6 Analysis of retroflex processes

The aim of the present chapter is to provide analyses in an OT framework (Prince & Smolensky 1993) for the diachronic and synchronic segmental changes described in chapter 4, which are caused by a retroflex context or which result in retroflexion or de-retroflexion. One exception to this general aim exists: this chapter does not account for processes that were attributed to misparsing errors of listeners only. Since no articulatory gestures are saved via such a misparsing process, no articulatory optimisation strategies apply, and therefore misparsing has no functional motivation in production. An analysis of a misparsing error in a functionally based OT production grammar is thus impossible. In chapter 4 a reassociation of cues was proposed as an alternative explanation for, for instance, a change from alveolar to retroflex in a back vowel context or a change from a high front vowel to a rounded high front vowel in a retroflex context. There I also illustrated the acoustic similarities between the original forms and the forms the listener derived from reassociation of cues. An OT formalization of these processes needs to be modelled in a perception grammar but this would be outside the scope of this book. Only one process below will include a formalization of a perception grammar, namely secondary palatalization of retroflexes in section 6.3.3.5. In that section, both production and perception grammar are modelled to illustrate that the gestural sequence of a retroflex and a palatal glide can be perceived as a secondarily palatalized retroflex.

This chapter is structured in the following way. Section 6.1 introduces the constraints on the perceptual specifications used here, section 6.2 deals with the constraints on the articulation, section 6.3 provides analyses for the processes discussed in chapter 4, and section 6.4 concludes. Together, these sections provide phonological accounts for the processes illustrated in chapter 4. Furthermore, cross-linguistic variation that could be found for some processes will be accounted for, either by phonetically motivated universal rankings of articulatory markedness constraints and language-specific rankings of faithfulness constraints, as in the case of vowel retraction and lowering (section 6.3.3.2), or by faithfulness constraints that are universally ranked plus language-dependent rankings of articulatory markedness constraints, as in the case of context-sensitive assimilation processes (section 6.3.6).

6.1 Constraints on perceptual representations

For the analysis of processes involving retroflexes, I assume underlying perceptual specifications as illustrated in section 5.4.1 above. Departing from Boersma (1998, 1999, 2003a, b), the perceptual specifications are represented as underlying representations or inputs in a traditional slashed line notation, such as /i/ for a high front vowel. The perceptual URs are associated with articulatory gestures that implement these specifications. Every output candidate to be evaluated is thus a pair of perceptual features correlated with articulatory gestures (Boersma 1998: 146): [*art*$_1$] /*perc*$_1$/. Boersma's notation does not list all the articulatory gestures and perceptual features present in a segment, but gives shorthands using the easily interpretable IPA symbols. The present exposition proceeds similarly. Furthermore, in the present analysis the output pairs [*art*$_1$] /*perc*$_1$/ are further abbreviated to one form, the traditionally used IPA transcription in square brackets, such as [i]. It has to be kept in mind, though, that this stands for a candidate output form with both articulatory and perceptual specifications.

Due to my assumption that underlying specifications are perceptual, faithfulness constraints (henceforth: faith constraints) only hold for the perceptual representations of items. Being faithful to an articulation is hence not possible, contrary to what is assumed in standard versions of OT (McCarthy & Prince 1993, 1995; Prince & Smolensky 1993). Three constraint families ensuring the faithfulness to features or segment content are distinguished here: *DELETE, *INSERT, and *REPLACE, following Boersma (1998). A further constraint family preventing the change in timing of two adjacent features or segments is used, namely the PATH constraints (Boersma 1998: 193f.).

*DELETE constraints militate against the deletion of underlying perceptual features, and are similar to McCarthy & Prince's (1995) IDENT. The *DELETE constraint family can prohibit deletion of single features, see for example (1a) and (1b).

(1) (a) *DELETE (+1F2): "Don't delete the underlyingly specified feature [+1F2]."
    (b) *DELETE (–2F3): "Don't delete the underlyingly specified feature [–2F3]."

Faithfulness to the combinations of features in a segment can be described by constraint conjunction. If a language has retroflex segments, for example, the two features [+1F2] and [–2F3] cooccur to form the class of 'retroflex'. Deletion of a retroflex segment violates a conjoint constraint as defined in (2a). In (2b) – (2d) constraints are formulated militating against feature combinations that determine specific manners of articulation (in a shorthand notation instead of listing all the cues for stops, fricatives, approximants, and so on, in detail). (2e) illustrates a constraint preserving combinations of features for manner and place.

(2) (a) *DELETE (+1F2 & –2F3): "Don't delete both underlyingly specified features [+1F2] and [–2F3] (i.e. a retroflex)."
    (b) *DELETE (stop): "Don't delete the underlyingly specified stop features (silence, burst, etc.)."
    (c) *DELETE (rhotic): "Don't delete the underlyingly specified rhotic features (formant weakening, etc.)."
    (d) *DELETE (fricative): "Don't delete the underlyingly specified fricative features (friction noise, intensity, etc.)."
    (e) *DELETE (ʈ ɖ): "Don't delete the underlyingly specified retroflex stop features."

Naturally, we can assume that faith constraints applying to one feature only are violated far more often than those for feature combinations, since the deletion of one feature is perceptually more tolerable than the deletion of several features.

We can see from the examples in (1) and (2) that the faith constraints can target three different types of arguments: single features as in (1a) and (1b); feature combinations for describing natural classes, which are usually given with shorthand notations and not with all features listed, such as (2b) – (2d); or thirdly feature combinations that describe specific segment classes, e.g. (2e) which targets the group of retroflex plosives. The last type of argument is notated with IPA symbols.

If only one feature is deleted, inserted, or changed, Boersma's constraints correspond to McCarthy & Prince's (1995) IDENT constraint, which militates against changes of single features,[1] If feature combinations making up a whole segment are deleted, inserted, or changed, the corresponding constraints in McCarthy & Prince's framework are Max-IO against deletion, DEP-IO against insertion, and both against segmental changes.

The second type of faith constraints used here are *INSERT constraints, which prohibit the insertion of surface features or feature clusters. *INSERT constraints are defined analogously to the *DELETE constraints. Examples are given where needed in the analysis below.

The third type of faith constraint used for the present analysis is the *REPLACE constraint family, which accounts for changes of one feature value into another value on the same perceptual tier. *REPLACE constraints depart from McCarthy & Prince's approach, where a process of feature change is formalized as violation of an IDENT constraint. What IDENT fails to capture is the possibility of gradual changes in feature-values, and the fact that a small change is better accepted (i.e. causes fewer constraint violations) than the deletion of a whole feature and the insertion of a new one. A definition of *REPLACE is given in (3), from Boersma (1998: 176f.).

(3) *REPLACE (*feature*: *value*$_1$, *value*$_2$ */ condition / left-env_right-env*):
"Do not replace a specified value (*value*$_1$) on a perceptual tier (*feature*) with a different value (*value*$_2$), under a certain *condition* and in the environment *left-env* and *right-env*."

Examples of universally ranked, gradient *REPLACE constraints that are sensitive to the context will be given in section 6.3.6 below.

Faithfulness to the underlying simultaneity or non-simultaneity of features will be expressed in terms of PATH constraints (Boersma 1998: 193f., based on Archangeli & Pulleyblank 1994). *INSERTPATH as defined in (4) militates against the insertion of a path between two features that was not specified in the underlying representation, see the definition in (4) (from Boersma 1998: 194).

(4) *INSERTPATH ($f \times g$): "A combined feature on the tiers *f* and *g* that is heard in the surface form, also occurs in the specification."

[1] Zoll (1996) subdivides McCarthy & Prince's (1995) IDENT constraint into MAX [F] and DEP [F], analogous to MAX-IO and DEP-IO.

Outputs violating *INSERTPATH constraints create a simultaneity of two features that was not present in the underlying representation.

*DELETEPATH constraints as defined in (5) (also Boersma 1998: 194) militate against the deletion of a path, which results in non-simultaneity of the underlyingly simultaneous features involved.

(5) *DELETEPATH ($f \times g$): "A specified combined feature on the tiers f and g appears (is heard) in the surface form."

Specific PATH constraints needed for the present analysis will be defined below when necessary.

6.2 Constraints on articulatory representations

Before defining the necessary constraints on the articulatory representations, we have to go back to the model of independent tongue parts introduced in 5.4.2, repeated here in figure 6.1, because it has consequences for possible articulations and therefore restricts our articulatory representations of segments.

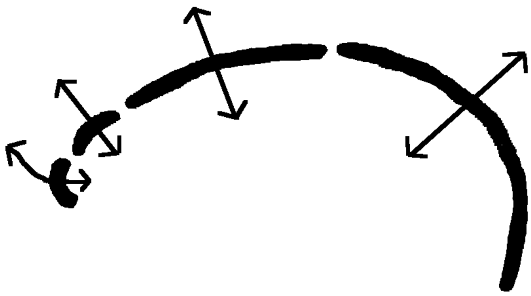

Figure 6.1 Abstract assumption on tongue parts and their movements on the vertical axis.

This model divides the tongue into four parts, the tip, blade, middle, and back (including the root), with borders as defined in chapter 2. Contrary to distinctions of the tongue in other models, for instance the coronal – dorsal distinction in FG as described in chapter 5, the present model does not assume that the separate tongue parts can act independently of each other. The four parts can separately be the active articulator in producing the restriction relevant for specific articulatory classes, but the movement of one part triggers certain movements of adjacent and even non-adjacent parts. This was illustrated in chapter 5. The raising of the tongue blade, for example, was shown to cause the tongue middle to rise as well, though not to the same extent as an active constriction of the tongue middle would. Restrictions on adjacent tongue parts can be expressed formally as in (6), which is not a complete list.

