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Reinterpreting Transparency in Nasal Harmony*

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1. Introduction

In this paper I examine crosslinguistic variation in nasal harmony. Three kinds of segment behavior are observed: *target segments* become nasalized in nasal harmony (/na/ → [nã̲]), *blocking or opaque segments* remain oral and block nasal spreading (/nata/ → [nãt̲a]), and *transparent segments* remain oral and do not block nasal spreading (/nata/ → [nãt̲ã]). The membership of these categories varies in limited ways across languages. The aim of the present work is to establish a unified understanding of nasal harmony, so that all patterns conform to one basic character—something that has not been achieved before. A second goal is to examine the wider implications for phonological theory, particularly the consequences for analysis of transparency and locality in feature spreading.

A central claim defended here is that all nasal harmony patterns are constrained by a hierarchy ranking segments according to their compatibility with nasalization. Previous work has suggested that a nasalization hierarchy is relevant only for defining sets of target segments versus blockers. However, this view is faced with a complementarity problem. First there appear to be no examples of a certain pattern predicted by the hierarchy, one in which all segments including obstruents are nasalized. Second, another system is isolated from the others, one where some obstruents act transparent and all remaining segments are targets. The crosslinguistic study presented here reveals that target and transparent segments pattern together with respect to the nasalization hierarchy: if a class of segments propagates nasal spreading (is targeted or behaves transparent), all higher-ranked classes also propagate nasalization. To explain this, I propose to analyze descriptively transparent segments together with targets of nasality spreading as a unitary class of permeable segments, i.e. segments that participate in nasal harmony. The possible outcomes for segments in feature spreading becomes accordingly simpler: they either undergo nasal spreading or they block. Systems with transparency emerge as instances where all segments undergo nasal spreading, achieving a unified typology of nasal harmony where the nasalization hierarchy exhaustively limits variation. Interestingly, this result finds support for a view of locality in which feature spreading occurs only between strictly adjacent segments (Gafos 1996; Ní Chiosáin and Padgett 1997), a notion that previously seemed to be denied by the nasal harmony data.

The unified typology obtains the hierarchical variation in segments permeated by nasalization versus blockers. However, segments undergoing nasalization are noted to have two possible phonetic outcomes: nasal or oral. The latter occurs only on permeable segments near the extreme of incompatibility with nasalization, typically voiceless obstruents. I argue that this transparency outcome arises as a derivational opacity effect, a phenomenon captured under Sympathy Theory (McCarthy 1997; Itô & Mester 1997). The effect arises in a correspondence mapping between a fully-nasalized but unpronounceable phonological output representation ([nãt̃ã]—unpronounceable because [t̃] cannot be phonetically-realized) and a similar but phonetically-possible output ([nãtã]).

This paper is organized as follows. In section 2 I lay out the cross-language typology of nasal harmony, drawing on generalizations established by an extensive survey of nasal harmony systems. Based on the co-patterning of target and transparent segments, I propose to merge these categories, producing a new, unified understanding of nasal harmony. In section 3 I develop an optimality-theoretic analysis. Bearing out the predictions of the theory, the range of attested patterns is obtained by exhausting the possible rankings of a spreading constraint in relation to a fixed hierarchy of nasalized segment markedness constraints. Section 4 turns to the different realizations for permeable segments, and develops an analysis of segment transparency as derivational opacity. Section 5 presents the conclusion.

2. A Crosslinguistic Typology of Nasal Harmony

As discussed in Walker 1995, a key discovery emerging from previous surveys of nasalization is that variation in the sets of supralaryngeal targets and blocking segments in nasal harmony conforms to the implicational nasal compatibility hierarchy in (1), where for each division, marked by a numeric label, all segments to the left are targets, while those to the right block (Schourup 1972; Piggott 1992; Cohn 1993a, b; note also Pulleyblank 1989).[1]

(1) ① Vowels ② Glides ③ Liquids ④ Fricatives ⑤ Obstruent Stops ⑥
← high———————*compatibility with nasalization*———————low →

In previous work this hierarchy of segments has been applied strictly to patterns with blocking, separating them from systems with transparency. However, I will argue that this core hierarchy governs all nasal harmony. As the basis for this study I draw on a database of nasal harmony patterns, comprising descriptions from over 75 languages—the most inclusive survey to date (Walker 1998, with foundation from Schourup 1972; Piggott 1992; Cohn 1993b; among others). Patterns included in this database are those in which nasalization spreads across syllables or targets nonvocalic segments in the syllable.[2] The crosslinguistic generalizations established in this research define the facts to be explained by the analysis.

