

Hierarchical Opacity Effects in Nasal Harmony: an optimality theoretic account

Rachel Walker
University of California, Santa Cruz

1. Introduction

It has been well-documented that nasal harmony systems exhibit limited variation (see, for example, van der Hulst & Smith 1982, Cohn 1987, 1990, Lieber 1987, Piggott 1992). This paper examines variation in the type of system which I will refer to as Hierarchical Opacity Nasal Harmony (HONH). In HONH all supralaryngeal segments are either triggers, targets, or opaque--none are transparent. As Piggott (1992) points out, this type of harmony is also characterized by systematic cross-linguistic variation in the sets of target and opaque segments, as illustrated in (1).

(1) TARGETS	OPAQUE SEGMENTS				EXAMPLE
i. Vowels	Glides	Liquids	Fricatives	Obstruent stops	<i>Sundanese</i>
ii. Vowels	Glides	Liquids	Fricatives	Obstruent stops	<i>Capanhua</i>
iii. Vowels	Glides	Liquids	Fricatives	Obstruent stops	<i>Urhobo</i>
iv. Vowels	Glides	Liquids	Fricatives	Obstruent stops	<i>Applecross Gaelic</i>

The pattern of variation that emerges in (1) is one in which the segments of the inventory are ranked in an invariable hierarchy with vowels as targets at one end and obstruent stops as opaque at the other.

The goal of this paper is to account for the systematic variation in HONH with a hierarchy of nasalized segments derived from the sonority hierarchy, and further to demonstrate that Optimality Theory (OT) (Prince & Smolensky 1993 (P&S 1993), McCarthy & Prince 1993a, b (M&P 1993a, b)) provides a framework in which the typological effects of this hierarchy can be directly obtained.

The paper is organized as follows. First, section 2 presents data exemplifying the hierarchical variation in (1). Section 3 then establishes a harmony scale of nasalized segments from which an intrinsically ranked nasalized segment constraint hierarchy is derived, and section 4 utilizes this hierarchy to develop an optimality theoretic analysis of the cross-linguistic variation. Section 5 turns to the implications for an alternative derivational approach and presents the conclusions.

2. Exemplification of hierarchical opacity in nasal harmony

I begin with an illustration of each of the HONH variations in (1). The first case, in which only vowels are targets, is exemplified in (2). The data here is from Sundanese, an Indonesian language spoken in Western Java (Robins 1957, Cohn 1990, Piggott 1992). Harmony from the nasal stop trigger is rightward in Sundanese¹. Nasalization is marked on segments with a tilde and nasal spans are also underlined in this section².

(2) Case (1i)	Vowels	Glides	Liquids	Fricatives	Obstruent stops	Direction →
a.	<u>nāĩān</u>	'wet'	f.	<u>māro</u>	'halve'	
b.	<u>kumāĩhā</u>	'how'	g.	<u>bnĩhār</u>	'be rich'	
c.	<u>nāĩjak</u>	'sift'	h.	<u>mĩ?āsĩh</u>	'love'	
d.	<u>māĩwur</u>	'spread'	i.	<u>nāĩtur</u>	'arrange'	
e.	<u>mōĩlohok</u>	'stare'	j.	<u>nūĩdag</u>	'pursue'	

Each of the data sets in this section is organized so that it begins with forms demonstrating vowels as targets and then progresses through the patterning of other segments in the hierarchy, ending with forms showing obstruent stops as opaque.

The second variation is illustrated by Capanahua, a Panoan language of South America (Loos 1967). In Capanahua, vowels and glides are targets, while liquids, fricatives and obstruent stops are opaque. As in Sundanese, nasal stops are the triggers, but harmony is leftward here³. In (3) [c] represents a coronal affricate.

(3) Case (1ii)		Vowels	Glides	Liquids	Fricatives	Obstruent stops	Direction ←
a.	<u>ʔ</u> ōnānmawu						'teach'
b.	pōjān						'arm'
c.	bāwīn						'catfish'
d.	warān						'squash'
e.	wurānjasāʔnu						'push it sometime'
f.	cipōnki						'downriver'
g.	bōōn						'hair'
h.	ciʔin						'by fire'

Warao and Malay also exhibit this particular pattern of opacity (Osborn 1966, Hendon 1966, Onn 1980).

In (4) data from the Nigerian language, Urhobo, demonstrates the third variation, where liquids are added to the set of targets (Kelly 1969, Sagey 1986). As in Capanahua, harmony is leftward here from nasal stops. In (4) [R] represents a fricative r-type segment (see Piggott 1992), [r] represents a liquid, and [B] a bilabial approximant. Note that although the sources do not provide a form with an obstruent stop, Kelly's description of the harmony indicates that these segments pattern as opaque.

