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Deriving Coda Conditions through the Generalized Local Conjunction of Markedness Constraints

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1 Introduction

It is a basic fact of phonology that, in all the world's languages, syllables with codas are more marked than codaless syllables. It is also a well-known fact that many languages that accept syllable codas limit the set of segments that may fill that position. These limitations, which have been called coda conditions (Itô, 1988), vary from language to language. Some concern place. In Finnish, a coda consonant can have only coronal place (Sulkala and Karjalainen, 1992). Others concern sonority. The West African language of Fanti bans all obstruents from coda position (Welmers, 1946). Still other coda conditions reflect *both* place markedness and sonority considerations. The Australian language Pitta Pitta, for instance, allows only coronal sonorants in word-medial coda position. (There are no word-final codas in the language.) Non-coronal sonorants cannot have a place specification of their own. Coronal obstruents are banned completely (Blake, 1979).

It is notable that these coda conditions reflect general markedness phenomena. Because segments with labial or dorsal place are more marked than segments with coronal place, it is not surprising that Lardil allows only coronal in codas. In addition, it is no surprise that a coda condition would disallow obstruents, as does Fanti. The fact that codas with higher sonority are less marked than those with lower sonority follows from a basic observation about sonority. Clements' Sonority Cycle claims that the optimal syllable bears a sonority profile that rises maximally from the beginning to the peak and falls minimally from the peak to the end (Clements, 1992). A syllable with a coda with higher sonority, then, will be more likely than a syllable with a coda with lower sonority to fulfill the criterion of falling minimally towards the end. This is because the syllable peak is likely to be a vowel, and the higher the sonority of the coda, the smaller the distance between its sonority and that of the peak. The existence of coda conditions like that of Pitta Pitta indicate that, in some languages, the dimensions of coda sonority and place markedness both play a role in restrictions on the coda inventory.

A proper account of the restrictions on codas should capture the connection of coda conditions with other markedness phenomena. In this paper, I propose to provide such an account within the framework of Optimality Theory: I will show that by taking constraint hierarchies of place markedness and coda sonority and conjoining them in the manner described by Gafos and Lombardi (1999), I can account for a range of coda conditions by the interaction of those hierarchies with faithfulness constraints.

In section 2, I introduce the constraint hierarchies. In section 3, I present Generalized Local Conjunction (Gafos and Lombardi, 1999), an operation by which I will conjoin the two constraint hierarchies. In section 4, I will present my proposal in detail, showing how the conjoined hierarchies can account for the coda condition of Pitta Pitta. In section 5, I will show that the coda conditions predicted by interpolating Faithfulness constraints into the proposed hierarchies are attested by a range of the world's languages.

2 Constraint Hierarchies

2.1 Coda Sonority

In Prince and Smolensky (1993), the authors present the scale Peak Harmony, which indicates that a more sonorous segment associated with a syllable peak is more harmonic (less marked) than a less sonorous segment associated with a syllable peak. The Peak Harmony Scale is seen in (1). In this scale, each segment should be understood as representative of segments of equal sonority.

(1) P/a ≻ P/i....≻ P/d ≻ P/t

This scale corresponds to a constraint sub-hierarchy in which the ranking is reversed and each constraint is a ban on the association of a segment with the syllable peak. The Peak Hierarchy is shown in (2).

(2) *P/t » ...» *P/l » *P/i » *P/a

This sub-hierarchy is universal. Languages may intersperse other constraints throughout the hierarchy, but the ranking of these constraints with respect to each other is fixed.

As discussed above, codas of higher sonority are more harmonic than those of lower sonority. Based on this observation, and following Clements, I posit a scale for codas akin to Prince and Smolensky's Peak Harmony. It follows in (3).

(3) C/approximant ≻ C/nasal ≻ C/obstruent

This scale corresponds to the universal sub-hierarchy of constraints shown in (4).

(4) CODA SONORITY
*C/obstruent » *C/nasal » *C/approximant

This hierarchy expresses one of the dimensions of markedness that plays a role in coda conditions.

