually intended by Flemming as reflecting a perceptual drive. We will show that reformulating APICAL→RETRO as an explicitly perceptually-oriented constraint leads to a simplification of the analysis of Walmatjari.

Flemming proposes APICAL→RETRO on the basis of the confusability of the various apicals with the laminals. He cites Anderson (1997) for reporting that anterior apicals (i.e. alveolars) in Arrernte are perceived as laminals 10 percent of the time, and that posterior apicals (i.e. retroflexes) are perceived as laminals only 1 percent of the time. It is thus good for the perception of apicality if an apical is pronounced as retroflex rather than as alveolar. For a formalisation of such constraints, Flemming refers to Flemming (2004), where contrast enhancement is expressed as a family of MINDIST constraints (Flemming [1995] 2002). Such constraints, however, evaluate whole inventories rather than sets of single output candidates, and are therefore notoriously difficult to incorporate in production tableaus that start from underlying forms (Flemming [1995] 2002: 33-35; Boersma 1998: 361; McCarthy 2002: 227).

This problem may have led Flemming to propose the provisional constraint APICAL→RETRO.

For the expression of contrast enhancement there exists an alternative to MINDIST that does not share its problems with evaluating linguistic expressions. Boersma's (1998) explicitly listener-oriented faithfulness constraints lend themselves both for expressing degrees of confusability (Boersma 2003) and for inclusion in production tableaus. The probabilistic version of these constraints can be formalised as in (6).

(6) *REPLACE(*x*,*y*,*p*%)

Do not pronounce an underlying *x* as something that the listener will perceive as *y* more than *p* percent of the time.

The present case of Walmatjari is unusual in that such confusion probabilities are actually known from Anderson's experiments with a related language. From the value of 10 percent mentioned above, for instance, we can conclude that pronouncing an underlying apical as anterior violates at least the constraint *REPLACE(apical, laminal, 9%), which means "do not pronounce an underlying apical as something that the listener will perceive as laminal more than 9 percent of the time".[3] This constraint is not violated by pronouncing an underlying apical as posterior, although this pronunciation does violate constraints like *REPLACE(apical, laminal, 0.5%), as can be concluded from the value of 1 percent mentioned above. We can abbreviate the *REPLACE constraints as IDENT([±lam],9%) and the like, where "±lam" stands for both values of the laminality feature (identifying [apical] with [–laminal]), and "9%" stands for the probability of perceiving the opposite feature value. Since it is worse for the speaker to be more confusing than to be less confusing, these *probabilistic faithfulness constraints* can be ranked in a fixed order (Boersma 2003: 43), here exemplified in (7) by a choice of three members of this continuous constraint family.

(7) *Fixed ranking of probabilistic faithfulness (excerpt)*

IDENT([±lam],90%) >> IDENT([±lam],9%) >> IDENT([±lam],0.5%)

In (5) and all earlier tableaus, APICAL→RETRO can simply be replaced with IDENT([±lam],9%) and the analysis would still work.[4] But there is more. The reformulation in terms of a faithfulness constraint connects it with an independently needed constraint that already appears in grammar (1), namely IDENT[lam]. As said before, Flemming uses this constraint to outrule the candidate [iⁱt̠] in (2a). But this constraint can be reformulated as a probabilistic faithfulness constraint. Anderson

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[3] Following Boersma (1998: 278), this constraint only exists for languages in which both apical and laminal are possible discrete feature values, i.e. languages where apicality is contrastive. This general restriction on faithfulness constraints compares favourably to Flemming's stipulative inclusion of the condition "contrastively" in his formulation of APICAL→RETRO (see our §2.1).

[4] There *are* empirical differences between the two constraints: APICAL→RETRO, being formulated as a markedness constraint, is violated by any apical alveolar in the output, while IDENT([–lam],9%), being a faithfulness constraint, is violated only if the underlying consonant is also apical. Moreover, in cases where an underlying laminal surfaces as apical, APICAL→RETRO will require that it be retroflex, whereas IDENT([+lam],*p*%) will require that it *not* be retroflex. The Walmatjari data cannot decide between any of these opposite predictions.

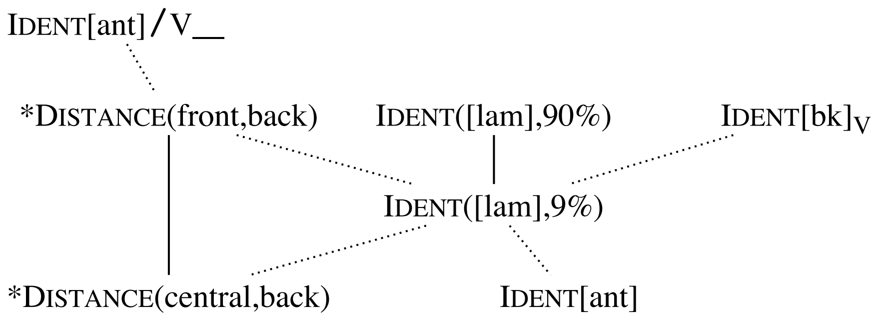
(1997: 390) states that a posterior laminal pronunciation leads to a 99 percent probability that it is perceived by Western Arrernte listeners as [+laminal], which means that if the underlying form contains an apical, this certainly constitutes a violation of IDENT([±lam],90%). This high-confusion faithfulness constraint is the probabilistic counterpart to Flemming's IDENT[lam], which is violated whenever an underlying apical is *articulated* as laminal. IDENT([±lam],90%) is universally ranked above IDENT([±lam],9%), as seen in (7). This ranking explains what happens if we take into account a fourth candidate in (5a), namely [i$^{\text{i}}$t̠], with a posterior laminal (i.e. postalveolar) plosive. The ranking in (8) handles the facts.

(8) *Walmatjari with a hierarchy of laminal faithfulness constraints*

iʈ	RETRO →BACKCLO	*DISTANCE (front,back)	IDENT [lam],90%	IDENT [lam],9%	*DISTANCE (central,back)	IDENT [ant]
a. i$^{\text{i}}$ʈ	*!					
☞ b. i$^{\text{i}}$t̻				*		*
c. i$^{\text{ɯ}}$ʈ		*!			*	
d. i$^{\text{i}}$t̠			*!	*		

The rankings of the constraints not included in (8) are analogous to Flemming's rankings in (1). IDENT[bk]$_V$ must outrank IDENT([±lam],9%), as we can see when adding a fifth candidate [ɯ$^{\text{ɯ}}$ʈ] to tableau (8). IDENT[ant]/V__ must outrank *DISTANCE(front,back) to prevent word-internal neutralisation of apicals. The complete ranking is in (9).

(9) *A grammar of Walmatjari without violable retroflex backness*

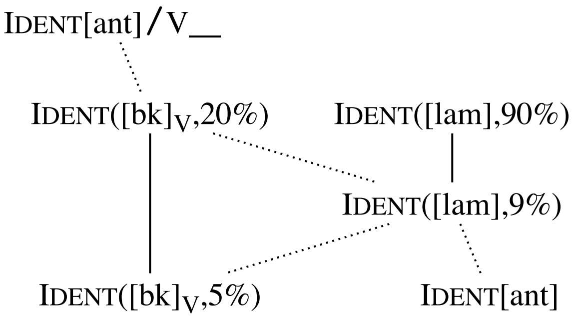


In (9), fixed rankings are depicted with solid lines, language-specific rankings with dotted lines. The constraint RETRO→BACKCLO, which is part of GEN, is not included. Compared with Flemming's ranking in (1), we have economised on two language-specific rankings, which should count as a simpler explanation of the facts. This reduction is partly due to the inviolability of retroflex backness, partly to the observation that Flemming's IDENT[lam] and APICAL→RETRO can be replaced with a fixed-ranked pair of probabilistic faithfulness constraints. Another virtue of the analysis in (9) is that all constraints are either straightforward articulatory effort constraints or listener-oriented faithfulness constraints, and no ambiguous constraints like APICAL→RETRO and AGREE[backness] are necessary.