(6) (a) *[tongue blade up, tongue middle down]
(b) *[tongue blade down, tongue middle up]

(c) *[tongue middle down, tongue back down]
(d) *[tongue middle up, tongue back up]

These restrictions are not active cooccurrence constraints (such as proposed for example by Calabrese 1988 or Hamilton 1996), as they need not be present in the phonology of the speaker. Instead, these statements express physical restrictions on the vocal apparatus, and formalize what is impossible to articulate. They restrict the number of possible output candidates (thus are part of Gen in traditional OT terms), as outputs can only be producible articulations (Boersma 1998: 278).

For complex articulations such as retroflex segments, the articulatory restrictions can be understood as some chain implication, as formalized in (7a).

(7) (a) [tongue tip up & back] → [tongue blade front & displaced], [tongue middle down], [tongue back up]
(b) [tongue blade up] → [tongue middle up], [tongue back down]

The interaction of the tongue parts for retroflex articulation as given in (7a) can account for several phonological restrictions of retroflexes as illustrated in sections 6.3.1 until 6.3.6.

It is important to note that the division of the tongue into parts and their interplay as assumed here is not exclusively designed for modelling retroflex articulations. (7b) gives the interactions of tongue parts for a laminal articulation: here the raising of the laminal area causes a concomitant raising of the tongue middle. This correlation can be found in phonetic accounts of laminals, which are often described as slightly palatalized. Furthermore, it can account for the fact that laminal but not apical stops show additional affrication: due to the raising of the tongue middle, laminals have a long area of constriction behind the closure, which promotes affrication in stop release.[2]

After clarifying these articulatory correlations and their restrictions on the vocal apparatus, we can now move on to the articulatory constraints necessary for our representations. Restrictions on articulation hold only for the articulatory form, and are therefore formulated as markedness constraints on the articulatory part of output. General restrictions on the effort of producing an articulation (described for instance by LAZY by Kirchner 1997) are further distinguished here into *GESTURE, *DISTANCE, *SYNCHRONIZE and *PRECISION constraints.

The first type of articulatory constraint described here is the *GESTURE constraint family as developed by Boersma (1998: 152). For our purpose, we need the following *GESTURE constraints:

(8) (a) *GESTURE (tongue tip: neutral to post-alveolar) = *GESTURE (retroflex): "do not articulate a retroflex segment."

[2] Kehrein (2002: 60f.) describes the correlation of laminality and affrication and ascribes it to the displacement and slowness of laminal articulations. Laminal articulations, however, are not by default displaced: laminal post-alveolars for example involve only a raising of the tongue blade but no displacement (recall section 5.4.2). Furthermore, it is not clear how the slowness of laminal gestures can account for the occurring affrication. The explanation proposed here with cooccurring tongue middle raising thus seems superior to the one given by Kehrein.

(b) *GESTURE (tongue tip: neutral to alveolar) = *GESTURE (apical alveolar): "do not articulate an apical dental or alveolar segment."
(c) *GESTURE (tongue back: neutral to retracted) = *GESTURE (retraction): "do not articulate a segment with a retracted tongue back."

The constraints in (8a–c) militate against specific articulatory classes, namely retroflexes, apical alveolar/dentals, and secondary articulations such as retraction for non-retroflex segments. If a language has retroflex segments, the constraint (8a) is very low ranked. If a language has an apical but no retroflex series, the constraints are ranked as *GESTURE (retroflex) >> *GESTURE (apical alveolar).

In addition to the constraints against the articulation of specific classes in (8), further constraints on articulation are needed that can account for the reluctance of the articulators to change their position from one gesture to another. Boersma's (1998: 150) *DISTANCE constraint family seems to meet this purpose, see (9), where | stands for an articulatory contour, i.e. a change in position (or tension) of the articulator.

(9) *DISTANCE (*articulator: a | b*): "An *articulator* does not move from location *a* to *b*, away from the neutral position."

For our purposes, we need specific *DISTANCE constraints as defined in (10).

(10) (a) *DISTANCE (tongue tip: retroflex | alveolar) = *DISTANCE (tip): "The tongue tip does not move from location post-alveolar to alveolar and vice versa."
(b) *DISTANCE (tongue back: retracted | fronted) = *DISTANCE (back): "The tongue back does not move from location retracted to fronted and vice versa."
(c) *DISTANCE (tongue tip: $manner_1$ | $manner_2$) = *DISTANCE (manner): "The tongue tip does not move from location $manner_1$ to $manner_2$ (e.g. from approximant to full closure)."

(10a) and (10b) militate against changes in place of articulation, whereas (10c) avoids a change in apical manner. Constraint (10b), which disallows a change in tongue back position, also militates against a change from flat tongue middle to high tongue middle by the articulatory restrictions on tongue movements elaborated above. It applies to all retroflex articulations due to the correlation stated in (7a) above.

A universal ranking of a specific *DISTANCE constraint family and its relevance for language-specific variation will be illustrated in section 6.3.3.2 below on vowel retraction and vowel lowering.

Besides *GESTURE and *DISTANCE, a third type of articulatory constraint family, namely *SYNC, is required for our analysis. *SYNC constraints describe the unwillingness of two gestures on different tiers to exactly finish the first gesture when the second starts. A general definition is given in (11) (Boersma 1998: 154).

(11) *SYNC (*articulator*$_1$: *from*$_1$ | *to*$_1$; *articulator*$_2$: *from*$_2$ | *to*$_2$): "the movement of *articulator*$_1$ from *from*$_1$ to *to*$_1$ is not synchronous with the movement of *articulator*$_2$ from *from*$_2$ to *to*$_2$."

The articulatory result of this constraint might be either an overlap or a delay between two gestures. For describing sequences of front vowels and retroflex consonants and the gestural overlap to be observed there, we need the following *SYNC constraint:

(12) *SYNC (tongue middle: raised | lowered; tongue tip: neutral | closed) = *SYNC (vowel| retroflex): "the lowering of the tongue middle (for the vowel) is not synchronized with the closure of the tongue tip (for the retroflex)."

A synchronization of the articulatory gestures is not specified in the underlying, perceptual representation. It can only be achieved by being faithful to the synchronization of the perceptual features, as stated in the PATH constraints in (4) and (5). Non-synchronization of gestures is therefore accepted as long as it does not result in a shift of the perceptual features.

A last articulatory constraint family that will be needed for the present analysis is *PRECISION as formulated in (13) (Boersma 1998: 155).

(13) *PRECISION (*articulator: position* | *environment*): "In a certain *environment*, a certain *articulator* does not work up the precision to put itself in a certain *position*."

This constraint family can account for the fact that some manner classes have to be articulated more precise than others. A trill, for instance, requires a more precise gesture than a flap, thus the following ranking holds:

(14) *PRECISION (trill) >> *PRECISION (flap)

6.3 Analysis of phonological processes of retroflexes

With the constraints restricting perceptual and articulatory specification in place, we can now formalize the patterning of the phenomena of retroflexion as illustrated in chapter 4, repeated here in (15) for convenience.

(15)

	input	*output*	*process*
(a)	/rt/	[ʈ]	retroflexion in rhotic context
(b)	/ut/	[uʈ]	retroflexion in back vowel context
(c)	/iʈ/	[it] or [ɨʈ]	deretroflexion or vowel retraction
	/ʈʲ/	[tʲ] or [ʈ]	deretroflexion or depalatalization
(d)	/Vʈ/	[Vʵʈ]	retroflexion of adjacent vowel
(e)	/ʈ/	(ω[t], [Ct]	phonotactic restrictions on retroflexes
(f)	/ʈt/	[ʈʈ]	local assimilation of retroflexes
	/ʈVt/	[ʈVʈ]	non-local assimilation of retroflexes

The following subsections 6.3.1 – 6.3.6 will analyse the processes (15a) – (15f), in that order.

6.3.1 Retroflexion via rhotics

Section 4.1.2 proposed two possible explanations for the process of retroflexion in rhotic context in (15a), repeated here in (16). Processes with a reversed order of rhotic and retroflex are not discussed here, as they can be treated identically.

(16) (a) rt > ɽt > ɽʈ > ʈ staged process (diachronically only)
(b) rt > ʈ

The process in (16a) involves several stages of the historical development, whereas (16b) consists of only one stage. Let us start with formalizing (16b). This process involves the collapse of two segmental categories with different manners but similar place into one (with different place), which can be expressed via the articulatory markedness constraint *DISTANCE (manner) defined above in (10c). Furthermore, the collapse involves a change in surface representation compared to the underlying perceptual representation. Part of the perceptual representations of the two input segments /r/ and /t/, the occurring output /ʈ/, and another possible output /ɽ/ is given in table 6.1.

Table 6.1 Partial perceptual representations of /r/, /t/, /ʈ/ and /ɽ/, with features specifying place of articulation and for manner.

	r	t	ʈ	ɽ
place	–2F3	0F3	–2F3	–2F3
manner	2trill	2stop	2stop	1trill 1stop

The trill /r/ in the first column and the flap /ɽ/ in the last column are both assigned the perceptual manner feature [trill], since a trill with a single contact sounds like a flap (Ladefoged & Maddieson 1996: 237). They differ in feature value, however: the trill has the value [2trill] and the flap the value [1trill], since the latter segment sounds less trill than the former. Both stop and flap are specified by the feature [stop], because flaps very often behave phonologically like stops. Again, the two segments differ in the feature values: stops are [2stop] and flaps [1stop].