(4) Case (1iii)		Vowels	Glides	Liquids	Fricatives	Obstruent stops	Direction ←
a.	ēwēn						'breath'
b.	ūjōBīn						'head'
c.	iRīrīn						'nine'
d.	oRwēn						'hunter'
e.	evūn						'belly'

Other languages reported to exhibit the Urhobo-type nasal harmony pattern include Ijo, Isoko, and Itsekeri (Williamson 1965, 1969, Mafeni 1969, Opubor 1969).

Applecross Gaelic illustrates the final variation, where only obstruent stops are opaque (Ternes 1973, van der Hulst & Smith 1982). Here a stressed nasal vowel is the trigger (bolded below), and harmony propagates in both directions.

(5) Case (1iv)		Vowels	Glides	Liquids	Fricatives	Obstruent stops	Direction ↔
a.	tʰ <u>u</u> īfār						'grandmother'
b.	fīā:v						'root'
c.	str <u>ā</u> ī:v						'string'
d.	kʰ <u>ā</u> īspaxk						'wasp'

Zande is also reported to have a similar case of nasalization in which fricatives are included in the set of targets (Tucker & Hackett 1959).

3. A hierarchy of nasalized segments

The hierarchical effects exemplified in section 2 must have a phonological source. I suggest that languages with HONH vary in terms of where they make the cut between segments that are sufficiently compatible with superimposed nasalization to be targets and those that are not. Generally the more sonorant a segment is, the more compatible it is with nasality as a noncontrastive secondary articulation (for discussion of scalar sonority see Zec 1988, Clements 1990 and references cited therein). Drawing on the notion of a harmony scale, as developed in P&S 1993, I propose that the implicational ranking of target and opaque segments thus results from the universal harmony scale of nasalized segments in (6), which derives from a phonetically grounded sonority hierarchy (but see also Hume & Odden 1994 for a somewhat different yet related generalization concerning

opacity based on an impedance hierarchy). In the following harmony scale ">" means 'is more harmonic than'.

(6) *Nasalized (N) Segment Harmony:*

N vowel > N glide > N liquid > N fricative > N obstruent stop

The scale in (6) reflects that fact that a vowel is the most harmonic with superimposed nasalization or most compatible and relative harmony of nasalized segments decreases gradiently through the hierarchy, ending with a nasalized obstruent stop. Nasal is combined with segments here without changing their distinctive specifications. For example, a nasalized obstruent stop will remain nonsonorant and noncontinuant in spite of the added nasality. This particular type of segment is not favoured phonetically, due to the conflict between nasality and nonsonorancy, and probably never occurs in natural language⁴.

From the harmony scale in (6), the nasalized segment constraint hierarchy in (7) may be derived, such that the less harmonic the element, the higher ranked the constraint against it (following P&S 1993). In the constraint hierarchies ">" means 'is ranked higher than'.

(7) *Nasalized (N) Segment Constraint Hierarchy:*

*N OBSTRUENT STOP » *N FRICATIVE » *N LIQUID » *N GLIDE » *N VOWEL

The feature cooccurrence constraints in this hierarchy may be restated in terms of distinctive features, but I will refer to the categories in (7) for ease of exposition.

The hierarchy in (7) governing possible targets and opaque segments is formalized as intrinsically ranked constraints, where the constraints may be violated in some languages. OT, which is based on the notion of ranked and violable constraints (see P&S 1993, M&P 1993a, b), thus provides an ideal framework in which to implement the effects this hierarchy.

4. Analysis of cross-linguistic variation

4.1 Ranking of the harmony constraints

I turn now to the details of an optimality theoretic analysis of variation in HONH. First of all, I analyze harmony as the effect of alignment constraints such as those in (8) (after Kirchner 1993, Pulleyblank 1993, Smolensky 1993, Cole & Kisseberth 1994 and others). Nasal is analyzed here as privative (see, for example, Trigo 1993, Steriade 1993a, b, 1994), although this is not crucial to the analysis.

- (8) a. ALIGN^{NASL}: Align (Nasal, L, PrWd, L)
 b. ALIGN^{NASR}: Align (Nasal, R, PrWd, R)

The constraint in (8a) is interpreted as requiring that the left edge of all nasal features be aligned to the left edge of some prosodic word, where violations are measured gradiently (M&P 1993b), and (8b) effects a parallel requirement for right edges. The direction of alignment will be specified on a language particular basis, yielding the cross-linguistic variation in directionality of harmony.