2.4 A faithfulness-only analysis

A further simplification of the constraints and their rankings in (9) can be performed by dismissing the *DISTANCE constraints. As mentioned above, Flemming defines AGREE[bk] not only articulatorily but also perceptually, namely as the need to maximise the auditory constancy of a vowel. This perceptual aspect can be formalised separately as probabilistic IDENT$[bk]_V$ constraints. IDENT($[bk]_V$,20%), for instance, states that a vowel with transitions into or out of a consonant with an opposite backness specification should not be pronounced in such a way that the listener will perceive it as a different vowel in more than 20% of the cases.[5] If we assume that a back transition [ᵚ] would cause more vowel quality confusion if attached to a front vowel than if attached to a central vowel, the sequence [iᵚʈ], i.e. a front vowel with back transitions, would violate something like IDENT($[bk]_V$,20%) whereas the sequence [ɨᵚʈ], i.e. a central vowel with back transitions, would violate only something like IDENT($[bk]_V$,5%). The two constraints have the fixed ranking IDENT($[bk]_V$,20%) >> IDENT($[bk]_V$,5%) and could replace the two *DISTANCE constraints in all the tableaus discussed so far. The resulting constraints and their rankings are given in (10).

(10) *A grammar of Walmatjari consisting of faithfulness constraints only*



This solution has again one language-specific ranking less than the one in (9). Note that generally a faithfulness-only solution can be compatible with input-output differences only if there are restrictions on GEN. In the current case, the restriction on GEN is the inviolability of RETRO→BACK. Given this restriction, an underlying |iʈ| cannot surface as [iⁱʈ] or [iᶤʈ] because these candidates cannot occur in any tableau. The choice between the remaining alternatives, like [iⁱt], [iⁱt̠], and [iᵚʈ], is then entirely relegated to the ranking of faithfulness constraints.

One could think that the interchangeability of *DISTANCE and IDENT would make one of the two families superfluous, and Flemming indeed collapses them into a single AGREE(backness) family. But the interchangeability is only coincidental. In general, a replacement of articulatory markedness constraints by perceptual faithfulness constraints (or the reverse) can only be performed in cases where both constraint families work in the same direction: in the present case, the articulatory reduction of the distance between vowel and consonant makes the vowel perceptually

[5] IDENT($[bk]_V$,*p*%) thus differs from the perceptual interpretation of AGREE[bk] in two empirical respects, namely its non-binarism (cf. *DISTANCE in §2.3), which is crucial here, and its dependence on the underlying value of [back] (cf. footnote 4), which Walmatjari shows no evidence for or against.

more distinct. This case is different from what is usually found in phonological processes, where articulatory reduction tends to diminish the perceptual recoverability of segments. In those cases, articulatory and perceptual drives necessarily have to be distinguished, and the most principled strategy is therefore to distinguish them in *all* cases, even in cases like the current where the two drives happen to work in the same direction.

2.5 Conclusion for Walmatjari

The Walmatjari evidence does not support Flemming's claim of violable backness in retroflex consonants. Not only do there exist several analyses of Walmatjari in which RETRO→BACKCLO is unviolated, in stark contrast with its ranking in (1), but putting this constraint in GEN helps us to achieve a reduction from 7 language-specific rankings, as in (1), to 5 or even 4 language-specific rankings, as in (9) or (10).

Whether the partially articulatory-based account of (9) or the faithfulness-only account of (10) is the correct analysis of Walmatjari cannot be decided on the basis of the available data. It seems useful to note that the two analyses are not equivalent with respect to the factorial typologies that they generate. For the underlying form |iʈ|, no ranking of the constraints in (10) can ever yield the form [ɯ^{ɯ}ʈ] as a winner, since this form violates all the constraints that [i^{ɯ}ʈ] does, namely IDENT([bk]$_V$,20%) and IDENT([bk]$_V$,5%), plus an additional high-confusion constraint in the same family, say IDENT([bk]$_V$,90%). Since the place assimilation under discussion does occur in the world's languages, as in Koḍagu (§3), the constraint set in (10) does not suffice for all languages. The constraint set in (9) does yield [ɯ^{ɯ}ʈ] as a possible winner for |iʈ|, as can be seen in (11) below. Since the analyses in §3 and §5 below require *DISTANCE constraints, we regard (9) as the most likely analysis of Walmatjari.

3 The linguistic evidence: Koḍagu

The second evidence for the violability of RETRO→BACKCLO in Flemming's account stems from Koḍagu, where vowels are retracted by following retroflexes. Such a situation can only occur if IDENT[bk]$_V$ is ranked below many other constraints, as shown in (11), which combines Flemming's tableaus (38) and (39) with some more candidates and our *DISTANCE constraints.

(11) *Koḍagu vowel retraction before retroflexes*

iʈ	RETRO→ BACKCLO	IDENT [ant]	IDENT [lam]	*DISTANCE (front,back)	*DISTANCE (central,back)	IDENT [bk]$_V$
a. i^{i}ʈ	*!					
b. i^{ɯ}ʈ				*!	*	
☞ c. ɯ^{ɯ}ʈ						*
d. ɨ^{ɯ}ʈ					*!	*
e. ɨ^{i}ʈ	*!					*
f. i^{i}t̠		*!				
g. i^{i}tʃ			*!			

The ranking of RETRO→BACKCLO cannot be determined on the basis of the data in (11), but Flemming finds some evidence in the fact that vowel retraction is blocked after tautomorphemic postalveolar consonants. Flemming's analysis is shown in tableau (12). The high-ranked constraint PALATO-ALVEOLAR→FRONTRELEASE (PA→FRREL) in this tableau states that palato-alveolar segments have to have a front release.

(12) *Flemming's analysis for blocking of vowel retraction in Koḍagu*

tʃeɖ	PA→ FRREL	AGREE[bk]	*FRONT RETROCLO	RETRO→ BACKCLO	IDENT $[bk]_V$
☞ a. tʃ^{i}e^{i}ɖ			*	*	
b. tʃ^{i}e^{i}ɖ		*!		*	
c. tʃ^{i}e^{ɯ}ɖ		*!			
d. tʃ^{i}ɤ^{ɯ}ɖ		*!			*
e. tʃ^{ɯ}ɤ^{ɯ}ɖ	*!				*

In tableau (12) RETRO→BACKCLO and even the universally stronger *FRONTRETROCLO are crucially outranked by AGREE[bk], maximally contradicting Hamann's (2003b) claim of inviolable retroflex backness. However, Flemming's analysis assumes, as it did in the case of Walmatjari, that a sequence of a front vowel and a retroflex consonant is realised with a front closing phase for the retroflex, as in (12a). As in the case of Walmatjari, we propose that a different candidate should win, namely (12c). This is achieved by moving RETRO→BACKCLO to the top, as in (13).

(13) *Reanalysis with undominated backness of retroflexes*

tʃeɖ	RETRO→ BACKCLO	PA→ FRREL	*DISTANCE (front,back)	*DISTANCE (central,back)	IDENT $[bk]_V$
a. tʃ^{i}e^{i}ɖ	*!				
b. tʃ^{i}e^{i}ɖ	*!			*	
☞ c. tʃ^{i}e^{ɯ}ɖ			*	*	
d. tʃ^{i}ɤ^{ɯ}ɖ			*	*	*!
e. tʃ^{ɯ}ɤ^{ɯ}ɖ		*!			*

We do not know which of the three phonetic forms, [tʃ^{i}e^{i}ɖ], [tʃ^{i}e^{i}ɖ] or [tʃ^{i}e^{ɯ}ɖ], is correct, since no articulatory or acoustic data on the realisation of the retroflex in this context in Koḍagu exists.[6]

6 If Koḍagu had allowed the central high-mid articulation [ɘ], a candidate [tʃ^{i}ɘ^{ɯ}ɖ] would have won, since this violates *DISTANCE(front,central) and *DISTANCE(central,back) but not the universally higher ranked *DISTANCE(front,back). But since the articulation [ɘ] is generally ruled out in Koḍagu, this language must either have a high-ranked articulatory constraint *[ɘ] (in a nativist view of GEN) or articulatory candidates containing [ɘ] are not even generated since they contain a non-acquired motor skill (in an emergentist view of GEN; Boersma 1998: 280, 292). We predict that a Koḍagu-like language that does have [ɘ] would choose [tʃ^{i}ɘ^{ɯ}ɖ], if backness faithfulness is ranked as low as it has to be here.