The output in (16b) is unfaithful to the underlying form in two ways: it violates *DELETE (0F3) since the underlying sequence [-2F3, 0F3] is realized as [-2F3], and it violates *DELETE (trill), since the underlying sequence trill – stop is realized as stop. This is formalized in the tableau in (17) on the next page, which models the retroflexion rule in Norwegian.

The faith constraints *DELETE (–2F3) and *DELETE (stop) secure the features [–2F3] (of a rhotic or a retroflex) and [stop], respectively. The winning candidate does not violate any of these, as it contains both features in the output.

(17)

/rt/	*DELETE (–2F3)	*DELETE (stop)	*REPLACE (2stop, 1stop)	*DISTANCE (manner)	*DELETE (trill)
[rt]				*!	
☞ [ʈ]					*
[r]		*!			
[t]	*!				*
[ɽ]			*!		

The constraint *REPLACE (2stop, 1stop) is necessary to exclude the last candidate, the flap, which does not violate *DELETE (stop) since it contains stop cues. *REPLACE (2stop, 1stop) has to be ranked below *DELETE (stop) because it is worse to delete the whole [2stop] feature than to replace its value by [1stop]. *DELETE (stop) must be higher ranked than *DELETE (trill) in Norwegian, as the winning candidate is faithful only to the underlying stop specification, not to the trill specification.

In section 4.1 we saw an example of a language where the winning candidate is faithful to the trill specification: in Yidgha, the sequence /rt/ developed to the retroflex /ɽ/. This development can be accounted for by a reverse ranking of the *DELETE (trill) and *DELETE (stop) constraints than in (17) (the ranking of *REPLACE (2stop, 1stop) below *DELETE (stop) remains fixed, of course). A complication in the Yidgha development is the manner change from a trill to a flap. The flap emerges as the winning candidate because it secures both manner features of the underlying specification.

(18)

/rt/	*DELETE (–2F3)	*DELETE (trill)	*DISTANCE (manner)	*DELETE (stop)	*REPLACE (2stop, 1stop)
[rt]			*!		
[ʈ]		*!			
[r]				*!	
[t]	*!	*			
☞ [ɽ]					*

To account for the order of the input segments, i.e. for the fact that the rhotic has to occur to the left of the target segment, we have to assume either context-sensitive faith constraints or context-sensitive markedness constraints. These context-sensitive faith constraints and their rankings would look like (19a) for Norwegian and (19b) for Yidgha, and the context-sensitive markedness constraints and their rankings like (20a) for Norwegian and (20b) for Yidgha, where *A* stands for all apical alveolars, and *r* for a trill.

(19) (a) *DELETE (trill / A_) >> *DELETE (trill / _A)
(b) *DELETE (stop / _r) >> *DELETE (stop / r_)

(20) (a) *DISTANCE (trill, non-trill) >> *DISTANCE (non-trill, trill)
(b) *DISTANCE (trill, stop) >> *DISTANCE (stop, trill)

The second explanation for retroflexion in a rhotic context with subsequent drop of the rhotic, (16a), has to be modelled in three diachronic stages, given in (21).

(21) (a) r > ɽ
(b) ɽt > ɽʈ
(c) ɽʈ > ʈ

Consider the process at stage one, shown in (21a), which describes the change of an apical rhotic into a retroflex one, caused by articulatory variation. As we already saw in the development in Yidgha, the apical trill and the retroflex flap show little perceptual difference. The trill, however, requires a more precise articulation than a flap, which is expressed by a *PRECISION (trill) constraint being higher ranked than a *PRECISION (flap) constraint, see (14) above. The only constraint preventing a development as in (21a) is the faith constraint *REPLACE (2trill, 1trill), which tries to make sure that the trill feature is realized as a trill and not as a flap. If both constraints are unranked with respect to each other, variation will emerge, as in (22):

(22)

/r/	*DELETE (trill)	*PRECISION (trill)	*REPLACE (2trill, 1trill)
☞ [r]		*	
☞ [ɽ]			*
[t]	*!		

This tableau is interpreted as the front apical rhotic winning in approximately 50 percent of the cases, and the retroflex rhotic in the other 50 percent of the cases (see Anttila 1995, Bermúdez-Otero 1996, and Löhken 1997 for OT models with such free variation). Let us assume that this variation eventually ceases and that the retroflex flap emerges as the established pronunciation of the rhotic in such a language (this might be caused by *PRECISION (trill) eventually being higher ranked than *REPLACE (2trill, 1trill)).

The next stage in the development of a retroflex series is the assimilation of a following alveolar to the retroflex rhotic, see (21b). Here, only a change in the place of articulation takes place, which is perceivable as a change from a sequence [–2F3, 0F3] to a continuous [–2F3]. This development is illustrated in tableau (23).

(23)

/ɽt/	*DELETE (–2F3)	*DELETE (trill)	*DELETE (2stop)	*DISTANCE (tip)	*DELETE (0F3)
[ɽt]				*!	
☞ [ɽʈ]					*
[ɽ]			*!		*
[t]	*!	*			
[ʈ]		*!			*
[rt]	*!				

In tableau (23) the constraint *DISTANCE (tip) militates against the change from one apical place of articulation to another, recall (10a). The faith constraints securing the trill and stop manner cues, as well as those for retroflex place, are ranked higher than the one for the alveolar place (*DELETE (0F3)), thus candidates three, four, and five, which delete either one manner or the retroflex, are worse than candidates one and two, which preserve both manner and retroflexion. The first candidate, which is most faithful to the input, loses due to the effort saving constraint *DISTANCE (tip) being ranked higher than the faithfulness constraint for the alveolar.

The third and last stage of the development of a retroflex series, (21c), is the reduction of the sequence rhotic retroflex plus retroflex of another manner to the non-rhotic retroflex. This process obviously involves ranking the faith constraint for the rhotic feature lower than in previous stages, and ranking the constraint *DISTANCE (manner) higher.

(24)

|ɽʈ|	*DELETE (2stop)	*DISTANCE (manner)	*DELETE (1trill)
[ɽʈ]		*!	
☞ [ʈ]			*
[ɽ]	*!		

6.3.2 Retroflexion via back vowels

As illustrated in section 4.2, front apicals can retroflex in a back vowel context. In Margany, for instance, the underlying sequence /un/ is produced as [uɳ]. The perceptual representations of these segments plus that of /i/ are given in table 6.2 (based on the specifications in table 5.11 and 5.12).

Table 6.2 Perceptual representations of /n/, /ɳ/, /u/ and /i/.

	n	ɳ	u	i
[F1]			–3	–3
[F2]	+1	+1	–4	+4
[F3]	0	–2	–2	
manner-specific	nasal	nasal		

The affinity of back vowels and retroflexes was described in 4.2 as articulatorily as well as perceptually motivated. Perceptually, a re-association of the [–2F3] of [u] as belonging to the formant structure of the consonant can occur. Articulatorily, a reduction of gestures occurs: the input sequence involves a tongue back gesture from the retracted /u/ to the non-retracted front coronal. In the output sequence, both [u] and retroflex are retracted. The reduced number of gestures can be captured by the *DISTANCE (back) constraint as defined in (10b), which militates against a change in tongue back position. The gestural change violates *DELETE (0F3) since the underlying sequence [–2F3, 0F3] is realized as a continuous [–2F3].

(25)

/un/	*REPLACE (–4F2, +4F2)	*DISTANCE (back)	*DELETE (0F3)
[un]		*!	
☞[uɳ]			*
[in]	*!		

The ranking of the perceptual faith constraint *REPLACE (–4F2, +4F2) above the faith constraint *DELETE (0F3) prevents a change from [u] to [i] in the output; instead, the consonant assimilates to the retracted tongue back of the vowel.

In section 4.2.2 it was observed that primarily nasals, laterals, and rhotics undergo such a change towards a retroflex place of articulation. Stops mainly change only if the other manner classes changed, too. This asymmetrical behaviour is due to the fact that nasals, laterals, and rhotics have weak place cues, which can hardly be distinguished from each other. In our OT analysis such a difference in manner can be expressed by faith constraints for stops being higher ranked than those for nasals, laterals, and rhotics.[3] The fact that in Margany apical nasals are retroflexed in back vowel context, but stops are not, (see section 4.2.1), can now be formalized with the two manner-specific faith constraints in (26).

(26) *DELETE (0F3 / plosives) >> * DELETE (0F3 / nasals)

Tableaux with this ranking and the two underlying forms /un/ and /ut/ are given in (27a) and (27b). In this tableau it becomes obvious that the two constraints *REPLACE (–4F2, +4F2) and *DISTANCE (back) have to be ranked with respect to each other in Margany (*REPLACE (–4F2; +4F2) has to be ranked above *DISTANCE (back)), otherwise [it] and [ut] would both be possible outputs of /ut/, which is not the case.

(27)

/un/	*DELETE (0F3 / stops)	*REPLACE (–4F2, +4F2)	*DISTANCE (back)	*DELETE (0F3 / nasals)
[un]			*!	
☞[uɳ]				*
[in]		*!		

/ut/	*DELETE (0F3 / stops)	*REPLACE (–4F2, +4F2)	*DISTANCE (back)	*DELETE (0F3 / nasals)
☞ [ut]			*	
[uʈ]	*!			
[it]		*!		

[3] See Boersma (1998: 217ff.) for an elaboration of the asymmetry in place assimilations and their formalization as implicational universals.

