# Consonant transparency and vowel echo

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## 1. Introduction

Coronals and laryngeals may exhibit transparency to vowel spreading, which has previously been analyzed as due to Place underspecification. Gutturals (pharyngeals, laryngeals and uvulars) may also show such transparency. But how can both coronals and laryngeals be underspecified? We need to distinguish them, and in some languages, both show transparency. And how can gutturals be transparent as well?

In Optimality Theory, markedness phenomena have been reanalyzed as the direct result of markedness constraints. These constraints allow us to have a more fine-grained approach to markedness, not a simple on or off choice as was allowed by underspecification. We will argue that consonant transparency effects can be directly related to markedness. We will follow up on two important suggestions of McCarthy (1994a):

- All spreading is local. Apparent "skipping" of segments actually means that it is acceptable to link the spreading feature to that segment. (Also Gafos 1996, 1998, Padgett 1994, NiChiosain and Padgett 1996.)

- The constraints regulating such linking follow the markedness patterns of the independent segments. That is, if coronals are less marked than noncoronals, then it is also less marked for coronals to bear vowel features and thus participate in local spreading.

Using a method of combining markedness hierarchies and the extended Place markedness hierarchy of Lombardi (1997) we will achieve a unified explanation of both


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coronal and guttural transparency, as well as a difference in behavior between sonorants and obstruents.

## 2. Data

In a number of languages the laryngeal consonants /ʔ, h/ are transparent to vowel spread. For instance, in Kashaya, vowels must be identical in morpheme-internal /VʔV/ and /VhV/ sequences.

(1) Kashaya (Buckley 1994)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| siʔi | 'flesh' | nihin | 'to oneself' | ʔaha | 'mouth' | maʔa | 'food;eat' |
| heʔen | 'how' | behe | 'bay nut' | ʔoho | 'fire, light' | yuhu | 'pinole' |

Other examples include Mazahua Otomi (Steriade 1995, Spotts 1953), Tiv (Archangeli and Pulleyblank 1994), Finnish illative singular, Yurok separative singular (Collinder 1965), Arbore, Nez Perce, Mohawk, Tojolabal, etc. (see Steriade 1987).

McCarthy (1991, 1994b) shows that the sounds traditionally called gutturals in Semitic–the pharyngeals, uvulars, and laryngeals–are a natural class defined by the Place feature Pharyngeal. This class of sounds also may exhibit transparency effects. For example, in Tiberian Hebrew, gutturals are prohibited in codas, so a vowel is epenthesized. The vowel gets its features by spreading from the previous vowel, through the guttural consonant:

(2) Tiberian Hebrew

| | | | |
|---|---|---|---|
| ya.ħalom | 'he dreams' | ħe.he.ziiq | 'he strengthened' |
| ya.ʕa.mood | 'he will stand' | ye.ʔe.soop | 'he will gather' |
| he.ʕe.miid | 'he made stand' | cf. nonguttural initial root: yiktob 'he writes' | |

Other examples include Iraqw, Hebrew (Rose 1996), Ge'ez (Hoberman 1995), and Tiberian Hebrew (McCarthy 1991, Rose 1996).

Another transparency class is shown by Najdi Bedouin Arabic (Abboud 1979) , which shows transparency of gutturals and of coronal sonorants. According to McCarthy (1994a), in non-final open syllables, short /a/ raises to a default high vowel (transcribed /i/, it is [i, u, ɨ] depending on context; /j/ is palatal stop):

(3)

| | | | | | |
|---|---|---|---|---|---|
| /katab/ | kitab | 'he wrote' | /nataf+aw/ | ntifaw | 'they (m.) pulled feather' |
| /rafaagah/ | rifaagah | 'companions' | /jamal+uh/ | jmiluh | 'his camel' |

McCarthy shows that if we assume all spreading is local, we can account for where raising does not occur: it is when the Pharyngeal vowel [a] can share features with the guttural.