There is an empirical difference between Flemming’s ranking and ours. Flemming’s ranking in (12) predicts that an underlying |tʃɤɖ| is pronounced as [tʃ^{i}e^{i}ɖ], whereas our ranking in (13) predicts that it is pronounced as [tʃ^{i}ɤ^{ɯ}ɖ], forced by backness faithfulness. In order to derive neutralisation, i.e. to ensure that an underlying |tʃɤɖ| is pronounced as [tʃ^{i}e^{ɯ}ɖ], we might invoke a possible asymmetry in the articulatory gestures, namely that the articulatory distance in [^{i}ɤ] could be larger than that in [e^{ɯ}], so that [tʃ^{i}e^{ɯ}ɖ] satisfies a higher *DISTANCE constraint than [tʃ^{i}ɤ^{ɯ}ɖ] does. But we may not have to go there. While there are indeed no tautomorphemic sequences like [tʃ^{i}ɤ^{ɯ}ɖ] in Koḍagu, the language does have cross-morphemic sequences like [-indʒ-ɤ], for which Flemming (p. 359) has to invoke output-output faithfulness (e.g. ranking IDENT$_{OO}$[bk] over AGREE[bk]) or level ordering. The analysis in (13), on the other hand, can readily account for the cross-morphemic sequences but would have trouble with the tautomorphemic restriction, for which we would have to invoke lexical restrictions (e.g. by moving richness of the base out of the lexicon). This means that both our account and Flemming’s account have to take recourse to devices that can handle opacity effects.

The Koḍagu evidence thus adds to the evidence from Walmatjari. In both cases, the constraint RETRO→BACKCLO was violated by a winning candidate in Flemming’s account but could be re-analysed as inviolable. That there are no violations of the more restrictive RETRO→BACK either, is shown with phonetic evidence in §4 and with phonological evidence in §5.

4 The phonetic evidence

In a footnote on page 339, Flemming mentions three pieces of data stemming from Russian, Gujarati, and Toda, to support his claim that retroflexes can be articulated with a front tongue body. The following subsections address the evidence and lead to the rejection of Flemming’s claim.

4.1 Russian

Flemming writes in his footnote: “there is good evidence that retroflexes can be produced with a front or central tongue-body position, most directly from X-ray data on palatalised retroflex sibilants in Russian (Keating 1991, 1993).” Keating (1991: 39) only briefly mentions that Russian has a surface contrast between retroflex and palatalised retroflex fricatives and that the “Russian palatalized retroflex looks straightforwardly like a palatalized version of the plain (curled) retroflex”. For the evidence we have to consult Keating (1993), who writes (p. 7): “There is a surface contrast in Russian between this [i.e. the plain retroflex] fricative and a palatalized variant, primarily resulting from cluster simplification.”

The ‘plain retroflexes’ that Keating refers to are the sounds traditionally referred to as ‘hard’ (velarised) postalveolar sibilants, occurring in words like /ʃ$^{(ɯ)}$ag/ ‘step’ and /ʒ$^{(ɯ)}$ena/ ‘wife’. Their alleged palatalised variants are the sounds traditionally referred to as ‘soft’ (palatalised) postalveolar sibilants, occurring in words like /ʃ^{j}ːi/ ‘soup’ and /voʒ^{j}ːi/ ‘reins’. It may be relevant to point out that phonologically these two types of sibilants are not velarised-palatalised pairs: unlike the alveolar pair /s$^{(ɯ)}$/–/s^{j}/ the postalveolars /ʃ$^{(ɯ)}$/ and /ʃ^{j}ː/ do not join in alternations with each other. Also, /ʃ^{j}ː/ is always long, in contrast to /ʃ$^{(ɯ)}$/, which becomes long only in cluster simplifications. All this does not preclude, of course, that /ʃ$^{(ɯ)}$/ and /ʃ^{j}ː/ could be *phonetically* paired, e.g. that both of them could be pronounced as retroflex, which is exactly what Keating (1993) claims.

Our discussion of the phonetics of /ʃ$^{(ɯ)}$/ and /ʃ^{j}ː/ starts with Keating's figure 5 (p. 10), which is apparently based on Bolla's (1982) drawings (pp. 158, 162) of the midsagittal plane, which are again based on X-ray tracings. In this picture we see two articulations, one velarised, the other palatalised. Keating's judgment that both of these sounds are retroflex is based on their alleged apicality, which Keating probably derives from the concaveness in the midsagittal plane.

However, Bolla's pictures are problematic if we want to determine the place of articulation or the active articulator. The extremely schematic drawings of the roof of the mouth do not allow an absolute determination of the place of articulation, and a comparison of the locations of the primary constrictions of /ʃ$^{(ɯ)}$/ and /ʃ^{j}ː/ with those of the velarised and palatalised anterior fricatives /s$^{(ɯ)}$/ and /s^{j}/ is disappointing: all four fricatives seem to have the same place of articulation. While these pictures show a good distinction between velarised and palatalised sibilants (e.g. by the distance between the tongue and the uvula), they are poor at discriminating places of articulation or active articulators. These shortcomings were pointed out by Keating & Lahiri (1993) who report in a discussion of palatal and velar consonants (p. 85) that "Bolla's (1981[b], 1982) X-ray tracings are point schematics and therefore not precise with respect to contact, but the accompanying palatograms and linguograms are useful". Moreover, in the case of sibilant fricatives large differences between the various sagittal sections can be expected, so that 3-dimensional information has to be included (Pike 1943; Malmberg 1963; Ladefoged & Maddieson 1996; Stone 1990; Stone, Faber, Raphael & Shawker 1992; Gafos 1999). Palatograms and linguograms are among the methods that provide information on changes in the sagittal sections along the transverse direction.

Bolla's (1982) palatograms and linguograms indeed shed light on the active articulator and the place of articulation of the sounds in question. The linguograms for /ʃ$^{(ɯ)}$/ and /ʒ$^{(ɯ)}$/ exhibit a convergence of the lateral contacts at the very tip of the tongue, showing that these sounds are apical; the linguograms for /ʃ^{j}ː, ʒ^{j}ː, s^{j}, z^{j}, s, z/ exhibit a convergence of the lateral contact areas at the tongue blade and no contact in the tongue tip area, showing that these sounds are laminal. Extending to the dorsal areas, the linguograms for /ʃ^{j}ː, ʒ^{j}ː, s^{j}, z^{j}/ exhibit broad lateral contact areas and a narrow medial contact-free area, showing that these sounds are palatalised, whereas /ʃ$^{(ɯ)}$, ʒ$^{(ɯ)}$, s$^{(ɯ)}$, z$^{(ɯ)}$/ have narrow lateral contact areas and a wide medial contact-free area, showing that these sounds are not palatalised. Finally, the palatograms show that /s, z, s^{j}, z^{j}/ have an alveolar contact while /ʃ^{j}ː, ʒ^{j}ː, ʃ$^{(ɯ)}$, ʒ$^{(ɯ)}$/ do not, which confirms the usual viewpoint of an alveolar versus postalveolar contrast.[7] These interpretations

[7] Judging from Bolla's palatograms, the contrast may be denti-alveolar versus alveolar rather than alveolar versus postalveolar. Apical alveolars do not fall under traditional definitions of retroflexes as apical or subapical articulations at the postalveolar or palatal region (e.g. Catford 1977) because of their anterior place of articulation. Hamann (2003b), however, illustrates that the apical anterior fricatives in Polish, Russian and Mandarin can all be considered retroflex on acoustic and phonological grounds and that retroflex fricatives therefore can have an alveolar place of articulation. The alleged palatalised retroflexes in Bolla (1982), on the other hand, lack not only a posterior place

of Bolla's (1982) data are summarised in table (14). We can conclude from all the reliable evidence in Bolla (1982) that /ʃ$^{(ɯ)}$, ʒ$^{(ɯ)}$/ are pronounced as velarised apical postalveolars ([ʂ^{ɯ} ʐ^{ɯ}]), and /ʃ^{j}ː, ʒ^{j}ː/ as palatalised laminal postalveolars ([ɕː ʑː]).