In OT the variations in the set of opaque segments will result from different rankings of the harmony alignment constraint(s) with respect to the nasalization constraint hierarchy in (7), but before examining these rankings, a constraint which contributes to opacity must be considered.

Following numerous previous analyses of harmony, I assume that target segments are underspecified for the harmony feature in the input, so harmony is feature-filling. Since nontarget supralaryngeal segments act as opaque even though they are unspecified for Nasal, it is evident that the nasal harmony targets must be strictly adjacent. This locality may be attributed to a constraint against the gapped

configuration, as in (9)⁵, where α , β , and γ are any supralaryngeal segment (for discussion of the gapping constraint see Kirchner 1993, Pulleyblank 1993, Itô, Mester, & Padgett 1994, Archangeli & Pulleyblank in press, and citations therein).

$$(9) \quad \text{NOGAP:} \quad \begin{array}{c} * \alpha \beta \gamma \\ \quad \backslash / \\ \quad \quad F \end{array}$$

The NOGAP constraint is never violated in the output of the nasal harmony examined here, so it will have undominated ranking.

The hierarchical variation effect of the harmony alignment ranking for HONH now may be made explicit. As a result of the undominated NOGAP constraint, Nasal can never skip associating to a segment in the attempt to achieve Nasal alignment. Since skipping segments is not an option in the optimal output, any nasalization constraints which dominate alignment will correspond to opaque segments, as it would be worse to form these nasalized segments than violate alignment. In contrast, for nasalization constraints which are dominated by alignment, it is better to violate these constraints by forming the nasalized segments, than it is to violate alignment instead. Accordingly, dominated nasalization constraints correspond to targets (see Smolensky 1993 for similar observations concerning this type of ranking effect).

The harmony constraint ranking pattern for the four sets of target and opaque segments from (1) is illustrated in (10). This illustration shows that the hierarchical variation in HONH simply results from different ranking of $\text{ALIGN}^{\text{NAS}}$ with respect to the invariably ranked nasalization constraints and NOGAP.

- (10) **Case (1i)**

Vowels	Glides	Liquids	Fricatives	Obstruent stops
--------	--------	---------	------------	-----------------

NOGAP, *N OBS STOP » *N FRIC » *N LIQ » *N GLIDE » $\text{ALIGN}^{\text{NAS}}$ » *N VOWEL
- Case (1ii)**

Vowels	Glides	Liquids	Fricatives	Obstruent stops
--------	--------	---------	------------	-----------------

NOGAP, *N OBS STOP » *N FRIC » *N LIQ » $\text{ALIGN}^{\text{NAS}}$ » *N GLIDE » *N VOWEL
- Case (1iii)**

Vowels	Glides	Liquids	Fricatives	Obstruent stops
--------	--------	---------	------------	-----------------

NOGAP, *N OBS STOP » *N FRIC » $\text{ALIGN}^{\text{NAS}}$ » *N LIQ » *N GLIDE » *N VOWEL
- Case (1iv)**

Vowels	Glides	Liquids	Fricatives	Obstruent stops
--------	--------	---------	------------	-----------------

NOGAP, *N OBS STOP » $\text{ALIGN}^{\text{NAS}}$ » *N FRIC » *N LIQ » *N GLIDE » *N VOWEL

For case (1i), where only vowels are targets, $\text{ALIGN}^{\text{NAS}}$ dominates just the constraint against nasalized vowels, as this is the only constraint alignment forces violations of. The other nasalization constraints are ranked above $\text{ALIGN}^{\text{NAS}}$ along with NOGAP, as they remain unviolated. Case (1ii) maintains the same ranking of the nasalization constraints and NOGAP with respect to each other but moves $\text{ALIGN}^{\text{NAS}}$ over the nasalized glide constraint as well as the nasalized vowel one. For case (1iii) $\text{ALIGN}^{\text{NAS}}$ moves up one more to dominate the constraint against nasalized liquids, and finally in case (1iv), $\text{ALIGN}^{\text{NAS}}$ moves up one more again so that only obstruent stops are opaque.

4.2 Ranking of the faithfulness constraints

In addition to the harmony constraint ranking, the ranking of the faithfulness constraints must be considered. Since nasal harmony is feature-filling, in many cases satisfying alignment will involve incurring violations of the faithfulness constraint against spreading, *SPREAD, which penalizes each non-underlying affiliation of a feature to a segment (see Itô, Mester, & Padgett 1993 and

Kirchner 1993). ALIGN^{NAS} forces violations of *SPREAD and thus must be ranked above it. This crucial ranking is illustrated in (11) with the Urhobo form /ewen/.