(4) No raising after a guttural

| | | |
|---|---|---|
| hajar *hijar | 'he abandoned' | X a s i r |
| Xasir | 'he lost' | \ \| |
| ʕarif | 'he knew' | Phar |
| ʁadar | 'he betrayed' | |
| ħasab | 'he counted' | |

(5) No raising before a guttural-/a/ sequence

| | | |
|---|---|---|
| daXal *diXal | 'he entered' | d a X a l |
| daʕas | 'he trampled' | \ \| / |
| saʔal | 'he asked' | Phar |
| šaħað | 'he begged' | |

Interestingly, there is no raising before coronal sonorant-/a/ sequences, so it must be possible to share the vowel across coronal sonorants too:

(6)

| | | |
|---|---|---|
| jalas *jilas | 'he sat' | j a l a s |
| jaraf | 'he washed away' | \ \| / |
| šanag | 'he beheaded' | Phar |
| bagarak | 'your (m.sg.) cattle' | |

## 3. Coronal transparency and implicational relations

Our survey of the data reveals previously unnoticed implicational relationships. First, if only one Place is transparent in a language, it is Pharyngeal (this includes /h, ʔ/, as will be discussed in section 4.2); and if Coronal is transparent, then Pharyngeal is also transparent.

The apparent counterexamples to the first generalization either lack Pharyngeal consonants or else lack them in the appropriate environment to show the transparency effect. These languages (with their transparent segments) include Mau (Paradis and Prunet 1989):/r, l/; French loans in Kinyarwanda ( Rose 1995): /r, l/; Fula (Paradis and Prunet 1989): /t, r, ɗ/; Guere (Paradis and Prunet 1989) /n, l, ɗ/. None of these languages actually show spreading to be blocked across gutturals: rather, they all simply lack gutturals (including laryngeals) in their inventories, so of course have no opportunity to show the effect with these consonants. (Similarly, as Paradis and Prunet point out, in Guere only a subset of the coronals can be intervocalic, and thus no special mechanism is involved in restricting spreading across the other coronals.)

Second, the data also shows that coronal sonorants and obstruents can be differentiated in spreading, and also show an implicational relationship: Coronal sonorants alone may be transparent (Bedouin, Kinyarwanda, Mau); but if coronal obstruents are transparent then coronal sonorants are transparent as well (Guere, Fula).

Thus the patterns to be accounted for are: Guttural transparency (Kashaya, Tiberian), guttural and coronal sonorant transparency (Bedouin) and gutturals and all coronals transparent (Fula).

## 4. Background of the analysis

### 4.1 Markedness and the locality of spreading

In McCarthy's analysis, raising is due to the fact that the pharyngeal vowel /a/ is more marked than the high vowel (additional constraints restrict the effect to nonfinal open syllables):

(7)

| /katab/ | *Phar | *Hi |
|---|---|---|
| ☞ kitab | * | * |
| katab | **! | |

But when the C is Pharyngeal and can share Place with the vowel, there are fewer markedness violations in the linked candidate:

(8)

| ʕarif | *Phar | *Hi |
|---|---|---|
| ☞ʕ a r i f<br>\| \|<br>Phar Hi | * | * |
| ʕ i r i f<br>\| \| \|<br>Phar Hi Hi | * | **! |

In a guttural-/a/ sequence there is also multiple linking, and so no raising:

(9)

| dahan | *Phar | *Hi |
|---|---|---|
| ☞ d a h a n<br>\ \|/<br>Phar | * | |
| d i h a n<br>/ \|<br>Hi Phar | * | *! |

The structure with spreading is the one with the fewest markedness violations. Both candidates have one violation of *Phar, but the one with raising has an additional violation of *Hi, which is fatal. Thus, the optimal candidate is the one with multiple linking across the pharyngeal consonant.

There is no raising before coronal sonorant-/a/ sequences, so it must be possible to share the vowel across coronal sonorants too:

(10) jalas *jilas 'he sat'

j a l a s
\ | /
Phar

But why is it possible to link Phar to an intervening coronal, but not to an intervening dorsal or labial? McCarthy suggests that this is due to the Place markedness hierarchy. If we assume the hierarchy *[-cor] >> *[cor], then adding a feature X to a sound, for example by spreading, results in the hierarchy *X,[-cor] >> *X,[cor]. (See section 6 for elaboration on this point). Thus, spreading across a noncoronal incurs a higher ranked violation than spreading across a coronal.[1] However, this leaves unresolved issues:

- Only coronal sonorants show transparency in this case.