2.1 *Hierarchical Variation in Blocking Segments*

I begin by considering nasal harmony patterns dividing their segments exhaustively into sets of targets and blockers. For patterns of this kind, a focal result of the database is that it corroborates the hierarchy in (1). The study finds that if a segment blocks nasalization, all segments less compatible by the nasalization hierarchy will also block. Further, if a segment becomes nasalized, all segments more compatible will be targets in nasal harmony. The range of possible blocking patterns in nasal harmony is thus considerably restricted. I exemplify the limited variation below.

A well-known example of the most restricted nasal harmony is found in Sundanese, an Austronesian language spoken in Western Java (Robins 1957; Cohn 1990). In this language nasalization spreads rightward from a nasal stop. Only vowels become nasalized and the remaining supralaryngeal segments block spreading, including glides.

(2) Sundanese

a.	ɲãĩ̃ãn	‘to wet’
b.	ŋãjak	‘to sift’
c.	mãwur	‘to spread’
d.	mõlohok	‘to stare’
e.	mãro	‘to halve’
f.	ɲĩ̃sər	‘to displace’
g.	ŋũdag	‘to pursue’
h.	ŋãtur	‘to arrange’

The Johore dialect of Malay, another Austronesian language, illustrates the second variant, in which glides as well as vowels undergo a rightward spreading of nasality from a nasal consonant (Onn 1980). Liquids and obstruents block spreading.

(3) Malay (Johore dialect)

a.	baŋõn	‘to rise’
b.	mãj̃ãŋ	‘stalk (palm)’
c.	mə̃nãw̃ãn	‘to capture’ (active)
d.	mə̃ratappi	‘to cause to cry’
e.	pəŋãw̃ãsan	‘supervision’
f.	pəmãndaŋãn	‘scenery’
g.	mãkan	‘to eat’

The Kolokuma dialect of Ijo, a Niger-Congo language of Nigeria, provides an example of the next hierarchical step, where liquids are added to the set of target segments (Williamson 1965, 1987). In this language, nasality spreads leftward from a nasal consonant or nasal vowel. Nasalization of the flap is apparent in (4c-d). Williamson (1987: 401) notes that prevocalic [l] and [n] are in complementary distribution, [l] occurring before oral vowels and [n] before nasal ones. In nasal vocalic contexts she posits /l/ as nasalizing to [n].

(4) Ijo (Kolokuma dialect)

a.	ũ̃mba	'breath'
b.	w̃ãĩ	'prepare sugarcane'
c.	j̃ãr̃ĩ	'shake'
d.	sɔ̃r̃ɔ̃	'five'
e.	sãnlo	'gills'
f.	izõŋgo	'jug'
g.	abãmu	'loft'
h.	otõŋgbolo	'mosquito'
i.	tɔ̃nĩ	'light (a lamp)'

The next most permissive nasal harmony, where nasality carries through fricatives, is found in the Applecross dialect of Scottish Gaelic, a Celtic language (Ternes 1973; van der Hulst & Smith 1982). Nasality spreads rightward from a stressed nasal vowel (usually in the initial syllable) until checked by an obstruent stop. It also nasalizes the onset of the syllable containing the stressed vowel, provided the onset is not an obstruent stop.[3] Three vowel lengths are distinguished: [ˑ] marks half-long, [ː] marks long, and short vowels are unmarked.[4]