Standard conventions for tableaux are followed here. Constraints are arranged in columns such that left to right orientation indicates descending ranking. A solid line separating columns signifies ranking, while a dotted line indicates no crucial ranking between the constraints in those columns. Constraint violations are signalled with the violating segments or an asterisk, and a fatal violation is identified with an exclamation mark. The hand icon marks the optimal output, and portions which are not relevant to the evaluation of a particular form are shaded.

(11) ALIGN^{NAS} » *SPREAD

e w e n [N]	ALIGN ^{NL}	*SPREAD
a. ✖ ē w ē n \\ // [N]		+++
b. e w ē n \\ // [N]	e!	++
c. e w ē n ∨ [N]	e!w	*
d. e w e n [N]	e!we	

Since candidates which do not violate *SPREAD are in fact of little interest to this discussion, this constraint will henceforth not be included in tableaux.

Next I consider PARSE^{NAS}. A form in which Nasal is not parsed must lose to one which violates either alignment or the nasalization constraints corresponding to targets. Accordingly, PARSE^{NAS} must outrank these constraints. As PARSE^{NAS} is actually never violated in the optimal output, it is grouped with the undominated constraints. The ranking is illustrated in (12) with the Sundanese form /maro/. Notice that the first two constraint columns are not crucially ranked here. Following Pulleyblank (1993), the unparsed Nasal feature in (12b) is interpreted as satisfying alignment on its tier, but this is not crucial to the analysis.

(12) Undominated ranking of PARSE^{NAS}

m a r o [N]	NOGAP PARSE ^N	*N OBS STOP *N FRICATIVE *N LIQUID *N GLIDE	ALIGN ^{NR}	*N VOWEL
a. ✖ m ā r o ∨ [N]			TO	*
b. m a r o <N>	*! PARSE ^N			

Finally, I turn to FILL^{NAS} violations. Notice that if another Nasal feature is inserted to avoid the gapping configuration, as signified by the N in (13b), this

inserted feature will not serve to satisfy alignment, since the underlying Nasal feature will still incur alignment violations. Accordingly, a candidate of this type which violates $FILL^{NAS}$ will be ruled out independent of the ranking of this constraint, as there will always be another form which has at least as good alignment but less nasalized segment constraint violations. The relevant candidates to consider are given in (13). Here the (b) form loses to the one in (a) because the (b) form has a nasalized [o] which (a) does not, and the two forms otherwise incur the same violations. Candidate (b) will also violate $FILL^{NAS}$ and perhaps an OCP constraint, but the ranking of these constraints is not crucial here.

(13) Nonoptimality of forms violating $FILL^{NAS}$

m a r o [N]	NOGAP	*N OBS STOP *N FRICATIVE *N LIQUID *N GLIDE	ALIGN ^N _R	*N VOWEL
a. m̄ a r o [N]			ro	*
b. m̄ a r ō [N] N			rō	**!

4.3 Exemplification of constraint ranking pattern for HONH

The overall ranking pattern for HONH that has been established is summarized in (14). Crucially, the ranking of nasalization constraints with respect to each other remains constant according to the intrinsically ranked hierarchy in (7).

(14)

NOGAP
 $PARSE^N$, N segment constraints » ALIGN^N » N segment constraints, *SPREAD

┌──────────────────┐
┌───┐
┌──────────────────┐
 Opaque segments Harmony Target segments

The constraint ranking pattern for HONH may now be exemplified for each of the opaque set variations introduced in (1). I consider first case (1i) illustrated in (15) for Sundanese. In this variation, vowels are the only targets, so the constraint against nasalized vowels is the only one ranked below alignment. In Sundanese, harmony is rightward, so Nasal alignment is specified as to the right. All other nasalization constraints as well as NOGAP and $PARSE^{NAS}$ are undominated.

In the optimal form in (15a), harmony extends only as far as the adjacent vowel, since extending any farther would violate one of the undominated constraints. In the optimal output, nasal alignment will thus be violated by [jak]. In (15b), Nasal links to every segment, but this candidate loses, since it violates the higher ranked constraints against nasalized glides and obstruent stops. Candidate (c) fails because it violates the undominated NOGAP constraint, and the form in (d) loses because of a PARSE violation. Candidate (e) is ruled out since it has one more alignment violation than the optimal form in (a). Notice that in addition to the extra alignment violation, the (e) form also has one more violation of the constraint against nasalized vowels. Thus, even in a form where the corresponding (a) and (e) candidates tie on alignment violations, candidate (e) would still lose on the next ranked constraint. This type of case is illustrated by the (a) and (e) candidates in the tableaux in (16-18).