2.2 Place Markedness

Coronals are cross-linguistically less marked than dorsals and labials. The markedness relation between dorsals and labials is less clear and I will assume no basic markedness relation between them. In addition, I will not consider the markedness of pharyngeal segments. Because the consonantal inventories of the languages discussed here largely lack segments of pharyngeal place, and because of the controversy surrounding the markedness of pharyngeals, I am not considering pharyngeal place in this proposal. For my analysis, I will make use only of the well-attested markedness phenomenon that can be captured by the harmonic scale in (5).

(5) [cor] ≻ [lab], [dor].

This scale corresponds to the universal markedness hierarchy seen in (6), in which each constraint is stated as a ban on [place].

(6) Place Markedness:
*[lab/dor] » *[cor]

The constraint *[lab/dor] is interpreted as either *labial or *dorsal, not both. The writing of the constraint as *[lab/dor] is simply meant to reflect that the individual constraints are not ranked with respect to one another.

3 Constraint Conjunction

3.1 Local Conjunction

Smolensky (1995) observes that some linguistic phenomena indicate that multiple constraint violations are worse when they occur in the same location. He formalizes this principle with the process of local conjunction. In this process, a constraint C_1 and a constraint C_2 can be conjoined into the constraint C_1 & C_2, which is violated when there is some domain of type D in which both C_1 and C_2 are violated. Universally, the locally conjoined constraint C_1 & C_2 is higher ranked than both of the individual constraints. Thus, C_1 & C_2 » C_1, C_2.

3.2 Generalized Local Conjunction

Local constraint conjunction joins individual constraints. However, there are phenomena, like place markedness and coda sonority, which appear to involve more than one dimension of markedness. These dimensions are expressed in constraint sub-hierarchies. If individual constraints can be conjoined, so, too, can hierarchies of constraints. A conjunction of hierarchies would yield a new hierarchy consisting of local conjunction of the constraints of the basic hierarchies. What, then, would be the formal mechanism by which hierarchies are conjoined?

One solution to this problem can be found in Gafos and Lombardi (1999). They introduce the operation of Generalized Local Conjunction as a way of conjoining hierarchies. The process is defined in (7). The symbol ✱ indicates the process of conjoining constraint hierarchies.

(7) Generalized Local Conjunction of two hierarchies $\mathbb{C}$ and $\mathbb{D}$ (GLC):
Given two constraint hierarchies $\mathbb{C} = C_1 \gg C_2 \gg \ldots C_n$ and $\mathbb{D} = D_1 \gg D_2 \gg \ldots D_m$, their generalized local conjunction $\mathbb{C}✱\mathbb{D}$ is defined by the rankings:
For every i, j, k, l: if $C_i \gg C_j \rightarrow C_i \,\&\, D_k \gg C_j \,\&\, D_l$
Else if i=j and $D_k \gg D_l \rightarrow C_i \,\&\, D_k \gg C_j \,\&\, D_l$
(Gafos and Lombardi, 1999:11)

When two hierarchies of two or more constraints are conjoined, the question of which hierarchy heads the ✱ operation becomes crucial: The process is not commutative.

If $\mathbb{C} = [C_1 \gg C_2]$ and $\mathbb{D} = [D_1 \gg D_2]$, $\mathbb{C}$ ✱ $\mathbb{D} \neq \mathbb{D}$ ✱ $\mathbb{C}$. The resulting hierarchy of the first operation is $[C_1 \,\&\, D_1 \gg C_1 \,\&\, D_2 \gg C_2 \,\&\, D_1 \gg C_2 \,\&\, D_2]$. The resulting hierarchy of the second operation differs in the ranking of the middle two constraints. It is $[C_1 \,\&\, D_1 \gg C_2 \,\&\, D_1 \gg C_1 \,\&\, D_2 \gg C_2 \,\&\, D_2]$. When a hierarchy heads the GLC operation it will be said to have priority over the second hierarchy. I will employ the GLC in my analysis.

4 Proposal

Recall the constraint sub-hierarchies introduced above. The sub-hierarchy introduced in (4), repeated below in (8), concerns coda sonority.

(8) CODA SONORITY
*C/obstruent » *C/nasal » *C/approximant

The coda sonority scale will be referred to as $\mathbb{S}$. The sub-hierarchy introduced in (6) reflects the universal place markedness relation. It is repeated in (9).