- The explanation for guttural and coronal transparency is different: It is crucial that the spreading vowel is the Pharyngeal /a/ to allow guttural transparency. But in most of our examples, ALL vowels spread.

Our analysis will follow on McCarthy's basic suggestion, but will unify the explanation of transparency of different Places and will account for the implicational relationships we have discovered.

### 4.2 Place markedness: arguments from epenthesis

Using Lombardi's (1996, 1997) extension of the Place markedness hierarchy will allow us to unify the explanation of coronal and guttural transparency, and account for the implicational relationships noted in section 3 above. Smolensky (1993) shows how in OT we can analyze epenthesis of unmarked Coronals without underspecification. Given the existence of a Place markedness hierarchy as in (11), we see in (12) that the least marked consonant will be chosen even though it is specified for Place.

(11) *Lab, *Dor >> *Cor

(12)

| /gao/ | Onset, Max | *Lab | *Cor |
|---|---|---|---|
| ☞ a. ga.to | | | * |
| b. ga.bo | | !* | |
| c. ga | !* | | |
| d. ga.o | !* | | |

The /t/ is not Placeless, but rather the constraint recording its markedness violation

[1] A similar approach, assuming Placeless laryngeals, involving locality of spreading is taken by Padgett (1994) to account for why harmony is possible across laryngeals and not other Places.

is the lowest ranked. Thus /t/ is chosen as the optimal epenthetic consonant, and we can analyze the 'unmarked' behavior of the coronal without the use of underspecification.

In fact, the most common epenthetic consonant is the glottal stop, not /t/. But the reasoning is the same. If the hierarchy also recognizes the markedness status of the Place of glottal stop, it will be chosen over the coronal.

(13) McCarthy (1989): ʔ, h: Phar, [+glottal] ʕ, ʜ: Phar, [-glottal]

(14) Lombardi (1996, 1997): Revised markedness hierarchy
*Dor, *Lab >> *Cor >> *Phar [2]

(15) Glottal stop as the optimal epenthetic consonant

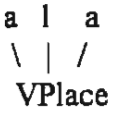
| /gao/ | Onset, Max | *Cor | *Phar |
|---|---|---|---|
| ☞ a. ga.ʔo | | | * |
| b. ga.to | | *! | |
| c. ga | *! | | |
| d. ga.o | *! | | |

This proposal allows a consistent cross-linguistic representation for laryngeals: we account for this "unmarked" behavior without Placelessness, so laryngeals have the same representation (Phar Place) here as they do in languages where they pattern with the gutturals.
Our other assumption about the features of glottal stop is that it is an obstruent, as argued in Lombardi's (1997) treatment of glottal stop epenthesis, and following Ladefoged (1971), Hyman (1975), Schane (1973), Lass (1976). See Bessell (1992) for a summary of claims about the major class features of [ʔ, h].

## 5. The analysis

### 5.1 Transparency of different Places

Recall again our assumption that spreading is local, so "transparency" means that a consonant is able to bear vowel features, as in (16):

(16)



Using Lombardi's (1997) Place markedness above, we create a hierarchy that evaluates the

[2] The true Pharyngeals are obviously marked (in the descriptive sense), but Lombardi (1996, 1997) argues that this must be due to some dimension of markedness other than their primary Place. Compare /θ/, which is marked despite its low-marked Coronal primary Place.

markedness of sharing vowel features with different Places. (See section 6 below for discussion of the formal mechanism of constraint conjunction.)

(17) *Dor&VPlace >> *Cor&VPlace >> *Phar&VPlace

*X&VPlace = "Do not share Vowel place with X"
Abbreviated in tableaux as "*X-VLink"

The ranking of whatever constraint drives spreading ('Harmony' below) will determine which consonants block spreading. First, (18) shows the ranking for a language where only Pharyngeals are transparent.