(15) Case (1i) illustrated by Sundanese

$\eta a j a k$ [N]	NOGAP PARSE ^N	*N OBS STOP *N FRICATIVE *N LIQUID *N GLIDE	ALIGN ^{NR}	*N VOWEL
a. $\eta \tilde{a} j a k$ V [N]			jak	*
b. $\eta \tilde{a} j \tilde{a} k$ \\ // [N]		ʝ!k		***
c. $\eta \tilde{a} j \tilde{a} k$ \\ // [N]	*! NOGAP		k	**+
d. $\eta a j a k$ <N>	*! PARSE ^N			
e. $\eta \tilde{a} j \tilde{a} k$ V [N] N			jak k!	**+

The tableaux in (16-18) illustrate the same basic constraint ranking for the other three variations presented in (1). Each of these tableaux is structured like the one for Sundanese in (15), such that the (a) candidate is optimal, (b) violates an undominated nasalization constraint, (c) violates NOGAP, (d) violates PARSE^{NAS}, and (e) incurs extra violations of a dominated nasalization constraint, due to an inserted Nasal feature. The crucial difference in each of these tableaux is that following the pattern in (10), the alignment constraint moves up one in each successive variation to dominate the next nasalized segment constraint in the hierarchy. Thus, for Capanahua (case (1ii)) in (16), where glides are also targets, the constraint against nasalized glides is ranked with the one against nasalized vowels below alignment.

(16) Case (1ii) illustrated by Capanahua

$w a r a n$ [N]	NOGAP PARSE ^N	*N OBS STOP *N FRICATIVE *N LIQUID	ALIGN ^{NL}	*N GLIDE *N VOWEL
a. $w \tilde{a} r \tilde{a} n$ V/ [N]			war	*
b. $w \tilde{a} r \tilde{a} n$ \\ // [N]		r!		***
c. $w \tilde{a} r \tilde{a} n$ \\ // [N]	*! NOGAP			***
d. $w a r a n$ <N>	*! PARSE ^N			
e. $w \tilde{a} r \tilde{a} n$ V/ / N [N]			war	**!*

For Urhobo (case (liii)) in (17), the constraint against nasalized liquids is also ranked below alignment, capturing the fact that liquids are targets.

(17) Case (liii) illustrated by Urhobo

i R i r i n [N]	NOGAP PARSE ^N	*N OBS STOP *N FRICATIVE	ALIGN ^N _L	*N LIQUID *N GLIDE *N VOWEL
a. ^{US} i R i r i n \\// [N]			iR	***
b. i R i r i n \\//// [N]		R!		*****
c. i R i r i n \ /// [N]	*! NOGAP			*****
d. i R i r i n <N>	*! PARSE ^N			
e. i R i r i n \\// N [N]			iR	*****!

Finally, for Applecross Gaelic (case (liv)) in (18), the nasalized fricative constraint joins the ones below alignment, so only obstruent stops are opaque.

(18) Case (liv) illustrated by Applecross Gaelic

s t r a i y [N]	NOGAP PARSE ^N	*N OBS STOP	Align ^N _L Align ^N _R	*N FRICATIVE *N LIQUID *N GLIDE *N VOWEL
a. ^{US} s t r a i y \\// [N]			st	****
b. s t r a i y \\//// [N]		t!		*****
c. s t r a i y \ /// [N]	*! NOGAP			*****
d. s t r a i y <N>	*! PARSE ^N			
e. s t r a i y \\// N [N]			st	*****!

The point demonstrated by the tableaux in (15-18) is that the simple reranking of the alignment constraint with respect to the nasalized segment hierarchy is sufficient to capture the cross-linguistic variation in target and opaque segments. Importantly, OT predicts that this type of cross-linguistic reranking should occur, so it predicts the variation.

5. Implications and conclusions

Section 4 established an OT analysis which predicts the hierarchical variation within HONH and the resulting typological effects. I will now briefly examine the implications of this analysis for the derivational approach to these facts proposed by Piggott (1992). Based on a survey of nasal harmony systems, Piggott develops an important typological study of languages with opacity versus those with transparency. Apart from the analysis of this basic distinction, variation within languages exhibiting opacity receives independent treatment using a principle of Contrastive Nasality. However, questions remained concerning this variation. I argue here that the OT analysis developed above explicates the hierarchical effects.