(9) PLACE MARKEDNESS
*[lab, dor] » *[cor]

The place markedness scale will be referred to as ℙ.

By the process of GLC, ℙ and 𝕊 can be conjoined. As noted above, different hierarchies would be derived depending on whether Place Markedness or Coda Sonority has priority. The hierarchy that results from the operation ℙ ✱ 𝕊 (Place has priority) is shown in (10).

(10) PLACE HAS PRIORITY
*C/obst&[**lab/dor**] » *C/nasal&[**lab/dor**] » *C/approx&[**lab/dor**] »
*C/obst&[**cor**] » *C/nasal&[**cor**] » *C/approx&[**cor**]

The hierarchy that results from the operation 𝕊 ✱ ℙ (Coda sonority has priority) is shown in (11).

(11) CODA SONORITY HAS PRIORITY
*C/**obst**&[lab/dor] » *C/**obst**&[cor] » *C/**nasal**&[lab/dor] »
*C/**nasal**&[cor] » *C/**approx**&[lab/dor] » *C/**approx**&[cor]

A language may give priority to place or to sonority. By using GLC to derive either the hierarchy in (10) or the one in (11), and by interpolating Faithfulness constraints in the resulting hierarchy, I can account for the coda conditions of Finnish, Fanti, and Pitta Pitta as well as many other languages. I will discuss Pitta Pitta in detail. Space considerations prevent detailed discussions of other languages.

4.1 Pitta Pitta

Pitta Pitta is an Australian language from the southwest corner of Queensland. Its consonantal inventory is shown in Table 1. It does not allow any consonants word-finally, a point that I will not discuss further. It does, however, allow word-medial codas, and these are regulated by a coda condition. Blake (1979) describes this condition in (12).

(12) The following consonant clusters may occur between vowels:
(a) homorganic nasal plus stop
(b) homorganic lateral plus stop
(c) apical nasal or lateral or *rr* plus labial or velar stop or nasal.

	Bilabial	Apico-alveolar	Apico-post-alveolar	Lamino-dental	Lamino-palatal	Dorso-velar
Stops	p	t	ʈ	t̪	t^{y}	k
Nasals	m	n	ɳ	ŋ̪	n^{y}	ŋ
Laterals		l	ɭ	l̪	l^{y}	
Rhotics		ɾ (flap) r (trill)	ɻ (somewhat retroflexed glide)			
Glides	w				y	w

Table 1: Pitta Pitta consonantal inventory (Blake, 1979)

Examples are shown in Tables 2 and 3.

Form	kim.pa	kun.ti	kaːa	kuŋ̪.t̪ɪ
Gloss	blood	house	go	mosquito
Form	ŋan^{y}·t^{y}a	pal̪.t̪apal̪t̪a	ŋal^{y}.t^{y}a	miŋ.ka
Gloss	I	flat	spittle	hole

Table 2: Pitta Pitta word-medial codas: homorganic clusters

Form	kun.para	yan.ka	kan.maɻi	in.ŋu	pil.pa
Gloss	shield	tell	water snake	you (fut.sub)	forehead
Form	wal.ka	pil̥.pa	waɭ.ka	war.pa	tar.ka
Gloss	child	penis, lightening	sun	young (of animal)	stand

Table 3: Pitta Pitta word-medial codas: non-homorganic clusters

The constraint ranking that derives this condition is the hierarchy that results from ℙ ✱ 𝕊, with the relevant Faithfulness constraints ranked between *C/obst&[cor] and *C/nasal&[cor]. This ranking is shown in (13).

(13) *C/obst&[lab/dor] » *C/nasal&[lab/dor] » *C/approx&[lab/dor] »
*C/obst&[cor] » FAITH » *C/nasal&[cor] » *C/approx&[cor]

Before I can demonstrate this ranking at work, however, I need to discuss two points.

The first point concerns rhotics. According to Blake (1979), Pitta Pitta has three rhotics, /ɾ/ (an apico-alveolar flap), /r/ (an apico-alveolar trill), and /ɻ/ (an apico-post-alveolar glide). Of these, we observe that only the trill is an acceptable word medial coda.