(18) Pharyngeal transparency (hypothetical examples)

| | *Dor-VLink | *Cor-VLink | Harmony | *Phar-VLink |
|---|---|---|---|---|
| ☞1a. i ʔ i \| / VPl | | | | * |
| 1b. iʔe | | | *! | |
| 2a. i t i \| / VPl | | *! | | |
| ☞ 2b. ite | | | * | |

In (1), with a Pharyngeal consonant, the violation of Harmony is higher ranked than the violation of the constraint dictating 'Do not share Vowel place with a Pharyngeal.' Thus candidate (1a), with spreading through the glottal stop, is optimal. In (2), with a Coronal, the violation of Harmony is lower ranked than the violation of 'Do not share Place with a Coronal', so the coronal blocks spreading and (2b) is optimal.

It is important to note that the only difference between languages like Kashaya and Tiberian is that their guttural systems differ. Harmony only across laryngeals is found in Kashaya because they are the only gutturals in the language. We know of no languages that have the whole set of gutturals but only spread across /hʔ/.

Tableau (19) below illustrates the ranking for a language where both coronals and pharyngeals are transparent.

(19) Coronal and Pharyngeal transparency (hypothetical examples)

| | *Dor-VLink | Harmony | *Cor-VLink | *Phar-VLink |
|---|---|---|---|---|
| ☞ 1a. i ʔ i<br>\|/<br>VPl | | | | * |
| 1b. iʔe | | *! | | |
| ☞ 2a. i t i<br>\|/<br>VPl | | | * | |
| 2b. ite | | *! | | |
| 3a. i k i<br>\|/<br>VPl | *! | | | |
| ☞ 3b. ike | | * | | |

Here Harmony is ranked above the constraints that penalize sharing vowel features with both Coronals and Pharyngeals. Hence, those consonants are transparent (1a, 2a). But Dorsals block spreading because of the high ranking of *Dor-VLink (3b).

## 5.2 Transparency of sonorants

We now turn to languages that differentiate sonorants and obstruents in spreading. We propose the following hierarchy that regulates sharing of vowel features with sonorants and obstruents, which presumably relates to the fact that it is preferable for similar sounds to interact (Itô, Mester and Padgett 1995):

(20) *VobsV >> *VsonV
\ | / \ | /
VPlace VPlace
Abbreviated: *VobsV, *VsonV

We combine this with (17) to yield the hierarchy (in part) in (21a), penalizing the structures in (21b):

(21)

a. *Cor & VPlace & VobsV >> *Cor & VPlace & VsonV >>
*Phar & VPlace & VobsV >> Phar & VPlace & VsonV

b.

*V $o^{Lab/Dor}$ V >> *V $s^{Lab/Dor}$ V >> *V $o^{Cor}$ V >> *V $s^{Cor}$V >> *V $o^{Phar}$ V >> *V $s^{Phar}$ V
\ | / \ | / \ | / \ | / \ | / \ | /
VPlace VPlace VPlace VPlace VPlace VPlace

*Cor&VPlace&VobsV = 'Do not share Vowel place with a coronal obstruent', etc. Abbreviated in tableaux: *CorObs-VLink, *CorSon-VLink, etc.

As the following tableaux show, the appropriate ranking of harmony will now yield differences in transparency in sonorants and obstruents following the pattern we have seen in the data.

(22) Coronal sonorant and Pharyngeal transparency (Bedouin Arabic)

| | *CorObs-VLink | Harmony | *CorSon-VLink | *PharSon-VLink | *PharObs-VLink |
|---|---|---|---|---|---|
| 1. katab<br>\|/<br>VPlace | *! | | | | |
| ☞ kitab | | * | | | |
| ☞2.daXal<br>\ \| /<br>VPlace | | | | * | |
| dixal | | *! | | | |
| ☞3. jalas<br>\|/<br>VPlace | | | * | | |
| jilas | | *! | | | |

In this ranking, it is worse to spread across a coronal obstruent than to violate Harmony, so in (1) the candidate without vowel assimilation is optimal. But the violation of Harmony is worse than spreading across either a coronal sonorant or any Pharyngeal; thus the winning candidates in (2) and (3) are those with assimilation across the consonant.