6.3.3 Non-occurrence of retroflexes with front vowels or palatalization

Section 4.3 gave examples of retroflex segments avoiding a front vowel context. This avoidance is realized in two ways, either by a change of the retroflex into an alveolar, or by a change of the front vowel. These avoidance processes are summarized in (28) and (29). Again, only one order of vowel and retroflex sequence is illustrated here, the reverse order follows from the same analysis (with context-sensitive constraints accounting for the direction of the process, as illustrated for retroflexion in rhotic context in (19) and (20)).

		input	*output*	*process*
(28)		/iʈ/	[it]	de-retroflexion
(29)	(a)	/iʈ/	[ɨʈ] or [ɯʈ]	retraction
	(b)	/ɛʈ/	[æʈ]	lowering
	(c)	/iʈ/	[iəʈ]	diphthongization (schwa insertion)
	(d)	/iʈ/	[yʈ]	rounding

Both strategies were also observed for secondary palatalization of retroflexes, see (27a) and (27b). Furthermore, secondary palatalization can also be realized as a separate palatal glide, see (27c).

		input	*output*	*process*
(30)	(a)	/ʈ^j/	[t^j]	de-retroflexion
	(b)	/ʈ^j/	[ʈ]	de-palatalization
	(c)	/ʈ^j/	[ʈj]	separate palatal

Let us look at front vowel – retroflex sequences first. As in the case of retroflexion in a back vowel context, accounted for in the previous section, the cause of avoidance of the front vowel context is that retroflexes have a flat tongue middle and a retracted tongue back. Front vowels, on the other hand, have a raised and fronted tongue middle. The change in tongue position from front vowels to retroflexes or vice versa requires a large gestural movement within a short time. This articulatory difficulty can be expressed by the markedness constraint *DISTANCE (back). Furthermore, the non-synchronicity of the gesture of tongue middle lowering (at the end of the vowel) with the gesture of tongue tip raising and closure (at the beginning of the retroflex) is accounted for with the *SYNC (vowel | retroflex) constraint as defined in (12). With these constraints in hand, we can now formalize the different avoidance strategies illustrated in (28) and (29).

6.3.3.1 De-retroflexion

Processes like (28), in which a segment is de-retroflexed before or after a front vowel, can be accounted for in a similar way as the retroflexion in back vowel context depicted in (25): the faith constraint securing the unchanged vowel and the *DISTANCE (back) constraint that militates against a tongue back movement are ranked above the faith constraint for the retroflex, see tableau (31) on the next page.

(31)

/iʈ/	*REPLACE (+4F2, –4F2)	*DISTANCE (back)	*DELETE (–2F3)
[iʈ]		*!	
[uʈ]	*!		
☞ [it]			*

The most faithful, first output candidate violates the constraint against a change in the tongue back position from retracted to fronted. The second candidate, with a back vowel instead of the underlying front vowel, violates the very high ranked *REPLACE (+4F2, –4F2) constraint that secures the vowel cues.

6.3.3.2 Vowel retraction and lowering

Let us now look at the cases with a change in the vowel quality, see (29). These processes occur in languages in which some gestural markedness constraints such as *DISTANCE (back) and *SYNC (vowel | retroflex) are higher ranked than the faith constraints for the vowels. Vowel retraction and vowel lowering can be modelled by high-ranked *DISTANCE (back) constraints, which have to be further refined for this purpose. Vowel retraction is caused by the large gestural distance between /i/ and the retroflex, stated as *DISTANCE (i-R) in (32).

(32) *DISTANCE (i-R): "The tongue does not move from raised middle and fronted back position for the high front vowel [i] to lowered middle and retracted back position for a retroflex, or vice versa."

The articulation of a distance from front high vowel to retroflex can be avoided by retracting the vowel to [ɨ] (as in Ponapean, Bunuba, Russian, or Polish). But even with this retracted tongue position, there is a distance to the retroflex gesture, because [ɨ] still involves a raising of the tongue middle (though no fronting of the tongue back). Articulating this distance between [ɨ] and a retroflex militates against the constraint *DISTANCE (ɨ-R). Some languages (such as Toda) have a further retraction of the high front vowel to [ɯ], where the tongue gesture is very close to that of the retroflex consonant. This distance is captured by the constraint *DISTANCE (ɯ-R). The decreasing gestural distances of the three vowel – retroflex combinations can be represented by ranking the three *DISTANCE (vowel – retroflex) constraints in the following way.

(33) *DISTANCE (i-R) >> *DISTANCE (ɨ-R) >> *DISTANCE (ɯ-R)

The ranking in (33) can be regarded to be universal in the sense that it is phonetically inviolable: the distance between the articulatory position for an [i] and that of a retroflex is always larger than that between the gesture of an [ɨ] and a retroflex. The universal ranking in (33) is part of the phonetic space where language-specific phonetic cues and gestures are chosen from, and is therefore specified in the phonetics of a speaker. It is, however, not present in every language-specific phonology, only in those that employ all gestures specified in this hierarchy: a language without any retroflex category does not contain the hierarchy in (30) in its phonology. Furthermore, the hierarchy interacts with language-specific faithfulness constraints in languages that employ retroflexes and all three vowel categories. This point will be further illustrated below.

Vowel retraction occurs also for the mid front vowel /e/, which retracts to the less distant [ɘ] before a retroflex for example in Ponapean. This is given by the universal constraint hierarchy in (34).

(34) *DISTANCE (e-R) >> *DISTANCE (ɘ-R)

As far as vowel *lowering* is concerned, the retraction hierarchies in (33) and (34) are inappropriate. We have to assume the same maximal distance for the high front vowel and the retroflex, i.e. the same *DISTANCE (i-R) constraint is ranked highest. The constraint on the other end of the hierarchy, however, militates against the distance between the retroflex and the lowest vowel [a], i.e. *DISTANCE (a-R), which is the minimal distance one can get for the process of high front vowel lowering. In-between these two extremes, constraints against articulating the distance between retroflex and [e], [ɛ], and [æ], respectively, can be stated. This results in the universal ranking given in (35).

(35) *DISTANCE (i-R) >> *DISTANCE (e-R) >> *DISTANCE (ɛ-R) >>
*DISTANCE (æ-R) >> *DISTANCE (a-R)

As we saw in section 4.3.2, vowel lowering is not restricted to the high front vowel, but sometimes also occurs with the high back vowel /u/ (e.g. in Kayardild, Gunya, Tamil, and Kannada). This vowel is lowered towards the mid back vowel [o] only; no further lowering (e.g. to the low back [ɑ]) occurs. The mid back vowel [o] has a lowered tongue middle and a slightly raised tongue back (towards the velum), and is thus nearly identical to the tongue position for a retroflex consonant. The nearly identical gestures of [o] and a retroflex result in a minimal distance for *DISTANCE (o-R), i.e., this constraint can be assumed to be lower ranked than any of the other distance constraints. For back vowel lowering, we can thus assume the following ranking:

(36) *DISTANCE (u-R) >> *DISTANCE (o-R)

The articulatory distance between [u] and a retroflex is the same as the distance between [ɯ] and a retroflex, since [u] and [ɯ] differ in the shape of the lips only. Thus, these two constraints are ranked equally. This and the fact that *DISTANCE (o-R) is the lowest ranked of all the *DISTANCE (back) constraints lead to a universal ranking of (33), (34), (35), and (36) as in figure 6.2 on the next page.

Violation of a higher-ranked *DISTANCE constraint implies simultaneous violations of the lower-ranked ones. The constraint rankings in figure 6.2 interact language-specifically with vowel faith constraints. A language with very high ranked vowel faith constraints (i.e. above *DISTANCE (i-R)) would disallow any vowel changes. Examples of other language-specific rankings are given below.

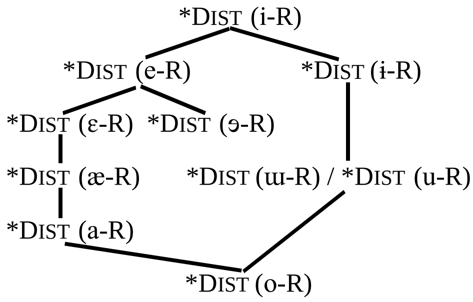

Figure 6.2 Ranking of *DISTANCE (back) constraints for vowel lowering and retraction, where the uppermost constraint *DISTANCE (i-R) is ranked highest, and the constraint *DISTANCE (o-R) is ranked lowest. The ranking of the constraints on the right side (responsible for vowel retraction) are not fixed with respect to those on the left side (responsible for vowel lowering). They can be ranked higher or lower (further developed in figure 6.3 and 6.4), as long as they preserve their inherent ranking.

Let us look at vowel retraction and vowel lowering successively.

Retraction. Taking the vowel retraction from /i/ to [ɨ] after retroflex fricatives in Russian as example, this process can be modelled as in (37), with a high-ranked *REPLACE (+4F2, –2F2) constraint militating against a retraction from /i/ to [ɯ], and a lower ranked *REPLACE (+4F2, +1F2), preventing a retraction from /i/ to [ɨ]. Between these two is ranked the *REPLACE (–2F3, 0F3) which prohibits a change in the retroflex fricative.

(37)

/ʂi/	*DIST (i-R)	*REPLACE (+4F2, –2F2)	*REPLACE (–2F3, 0F3)	*REPLACE (+4F2, +1F2)	*DIST (ɨ-R)
[ʂi]	*!				*
☞ [ʂɨ]				*	*
[si]			*!		
[ʂɯ]		*!		*	

In Toda, the front high vowel is retracted as far as the back vowel [ɯ], as given in tableau (38). The *REPLACE (+4F2, –2F2) constraint is lower ranked than in tableau (37), allowing a further retraction of the vowel to [ɯ].