This observation requires a discussion of rhotics, troublesome segments that they are. According to Ladefoged (1993), in the world's languages there are ten sounds that can be classified as rhotics. Some are classified as approximants, others are classified as trills, taps, or flaps. What is the sonority of these segments? It may be that the sonority of rhotics varies according to their phonetic realization, and it may also be that markedness considerations other than sonority play a role in how rhotics pattern in syllables.

Here, I will assume that the apico-alveolar flap and apico-post-alveolar glide are banned from word-medial coda position in Pitta Pitta for considerations of markedness that may or may not concern sonority or place. What precisely those considerations are is beyond the scope of this analysis.

The second point I wish to address is the structure of homorganic clusters. I assume that codas that are homorganic to the following onset have no place of their own. The form /kimpa/, then, will have the structure in (14).

(14)
```
σ   σ
/|\ /|\
kim.pa
  \ |
  [lab]
```

The coda consonant /m/ would therefore not violate the constraint *[lab], nor would it violate the conjoined constraint *C/nasal&*[lab/dor]. The below tableau shows the constraint interaction for the input /kimpa/.

/kim.pa/	*C/PLACE	FAITH	*C/NASAL& [COR]	*C/APPROX& [COR]
☞a. kim.pa \ | [lab]				
b. kim.pa | | [lab][lab]	*!			
c. kin.pa | | [cor][lab]		*! (IDENT-IO (PLC))	*	
d. kip.pa \ | [lab]		*! (IDENT-IO (MAN))		

e. kima.pa		*! (DEP-IO)		
f. ki^{n}m· pa		*! (MAX-IO)		

Tableau for /kim.pa/

In this tableau, the constraint *C/PLACE stands for the constraints *C/obst&[lab/dor], *C/nasal&[lab/dor], *C/approx&[lab/dor] and *C/obst&[cor]. FAITH stands for the constraints IDENT-IO (PLACE), IDENT-IO (MANNER), MAX-IO and DEP-IO. Because Pitta Pitta does not show alternation, we cannot be certain of the ranking of the Faithfulness constraints. We know only that one Faithfulness constraint must be ranked between *C/obst&[cor] and *C/nasal&[cor]. Candidate (a) is faithful, as is candidate (b), because the input does not specify association lines. Of those two, (a) emerges as optimal, because, due to its doubly-linked structure, it does not violate *C/nasal&[lab/dor], whereas candidate (b) does. Candidates (c), (d), (e), and (f) are unfaithful and sub-optimal.

The tableau below shows the constraint interaction for the input /walka/. The constraints are as they are above.

/walka/	*C/PLACE	FAITH	*C/NASAL& [COR]	*C/APPROX& [COR]
☞a. walka				*
b. wakka \\ | [dor]		*! (IDENT-IO (MAN)) * (IDENT-IO (PLC))		
c. walaka		*! (DEP-IO)		
d. wa^{n}l·ka		*! (MAX-IO)		

Tableau for /wal.ka/

Candidate (a), the faithful candidate, incurs a violation of *C/APPROX&[COR], but because this constraint is low-ranked, it emerges as optimal. Candidates (b), (c), and (d), through they do not incur any violations of markedness constraints, are unfaithful and therefore sub-optimal.

The word-medial coda condition of Pitta Pitta is complex in that involves the dimension of place markedness as well as the dimension of sonority. This proposal is able to account for this coda condition, as well as the coda conditions of many other languages, with a unified account that is built on basic observations about markedness.

5 Implications

Using Generalized Local Conjunction (GLC), I conjoined the hierarchies of Coda Sonority and Place Markedness. By giving priority to either Coda Sonority or Place Markedness, the GLC operation resulted in two hierarchies, ℙ ✱ 𝕊 and 𝕊 ✱ ℙ. By interpolating ℙ ✱ 𝕊 with Faithfulness constraints, I accounted for the word-medial coda condition of Pitta Pitta.