First I will review the Contrastive Nasality account of the variation in opaque sets. Based on his survey of nasal harmony systems, Piggott proposes that [\pm nasal] can be a dependent of a Soft Palate (SP) articulator node, and HONH ("type A" nasal harmony for Piggott) results from spreading of this node to segments unspecified underlyingly for SP. To explain HONH, Piggott posits the Contrastive Nasality Principle:

(19) *Contrastive Nasality* (Piggott 1992: 44)

- a. If [+nasal] is an underlying property of [+consonantal] segments, then other segments specified underlyingly for an SP node must also be [+consonantal].
- b. The segments specified for the SP node must otherwise constitute a natural class that is not limited to sonorants.

Part (a) of Contrastive Nasality predicts that if a language has underlying nasal stops, only consonants may be specified for SP underlyingly. In fact, all of the languages in HONH examined here do have underlying nasal stops, so the SP node should be absent in the underlyingly representation of the vowels. As Piggott assumes that node spreading may only occur to segments unspecified for that structure and the presence of the node on a segment will arrest spreading, (19a) thus correctly predicts that the opaque segments for HONH will be restricted to the consonants underlyingly specified for SP, and vowels will always be targets due to their lack of specification for SP.

In languages with underlying nasal stops (i.e. most, if not all languages), part (b) of Contrastive Nasality governs which subclasses of the consonants can be specified for SP if it is not present on all of them. (19b) states that this group will be a natural class that is not limited to sonorants. Piggott identifies the natural classes of consonants which may contain segments specified for SP as: (i) sonorants, (ii) non-approximants (fricatives and stops), (iii) stops (1992: 44). In combination with (19a), (19b) thus restricts the possible sets of opaque segments to the ones shown in (20), yielding the hierarchical patterns in (1). In this approach, glides are analyzed as varying cross-linguistically for [\pm consonantal], collapsing (1i-ii) into a case in which SP is present on all consonants⁶.

(20)	<u>OPAQUE SETS</u>	<u>NATURAL CLASS SPECIFIED FOR SP</u>
	Stops	Stops
	Fricatives, Stops	Non-approximants
	(Glides), Liquids, Fricatives, Stops	Consonants

Since the natural class of consonantal sonorants may not alone be specified for SP, an opaque set comprised of liquids and glides or just liquids is ruled out.

Although Contrastive Nasality appears to yield the variation, closer examination raises some questions concerning this approach. First of all, there is a conceptual issue. In order to capture the hierarchical opacity, the fact that the set of

opaque segments is not limited to the natural class of sonorants must be stipulated in part (b) of the principle, yet no independent motivation is given for the exclusion of the class of sonorants here. Furthermore, the natural classes relevant for SP specification are listed, but the phonological source of this particular group of classes is unclear, as it is not assigned a formal status in the theory.

Significantly, the constraint hierarchy approach for HONH developed here explicates the variation in opaque sets. This analysis actually predicts the attested variation and resulting typology, based on the nasalization constraint hierarchy derived from the phonetically grounded sonority scale. The OT framework provides a means of directly obtaining the effects of this hierarchy by allowing simple re-ranking of one constraint to capture the variation across languages. As a result, the variation in opaque sets emerges as a natural and expected phenomenon.

The Contrastive Nasality account also faces an empirical question. Concerning triggers in HONH, part (a) of Contrastive Nasality predicts that in languages with nasal stops, only consonants may trigger SP spreading to realize HONH, since the SP node is only specified underlyingly on consonants. However, this claim presents a problem for languages that even Piggott cites as examples of HONH. In both Applecross Gaelic (Ternes 1973) and Warao (Osborn 1966), nasal vowels can trigger nasal harmony, so they should have an underlying SP node which spreads; but both of these languages also have underlying nasal stops, so part (a) of Contrastive Nasality predicts that they could not be specified underlyingly for SP. These conflicting predictions result in a contradiction.

An important consequence of the constraint hierarchy analysis is that it resolves this empirical dilemma. This analysis predicts that any segment which is contrastively specified for Nasal can trigger harmony. It thus predicts the occurrence of languages like Applecross Gaelic and Warao with vocalic triggers in addition to the existence of languages with consonantal triggers.

These results demonstrate that the constraint hierarchy analysis developed here offers an account for the hierarchical effects which not only yields the correct empirical predictions, but also provides insight into the source of the variation.