(14) *Interpretation of the evidence in Bolla (1982)*

	X-ray			linguogram	palatogram	
	place (unreliable)	articulator (unreliable)	dorsum	articulator	place	palatalised
s$^{(ɯ)}$ z$^{(ɯ)}$	?	apical	velarised	laminal	alveolar	no
s^{j} z^{j}	?	apical	palatalised	laminal	alveolar	yes
ʃ$^{(ɯ)}$ ʒ$^{(ɯ)}$	?	apical	velarised	apical	postalveolar	no
ʃ^{j}ː ʒ^{j}ː	?	apical	(palatalised)[8]	laminal	postalveolar	yes

Bolla's (1981) earlier data of the same set of Russian sounds from another speaker show the same systematic difference in active articulator: whereas /ʃ$^{(ɯ)}$/ and /ʒ$^{(ɯ)}$/ are apical, the palatalised /ʃ^{j}ː/ and /ʒ^{j}ː/ are laminal.[9] Additionally, the palatalised sounds show a very prominent raising of the tongue middle. All four sounds are articulated at the postalveolar region. Thus, /ʃ$^{(ɯ)}$, ʒ$^{(ɯ)}$/ in Bolla (1981) are pronounced as velarised apical postalveolars ([ʂ^{ɯ} ʐ^{ɯ}]), and /ʃ^{j}ː, ʒ^{j}ː/ as palatalised laminal postalveolars ([ɕː ʑː]).

Keating supplies further data on the alleged Russian palatalised retroflex from Akishina & Baranovskaja (1980) and Matusevič & Ljubimova (1964). Keating's figure 6 on page 12, which stems from Akishina & Baranovskaja (1980: 63, figure 16), shows /ʃ$^{(ɯ)}$/ as an apical (post-)alveolar with a retracted tongue body, and /ʃ^{j}ː/ as an apical dental with a raised tongue middle. Keating (p. 7) remarks on the latter sound: "Note how the movement of the tongue moves the blade forward […], so that the primary constriction is slightly fronted under palatalization". The /ʃ$^{(ɯ)}$/ is thus realised as [ʂ^{ɯ}], whereas the palatalised /ʃ^{j}ː/ is realised as an apical dental [s̺̪^{j}].[10] Two things have to be said about this apical dental. First, it does not fall together with /s^{j}/, which Akishina & Baranovskaja report as being a palatalised laminal dental. Second, the apicality of this sound only occurs for some speakers, not on a dialect-specific basis, but as a function of the structure of the tongue ("po ukladu jazyka", Akishina & Baranovskaja p. 63); we interpret this as implying that for other speakers this sound is laminal and postalveolar.

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of articulation but also the apical articulator, and do not even fall under Hamann's lenient definition of retroflex.

8 Bolla's /ʒ^{j}ː/ shows no raised tongue middle, i.e. no palatalization. Perhaps this is a result of the following vowel, which is /u/, or of the fact that this phoneme can merge with /ʒ$^{(ɯ)}$ː/ (Panov 1979:26) and can therefore be pronounced as [ʐ^{ɯ}ː].

9 The X-ray tracings in Bolla (1981) are less schematic than those in Bolla (1982) and allow a more precise interpretation. It has to be added, however, that the linguograms for the velarised postalveolar fricatives from the same source show only little lateral contact at the tongue blade and none at the tongue tip. This is puzzling especially since the palatalised postalveolars have slightly more fronted lateral contact areas, covering almost the whole length of the blade. A possible explanation for these findings is a sub-apical articulation of the velarised sounds.

10 The apical dental is not even retroflex according to Hamann's lenient definition of retroflexion (fn. 7).

Keating's (1993) figure 7 on page 12, based on the x-ray data by Matusevič & Ljubimova (1964), shows /ʃ$^{(ɯ)}$/ as an apical alveolar sound with slight velarisation and /ʃ^{j}ː/ as a palatalised, laminal postalveolar sound. On the latter, Keating (p. 11) herself notes "the palatalized variant is not retroflexed". We interpret these two sounds as [ʂ^{ɯ}] and [ɕː], respectively.

In addition to the data compiled by Keating, we include a study by Koneczna & Zawadowski (1956) in our discussion because it provides both medial and lateral sagittal x-ray tracings of the sounds in question. Both speakers of this study realise /ʃ$^{(ɯ)}$, ʒ$^{(ɯ)}$/ as apical alveolars with velarisation (the velarisation is stronger in the lateral sections) (figures 218-223), and /ʃ^{j}ː, ʒ^{j}ː/ as palatalised laminal postalveolars ([ɕː ʑː]) (figures 241-245).

Summing up, the x-ray data compiled by Keating and the additional data from Bolla (1981) and Koneczna & Zawadowski (1956) illustrate that the alleged secondarily palatalised retroflex fricative in Russian has two different surface realisations: a laminal postalveolar with raised tongue middle [ɕː] (as in Matusevič & Ljubimova 1964, Bolla 1981 and 1982, and Koneczna & Zawadowski 1956), or a rare apical dental with raised tongue middle [s̺̪^{j}ː] (for some speakers in Akishina & Baranovskaja 1980), neither of them being both apical and postalveolar, i.e. retroflex. Keating's data therefore give no evidence for the existence of a palatalised retroflex in Russian.

4.2 Gujarati

According to Flemming (2003: 339, footnote 4), "the combination of palatographic and acoustic evidence in Dave's (1977) study of Gujarati strongly suggest[s] that the retroflexes are produced with a front or central tongue-body position following front vowels in this language". We will discuss both types of evidence.

As for Dave's palatographic evidence, we see that the palatograms show a slightly more fronted place of articulation for the retroflex stops [ʈ ɖ] in the context of the vowel [i] compared to the contexts [u] and [a] (p. 38). The same holds for [ɭ] and [ɳ] (pp. 44 and 47, respectively), whereas the rhotic [ɽ] is not influenced by the vowel [i] (p. 41). Dave's palatographic data thus show that the place of articulation of all retroflexes apart from the rhotic is slightly fronted in [i] context. It does not give any evidence for a correlation between vowel context and the tongue-body position of retroflexes, since we cannot conclude that a fronted place of articulation in retroflexes is accommodated by a fronted tongue body. The independence of contextual fronting of place of articulation and tongue-body retraction in retroflexes is established by Wiltshire & Goldstein's (1998) EMMA study on Tamil dentals and retroflexes, which for the retroflexes (but not for the dentals) shows strong vowel effects on the receiver coils at the tongue tip and tongue underside. For retroflexes (and dentals) the vowel context strongly influenced the receivers on the tongue body in their vertical position, but not in their horizontal position.[11] Wiltshire & Goldstein (1998) comment that "the

[11] Wiltshire and Goldstein distinguish between the 'tongue body' and the 'tongue dorsum'. From their graphs 1 and 2, it can be seen that the horizontal 'tongue body' position (which is the more anterior of the two) strongly depends on the place of articulation (retroflex plosives are more back than dental plosives by 6 to 7 millimetres, depending on the vowel context) and hardly depends on the vowel context (0 millimetres difference between [i] and [u] contexts, for both places of articulation). For the

particular tongue tip gesture of these consonants [i.e. both retroflexes and dentals] seems to place some constraint on other parts of the tongue" (p. 221) and that "we do see a strong horizontal effect of the retroflex versus dental gesture, as the entire body of the tongue is retracted for retroflex consonants" (p. 224). Their data thus indicate that retroflexes are more context-dependent than dentals in their position of the tongue tip and underside, but that the horizontal position of the tongue body in retroflexes is not influenced by adjacent vowels.