(38)

/iʈ/	*DIST (i-R)	*REPLACE (–2F3, 0F3)	*DIST (ɨ-R)	*REPLACE (+4F2, –2F2)	*REPLACE (+4F2, +1F2)	*DIST (ɯ-R)
[iʈ]	*!		*			*
[ɨʈ]			*!		*	*
[it]		*!				
☞[ɯʈ]				*	*	*

Retraction of the high front rounded /y/ to the back [u], observable in Pingding Chinese, can be modelled in the same way as the vowel retraction in Toda (by replacing *DISTANCE (i-R) with *DISTANCE (y-R)), as rounding does not change anything in the distance between vowel and retroflexion gesture. This process is not illustrated here.

Ponapean shows retraction of the mid-front vowel /e/ to [ɘ], which is accounted for in (39), where *REPLACE (1trill, 2trill) militates against a change from underlying flap to surface trill.

(39)

/ɽe/	*DISTANCE (e-R)	*REPLACE (1trill, 2trill)	*REPLACE (+4F2, +1F2)
[ɽe]	*!		
☞[ɽɘ]			*
[re]		*!	

According to the general constraint hierarchy of *DISTANCE constraints in figure 6.2, this retraction implies that the high front vowel also retracts, if it exists in the language under consideration, since *DISTANCE (i-R) is ranked higher than *DISTANCE (e-R). And indeed, the Ponapean /i/ retracts to [ɨ], see the data in (21) in chapter 4. However, due to the flexible ranking of the constraints *REPLACE (vowel features), languages that only show a retraction of the mid vowel are possible.

The possible rankings of the markedness constraints for vowel retraction and the respective faith constraints for the vowels are summarized in figure 6.3.

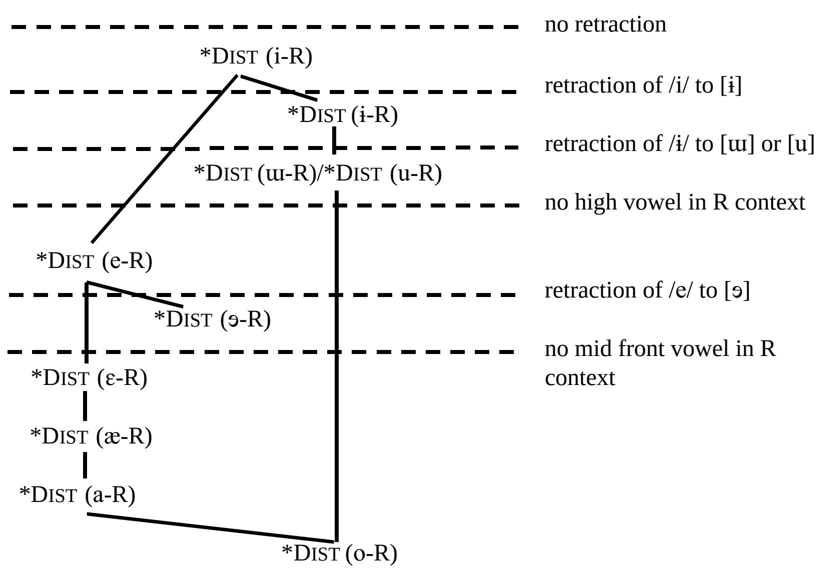

Figure 6.3 Ranking of the *DISTANCE (back) constraints and vowel place faith constraints (indicated by the dashed lines) for vowel retraction.

In figure 6.3, I make two assumptions. First, the constraints securing the F1 of the vowels (against vowel lowering) are ranked high (thus, lowering is not included in this figure). Second, all constraints on the F2 of the vowels are ranked at the same height, namely that of the dashed lines.

The position of the partial ranking *DISTANCE (e-R) >> *DISTANCE (ɘ-R) is not fixed in figure 6.3, i.e. it can be placed higher than indicated here, as is the case for Ponapean, see figure 6.4 below. This partial ranking, however, has to stay lower than *DISTANCE (i-R), since the gestural distance between [i] and a retroflex is unquestionably larger than that between [e] and a retroflex.

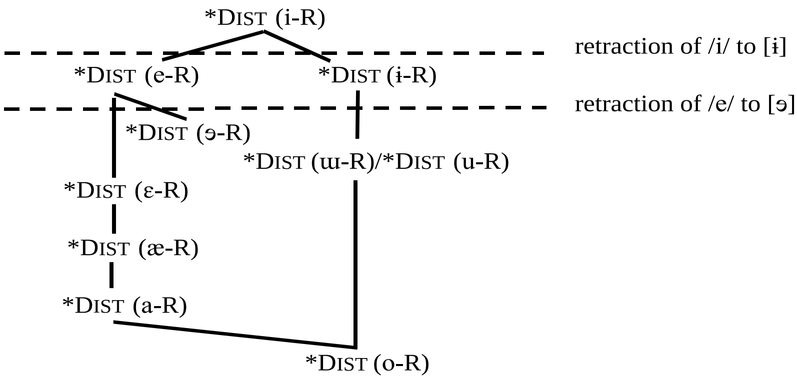

Figure 6.4 Ranking of the *DISTANCE (back) constraints and vowel height faith constraints (indicated by the dashed lines) for vowel lowering in Ponapean.

In figure 6.4, two rankings for the vowel faith constraints are possible: either *REPLACE (+4F2, –2F2), which militates against the change from [i] to [ɯ], is ranked below *DISTANCE (i-R), i.e., at the height of the first dashed line, or below *DISTANCE (ɨ-R) and *DISTANCE (e-R), i.e., at the height of the second dashed line. The vowel faith constraint *REPLACE (+4F2, +1F2), against a change from [e] to [ɘ] has to be ranked below the second dashed line. If it were ranked higher, no retraction of [e] would take place.

Lowering. Vowel lowering and the different rankings necessary to account for it are depicted in figure 6.5 on the next page. Here, the F2 faith constraints are assumed to be ranked high (no vowel retraction occurs) and all the vowel faith constraints are at the same height (at that of the dashed lines).

For the process of vowel lowering, Kayardild will be discussed as a representative language. In this language both high front /i/ and high back /u/ are lowered. The respective rankings are shown in figure 6.6, also on the next page.

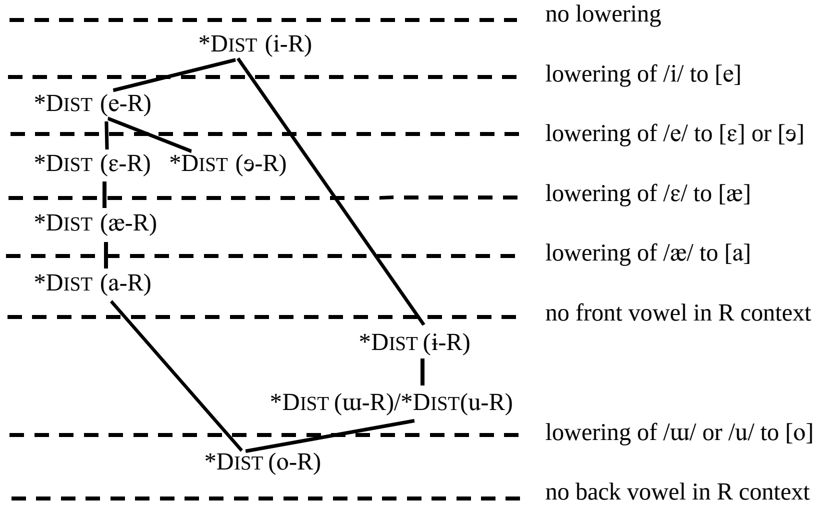

Figure 6.5 Ranking of the *DISTANCE (back) constraints and vowel height faith constraints (indicated by the dashed lines) for vowel lowering.

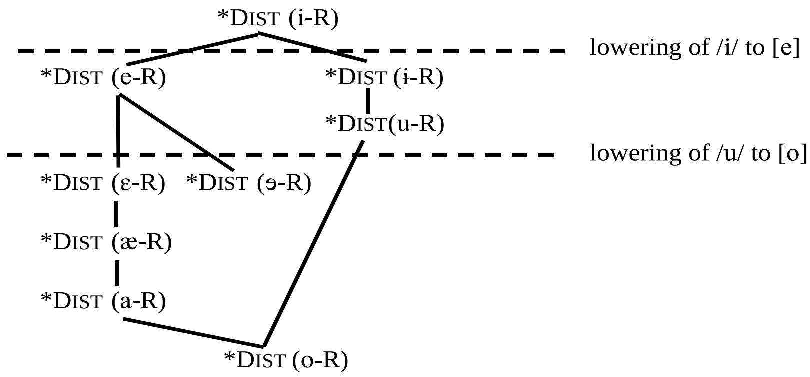

Figure 6.6 Ranking of the *DISTANCE (back) constraints and vowel height faith constraints (indicated by the dashed lines) for vowel lowering in Kayardild.

The two lowering processes in Kayardild are given in (40) (in the following tableaux the candidate with a faithful vowel but a changed retroflex and the respective constraint are not included anymore). The vowel faith constraint *REPLACE (–3F1, –1F1), which militates against a change from /i/ to [e] and from /u/ to [o], has to be lower ranked than the *DISTANCE (e-R) and *DISTANCE (u-R) constraints, otherwise no vowel lowering would take place. The vowel faith constraint *REPLACE (–3F1, +1F1) has to be high ranked to avoid a further lowering of /i/ to [ɛ], see the third candidate [ɛʈ].