Footnotes

* Thanks to Junko Itô, Armin Mester, and Jaye Padgett for their ongoing comments on this work. Thanks also to Sharon Inkelas, Greg Lamontagne, Joe Pater, Keren Rice, and Moira Yip as well as audience members at ESCOL and WECOL 1994 for their suggestions. Any errors are of course my own. This research was supported by SSHRC fellowship 752-93-2397.

1. Terms such as "target" and "trigger" are used here in a theory-neutral sense simply to identify the type of patterning of segments.

2. In nasal contexts I follow the traditional transcription for these languages by showing a tilde on [h] but not on [ʔ]. Laryngeals (h, ʔ) in languages with HONH typically do not block harmony (see (2b) for example). However, it is not clear that laryngeals should be grouped with the target segments. Cohn (1990) concludes that Nasal is not phonologically relevant for laryngeals, although they may be phonetically nasalized in the context of nasalized segments. Since the focus of this paper is hierarchical variation of phonological targets and blockers, I will not be concerned with the phonetic nasalization of laryngeals here; but see McCarthy (1994) for discussion of a means of implementing spreading onto apparently transparent segments.

3. Nasal stops in Capanahua do not surface in certain environments, but are shown in all examples as they condition nasalization. Similarly, final stops in Urhobo, which condition HONH, do not actually surface in the phonetic output.

4. As pointed out to me by Greg Iverson, the universal absence of nasalized obstruent stops could be handled with a numeric scale of sonority, such that obstruent stops had a sonorancy value of zero and segments ranked higher had progressively higher sonorancy values. A constraint requiring that nasalization implies sonorancy (i.e. a nonzero sonorancy value) would then account for the absence of nasalized obstruent stops. In OT this constraint would presumably be part of GEN, as it appears to be respected in all languages.
5. The *EMBED constraint proposed by Smolensky (1993) performs a similar function to NOGAP in a framework with binary features.
6. Rather than grouping glides with vowels or consonants on a language particular basis, the scalar sonority analysis developed here treats glides as consistently intermediate between vowels and consonants with respect to sonority. The two approaches make different predictions. By according glides an intermediate status, the scalar sonority approach is consistent with the patterning of glides in languages such as Gere (Paradis 1988, 1990) where glides exhibit alternations with both vowels and consonants. However, this dual-type patterning of glides is not as readily explained under an analysis in which glides are grouped with just one of the sets of consonants or vowels on the basis of their [consonantal] specification, pointing to a strength of the sonority-based approach.

References

- Archangeli, Diane & Douglas Pulleyblank, in press. *Grounded Phonology*. Cambridge: MIT Press.
- Clements, G. N. 1990. The Role of the Sonority Cycle in Core Syllabification. *Papers in Laboratory Phonology I*, ed. by J. Kingston and M. Beckman, 283-333. Cambridge: Cambridge University Press.
- Cohn, Abigail. 1987. A Survey of the Phonology of the Feature [+/- nasal]. Ms. University of California, Los Angeles.
- Cohn, Abigail. 1990. *Phonetic and Phonological Rules of Nasalization*. UCLA Working Papers in Linguistics. 76.
- Cole, Jennifer & Charles Kisseberth. 1994. An Optimal Domains Theory of Harmony. To appear in *Studies in Linguistic Sciences*. 24.2.
- Hendon, Rufus S. 1966. *The Phonology and Morphology of Ulu Muar Malay*. New Haven: Yale University Publications in Anthropology, no. 70.
- Hulst, Harry van der & Norval Smith. 1982. Prosodic Domains and Opaque Segments in Autosegmental Theory. *The Structure of Phonological Representations (part II)*, ed. by Harry van der Hulst & Norval Smith, 311-336. Dordrecht: Foris.
- Hume, Elizabeth & David Odden. 1994. *Contra [Consonantal]*. To appear in *Studies in the Linguistic Sciences*. 24.2.
- Itô, Junko, Armin Mester, & Jaye Padgett. 1993. Licensing and Redundancy: Underspecification in Optimality Theory. Linguistics Research Center, report no. LRC-93-07. University of California, Santa Cruz.
- Itô, Junko, Armin Mester, & Jaye Padgett. 1994. NC: Licensing and Underspecification in Optimality Theory. To appear in *Linguistic Inquiry*.
- Kelly, John. 1969. *Urhobo. Twelve Nigerian Languages*, ed. by Elizabeth Dunstan, 153-161. New York: Africana Publishing Corp.
- Kirchner, Robert. 1993. *Turkish Vowel Harmony and Disharmony: An Optimality Theoretic Account*. Paper presented at Rutgers Optimality Workshop I (ROW I). Rutgers University.
- Lieber, Rochelle. 1987. *An Integrated Theory of Autosegmental Processes*. Albany: SUNY Press.