Turning to Dave's acoustic data, we see that the only vowel-dependent measurements are those of the steady state of the formants and the end points of transitions into and out of retroflex (and dental) consonants. All measurements show a lowered third formant (F3) into the retroflex articulation, independent of the vowel context. Furthermore, the vowel transitions preceding retroflex stops have a locus for the second formant (F2) at around 2100 Hz (p. 187), which means a rising F2 for central and back vowels, and a slight lowering of F2 for front vowels. The F2 values for the front vowels do not reach as far down as the endpoint of the F2 values for non-front vowels. Liquid and nasal retroflexes have a similar shape of F2 transitions. According to Stevens & Blumstein (1975), whom Dave refers to in the interpretation of his measurements (p. 123), the F2 of an apical sound reflects the size of the cavity behind the closure. Thus the slightly higher F2 values for retroflexes in a front vowel context corroborate the palatographic findings that the retroflexes in this context are articulated with a more fronted place of articulation. No inference about the position of the tongue body can be made from this observation.

We conclude that in contradistinction to Flemming's claim, Dave's palatographic and acoustic evidence do not suggest that Gujarati retroflexes are "produced with a front or central tongue-body position following front vowels". Instead, the same evidence rather seems to support Hamann's claim of inviolable tongue-body backness.

4.3 Toda

The third piece of evidence by Flemming on the existence of retroflexes with a fronted or centralised tongue body stems from Toda, which is described as having a palatalised retroflex trill, e.g. by Spajić, Ladefoged & Bhaskararao (1996). In their phonetic study on the trills in Toda, Spajić et al. provide only one spectrogram of the sound in question (p. 19)[12], and describe the general impact of secondary palatalisation on all three rhotics in this language as "a steadily rising F2 from the onset of the preceding vowel through to the ^{j} release of the rhotic" (p. 18). This is, however, no evidence that the so-called palatalised retroflex is indeed what it is called. The change in F2 is very likely to indicate a change during the articulation of this sound, namely from retroflex to a palatalised non-retroflex rhotic or even a palatal glide. As pointed out in Hamann (2003b: 49ff), the palatalised segment is also

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question of the present section it would be relevant to find out where the point of maximum tongue-body/dorsum constriction is. Despite the imprecision caused by the use of only two receiver coils on the tongue body/dorsum, the graphs suggest that the maximum constriction is velar for the [i] context, and uvular for the [u] context, i.e. both are 'back'.

[12] Interestingly, Spajić et al. were able to elicit the palatalized retroflex trills from three of their six subjects only (see their table 2 on page 4 and its description on page 5).

considerably longer than its plain counterpart (110 vs. 190 ms), which is another argument in favor of a sequential articulation of a rhotic and a glide. Furthermore, Sakthivel (1976, 1977) transcribes the palatalised retroflex rhotic, like all palatalised segments in Toda, as a sequence of retroflex plus palatal glide, indicating that the sounds in question consist of a sequence of two segments. We take these acoustic and orthographic arguments as evidence for the sequentiality of retroflex and palatalisation in the Toda retroflex rhotic. Unfortunately, no data on the articulation of this sound from Spajić et al.'s study exist (Peter Ladefoged p.c.) to corroborate or contradict this evidence.

We have to point out that we do not contest the possibility that speakers of Toda structurally interpret the sound under discussion as the palatalised counterpart of the plain retroflex, i.e. as a palatalised retroflex. We do contest, however, the idea that this sound combines simultaneous retroflex and palatalisation *articulations*. This distinction between articulatory and phonological representations is addressed in more detail in §5.

4.4 Conclusion of the phonetic evidence

Summarising the evidence of the alleged retroflexes with a front or central tongue body, we see that there is no clear instance of such sounds. The two cases of so-called palatalised retroflexes in Russian and Toda either showed a different primary articulator, namely the lamina instead of the apex (in Russian), a different place of articulation, namely dental instead of postalveolar (also in Russian), or some change within the segment from retroflex to non-retroflex (in Toda). The fronting of retroflexes in front vowel contexts that is observable in Gujarati does affect the place of articulation, but articulatory data from Wiltshire & Goldstein on Tamil show that one cannot in general infer from coronal fronting that the tongue body is fronted simultaneously.

The phonetic evidence thus adds to the phonological evidence of §2 and §3 in not showing any evidence for non-back articulations of retroflex consonants.

5 Directionality effects

Hitherto we have neglected the difference between RETRO→BACK and RETRO→BACKCLO. If these constraints act differently in phonology, it will be hard to maintain that both of them should be included in GEN. And indeed, if Hamann's (2003b) claim of inviolable retroflex backness is correct, it is the more restrictive of the two, namely RETRO→BACK, that will have to be included in GEN. In this section we indeed argue that this is the case, and that RETRO→BACKCLO is a superfluous constraint. In this we depart radically from Flemming (2003), who argues that RETRO→BACKCLO is needed in grammars but RETRO→BACK is superfluous.

We first have to observe that in all tableaus in §2 and §3, RETRO→BACKCLO can be replaced with RETRO→BACK without any empirical differences, because all of these tableaus describe phenomena occurring at the closing phase. To observe empirical differences between the two constraints, we have to consider differences between the behaviour of retroflex consonants at their closing and release phases. Such differences exist, but we argue in the following sections that these differences are due to detailed articulatory behaviour during the intermediate *closed* phase, which can and should be accounted for by making a more principled distinction between articulatory and perceptual representations than Flemming's paper did.

5.1 Flapping out

This section provides articulatory, acoustic and perceptual descriptions of the change in place of articulation that occurs during the closed phase of retroflex stops. This so-called flapping out is widely held responsible for the fact that retroflex stops interact more with preceding than with following vowels.

The source of Flemming's distinction between RETRO→BACK and RETRO→BACKCLO is his observation (p. 345) that "retroflexes primarily interact with preceding vowels", which he interprets "as a consequence of the fact that many retroflexes are only fully retroflexed at the onset of constriction, because the constriction is released via an anterior movement of the tongue tip". The observation is correct, as palatographic studies of retroflex consonants prove. In Ladefoged's (1964) study on the voiced retroflex stop [ɖ] in Ewe, the palatogram shows a large contact area at the roof of the mouth, though the active articulator is the tongue tip, only, as the matching linguogram attests. The tongue tip therefore must have moved along the palate during the closed phase of the Ewe stop, a phenomenon that Ladefoged refers to as 'flapping out' (for the use of this term, see also Bhat 1973: 47).[13] Flapping out in retroflexes involves a tongue tip movement from posterior to anterior position (and not vice versa) as observable e.g. from Simonsen, Moen & Cowen's (2000) electropalatographic study on Norwegian retroflex stops, where the contact on the palate is further back at the beginning of the closed phase than at the release of the stop (both for an /i/ and an /a/ context). Further studies that attest flapping out are Dave (1977) on Gujarati retroflex stops, Dart (1991) and Dart & Nihalani (1999) on retroflex stops in Malayalam, Butcher (1995) on retroflex stops in Australian languages, Shalev, Ladefoged & Bhaskararao (1993) on retroflex stops in Toda, Krull, Lindblom, Shia & Fruchter (1995) on Swedish, Hindi, and Tamil retroflex stops and Spajić et al. (1996) on the retroflex trill in Toda.[14]

The occurrence of flapping out seems to depend on the manner of retroflex articulation. The studies mentioned above show that retroflex stops and trills are flapped out, but there are no articulatory studies to our knowledge that indicate flapping out for retroflex fricatives or affricates. The non-flapping out in retroflex fricatives and affricates, i.e. their retroflexion up to the release of the constriction, can account for the fact that these segments interact with following high front vowels. This interaction results either in back vowels or in non-retroflex fricatives or

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[13] Flapped-out retroflex stops are not identical with retroflex flaps. The latter lack a release burst and have a shorter duration than the flapped out stops (Anderson & Maddieson 1994: 134, who refer to flapping out as a dynamic hold phase).