(40)

/iʈ/	*DIST (i-R)	*REPLACE (–3F1, +1F1)	*DIST (e-R)	*DIST (u-R)	*REPLACE (–3F1, –1F1)	*DIST (o-R)
[iʈ]	*!		*			
☞ [eʈ]			*		*	
[ɛʈ]		*!			*	

/uʈ/	*DIST (i-R)	*REPLACE (–3F1, +1F1)	*DIST (e-R)	*DIST (u-R)	*REPLACE (–3F1, –1F1)	*DIST (o-R)
[uʈ]				*!		*
☞ [oʈ]					*	*

The vowel lowering process in Norwegian is phonetically unusual, as it involves lowering of the mid front vowel /ɛ/ only (recall the data from (25) in chapter 4), see (41).

(41)

/ɛʈ/	*REPLACE (+1F1, +3F1)	*DISTANCE (ɛ-R)	*REPLACE (+1F1, +2F1)	*DISTANCE (æ-R)
[ɛʈ]		*!		
☞ [æʈ]			*	*
[aʈ]	*!		*	

The high front vowel /i/ in Norwegian does not change, although we would expect it from our universal phonetic constraint ranking in figure 6.2 and 6.4 to undergo lowering, since the *DISTANCE (i-R) constraint is higher ranked than the *DISTANCE (ɛ-R) constraint. This exception has to be treated as language-specific and phonetically unmotivated, formalized by a high faith constraint for the vowel /i/, see (42).

(42)

/iʈ/	*REPLACE (–3F1, –1F1)	*DISTANCE (i-R)	*DISTANCE (e-R)
☞ [iʈ]		*	*
[eʈ]	*!		*

Therefore Norwegian is assumed to show the following interaction of *DISTANCE constraints and perceptual faith constraints (*REPLACE) with respect to the process of vowel lowering, where the constraint *REPLACE (–3F1, –1F1) militates against the lowering of /i/ (very high ranked), and the constraint *REPLACE (+1F1, +2F1) against the lowering of /ɛ/.

(43) *REPLACE (–3F1, –1F1) >> *DISTANCE (i-R) >> *DISTANCE (ɛ-R) >> *REPLACE (+1F1, +2F1) >> *DISTANCE (æ-R)

6.3.3.3 Vowel diphthongization

Vowel diphthongization differs from the processes of vowel lowering and retraction, in that it involves a change of part of the vowel only. During the articulation of the vowel the tongue retracts, lowers, or assumes a neutral position, before moving on to the retroflex articulation. This near-neutral position results in a schwa-like offglide, and thus a diphthongization of the vowel. The present analysis is not concerned with the exact phonetic realization of the second half of the vowel. It is represented as a schwa, but if a retracted front high vowel or a front mid vowel were assumed, the formalization would not change. The articulation responsible for such a vowel change can be modelled with the *SYNC (vowel | retroflex) constraint defined in (12): the tongue middle lowering is not synchronized with the tongue tip raising and closure, and thus occurs already when the tongue tip is not raised yet. The reverse process, a raising of the tongue tip far before a tongue tip closure is made, occurs in the process of vowel retroflexion, discussed in section 6.3.4 below. Vowel retroflexion is also accounted for by *SYNC (vowel | retroflex).

Diphthongization of /i/ in Gugada is taken here as an example to show the relevant constraint interaction, see tableau (44).

(44)

/iʈ/	*REPLACE (+4F2, +1F2)	*SYNC (vowel | retroflex)	*INSERT (0F1 & 0F2)
[iʈ]		*!	
[ɨʈ]	*!	*	
☞ [iəʈ]			*

The winning candidate does not violate any vowel faith constraint, for instance *REPLACE (+4F2, +1F2) if vowel retraction is assumed, because the vowel is, at least partly, still perceivable. [iəʈ] does, however, violate a *INSERT (0F1 & 0F2) constraint since a new segment feature (the schwa) emerges that was not specified in the underlying representation.

6.3.3.4 Vowel rounding

The vowel rounding processes in Wembawemba and Wergaia are assumed here to occur only together with de-retroflexion, following Flemming's (1995, 2002) proposal discussed in sections 4.3.3 and 5.3.1. Vowel rounding can thus be interpreted as a strategy to preserve the underlying retroflex specification, i.e. [–2F3], as rounding causes a similar cue of lowered F3, by realizing it on the vowel. An example illustrating vowel rounding is modelled in tableau (45).[4]

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[4] The possible candidate [it^w] that was introduced in the discussion on vowel rounding by Flemming in section 5.3.2 is not included in this tableau. In order not to let this candidate win, information on the low perceptibility of the feature [–2F3] on a stop, compared to its high perceptibility if it is realized on a vowel, has to be included. This can be done by incorporating the probability of the features to be properly perceived, i.e. categorized, see Boersma (1998: 285f.).

(45)

/iʈ/	*DISTANCE (i-R)	*DELETE (–2F3)	*REPLACE (+4F2, +2F2)	*DELETEPATH (stop × –2F3)	*GESTURE (lips)
[iʈ]	*!				
[it]		*!		*	
☞[yt]			*	*	*

The most faithful candidate is articulatorily too complex and violates the high-ranked *DISTANCE (i-R) constraint. The second candidate is articulatory less complex, but does not realize the underlying [–2F3] specification. The winning candidate preserves this feature but violates the faith constraints *REPLACE (+4F2, +2F2) and *DELETEPATH (stop × –2F3), the latter militating against the movement of the [–2F3] feature from the consonant to the vowel (recall the definition of *DELETEPATH in (5)). Furthermore, the winner violates the markedness constraint *GESTURE (lips), because it includes additional rounding of the lips. In Wembawemba and Wergaia, these three constraints have to be lower-ranked than the constraint preserving the [–2F3] feature value and the constraint against a gestural movement from front high vowel to retroflex. This ranking is unexpected since there is no observable optimisation, neither articulatory nor perceptual. Perceptually, the faithfulness to both underlying segment classes (low ranked *REPLACE (+4F2, +2F2) and *DELETEPATH (stop × –2F3)) is less important than the preservation of one single cue (high ranked *DELETE (–2F3)). Articulatorily, one gesture is saved (expressed by the high ranked *DISTANCE (i-R)) at the cost of having an additional gesture (the low ranked *GESTURE (lips)). This unusual ranking might explain why such a process is cross-linguistically extremely rare.

In sections 4.3.2.1 and 4.3.3, Koḍagu was shown to retract vowels before retroflexes, and retract and round vowels between a labial and a retroflex. The example word [poːɽ] is analysed in (46), assuming /peːɽ/ as the non-rounded and non-retracted input to the diachronic development in Koḍagu. A *SYNC constraint that militates against the synchronization of the end of labialization and the beginning of the vowel, termed *SYNC (labial | vowel), can account for the rounding of the following vowel.

(46)

/peːɽ/	*DISTANCE (e-R)	*SYNC (labial | vowel)	*REPLACE (+4F2, –4F2)	*REPLACE (+4F2, –2F2)
[peːɽ]	*!	*		
☞ [poːɽ]			*	*
[pøːɽ]	*!			
[pɤːɽ]		*!		*

Both the first, most faithful candidate and the third candidate, which shows no retraction but only vowel rounding, violate the *DISTANCE (e-R), because they do not reduce the distance between the vowel and the retroflex gesture. The fourth candidate, without rounding, reduces the gestural distance, but violates the *SYNC (labial | vowel) constraint, which is higher ranked than the vowel faith constraints. Thus, the rounded, retracted vowel wins.

6.3.3.5 Secondary palatalization

For secondary palatalization of retroflexes, the account looks slightly different from those for the vowel – retroflex sequences with respect to possible outputs. Since the articulation of a palatalized retroflex is assumed here to be impossible (as illustrated in section 2.5), there is no possible output candidate of this type. Instead, the three realizations as given in (30) and repeated here in (47) are observable in natural languages. Let us discuss them subsequently.

		input	*output*	*process*
(47)	(a)	/ʈʲ/	[tʲ]	de-retroflexion
	(b)	/ʈʲ/	[ʈ]	de-palatalization
	(c)	/ʈʲ/	[ʈj]	separate palatal

The first realization of retroflex palatalization is a non-retroflex, palatalized segment. This process can be found in Russian for the fricative /ʂ/, which palatalizes to the segment [ʃ] (the palato-alveolar fricative shows some inherent palatalization due to its domed tongue body, and is thus not represented with additional secondary palatalization). Palatalization of coronals is realized as a raising of the second and third formant, and will be represented here by the feature [+2F3]. The constraint *DELETE (+2F3) thus militates against the deletion of the palatalization cues.

(48)

/ʂ+ʲ/	*DELETE (+2F3)	*REPLACE (–2F3, +2F3)
[ʂ]	*!	
☞ [ʃ]		*

Since the non-realization of palatalization cues is not an option in the symmetric system of Russian consonants, which are either palatalized or non-palatalized, the constraint *DELETE (+2F3) is very highly ranked and prohibits the non-palatalized first candidate. Instead, a change in the inherent cues of the fricative from retroflex to palato-alveolar is acceptable. Thus, the second candidate wins.