Further support for this analysis comes from the fact that a factorial typology of FAITH and the hierarchies ℙ ✱ 𝕊 and 𝕊 ✱ ℙ predicts a range of coda conditions that are attested in the world's languages. Consider the hierarchy resulting from ℙ ✱ 𝕊, shown above in (10) and repeated in (15):

(15) PLACE HAS PRIORITY
*C/obst&[**lab/dor**] » *C/nasal&[**lab/dor**] » *C/approx&[**lab/dor**] »*C/obst&[**cor**] » *C/nasal&[**cor**] » *C/approx&[**cor**]

RANKING	CONDITION
(1) FAITH » *C/obst&[**lab/dor**] » *C/nasal&[**lab/dor**] » *C/approx&[**lab/dor**] » *C/obst&[**cor**] » *C/nasal&[**cor**] » *C/approx&[**cor**]	All segments are allowed
(2) *C/obst&[**lab/dor**] » FAITH » *C/nasal&[**lab/dor**] » *C/approx&[**lab/dor**] » *C/obst&[**cor**] » *C/nasal&[**cor**] » *C/approx&[**cor**]	Labial and dorsal obstruents are banned. All other segments are allowed
(3)*C/obst&[**lab/dor**] » *C/nasal&[**lab/dor**] » FAITH » *C/approx&[**lab/dor**] » *C/obst&[**cor**] » *C/nasal&[**cor**] » *C/approx&[**cor**]	Labial and dorsal obstruents and nasals are banned.
(4) *C/obst&[**lab/dor**] » *C/nasal&[**lab/dor**] » *C/approx&[**lab/dor**] » FAITH *C/obst&[**cor**] » *C/nasal&[**cor**] » *C/approx&[**cor**]	All labial and dorsal segments are banned. All coronals are allowed.
(5) *C/obst&[**lab/dor**] » *C/nasal&[**lab/dor**] » *C/approx&[**lab/dor**] » *C/obst&[**cor**] » FAITH »*C/nasal&[**cor**] » *C/approx&[**cor**]	All labial and dorsal segments and coronal obstruents are banned.
(6) *C/obst&[**lab/dor**] » *C/nasal&[**lab/dor**] » *C/approx&[**lab/dor**] » *C/obst&[**cor**] » C/nasal&[**cor**] » FAITH » *C/approx&[**cor**]	Only coronal approximants are allowed.
(7) *C/obst&[**lab/dor**] » *C/nasal&[**lab/dor**]	All segments with place

» *C/approx&**[lab/dor]** » *C/obst&**[cor]** » C/nasal&**[cor]** » *C/approx&**[cor]** » FAITH	are banned.

Table 4: Place Has Priority

Consider also the hierarchy resulting from 𝕊 ✱ ℙ, shown above in (11) and repeated here in (16)

(16) SONORITY HAS PRIORITY
*C/**obst**&[lab/dor] » *C/**obst**&[cor] » *C/**nasal**&[lab/dor] » *C/**nasal**&[cor] » *C/**approx**&[lab/dor] » *C/**approx**&[cor]

RANKING	CONDITION
(8) FAITH » *C/**obst**&[lab/dor] » *C/**obst**&[cor] » *C/**nasal**&[lab/dor] » *C/**nasal**&[cor] » *C/**approx**&[lab/dor] » *C/**approx**&[cor]	All segments are allowed
(9) *C/**obst**&[lab/dor] » FAITH » *C/**obst**&[cor] » *C/**nasal**&[lab/dor] » *C/**nasal**&[cor] » *C/**approx**&[lab/dor] » *C/**approx**&[cor]	Labial and dorsal obstruents are banned. All other segments are allowed
(10) *C/**obst**&[lab/dor] » *C/**obst**&[cor] » FAITH » *C/**nasal**&[lab/dor] » *C/**nasal**&[cor] » *C/**approx**&[lab/dor] » *C/**approx**&[cor]	All obstruents are banned. All nasals and approximants are allowed.
(11)*C/**obst**&[lab/dor] » *C/**obst**&[cor] » *C/**nasal**&[lab/dor] » FAITH » *C/**nasal**&[cor] » *C/**approx**&[lab/dor] » *C/**approx**&[cor]	All obstruents and labial and dorsal nasals are banned.
(12) *C/**obst**&[lab/dor] » *C/**obst**&[cor] » *C/**nasal**&[lab/dor] » *C/**nasal**&[cor] » FAITH » *C/**approx**&[lab/dor] » *C/**approx**&[cor]	All nasals and obstruents are banned. All approximants are allowed.
(13) *C/**obst**&[lab/dor] » *C/**obst**&[cor] » *C/**nasal**&[lab/dor] » *C/**nasal**&[cor] » *C/**approx**&[lab/dor] » FAITH » *C/**approx**&[cor]	Only coronal approximants are allowed. All other segments are banned.
(14) *C/**obst**&[lab/dor] » *C/**obst**&[cor] » *C/**nasal**&[lab/dor] » *C/**nasal**&[cor] » *C/**approx**&[lab/dor] » *C/**approx**&[cor] » FAITH	All segments with place are banned.