[14] Krull et al. (1995) and Spajić et al. (1996) infer the movement during stop closure from differences in VC and CV formant transitions. Shalev et al. (1993) do not mention a flapping out or movement during the closure, but the palatogram on p.104 shows larger palatal contacts for the voiceless retroflex stop than for the voiceless apical alveolar stops. Further palatographic studies on retroflex stops such as Dixit (1990) and Dixit & Flege (1991) cannot be positively interpreted as support for flapping out as they provide no acoustic recordings to judge differences in formant transitions, and neither linguograms of the retroflexes nor palatograms of anterior apicals to estimate the proportion of the palatal contact area.

affricates. A language that centralises /i/ after retroflex fricatives or affricates is Polish, where this process is part of the so-called retraction rule (Booij & Rubach 1987). Languages that change the retroflex articulation, i.e. pronounce |ʂi| as [^{i}ʃ^{i}i] or [^{i}ɕ^{i}i] are Acoma, where |ʂ| neutralises into its laminal counterpart /ʃ/ if the following vowel is /i/ (Miller 1965, Flemming 2003), Gujarati, which developed a laminal alveolopalatal from a retroflex fricative before a high front vowel (Pandit 1954, Flemming 2003), certain Chinese dialects, where retroflex affricates and fricatives are in complementary distribution with alveolopalatals and only the latter occur before high front vowels (Yip 1996), Molinos Mixtec, where a following high front vowel laminalises the retroflex fricatives (Hunter & Pike 1969, Flemming 2003), and Chácobo, where a retroflex fricative is realised as a laminal postalveolar between high front vowels (Prost 1967, Bhat 1973). The interaction of retroflex fricatives and affricates with following vowels and its possible cause in the non-flapping out for fricatives and affricates was already observed by Bhat (1973: 47) and Flemming (p. 346 fn. 12). Hamann (2003b: 201) offers an articulatory explanation for these manner-specific differences in flapping out: a quick, ballistic movement of the tongue tip as required for stops, flaps, and trills enables a flapping out, whereas more static positions of the tongue tip (and the tongue in general), as necessary in fricatives and affricates in order to maintain the turbulent air flow, seem to prohibit flapping out. Furthermore, retroflex fricatives do not seem to involve the same kind of curling of the tongue tip as plosives, as Keating (1991: 35) observed for the retroflex fricatives in Indian languages, though they usually share the same place of articulation. This observation is attested by Hamann (2003b) who did not find an articulation of a retroflex fricative comparable to the extreme tongue tip curling that is found in the articulation of the Tamil retroflex stop (for the latter, see Ladefoged & Maddieson 1996: 27). The lesser degree of tongue tip curling could be another reason why retroflex fricatives do not undergo flapping out, if flapping out is interpreted as the quickest possible release from an extreme position of the tongue tip.

Acoustically, flapping out can be observed as an asymmetry in VC and CV formant transitions. The third formant (F3) of the transitions mirrors the size of the front cavity of a consonant. Retroflex articulations have larger front cavities than alveolar articulations (Keating 1991), resulting in a lower F3 (Stevens 1998). Since the lowering of F3 during VC transitions of retroflex stops is more prominent than its raising during CV transitions, this can be interpreted as a movement of the tongue tip from a postalveolar to an alveolar place of articulation during the closed phase and a concomitant reduction of the front cavity.

Perceptually, listeners seem to compensate for flapping out, i.e. they perceive flapped-out stops as retroflex rather than as retroflex-alveolar sequences. This is due to the fact that listeners pay more attention to the VC cues of retroflexes than to their CV cues. Hamann (2003a) tested this asymmetry in a so-called cross-splicing experiment where recorded Norwegian intervocalic dental and retroflex plosives were cut in the midst of the closed phase and re-combined in such a way that the resulting signal had VC cues of one place of articulation and CV cues of the other. Six Norwegian and six German listeners had to categorise these signals (four repetitions of each stimulus item in intervocalic [a] and [i] context) as either one segment or the other, or neither. The Norwegian (native) listeners perceived [ʈt] as <ʈ> in 90 percent of the cases and [tʈ] as <t> in 81.3 percent of the cases. While this preference for the VC cues could be due to language-specific perception (according to Öhman 1966, a poor recognition of CV cues by Swedish listeners could be attributed to the nearly exclusive postvocalic occurrence of retroflexes), the German listeners, who do not have retroflex stops in their language, showed the same VC bias, perceiving [ʈt] as <ʈ> 66.4 percent of the time and [tʈ] as <t> 59.5 percent of the time. Both groups thus show a dominance of the VC cues (both for retroflexes and dentals) in their perception, confirming Steriade's (1995, 2001) observation that retroflex VC cues are auditorily 'stronger' than retroflex CV cues.

The distinction between the articulation and perception of flapping out will be used in the following section for a detailed and observationally correct formalisation of directionality effects in retroflex segments.

5.2 How to formalise flapping-out effects

The articulation of the flapping-out gesture in retroflexes, which was elaborated in the preceding section, can explain directionality effects. In Koḍagu, a retroflex plosive backens the preceding but not the following vowel, so that an underlying |iɖi| will have the phonological surface form /ɯɖi/. This asymmetry can be explained if we assume that flapping out occurs during the closed phase of the stop. If flapping out occurs, the plosive will have an alveolar, i.e. [+ant], place of articulation when the stop reaches its release phase. This anteriority is articulatorily compatible with a fronted tongue body, which is the preferred tongue body position for a following /i/. Table (15) shows the articulatory score.

(15) *Articulatory score for an intervocalic flapping-out gesture*

	preceding vowel	closing phase	closed phase	release phase	following vowel
back	+	+	+ –	–	–
anterior		–	– +	+	
laminal		–	–	–	
transcription	ɯ	^{ɯ}	ɖ d	^{i}	i

We will abbreviate (15) as [ɯ^{ɯ}ɖ͡d^{i}i]. The crucial question now is which constraints are violated by this form. We first see that constraint RETRO→BACK, which simply states that retroflex articulations must be made with tongue body backness, is not violated, since the articulatory combination [–back,–ant,–lam], i.e. a retroflex without tongue-body backing, does not realise anywhere during the articulation: as soon as the tongue body position changes to [–back], the tongue tip position changes to [+ant].[15] The matter is different for the IDENT([ant],*p%*) family, since the recoverability of the underlying retroflex must be worse than for the impossible articulation *[ɯ^{ɯ}ɖ^{i}i], because the articulation contains an alveolar, i.e. [+ant], part, namely [d]. From the confusion probabilities mentioned in §5.1, however, we know that the plosive in

[15] An alternative formulation of this constraint could be *[–back,–ant,–lam], if it is understood that the three features are articulatory. But such a formulation would look like a structural constraint that militates against fronted retroflexes as phonological structures. We have nothing against fronted retroflexes in lexical representations or in phonological surface forms.

[ɯ^{ɯ}ɖ͡d^{i}i] is still largely perceived as a retroflex, i.e., it violates IDENT([ant],5%) but not the higher-ranked IDENT([ant],90%) that would be violated by pronouncing an underlying |iɖi| as the fully anterior [i^{i}d̪^{i}i]. With this information we can draw the tableau for Koḍagu.

(16) *Koḍagu vowel retraction before retroflexes*

iɖi	RETRO →BACK	IDENT [ant],90%	*DISTANCE (front,back)	IDENT [bk]$_V$	IDENT [ant],5%
a. i^{i}ɖ^{i}i	*!*				
b. i^{ɯ}ɖ^{ɯ}i			*!*		
c. ɯ^{ɯ}ɖ^{i}i	*!			*	
d. ɯ^{ɯ}ɖ^{ɯ}i			*!	*	
e. ɯ^{ɯ}ɖ^{ɯ}ɯ				**!	
☞ f. ɯ^{ɯ}ɖ͡d^{i}i				*	*
g. i^{i}d̪^{i}i		*!			*

Candidate (16c) has no flapping out, therefore violates the unviolable RETRO→BACK, and would not occur in the tableau if RETRO→BACK were part of GEN. Candidate (16d) has a big transition-vowel mismatch [^{ɯ}i], therefore violates *DISTANCE(front,back).[16] Candidate (16f), with the flapping-out gesture, remains as the winner, since it violates IDENT([ant],*p*%) to a relatively small extent.