The reverse ranking of the two faith constraints results in the realization of the retroflex as non-palatalized, the second output occurring for the process of palatalizing retroflexes, as depicted in (47b). This strategy can be found in Lewis Scots Gaelic, illustrated in section 4.3.2.5. The following tableau accounts for the underlying sequence /ʈ+ʲ/ in the Lewis dialect:

(49)

/ʈ+ʲ/	*REPLACE (–2F3, +2F3)	*DELETE (+2F3)
☞ [ʈ]		*
[tʲ]	*!	

A problem concerning this realization strategy is the fact that the resulting form is ambiguous, since the hearer is not provided with any perceptual cues as to whether the segment is palatalized or not. The Lewis form [paːʈ] ‘a poet’, for example, can be both nominative singular (without underlying palatalization) and genitive singular (with underlying but not realized palatalization for the genitive). Additional contextual information is needed to disambiguate the two forms.

The last possibility of realizing palatalization on a retroflex segment is doing so not simultaneously but instead with a following palatal glide (45c). It was claimed in 2.5.2 that this is the strategy applied in Toda. Toda palatalization of retroflexes can therefore be modelled as follows, where *DELETEPATH (stop × +2F3) militates against a change in the overlap of palatalization and stop cues (see definition of *DELETEPATH constraints in (5)).

(50)

/ʈ+ʲ/	*REPLACE (–2F3, +2F3)	*DELETE (+2F3)	*DELETEPATH (stop × +2F3)
[ʈ]		*!	
☞ [ʈj]			*
[tʲ]	*!		

As explained in section 2.5.2, Toda is assumed to have a phonological category of a palatalized retroflex, though articulatory this is impossible. Some special restriction must be therefore assumed in the perception grammar to prevent the listener from categorizing the articulatory output $[ʈj]_{art}$ as two consecutive segments, analysing it as one complex segment [ʈʲ] instead. In a perception grammar, so-called *WARP constraints (Boersma 1998: 164) require that the cues of a segment given in the input are categorized as such. For our purpose, a *WARP (+2F3) constraint requires that the input segment $[j]_{art}$ is categorized as such, and the *WARP (stop | +2F3) constraint that the input $[ʈj]_{art}$ is perceived as the sequence of the two segments $[ʈj]_{perc}$.[5] This perception process is modelled in tableau (51).

(51)

$[ʈj]_{art}$	*/ʈj/	*WARP (+2F3)	*WARP (stop | +2F3)
$[ʈj]_{perc}$	*!		
☞ $[ʈ^j]_{perc}$			*
$[ʈ]_{perc}$		*!	

The constraint */ʈj/ is a language-specific phonotactic constraint acquired by the learner via probabilistic knowledge of the occurrence of specific segment sequences in the language. It prohibits the categorization of the sequence $[ʈj]_{art}$ as $[ʈj]_{perc}$ because the glide /j/ does not occur in this position in Toda, and it thus prevents the most faithful first candidate from winning. The third candidate, the one without the glide, violates the high ranked *WARP (+2F3) constraint. The $[ʈj]_{art}$ sequence,

5 Boersma’s *WARP constraints are applied only to single vowel segments and used to model the miscategorization of these vowels as acoustically very close ones. This constraint family is not applied by Boersma to segmental sequences as done here.

therefore, can only be interpreted as a palatalized retroflex.

It must be noted that there is a slight mismatch exemplified in (50) and (51). The faith constraints in (50) refer to rich perceptual features, whereas the perceptual results of (51) are more abstract featural representations (in accordance with Boersma 1998).[6]

6.3.4 Retroflexion of vowels

Retroflexion of vowels was illustrated in section 4.5.2 to originate from a tongue tip raising at the beginning of the vowel gesture. This is a different kind of non-synchronization of vowel and retroflex gestures than described for the diphthongization in section 6.3.3.3. It is caused, however, by the same drive of avoiding effortful synchronizations of gestures, captured by the *SYNC (vowel | retroflex) constraint as defined in (12) above. Vowel retroflexion of /a/ in Margany, for example, can then be accounted for as follows:

(52)

/aʈ/	*SYNC (vowel | retroflex)	*INSERTPATH (–3F3 × +3F1)
[aʈ]	*!	
☞ [a˞ʈ]		*

The non-synchronization of the two gestures results in a change in the vowel quality, which violates the *INSERTPATH (–3F3 × +3F1) constraint (see the definition of *INSERTPATH constraints in (4)).

6.3.5 Phonotactics of retroflex segments

Section 4.6 illustrated that retroflex segments often do not occur in those positions where the retroflex is not well perceivable, namely post-consonantally. This was accounted for by the weaker CV cues of retroflexes, which are perceptually close to those of apical alveolars, compared to the more distinct VC cues. Such a proposal was formalized already by Steriade (1995, 2001a), as discussed in section 5.3.3. Steriade assumes that these are cases of neutralization of apical contrast. In the following formalization I assume that phonotactic restrictions of this class are not explained by reference to its distinctiveness with the presence of other classes in the same inventory. Instead, it is assumed that the retroflex does not occur in specific positions in certain languages because its *GESTURE (retroflex) constraint interacts with a family of *DELETE (–2F3) constraints as defined in (2a) above, which are sensitive to the context restriction as given in (53).

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6 If the grammar model exemplified in (51) is applied to (50) and all earlier tableaux in this chapter, the formulation of the faith constraints would have to be modified appreciably, since they would have to refer to abstract features. In (50) the perceptual part of the second candidate would become $[ʈ^j]_{perc}$, i.e., the winning candidate of (51). This means that the second candidate in (50) would become completely faithful to the underlying form, and hence would violate no faith constraints at all. A formulation of the current theory in terms of more abstract features has to be postponed until future research.

(53) *DELETE (–2F3 / V_V) >> *DELETE (–2F3 / V_C) >> *DELETE (–2F3 / C_V) >> *DELETE (–2F3 / C_C)

This ranking of contexts incorporates the fact that retroflex cues are most prominent in a V_V context, and least prominent in C_C context, like all consonantal cues. The ranking of the intermediate two constraints *DELETE (–2F3 / V_C) and *DELETE (–2F3/ C_V) incorporates that the VC cues of retroflexes are stronger than their CV cues. The constraint hierarchy in (53) is hence a universal comparison of the contrastiveness of retroflex cues in specific positions. As was the case for the universal gesture hierarchies for vowel retraction and vowel lowering in section 6.3.3.2, this hierarchy is phonetically motivated and assumed to be present in the universal phonetic knowledge. It does not exist in the phonology of every language. Languages with no retroflex gesture at all *could* be described as ranking *GESTURE (retroflex) above the complete hierarchy of (53). But as there is no need to refer to a non-learned gesture with a specific *GESTURE constraint and, more importantly, to include information on the possible contexts of occurrence for this non-existing segment class in the grammar of this language, such a formalization is not proposed here.

For a language such as Kashmiri which allows retroflex segments in all positions, the *GESTURE (retroflex) constraint could similarly be assumed to be ranked below the hierarchy in (53). But again, this language needs no further information on slight differences in the perceptibility of retroflex cues in specific positions, since these differences are not relevant for the phonology of this language. Therefore, the hierarchy in (53) is not assumed to be part of the grammatical knowledge of Kashmiri speakers. The hierarchy in (53) is only present in the grammar of a language if there are cue-specific prosodic restrictions. On the other hand, the Djapu dialect of Dhuwala-Dhuwal, a language with retroflex segments in postvocalic position only, has the *GESTURE (retroflex) constraint ranked between the *DELETE (–2F3 / V_C) and *DELETE (–2F3 / C_V) on the hierarchy, and this ranking is contained in the grammar.

Several languages, such as the Australian language Bunuba, have no retroflex in initial position. In section 4.6.2 it was proposed that this behaviour is not phonetically motivated, as it comprises both postvocalic and postconsonantal positions. This restriction has to be stored in the phonology language-specifically, namely as ranking of the *GESTURE (retroflex) constraint below faith constraints securing the retroflex features in non-initial context and above faith constraints for retroflex cues in general.

These languages do, however, allow a retroflex segment in word-initial position if the consonant in the following syllable is retroflex. These are cases of long-distance assimilation to be formalized in the next section, independent of the general phonotactics.

Lastly, some Australian languages show variation in the actual articulation of the retroflex (and the alveolar) in initial position, for instance observed by McGregor (1990) for Gooniyandi. For these cases, Boersma's *PRECISION constraints as defined in (13) can be applied to a specific context, see (54).

(54) *PRECISION (tongue tip: retroflexed | ($_{\omega}$_): “In word-initial position, the tongue tip does not work up the precision to put itself in a retroflex position.”

This lack of precision in the articulation of the retroflex segment may result in an apical alveolar (i.e. a non-displaced apical articulation) in some cases and therefore account for the variation found in languages such as Gooniyandi.

6.3.6 Assimilation of retroflexion

Assimilation processes are gesture reductions licensed by the weak perceptibility of the cues that are lost by the assimilation. In our FP-OT framework, apical assimilation involving retroflexes can be depicted as being triggered by a high-ranked *DISTANCE (tip) constraint (defined in (10a)), which militates against the change from one tongue tip posture to another. Furthermore, assimilation violates faith constraints of the segment changed. As was defined already above in section 6.3.5, the cues for retroflexes are stronger in VC position than in CV position, leading to a context-sensitive *DELETE (–2F3) constraint ranking for phonotactic restrictions in (55a), analogously to (53). A similar context hierarchy can be assumed for the constraint *DELETE (0F3) which militates against the deletion of the mid F3 cues of apical alveolars, see (55b).