In the following tableau, we see that reranking allows us to still account for languages where only gutturals, not coronals, are transparent. With Harmony ranked lower than *CorSon-VLink, but above the *Phar-VLink constraints, spreading is optimal in (1) across a glottal stop, but is prevented across a coronal in (2).

(23) Pharyngeal transparency (Kashaya)

| | *CorObs-VLink | *CorSon-VLink | Harmony | *PharSon-VLink | *PharObs-VLink |
|---|---|---|---|---|---|
| ☞1. i?i<br>\|/<br>Vplace | | | | | * |
| i?e | | | *! | | |
| 2. ili<br>\|/<br>VPlace | | *! | | | |
| ☞ ile | | | * | | |

## 6. Generalizing Local Conjunction

Consider the two markedness hierarchies that seem to play a role in defining the classes of transparent consonants.

(24) Place Markedness: *Dor/Lab >> *Cor >> *Phar (A >> B >> C)

Sonorancy: *VoV >> *VsV (D >> E)
\|/ \|/
VPlace VPlace

In what follows, we abbreviate these hierarchies as A >> B >> C and D >> E respectively. Some of classes of transparent consonants we have seen can be expressed by interspersing the HARMONY imperative within these two basic hierarchies. For instance, for a language where all pharyngeals are transparent HARMONY >> C and HARMONY >> D. Similarly, for a language where all coronals and pharyngeals are transparent HARMONY >> B, and when all sonorants are transparent (Barra Gaelic), HARMONY >> D. Crucially, however, no ranking between HARMONY and the constraints of the two basic hierarchies can derive the class of transparent segments in Bedouin Arabic, namely, the class of coronal sonorants and all pharyngeals. For example, if we rank HARMONY as in A >> HARMONY >> B >> C and D >> HARMONY >> E, the resulting transparent class consists of the sonorant coronals and the sonorant pharyngeals (hence, excluding /h ʔ/). Or, if we rank A >> HARMONY >> B >> C and HARMONY >> D >> E, the transparent consonants would be all the coronals and all the pharyngeals.

What is needed then is a new markedness hierarchy penalizing spreading through consonants which combine properties from the place markedness and the sonorancy hierarchies. In particular, a subhierarchy is needed where spreading of VPlace through a coronal obstruent incurs a worse violation than spreading of VPlace through a coronal sonorant. In other words, B&D, the local conjunction of B and D, should be ranked higher than HARMONY, which in turn should be ranked higher than B&E (and also C&D, C&E). However, using local

conjunction of two constraints, as defined in (25) below (Smolensky 1993), cannot arrive at the rankings we require.

(25) The Local Conjunction of $C_1$ and $C_2$ in domain D, $C_1 \&_l C_2$, is violated when there is some domain of type D in which both $C_1$ and $C_2$ are violated. Universally, $C_1 \&_l C_2 >> C_1, C_2$.

In (26) we have taken local conjunctions for every constraint in the first hierarchy A >> B >> C, corresponding to the Place Markedness hierarchy, with every constraint in the second hierarchy D >> E, corresponding to the Sonorancy hierarchy. The point is that rankings like A&D >> A&E, B&D >> B&E and C&D >> C&E do not follow from the logic of local conjunction.

(26) Basic Hierarchies: A >> B >> C
D >> E
Subhierarchies from local conjunction of the basic hierarchies:
A&D >> A, D and A&E >> A, E and A&D >> A&E ?
B&D >> B, D and B&E >> B, E and B&D >> B&E ?
C&D >> C, D and C&E >> C, E and C&D >> C&E ?

It seems useful to define this intuitive and useful new operation that would provide us with these rankings needed to account for our data. This operation should generate a new hierarchy from two basic hierarchies, where the constraints of the new hierarchy are local conjunctions of constraints from the two basic hierarchies. We call it 'generalized local conjunction' because it involves constraint conjunction but the arguments being conjoined can be constraint hierarchies. Notationally, we employ the $\propto$ operator.