Table 5: Coda Sonority Has Priority

Tables 4 and 5 reveal that rankings (1) and (8), (7) and (14), (2) and (9), and (6) and (13) yield identical conditions. Thus, what are apparently fourteen conditions are actually only 10. Despite the variety of these conditions, all but one can be found among the world's languages, as seen in Table 6. It should be said that each language's coda condition is not necessarily a seamless fit with the condition predicted by the ranking. Some require further explanation, such as the discussion of rhotics in the analysis of Pitta Pitta's coda condition above. For more information, see Woods (2000).

#	Condition	Ranking Number(s)	Language(s)
1	All segments are allowed.	(1), (8)	ENGLISH
2	Labial and dorsal obstruents are banned. All other segments are allowed.	(2), (9)	GALICIAN SAWERU (West-Papuan)
3	Labial and dorsal obstruents and nasals are banned. All other segments are allowed.	(3)	SPANISH
4	Labial and dorsal segments are banned. All coronals are allowed.	(4)	FINNISH, LARDIL (Pama-Nyungan)
5	All labial and dorsal segments and coronal obstruents are banned. Coronal nasals and approximants are allowed.	(5)	PITTA PITTA, JAFFNA TAMIL
6	All segments except coronal approximants are banned.	(6), (13)	ITALIAN
7	All obstruents are banned. All nasals and approximants are allowed.	(10)	FANTI, GUMBAYNGGIR (Pama-Nyungan, Gumbaynggiric)
8	All obstruents and labial and dorsal nasals are banned. Coronal nasals and all approximants are allowed.	(11)	WARGAMAY (Pama-Nyungan, Dyirbalic)
9	All obstruents and nasals are banned. All approximants are allowed.	(12)	Not yet attested
10	All segments with place are banned.	(7), (14)	JAPANESE

Table 6: Typology of Coda Conditions and languages that attest them

Finally, it is necessary to discuss the absence of a language that attests condition #9. It should be noted that what distinguishes condition #9 from condition #6 is the set labial and dorsal approximants. This set is extremely scarce in the world's languages. Ladefoged (1993) gives the set of all labial and dorsal approximants as those in (17):

(17) ʋ, labial dental approximant; ɫ, velar approximant
ʟ, velar lateral approximant; w, labial and dorsal approximant

The first three of these segments are only rarely found in languages. According to Ladefoged and Maddieson (1996), /ʋ/ and /ɰ/ are found in less than 2 percent of the world's languages. /ʟ/ is similarly scarce. /w/ may not surface as a coda for other reasons; for instance: the phonotactics of a language might convert all glides to vowels post-vocally. Thus the absence of a language with this condition does not weaken the analysis. That all other conditions are attested is evidence of the strength of the proposal.

6 Conclusion

In this paper, I have shown that a diverse range of coda conditions can be explained by the interaction of markedness constraints. Using the Generalized Local Conjunction (GLC), I conjoined the universal hierarchies of Place Markedness and Coda Sonority. By interpolating Faithfulness constraints with the resulting hierarchies, I predict the coda conditions of a range of the world's languages.

Other analyses of the Coda Conditions in individual languages (e.g. Prince and Smolensky, 1993) have posited an ad hoc constraint, CODACOND that simply states the particular condition of that language. There is no need for a constraint called CODACOND. The phenomena that had in previous analyses been captured by that constraint can, I have shown here, be captured through the interaction of universal markedness constraints.

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