(55) (a) *DELETE (–2F3 / V_) >> *DELETE (–2F3 / C_)
(b) *DELETE (0F3 / V_) >> *DELETE (0F3 / C_)

These two constraint rankings cannot be ordered with respect to each other in any specific way, as there is no motivation why for example the deletion of a retroflex before a vowel should be perceptually more acceptable than the deletion of an apical alveolar in the same environment. With these two constraint rankings and their flexible, language-specific ranking with respect to each other, the assimilation processes illustrated in section 4.7 can be modelled.

For *progressive* assimilation of an *alveolar to a retroflex* the two constraint families in (55) have interact as follows:

(56) *DELETE (–2F3 / V_) >> *DELETE (0F3 / C_)

The progressive and iterative assimilation in Swedish and Norwegian is illustrated in the tableau in (57), where just a consonant sequence but not the whole word is given. The sequence occurs after a vowel.

(57)

/ɳts/	*DISTANCE (tip)	*DELETE (–2F3 / V_)	*DELETE (0F3 / C_)
[ɳts]	*!		
☞ [ɳʈʂ]			**
[nts]		*!	

Progressive assimilation of a retroflex to an alveolar requires the ranking of the constraint saving the alveolar cues postvocalically above the constraint saving the retroflex cues postconsonantally, see (58).

(58) *DELETE (0F3 / V_) >> *DELETE (–2F3 / C_)

Kannada has such a process, illustrated in (59), which again only shows the relevant consonant clusters and the essential constraints.

(59)

/dɭ/	*DISTANCE (tip)	*DELETE (0F3 / V_)	*DELETE (–2F3 / C_)
[dɭ]	*!		
[ɖɭ]		*!	
☞ [dl]			*

For *regressive assimilation of an alveolar to a retroflex*, a ranking of all the faith constraints for the retroflex (55a) above the faith constraints for the alveolars (55b) must be assumed, see (60).

(60) *DELETE (–2F3 / V_) >> *DELETE (–2F3 / C_) >> *DELETE (0F3 / V_) >> *DELETE (0F3 / C_)

An example from Sanskrit is given in (61):

(61)

/tɖ/	*DISTANCE (tip)	*DELETE (–2F3 / C_)	*DELETE (0F3 / V_)
[tɖ]	*!		
☞ [ʈɖ]			*
[td]		*!	

The ranking in (60) predicts that *progressive* assimilation of alveolar to retroflex place of articulation occurs as well, i.e., that it is always the place cue of the retroflex that wins in Sanskrit. This proposal differs from Steriade's (1995) analysis of Sanskrit, which treats regressive assimilation of alveolars to retroflexes as being morphologically conditioned: spreading occurs from the cues of the content words to those of the functional words. Whitney (1889, §196) illustrates that retroflexes in Sanskrit can influence adjacent dentals, but does not describe the reverse process nor gives examples for it, thereby supporting the present analysis of Sanskrit.

Lastly, the process of *regressive assimilation of a retroflex to an alveolar* has to be discussed. This involves the following ranking of the cue constraints:

(62) *DELETE (0F3 / V_) >> *DELETE (0F3 / C_) >> *DELETE (–2F3 / V_) >> *DELETE (–2F3 / C_)

This process of regressive alveolar assimilation occurs in Punjabi, see (63).

(63)

/ɳn/	*DISTANCE (tip)	*DELETE (0F3 / C_)	*DELETE (–2F3 / V_)
[ɳn]	*!		
[ɳɳ]		*!	
☞ [nn]			*

Section 4.7.1 also included the *assimilation of a retroflex to a non-coronal* velar or palatal with the example of Colloquial Tamil. For such a process the *DISTANCE (back) constraint (as defined under 10b) that accounts for the unwillingness of a change in articulator from retracted tongue back for the retroflex to the raised tongue back for the velar has to be ranked above the coronal faith constraint *DELETE (+1F2), see (64) (the velar feature [–2F2] was introduced in table 5.10).

(64)

/ʈk/	*DISTANCE (back)	*DELETE (–2F2)	*DELETE (+1F2)
[ʈk]	*!		
[ʈʈ]		*!	
☞ [kk]			*

From the data at hand, we cannot determine whether the *DELETE constraints have to be formulated as context-sensitive or not, i.e. whether /ʈ/ is always assimilated independent of the context.

The examples of *long-distance assimilation* in section 4.7.2 were restricted to assimilation of an alveolar towards a retroflex, for the obvious reason that non-coronal segments are not affected by a distant retroflex. It was assumed that the retroflex gesture is held during the interval between the two surface retroflex segments. In contrast to local assimilation, it is not an adjacent gesture that is changed in this type of assimilation, and hence the direct context of the two segments involved in the process does not matter. It is a ranking between *REPLACE (0F3, –2F3) and *REPLACE (–2F3, 0F3) that simply decides on the winning cues and hence on the direction of assimilation.

The Sanskrit *nati rule* exemplifies *progressive long-distance assimilation.* Only the alveolar nasal can undergo it, and the output violates the manner-specific constraint *REPLACE (0F3, –2F3 / nasal), which militates against the replacement of an alveolar by a retroflex nasal. Tableau (65) illustrates the process. In the following examples, dots are used to indicate intervening, non-coronal material.

(65)

/ʂ...n/	*REPLACE (–2F3, 0F3)	*DISTANCE (tip)	*REPLACE (0F3, –2F3 / nasal)
[ʂ...n]		*!	
[s...n]	*!		
☞[ʂ...ɳ]			*

The *DISTANCE (tip) constraint is assumed to be sensitive to the change in place of articulation, only, but is not violated by a change from apical fricative to stop which also involves a slight change of tongue tip position.

Long-distance assimilation in Sanskrit is blocked by non-nasal coronals between the trigger retroflex and the nasal, see (66).

(66)

/s̺.t.n/	*REPLACE (–2F3, 0F3)	*REPLACE (0F3, –2F3 / stop)	*DISTANCE (tip)	*REPLACE (0F3, –2F3 / nasal)
☞[s̺.t.n]			*	
[s.t.n]	*!			
[s̺.t.ɳ]			**!	*
[s̺.ʈ.n]		*!	*	
[s̺.ʈ.ɳ]		*!		*

The third candidate, in which /n/ is retroflexed after a retroflex despite the intervening alveolar, violates the *DISTANCE (tip) constraint twice because of the changes from retroflex to alveolar and from alveolar to retroflex articulation. The fourth candidate, a retroflexion of the plosive instead of the nasal, shows that it is necessary to distinguish the *REPLACE constraints according to the manner of the segments: stops with their stronger cues allow less changes than nasals, therefore *REPLACE (0F3, –2F3 / stop) is higher ranked than *REPLACE (0F3, –2F3 / nasal) (see Boersma's 1998 argumentation and Steriade's 2001 proposal). The last candidate, where both underlying apicals are retroflexed, violates both manner-specific *REPLACE constraints.

6.4 Conclusion

In the present chapter it was shown that processes involving retroflex segments could be modelled by assuming underlying perceptual representations, with additional articulatory restrictions on their realization. Underlying articulatory features are absent in my account. Furthermore the present chapter showed that is not necessary to stipulate additional devices such as a P-map (Steriade 2001a, b) that stores information on perceptual difference since the constraints in the grammar refer directly to cues and cue combinations. For the class of retroflexes, the low F3, i.e. the feature [–2F3], plays a large role in quite a number of processes. At the same time, the retraction of the tongue tip concomitant with retroflex articulation imposes restrictions on the realization of specific sequences and accounts for phonological processes such as front vowel lowering or retraction in a retroflex context or a change of the retroflex in secondary palatalization.

The analyses of the phonological processes were illustrated with mainly only one example language each from the respective sections in chapter 4. Examples from further languages given in chapter 4 were not discussed here in order not to obscure the analysis. Detailed accounts for these non-discussed languages, especially of languages that involve more than one process, are left for future work.

The analyses presented here included observations on cross-linguistic variations and descriptions of these variations with universal constraint hierarchies that interact with language-specific constraints. Two such cases were discussed, the process of vowel retraction and lowering (6.3.3.2), where universally ranked articulatory markedness constraints interact with perceptual faith constraints, and assimilation processes (6.3.6), where universally ranked faith constraints interacted with markedness constraints that are language-specifically ranked. As explained before, these rankings are grounded in the phonetic equipment of humans and are in this sense universal: either the constraint of a more complex articulation is higher ranked than one militating against a less complex articulation, or the constraint against a cue in a perceptually less salient context is higher ranked than the constraint against the same cue in a perceptually more salient context. These universal constraint hierarchies are assumed to be part of the phonetic knowledge available to a speaker, and not to belong to a separate innate Universal Grammar. Furthermore, they are not present in the phonology of every single language, but only in those that actually refer to these phonetic details in their phonological processes. The process of vowel lowering in Norwegian (see tableaux (41) and (42)) illustrated that a language can partly follow such universal hierarchies (the lowering of the vowel [ɛ]) but show idiosyncratic behaviour for other parts due to high-ranked faith constraints (as in the case of non-lowering of the vowel [i]).

In sum, the present chapter addressed and covered large parts of the discussion of all previous chapters of this dissertation: it dealt with the phonological processes involving retroflexes as illustrated in chapter 4 in the framework of FP introduced in chapter 5, thus summarized and brought to a conclusion the phonological part of this dissertation. Moreover, by specifying the class of retroflexes by perceptual features [–2F3] and [+1F2], based on the perceptual cues that were the topic of chapter 3, and by restricting their coarticulations by their articulatory characteristics, as described in chapter 2, it incorporated the phonetic definition of retroflexes given in the first part of the thesis.