(27) Generalized Local Conjunction of two hierarchies $\mathbb{C}$ and $\mathbb{D}$ (GLC): Given two constraint hierarchies $\mathbb{C} = C_1 >> \ldots >> C_n$ and $\mathbb{D} = D_1 >> \ldots >> D_m$, their generalized local conjunction, $\mathbb{C} \propto \mathbb{D}$, is the hierarchy defined by the rankings:

$\forall$ i, j, k, l: if $C_i >> C_j$ $\Rightarrow$ $C_i \& D_k >> C_j \& D_l$,
else if i = j and $D_k >> D_l$ $\Rightarrow$ $C_i \& D_k >> C_i \& D_l$

Consider, for example, the generalized local conjunction of $C_1 >> C_2$ with a constraint D. The $\mathbb{D}$ hierarchy in this case consists of just one constraint. The resulting hierarchy is $C_1 \& D >> C_2 \& D$. This instance of generalized local conjunction is used to derive the hierarchy in (17) above, repeated below.

(28) [*Dor >> *Cor] $\propto$ VPlace = *Dor & VPlace >> *Cor & VPlace

Assuming two basic hierarchies of two constraints each, $C_1 >> C_2$ and $D_1 >> D_2$, then $[C_1 >> C_2] \propto [D_1 >> D_2]$ is $C_1 \& D_1 >> C_1 \& D_2 >> C_2 \& D_1 >> C_2 \& D_2$. It is clear that the $\propto$ operation results in a total ranking of all constraints created from local conjunctions of the constraints of the two basic hierarchies. Generalized local conjunction offers us the formal tools to derive the desired class of transparent segments in Bedouin Arabic, the class of

sonorant coronals and all pharyngeals. As shown below, the generalized local conjunction of the Place Markedness and the Sonorancy hierarchy, yields the hierarchy used in (21) above.

(29) [*Dor/*Lab >> *Cor >> *Phar] ∝ [*VoV >> *VsV] =
\|/ \|/
VPlace VPlace

*V $o^{Dor/Lab}$ V >> *V $s^{Dor/Lab}$ V >> *V $o^{Cor}$ V >> *V $s^{Cor}$ V >> *V $o^{Phar}$ V >> *V $s^{Phar}$ V
\ | / \ | / \ | / \ | / \ | / \ | /
VPlace VPlace VPlace VPlace VPlace VPlace

Note that the '∝' operation is not commutative. From the definition above the inequality [$C_1$ >> $C_2$] ∝ [$D_1$ >> $D_2$] ≠ [$D_1$ >> $D_2$] ∝ [$C_1$ >> $C_2$] holds. By expanding each of the generalized conjunctions, we see that $C_1$&$D_1$ >> $C_1$&$D_2$ >> $C_2$&$D_1$ >> $C_2$&$D_2$ ≠ $C_1$&$D_1$ >> $C_2$&$D_1$ >> $C_1$&$D_2$ >> $C_2$&$D_2$. Thus when writing [$C_1$ >> $C_2$] ∝ [$D_1$ >> $D_2$] we say that the hierarchies are combined by giving priority to [$C_1$ >> $C_2$]. (See McCarthy 1994a where the intuition we formalize here originates).

There are other proposals in the literature that define similar but also crucially different operations. Specifically, Spaelti (1997: p. 143) and Aissen (1998, p. 22) extend local conjunction as shown in (30) below (see also Artstein 1998 who follows Aissen).

(30) The local conjunction of $C_1$ with subhierarchy [$C_2$ >> $C_3$ >>... >> $C_n$] yields the subhierarchy [$C_1$ & $C_2$ >> $C_1$ & $C_3$ >>... >> $C_1$ &$C_n$] (Aissen 1998: p. 22)

When two subhierarchies are involved the definition in (30) is put to use by taking local conjunctions of each of the constraints of the first hierarchy with each of the constraints of the second hierarchy and vice versa. For instance, when $C_1$ >> $C_2$ and $D_1$ >> $D_2$ are two subhierarchies, then we may arrive at the partial order $C_1$ & $D_1$ >> {$C_1$ & $D_2$, $C_2$ & $D_1$} >> $C_2$ & $D_2$. This ranking corresponds to two total orderings, one for each ranking of $C_1$ & $D_2$, $C_2$ & $D_1$. Closer to our interests, when $\mathbb{C}$ consists of three constraints, and $\mathbb{D}$ of two, then applying local conjunctions in the way defined above yields the following.