5.3 Flemming's formalisation of flapping-out effects

In contradistinction with our analysis in §5.2, Flemming decides not to include the flapping-out gesture in the articulatory notation and writes the articulation [ɯ^{ɯ}ɖ͡d^{i}i] simply as [ɯ^{ɯ}ɖ^{i}i]. This transcription is a hybrid: the superscript tongue body markers [^{ɯ}] and [^{i}] suggest an articulatory transcription, but the use of the single [ɖ] suggests a perceptual transcription, because this sound is perceived as /ɖ/ but articulated as [ɖ͡d]. This would not be bad in itself, but carries with it the danger of further mistakes. And indeed Flemming takes the articulatorily imprecise transcription [ɯ^{ɯ}ɖ^{i}i] at face value, so that he cannot make any distinction between the candidates (16c) and (16f). The form Flemming writes as "[ɯ^{ɯ}ɖ^{i}i]" then necessarily has to violate RETRO→BACK, even if it is pronounced as [ɯ^{ɯ}ɖ͡d^{i}i]. By this move, the constraint RETRO→BACK loses its articulatory definition and must mean something like "segments that are perceptually (phonologically) retroflex cannot be articulated with a back tongue body". Since this confusingly formulated constraint is routinely violated in flapping-out forms, Flemming is forced to continue along the same path and conclude that the constraint RETRO→BACK should be abandoned in favour of a constraint RETRO→BACKCLO, which restricts the requirement of a backed tongue body for retroflexes to the closing phase.

[16] An analysis in terms of IDENT([bk]$_V$,*p*%) instead of *DISTANCE, analogously to §2.4, would fail here.

5.4 Empirical differences between the two approaches

Whether one writes a fully articulatory [ɯ^{ɯ}ɖ͡ɖ^{i}i] with a fully articulatory RETRO→BACK, as we do in §5.2, or a hybrid [ɯ ^{ɯ}ɖ^{i}i] with a hybrid RETRO→BACKCLO, as Flemming (2003) does, is not just a notational matter. Empirical differences will emerge for retroflex segments that have no flapping out. As explained in §5.1, such segments exist in the form of retroflex fricatives and affricates.[17] It is expected, then, that retroflex fricatives and affricates interact with the following vowel to a larger extent than retroflex plosives do. A case discussed by Flemming in which a retroflex fricative is indeed modified by a following vowel is Acoma, where an underlying retroflex |ʂ| neutralises into its laminal counterpart /ʃ/ if the following vowel is /i/.[18] With an unconditional RETRO→BACK, the analysis simply becomes that in (17).

(17) *Acoma laminalisation*

ʂi	RETRO →BACK	*DISTANCE (front,back)	IDENT $[bk]_V$	IDENT [ant]	IDENT [lam]
a. ^{i}ʂ^{i}i	*!*				
b. ^{ɯ}ʂ^{i}i	*!				
c. ^{ɯ}ʂ^{ɯ}i		*!			
☞ d. ^{i}ʃ^{i}i					*
e. ^{ɯ}ʂ^{ɯ}ɯ			*!		
f. ^{i}s^{i}i				*!	

For Acoma laminalisation to work with our constraint set, it is enough that laminal faithfulness is ranked below the other faithfulnesses and below the transition-vowel agreement constraint *DISTANCE(front,back). By contrast, Flemming's constraint RETRO→BACKCLO is insufficient for Acoma. If RETRO→BACK is replaced with RETRO→BACKCLO, candidate (17b) is no longer ruled out, since this constraint does not punish the retroflex fronting in [^{ɯ}ʂ^{i}]. In order to rule out [^{ɯ}ʂ^{i}] and with it candidate (17b), Flemming takes recourse to a constraint that he himself describes as 'somewhat ad hoc' (p. 361): PALATALISATION "closure [i.e. closing phase] and release of a consonant must be front before a front vowel." This is overtly an assimilation constraint, but of what kind? It cannot be an articulatory constraint, because it prefers the articulatorily more effortful [^{i}ʂ^{i}i], which has two tongue body gestures (backing in [^{i}ʂ] and fronting in [ʂ^{i}]), to the articulatorily less effortful [^{ɯ}ʂ^{i}i], which has only one

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[17] We are aware of languages in which retroflexes other than fricatives and affricates interact with following vowels, namely Khonoma Angami (Blankenship et al. 1993), where a retroflex approximant /ɻ/ is laminalised before a front vowel, and Ponapean (Rehg 1973), where front vowels surface as retracted after [ɽ] and [ʈʂ]. As a possible explanation, Hamann (2003b) proposes that retroflex approximants, like the fricatives and affricates, do not show any flapping out gesture before the end of the segment, due to their strong internal acoustic cues, the continuous formants. A formalisation of these data would go beyond the scope of this article.

[18] According to Miller (1965), Acoma has the retroflexes [ɖʐ, ʈʂ, ʂ, ʈʂ^{ʔ}, ʂ^{ʔ}], none of which occurs before front vowels. The plain retroflex fricative is taken exemplarily in the following description and analysis.

tongue body gesture. It therefore has to be a perceptually motivated constraint, inspired by the wish to have a very early nonlocal auditory cue for vowel fronting. The first [$^{\mathrm{i}}$] in [$^{\mathrm{i}}$ʂ$^{\mathrm{i}}$i] or [$^{\mathrm{i}}$ʃ$^{\mathrm{i}}$i], then, is the element that presumedly has to play this role as a frontness enhancer. But precisely this [$^{\mathrm{i}}$] tends to be inaudible in phrase-initial tokens of [$^{\mathrm{i}}$ʃ$^{\mathrm{i}}$i] (or at least of affricates like [$^{\mathrm{i}}$t͡ʃ$^{\mathrm{i}}$i]), which abound in Acoma. This makes a perceptual interpretation of PALATALISATION unlikely, so that we must sympathise with Flemming's verdict that this constraint is ad-hoc. An analysis with a simple context-free RETRO→BACK constraint does not require it anyway.

There are three remaining issues that have to be resolved. The first is the typological finding that underlying |ʂi| sequences tend to turn into /ʃi/ or /ɕi/ sequences rather than /si/ sequences. From tableau (17) we see that if cross-linguistically IDENT[lam] were equally likely to outrank IDENT[ant] than the reverse, we would expect to see as many languages that pronounce |ʂi| as [$^{\mathrm{i}}$s$^{\mathrm{i}}$i] as languages that pronounce |ʂi| as [$^{\mathrm{i}}$ʃ$^{\mathrm{i}}$i] or [$^{\mathrm{i}}$ɕ$^{\mathrm{i}}$i]. This is, however, not in accordance with the typological data. Besides Acoma, we know of Gujarati (Pandit 1954, Flemming 2003), certain Chinese dialects (Yip 1996), Molinos Mixtec (Hunter & Pike 1969, Flemming 2003) and Chácobo (Prost 1967, Bhat 1973) that pronounce |ʂi| as [$^{\mathrm{i}}$ʃ$^{\mathrm{i}}$i] or [$^{\mathrm{i}}$ɕ$^{\mathrm{i}}$i]. No language is known to us where |ʂi| is realised as [$^{\mathrm{i}}$s$^{\mathrm{i}}$i]. The attested asymmetry cannot very well be described within a feature theory that relies on the articulatory features [ant] and [lam], because such a theory has no way to prefer a change of [–lam] into [+lam] to a change of [–ant] into [+ant]. We propose instead that the asymmetry has an auditory cause, and that the phonology has to take this into account. Auditorily, [ʂ] is much closer to [ʃ] or [ɕ] than to [s]; the four sounds can be seen as lying along the acoustic continuum of the *spectral centre of gravity*, which is lowest for [ʂ], higher for [ʃ], slightly higher for [ɕ], and highest for [s] (see Gordon, Barthmaier & Sands 2002 for several languages, and Żygis & Hamann 2003 for Polish). This means that a pronounced [ʃ] or [ɕ] is much more likely to be perceived as /ʂ/ (say, 20 percent) than a pronounced [s] is (say, 5 percent). The facts can now be accounted for within a feature theory that relies on a single, auditory-based scalar feature [sibilant place], with the three values alveolar, postalveolar (including alveolopalatal), and retroflex. Pronouncing |ʂi| as [$^{\mathrm{i}}$s$^{\mathrm{i}}$i] would then violate IDENT([sibilant place],95%) whereas pronouncing it as [$^{\mathrm{i}}$ʃ$^{\mathrm{i}}$i] or [$^{\mathrm{i}}$ɕ$^{\mathrm{i}}$i] would only violate the universally lower ranked IDENT([sibilant place],80%).