- Loos, Eugene Emil. 1967. The Phonology of Capanahua and its Grammatical Basis. Doctoral dissertation, University of Texas-Austin. [Published, University of Oklahoma: Summer Institute of Linguistics Publication. 20.]
- Onn, Farid M. 1980. Aspects of Malay Phonology and Morphology. Doctoral dissertation. Universiti Kebangsaan Malaysia, Bangi.
- Opubor, Alfred E. 1969. Itsekeri. Twelve Nigerian Languages, ed. by Elizabeth Dunstan, 125-132. New York: Africana Publishing Corp.
- Osborn, Henry A. Jr. 1966. Warao I: Phonology and Morphophonemics. *International Journal of American Linguistics*. 32.2.108-123.
- Mafeni, Bernard. 1969. Isoko. Twelve Nigerian Languages, ed. by Elizabeth Dunstan, 115-124. New York: Africana Publishing Corp.
- McCarthy, John. 1994. On Coronal 'Transparency'. Paper presented at TREND workshop. University of California, Santa Cruz.
- McCarthy, John & Alan Prince. 1993a. Prosodic Morphology I: Constraint Interaction and Satisfaction. Ms. University of Massachusetts, Amherst and Rutgers University.
- McCarthy, John & Alan Prince. 1993b. Generalized Alignment. To appear in *Yearbook of Morphology*.
- Paradis, Carole. 1988. Towards a Theory of Constraint Violations. *McGill Working Papers in Linguistics*. 5.1.1-43.
- Paradis, Carole. 1990. "Focus" in Gere Configurational Constraints. *Current Approaches to African Linguistics*, vol. 7, ed. by J. Hutchison & V. Manfredi, 53-62. Dordrecht: Foris.
- Piggott, Glyne. 1992. Variability in Feature Dependency: The Case of Nasality. *Natural Language and Linguistic Theory*. 10.33-77.
- Prince, Alan & Paul Smolensky. 1993. Optimality Theory: Constraint Interaction in Generative Grammar. Ms. Rutgers and University of Boulder at Colorado.
- Pulleyblank, Douglas. 1993. Vowel Harmony and Optimality Theory. To appear in *Proceedings of the Workshop on Phonology*, University of Coimbra, Portugal.
- Robins, R. H. 1957. Vowel Nasality in Sundanese. *Studies in Linguistic Analysis*, 87-103. London: Basil Blackwell.
- Sagey, Elizabeth. 1986. The Representation of Features and Relations in Nonlinear Phonology. Doctoral dissertation, MIT.
- Smolensky, Paul. 1993. Optimality, Markedness, and Underspecification. Paper presented at Rutgers Optimality Workshop I (ROW I). Rutgers University.
- Steriade, Donca. 1993a. Closure, Release and Nasal Contours. *Phonetics and Phonology*, vol. 5, ed. by M. Huffman and R. Krakow. Academic Press.
- Steriade, Donca. 1993b. Orality and Markedness. *Berkeley Linguistics Society*, ed. by B. Keyser and J. Guenther, vol. 19. University of California, Berkeley.
- Steriade, Donca. 1994. Underspecification and Markedness. To appear in *Handbook of Phonology*, ed. by J. Goldsmith. London: Basil Blackwell.
- Ternes, Elmar. 1973. The Phonemic Analysis of Scottish Gaelic. (*Forum Phonetikum* 1.) Hamburg: Helmut Buske Verlag.
- Trigo, Loren. 1993. The Inherent Structure of Nasal Segments. *Phonetics and Phonology*, vol. 5, ed. by M. Huffman and R. Krakow. Academic Press.
- Tucker, A. N. & P. E. Hackett. 1959. Le groupe linguistique Zande. *Tervuren: Annales du Musée Royal di Congo Belge*.
- Williamson, Kay. 1965. A Grammar of the Kolokuma Dialect of Ijo. Cambridge: Cambridge University Press.
- Williamson, Kay. 1969. Ijo. Twelve Nigerian Languages, ed. by Elizabeth Dunstan, 97-114. New York: Africana Publishing Corp.
- Zec, Draga. 1988. Sonority Constraints on Syllable Structure. Doctoral dissertation. Stanford University.