(31) $C_1$ >> $C_2$ >> $C_3$
$D_1$ >> $D_2$

| | | |
|---|---|---|
| $D_1$, $C_1$ >> $C_2$ >> $C_3$ | → | $C_1$ & $D_1$ >> $C_2$ & $D_1$ >> $C_3$ & $D_1$ |
| $D_2$, $C_1$ >> $C_2$ >> $C_3$ | → | $C_1$ & $D_2$ >> $C_2$ & $D_2$ >> $C_3$ & $D_2$ |
| $C_1$, $D_1$ >> $D_2$ | → | $C_1$ & $D_1$ >> $C_1$ & $D_2$ |
| $C_2$, $D_1$ >> $D_2$ | → | $C_2$ & $D_1$ >> $C_2$ & $D_2$ |
| $C_3$, $D_1$ >> $D_2$ | → | $C_3$ & $D_1$ >> $C_3$ & $D_2$ |

Note that the constraint $C_1$ & $D_2$ remains unranked with respect to $C_2$ & $D_1$ or $C_3$ & $D_1$. The partial rankings above are consistent with $C_3$ & $D_1$ >> $C_1$ & $D_2$ (in fact, there are five possible total orderings of the constraints one of which includes this particular ranking relationship). This ranking would correspond the implicational statement "If pharyngeal obstruents are transparent then labial and dorsal sonorants are transparent." This pattern of transparency is

not attested. We chose to define the operation of GLC in a way that results in a total ordering of the constraints and captures the generalizations emerging from our data.

To conclude, we have provided the formal means that allow us to arrive at a markedness hierarchy by conjoining constraints from the two dimensions of markedness playing a role in consonant transparency. We have also shown that alternative ways of conjoining hierarchies of constraints do not achieve the results of our more constrained operation of generalized local conjunction.

## 7. Directions for future research

We have shown that the resources of OT can be used to construct an account of consonant transparency as a direct result of independently supportable markedness relationships. Our proposal has many implications that cannot be addressed here for reasons of space. A number of the straightforward predictions of our proposal appear to be borne out by the data. For example, some languages show vowel echo over all consonants, usually in epenthesis or a limited morphological context, where the vowel appears to lack underlying features of its own (see Halle and Vaux 1994 for a number of examples). These languages show the HARMONY imperative ranked above the entire anti-linking hierarchy. Another pattern, showing the sonorancy scale in its unconjoined form, appears in Barra Gaelic (Clements 1986, Bosch 1998), where all sonorants are transparent to spreading to an epenthetic vowel; this is accounted for by the ranking *VoV >> HARMONY >> *VsV. Other cases show the possibility of other markedness scale interactions. McCarthy (1998) analyzes a Selayarese MSC as the result of the fact that only /r, l, s/ are transparent to spreading; here we see the Place markedness scale combined with [stop]/[cont] markedness: *VPlace & [stop] >> *VPlace & [cont], which will allow spreading over coronal fricatives but not coronal stops.

One remaining open question is the treatment of uvulars. Uvular stops are apparently never transparent, even when other Pharyngeals are: Kashaya, Jibbāli, (McCarthy 1991), Tigre (McCarthy 1993). McCarthy (1994b) notes that uvular fricatives pattern with both the Pharyngeals and the Dorsals in Arabic MSCs, but that uvular stops class only with the Dorsals. He proposes that uvulars have complex Dorso-Pharyngeal Place; to account for the difference, he suggests that the Pharyngeal MSC applies to approximants only. The latter suggestion cannot lead to the answer here, however. If the uvular stop blocked spreading because it is an obstruent, so would /ʔ, h/ under our assumptions. We believe that the solution will be based on a suggestion of Goldstein (1994): the Place features of uvulars are not exactly the same, in that the articulation of the uvular stop involves an oral component that the uvular fricatives, as well as the other Pharyngeals, lack.

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