(5) Scottic Gaelic (Applecross dialect)

a.	/frĩaˑv/	[ˈf̃r̃ĩãˑṽ]	'root' (pl.)
b.	/ʃɛ̃nɛˑvar/	[ˈʃ̃ɛ̃nɛ̃ˑṽãr̃]	'grandmother'
c.	/ʟãːɟ/	[ˈʟ̃ãːɟ̃]	'hand'
d.	/ãhuç/	[ˈãh̃ũç̃]	'neck'
e.	/sŋãˑnʲdʲan/	[ˈs̃ŋãˑnʲdʲan]	'thread'
f.	/tʰãhusk/	[ˈtʰãh̃ũs̃k]	'fool'
g.	/strãiˑɣ/	[ˈstr̃ãĩˑɣ̃]	'string'
h.	/kʰɔ̃ispaxk/	[ˈkʰɔ̃ĩs̃paxk]	'wasp'

The above examples illustrate four hierarchical variations in the set of segments undergoing nasal harmony. In general terms, the hierarchy governing the patterns has five segmental classes: Vowel, Glides, Liquids, Fricatives, and Obstruent Stops, where each different set of participating segments corresponds to a step in the hierarchy (see (1)). Yet there is a further step at either end of the hierarchy that must also be considered. The step at the leftmost extreme (marked ①) corresponds to a variant in which all segments block nasal spreading. This describes a language with no nasal harmony, a widely attested occurrence—Standard Spanish is an example. The step at the opposite extreme (marked ⑥) characterizes a system where all segments are nasalized including all obstruents. However, there are no surface-true examples of this kind. We are thus confronted with a seeming lack of exhaustivity in the hierarchical typology: all step-wise variants are attested except for the sixth and final step. In addition to this apparent gap, there is another pattern discussed below that appears to stand apart from the others—a system in which some obstruents behave transparent and the remaining segments are targets. These two observations present a basic complementarity puzzle in the descriptive typology of nasal harmony: there is no pattern in which all segments, including obstruents, undergo nasalization, and on the other hand, obstruents are the only segments that behave transparent. Resolving this issue is the focus of the next section.

2.2 Patterns with Segmental Transparency

The separate pattern with transparent segments is particularly prevalent in the Amazonian family; well-known examples include Barasano (Tucanoan; Colombia) and Guaraní (Tupí; Paraguay). The language examined here is Tuyuca, a Tucanoan language of Colombia and Brazil (Barnes 1996). Its consonant inventory consists of [p, b/(m), t, d/(n), k, g/(ŋ), s, r, w, j, h]. Voiced stops are obstruents in their basic character, but they are variably realized as oral or nasal in outputs, as determined by nasal harmony contexts (see Walker 1998 for evidence supporting their basic obstruent status). Morphemes in Tuyuca are descriptively characterized as nasal or oral as a whole (see (6)). In an oral morpheme, all segments are oral; in a nasal morpheme, all segments are produced with nasalization except for voiceless obstruents. In oral morphemes all voiced stops are produced as obstruent stops, and in the output of nasal morphemes they are realized as fully nasal sonorant stops. Because nasality spreads to all nasalizable segments in a nasal morpheme, it is impossible to unambiguously pinpoint the segment from which spreading originates. For ease of exposition, I will simply assume that nasality originates in the first vowel of a morpheme.[5] In Tuyuca, spreading from the source segment is bidirectional in the morpheme, and it is not blocked by any segment. Voiceless obstruents are transparent to nasal harmony in the sense that they remain oral and yet they do not prevent nasalization from spreading past them to other segments.

(6) Tuyuca

Oral			Nasal		
a.	wati	'dandruff'	k.	w̃ãtĩ	'demon'
b.	keero	'lightning bug'	l.	kẽẽr̃õ	'a dream'
c.	oso	'bat'	m.	j̃õsõ	'bird'
d.	bota	'post'	n.	ẽmõ	'howler monkey'
e.	pade	'work'	o.	w̃ĩnõ	'wind'
f.	sɨge	'to follow'	p.	tɨ̃ŋõ	'Yapara rapids'
g.	pee	'to bend'	q.	pẽẽ	'to prepare soup'
h.	bipi	'swollen'	r.	mĩpĩ	'badger'
i.	diti	'to lose'	s.	nĩtĩ	'coal'
j.	aka	'give food'	t.	ãkã	'choke on a bone'