The second issue to be resolved is the omission from tableau (17) of the 'flapping-out' candidates [ᵚʂ͡s$^{\mathrm{i}}$i] and [ᵚʂ͡ʃ$^{\mathrm{i}}$i], which would win if they were faithfully perceived as /ʂi/, analogously to what happens in (16). Because of the different way in which fricatives are articulated when compared with stops (§5.1), there will be articulatory constraints that rule out these candidates.[19]

The third issue to be resolved is the fact that there are cases of retroflex fricatives that do interact with following vowels but do not interact with preceding vowels: Acoma (as Flemming's example [sˀidʲaːtiʂatʲə] illustrates), Molinos Mixtec (Hunter & Pike 1969, Flemming 2003), and Polish (Booij & Rubach 1987). These three cases are

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19 One may think that listener-oriented constraints that require fricatives not to change, i.e. probabilistic IDENT(place), could work as well. However, such constraints are violated to an even stronger extent in the attested forms, so they would work only when conjoined with articulatory constraints.

problematic for both Flemming's and our account, and have to be shelved for the moment.

The three issues can thus either be resolved (by proposing an auditory-based place feature and by taking into account articulatory differences between fricatives and stops) or do not distinguish between the two competing approaches.

6 Conclusion

In her survey of 117 languages with retroflex consonants, Hamann (2003b) found no evidence for retroflex articulations without tongue-body backness. Flemming (2003) did not deliver convincing arguments either: there is no phonetic evidence for non-back retroflexes, i.e., the phonetic evidence is compatible with a top-ranked RETRO→BACK, and there is no phonological evidence either, since the cases of Walmatjari and Koḍagu, where Flemming's analysis required a dominated RETRO→BACK(CLO), can be reanalysed with a top-ranked RETRO→BACK. Until a language is found that does have non-back retroflexes, we must assume that these sounds do not exist and that GEN, the candidate generator in OT, does not generate candidates that include sequences like [^{i}ʈ], [ʈ^{i}], [^{ɨ}ʈ], [ʈ^{ɨ}], [^{i}ʂ], [ʂ^{i}], [^{ɨ}ʂ], [ʂ^{ɨ}]. Imposing this universal restriction on GEN simplifies the analyses of all the languages discussed here, since at least one constraint can be left out of the tableaus and at least one language-specific ranking can be left out of the constraint hierarchies.

But a more general point can be made. By making a principled distinction between articulatory-phonetic and perceptual-phonological representations, and between articulatory and faithfulness constraints, we achieve theoretical as well as analytical advantages over Flemming's approach. To see this, consider the similarities and differences between the two approaches.

The similarity between the two approaches is that both approaches use faithfulness constraints (IDENT) for the three phonological features involved, namely the coronal place feature [ant], the coronal articulator feature [lam], and the dorsal place feature [back]. We regard these constraints, especially in their probabilistic form, as being capable of handling the speaker's listener-oriented drives, since they evaluate the similarity between the speaker's underlying form (which is what the listener will ultimately have to reconstruct) and the listener's perception of each articulatory candidate. IDENT constraints have the desirable property that they are aprioristic rather than ad-hoc, i.e., they can be assumed (by the linguist) to exist for every phonological feature used in the language and do not have to be posited specifically for the case of retroflex consonants.

The difference between the two approaches lies in the remaining constraints, namely those that evaluate the output form only. In our approach, these constraints are solely articulatory: RETRO→BACK (in GEN) expresses an articulatory incompatibility in a context-free way, and *DISTANCE(tongue body) militates against tongue body movements, again in a context-free way. In an emergentist view of the learning of articulatory restrictions, both of these constraints are aprioristic: if no non-back retroflexes are ever pronounced during articulatory learning, the learner will never propose any articulatory candidates that contain simultaneous coronal retroflexion and tongue-body frontness; and once the learner learns that tongue body movements are capable of implementing a phonological feature (e.g. [back]), she will create articulatory constraints against such movements. In contradistinction, Flemming proposes no fewer than five constraints, which moreover are typical hybrid *markedness* constraints that often partly express perceptual considerations, thus partly performing a task that independently necessary faithfulness constraints were designed for and can perform better: RETRO→BACKCLO and *FRONTRETROCLO militate against segments that are *articulatorily* non-back and *perceptually* retroflex (§5.3); APICAL→RETRO expresses the *perceptual* enhancement of apicality; AGREE[bk] has a partly *perceptually* oriented interpretation that partly duplicates IDENT$[bk]_V$; and PALATALISATION must express a nonlocal, and therefore *perceptually* informed, assimilation (§5.4). In general, such constraints tend to be proposed because they directly express a tendency observed by the analyst, and therefore run the risk of being ad-hoc, i.e. proposed on the basis of the case at hand. This is also true of at least four of Flemming's five markedness constraints (the possible exception is AGREE[bk]), each of which was proposed on the basis of language data on retroflex-backness interaction. If a case can be handled with aprioristic constraints, as we have shown to be possible with the present case, such an analysis has a theoretical advantage over an analysis in terms of ad-hoc constraints, because no new stipulations have to be made.

Apart from a theoretical advantage, our approach has an analytical advantage over Flemming's in terms of simplicity of analysis, i.e., our approach requires fewer output-evaluating constraints and fewer language-specifically stipulated rankings. The actions of Flemming's ad-hoc markedness constraint APICAL→RETRO in Walmatjari can be performed by the aprioristic faithfulness constraint family IDENT([lam],*p*%), thus disposing of Flemming's postulation of the ranking of IDENT[lam] over APICAL→RETRO. The actions of Flemming's hybrid markedness constraint AGREE[bk] can be performed by the solely articulatory constraint family *DISTANCE(tongue body) or by the aprioristic faithfulness family IDENT($[bk]_V$,*p*%). Most importantly, the actions of Flemming's hybrid markedness constraints RETRO→BACKCLO and *FRONTRETROCLO can be performed by the solely articulatory constraint RETRO→BACK, which also renders the ad-hoc 'gapping' PALATALISATION constraint superfluous in the analysis of fricatives in Acoma. It is interesting to realise that aprioristic constraints that were designed by Boersma (1998, 2003) and Hamann (2003b) before Flemming's facts and analysis were published, achieve a simpler analysis than the ad-hoc constraints that Flemming tailored directly to his selection of the facts.

To sum up, the theoretical and analytical advantages of our approach over that of Flemming (2003) were brought about by a combination of Hamann's (2003b) unviolated retroflex backness, Boersma's (2003) probabilistic faithfulness, a principled distinction between articulatory and faithfulness constraints, and a principled distinction between articulatory-phonetic and perceptual-phonological representations. A third difference between the two approaches, however, must lie in the typologies they generate. Having fewer constraints and fewer language-specific rankings leads to a more restricted typology; using more detailed articulatory representations leads to more implicational universals (e.g. we predict that there are languages in which fricatives but not plosives change a following vowel); and reformulating markedness constraints as faithfulness constraints renders their effects dependent on the underlying form. These typological issues are addressed in detail neither in Flemming's paper nor in ours and must largely be left as an object of future research.

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