Systems like that of Tuyuca, with a set of transparent segments, have resisted a unified account with the others forming the hierarchical typology. Their apparent differences have led previous analysts to posit them as a second type of nasal harmony. For instance, in an important paper on this subject, Piggott (1992) seeks explanation from parametrized representations, proposing that systems with transparency differ from those with blocking in the dependency of [nasal] in the segment structure. While Piggott's study represents a significant contribution in this area, two major problems confront the dual representation approach. First, variable dependency must be stipulated for [nasal] to distinguish the two nasal harmony patterns—no independent evidence has been discovered for variable feature dependency. Second, no explanation is offered for the essential complementarity noted above: *all* segments have the potential to block spreading; all segments *except* (some) obstruents have the potential to be targets in nasal harmony, and *only* obstruents ever act transparent.[6] This complementarity strongly suggests that the two kinds of patterns can be united into a whole, and that is the direction I propose to take here.

Recall that in the hierarchical typology, the final step, in which nasality carries through all segments in nasal harmony, appears to be unattested. To produce a unified typology, I propose that patterns in which no segments block and some obstruents act transparent (e.g. Tuyuca) belong to this last hierarchical slot. Accompanying this move is an analytical claim that obstruent stops can undergo nasal harmony. In Tuyuca, we see evidence of voiced obstruent stops undergoing nasal spreading in their becoming nasalized in nasal morphemes. In contrast, voiceless obstruent stops are transparent (i.e. oral) in the output of nasal morphemes; however, there is typological evidence that voiceless stops pattern with targets of nasality spreading.

The basis for the typological argument comes from generalizations concerning transparent segments in the nasal harmony database. From the database it emerges that segments acting transparent to nasal harmony pattern together with targets in relation to the nasal compatibility hierarchy: if a segment is *permeated* by nasal harmony, that is, if it is targeted or behaves transparent, then all more compatible segments are also permeated by nasal spreading. There are thus patterns in which voiced stops undergo nasalization and voiceless stops act transparent but none in which voiceless stops are transparent but other segments block. In addition, transparency is always limited to obstruents and targeting of all obstruents is precisely the pattern missing in the hierarchical variants.

To explain these generalizations, I propose that transparent segments and targets be analyzed together as a single category of segment patterning, characterized as *permeable segments* (borrowing terminology from Ní Chiosáin & Padgett 1997). Grouping transparent segments in the same class as targets in relation to the typology of nasal harmony fills the gap in the expected hierarchical variation and achieves a unitary view of cross-language variation.

An important result of merging target and transparent segments is illustrated in (7): the nasalization hierachy is now reinterpreted as representing possible bifurcations between blockers and permeable segments. This move obtains a unified typology that exhausts all of its expected variants. Observe that a transparency system like that of Tuyuca is now slotted in as an instance of step ⑥, where all segments are permeated by nasality spreading.

(7) Unified hierarchical variation in nasal harmony:

_①_Vowels___Glides___Liquids___Fricatives___Obstruent stops___ *Spanish*
___Vowels_②_Glides___Liquids___Fricatives___Obstruent stops___ *Sundanese*
___Vowels___Glides_③_Liquids___Fricatives___Obstruent stops___ *Malay (Johore)*
___Vowels___Glides___Liquids_④_Fricatives___Obstruent stops___ *Ijo (Kolokuma)*
___Vowels___Glides___Liquids___Fricatives_⑤_Obstruent stops___ *Gaelic (Applecross)*
___Vowels___Glides___Liquids___Fricatives___Obstruent stops_⑥_ *Tuyuca*

← permeable segments————————————blockers →

The unified typology partitions segmental behavior in nasal harmony into a simple two-way distinction: segments are either permeated by nasal harmony or they block propagation of nasality. In the following section I propose a core analysis deriving the result of the typology in (7) differentiating between just the classes of permeable segments and blockers. Beyond this, there are two possible realizations within the class of permeable segments: they are either nasalized or oral ('transparent'). Section 4 develops the account further to explain these different outcomes.

3. Analysis of the Unified Typology

I formalize the analysis in the constraint-based framework of Optimality Theory (OT; Prince and Smolensky 1993). I assume a basic familiarity with the underpinnings of OT and its formalisms. To characterize the basic typology of nasal harmony, two kinds of constraints will be needed: nasal markedness and spreading. I begin with the former, arguing that they are arrayed in a hierarchy according to the compatibility of certain features in combination with [+nasal], which corresponds to the property of having a lowered velum.[7] I then go on to discuss the spreading constraint that drives nasal harmony. Factorial ranking of the spreading constraint in relation to the nasal markedness hierarchy will achieve the crosslinguistic variation.

3.1 The Constraints

It is the task of any cross-language account of nasal harmony to explain the hierarchical implications limiting the range of attested patterns. Building on a proposal initially made by Schourup (1972), I assume that all variation in the set of permeable segments is based on the phonetically-grounded harmony scale of nasalized segments in (8), which corresponds to the nasalization hierarchy in (1). (The notion of a harmony scale follows Prince & Smolensky 1993). Hierarchical (in)compatibility of nasalization has also been raised in the work of Pulleyblank (1989), Piggott (1992), Cohn (1993a, b), Walker (1995, 1998), Padgett (1995b, with application to patterns of nasal place assimilation), and Boersma (1998, 1999).

(8) Nasal vowel $\succ$ Nasal glide $\succ$ Nasal liquid $\succ$ Nasal fricative $\succ$ Nasal obstruent stop

The scale in (8) is segregated by segmental class. In general, nasality spreading makes class-based distinctions in the segments it permeates; however, if it were necessary, finer distinctions could be made by scaling nasalization of individual segments. The segment categories can be expressed formally in terms of feature specifications, for example, nasalized liquids will be [+nasal, +approximant, +consonantal]. (The particular choice of features is not crucial to what follows.)

Importantly, the segment classes are ranked under the condition of simply combining nasality with the other featural properties describing a given class of sounds. The highly incompatible nasalized fricatives thus remain [+continuant] and nasalized obstruents remain [-sonorant].

Of course, the most harmonic nasal segment of all is a sonorant stop, e.g. [m, n, ŋ]. Across inventories, these are unquestionably the most widely attested nasal segments (Ferguson 1975; Maddieson 1984; Pulleyblank 1989; Cohn 1993a). Nasality is intrinsic to the harmonic nature of these segments; in fact, it is not clear that this sort of sonorant stop ever occurs without [+nasal] (but see Piggott 1992; Rice 1993 for some suggested instances).[8] Nasal sonorant stops will appear at the leftmost extreme of the harmony scale. Since nasality is essentially basic in these segments, I have not listed them above in order to maintain expositional focus on the effect of scalar compatibility in segments acquiring nasality. After nasal (sonorant) stops, vowels are the next most widely attested nasal segments in inventories and they are most susceptible to acquiring nasalization in nasal spreading. The relative harmony of nasalized segments continues to decrease gradiently moving rightward through the hierarchy. Notice that although the scale in (8) resembles the sonority hierarchy (see Blevins 1995 and citations therein), it critically differs in the treatment of nasal (sonorant) stops, which are top-ranked in nasal harmonicity but medial in terms of sonority. The two hierarchies thus cannot be fully equated.[9] Cohn (1993a) notes, however, that sonority plays a role in determining the compatibility of nasalization with continuants. I suggest that the similarity in the scales stems from the sonority and nasalization hierarchies having an overlapping basis in perceptibility. In the case of sonority, the basis of perceptibility is something akin to acoustic intensity. For the nasalization hierarchy the scale reflects nasal perceptibility (in addition to articulatory compatibility, as noted below). A nasal stop will be the best in conveying perceptible nasalization, since the acoustic properties of a nasal stop stem solely from nasal airflow. For continuants, nasal airflow is combined with oral airflow. Here it seems that perceptibility of nasalization is enhanced by greater sonority, hence the overlap in the two hierarchies.[10]

Overall, it is both articulatory/aerodynamic and acoustic/perceptual factors that contribute to the basis for the nasalization hierarchy, as noted by Cohn (1993a). For example, it is difficult to produce an audibly nasalized fricative because such a sound segment has articulatory/aerodynamic and acoustic/perceptual demands that are hard to satisfy at the same time. The nasal property requires that the segment be produced with a lowered velum, and nasal airflow undermines the build-up of pressure behind the oral constriction needed to produce frication (Ohala & Ohala 1993; Cohn 1993a; Ohala, Solé, & Ying 1998). As a consequence, perceptible achievement of either nasality or frication generally suffers in the production of nasalized fricatives. In an instrumental study of Coatzospan Mixtec, Gerfen (1996) finds that nasal airflow can be maintained during a voiceless coronal fricative with strongly audible frication, but the acoustic cues for nasalization are weak—the fricative is typically perceived as oral. On the other hand, in research on other languages it has been noted that nasalized voiced fricatives produced with clearly perceptible nasalization typically lose audible frication (Ohala 1975; Cohn 1993a; Ladefoged & Maddieson 1996).

With the harmony scale in (8), we can explain the variation in nasal harmony as variability in where languages make the cut between segments that are sufficiently compatible with [+nasal] to propagate nasalization and those that are not. Since OT is based on the notion of ranked and violable constraints, it is well-suited to capturing this insight. To implement the harmony scale in OT, it must be recast in terms of the nasalized segment constraint hierarchy in (9), where the less compatible a segment is with nasality, the higher-ranked its constraint (Walker 1995; see Prince & Smolensky 1993 for similar derivations of constraint hierarchies from harmony scales). For ease of exposition, I again refer to segment classes, rather than listing their featural description.

(9) *NASOBSTRUENTSTOP » *NASFRICATIVE » *NASLIQUID » *NASGLIDE » *NASVOWEL

This markedness gradation represents a universal scaling of nasal feature cooccurrence constraints, and it will achieve the hierarchical implications for sets of blocking and permeable segments.

The nasalized segment constraints will conflict with the constraint driving the spread of [+nasal]. In autosegmental representations, the standard assumption is that spreading produces outcomes in which a feature is multiply-linked across a span of segments, as in (10). This modeling has a basis in understanding spreading as the extension of a gesture or property, motivated by functional/dynamic considerations discussed below.

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(10)   INPUT     s1  s2  s3                 OUTPUT    s1  s2  s3
                 |              →                      \  |  /
                [F]                                      [F]
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Following a proposal first made by Kirchner (1993), the multiple linking outcome can be achieved using featural alignment constraints to drive feature spreading (see also Smolensky 1993; Cole & Kisseberth 1995; Akinlabi 1996; Pulleyblank 1996; among others; see McCarthy & Prince 1993 on the general notion of alignment). A rightward [nasal] spreading constraint is given in (11). This formulation follows Zoll (1996), Walker (1998), and Ní Chiosáin & Padgett (1998) in making aspects of feature alignment more precise.

(11) ALIGN-R([+nasal], PrWd): (henceforth SPREAD-R(+nasal))
Let n be a variable ranging over occurrences of the feature specification [+nasal], S be the sequence of ordered segments $s_1 \ldots s_k$ in the prosodic word domain, and $s_i \delta n$ mean that n is dominated by s_i. Then $\forall s_i, n[s_i \delta n \rightarrow \forall s_j[s_j \delta n]]$, where $s_j > s_i$.

Stated less formally, for every occurrence of a [+nasal] feature in a prosodic word, if that [+nasal] feature is dominated by some segment, it must also be dominated by every segment appearing to the right of that segment in the prosodic word. Following the analysts cited above, violation is taken as gradient; for any [+nasal] feature and the rightmost segment dominating it, a mark is accrued for each segment appearing to the right of that dominating segment in the prosodic word. Let us consider the evaluation of the structures in (12) in relation to this constraint (assuming the string of segments corresponds to a PrWd). The structure in (12a) perfectly satisfies SPREAD-R(+nasal) since there is one occurrence of [+nasal] and it is linked to the rightmost segment of the string. The structure in (12b) incurs one violation for s_3 to the right of [+nasal], and (12c) accrues four violations, three for each of the segments to the right of the first [+nasal] feature specification (s_2, s_3, s_4) and one for the segment (s_4) to the right of the second [+nasal] feature.

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(12)   a.   s1  s2  s3      c.   s1  s2  s3      c.     s1  s2  s3  s4
             \  |  /                 |                  |   |   |   |
              [+N]                 [+N]             [+N][-N][+N][-N]
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Leftward spreading will be achieved by a parallel constraint to (11) substituting $s_j < s_i$ for the final restriction. Bidirectional spreading will result from eliminating any precedence restriction on s_j.

Nasal spreading constraints and the nasalized segment hierarchy will together derive the hierarchical effects in nasal harmony. These constraints conflict in a word containing a nasal segment. Satisfying spreading requires selection of an output containing nasalized segments. On the other hand, optimizing with respect to nasal markedness means avoiding formation of nasalized segments, which forces violation of spreading. Before exhibiting these resolutions, however, it is necessary to address the unitary analytical treatment of segments propagating nasality.

The segments that nasality carries through in spreading are the class of permeable segments, merging targets and descriptively transparent segments, as established above. Grouping these segments that propagate nasal harmony into one class is critical to achieving a unified view of variation in nasal harmony as well as a typology that exhaustively attests the possibilities predicted by the nasalization hierarchy. To achieve a unitary analysis of permeables, I posit all permeable segments as participants in nasal spreading. This claim is a conservative one; there is an unambiguous need in the theory for representations in which a spreading feature becomes the property of a permeated segment: this is the usual outcome for nasal harmony and for feature spreading in general. The crosslinguistic typology of nasal harmony provides evidence strongly suggestive of extending this view to transparent segments. It has shown us that nasality spreads from segment to segment. Importantly, apparent skipping of segments in nasal spreading does not occur as an alternative to blocking for the set of nonparticipant segments; patterns with descriptively transparent segments instead fill the slot where we expect to find all segments undergoing nasalization. This is explained if transparency is actually the outcome for a participant segment near the extreme of incompatibility with nasalization.

Analyzing all permeable segments as participants also has basis in insights stemming from the dynamic modeling of Articulatory Phonology (Browman & Goldstein 1986 et seq.), where spreading is conceptualized as the overlap of a gesture across segments. Functionally, this overlap is motivated by demands to increase perceptibility or articulatory ease, as discussed for example by Boersma (1998). The dynamic modeling entails that the spreading gesture is a continuous one: an overlap cannot be represented by repeating the gesture after an interruption. In the formal representation of phonological features, this attribute is instantiated by viewing each occurrence of a feature specification as a continuous and unitary entity (Scobbie 1991). In their important work on locality in spreading, Ní Chiosáin & Padgett (1997) make a formal proposal in their definition of a *convex* featural event (drawing on Bird & Klein 1990):

(13) A featural event F is convex iff it satisfies the following condition:
For all segments, α, β, γ, if α precedes β, β precedes γ, α overlaps F and γ overlaps F, then β overlaps F.

As Ní Chiosáin and Padgett point out, it is reasonable to assume that convexity holds of phonological representations without exception—it incorporates the understanding brought to phonological theory by dynamic studies. In OT, Ní Chiosáin and Padgett thus propose that convexity is a fundamental property that constrains the set of candidates that Gen produces.

An important corollary of this conception is that a gapped configuration like that in (14) is universally ill-formed under an interpretation where [F] is not a property of β.

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(14)    *α  β  γ          where [F] is a feature and α, β, and γ are any segment
          \    /
           [F]
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This view is called *strict segmental locality*, since it enforces segmental adjacency in feature linking (Ní Chiosáin & Padgett 1993, 1997, 1998, foundation from McCarthy 1994; Flemming 1995a; Padgett 1995a; Gafos 1996; Walker & Pullum 1999). Ní Chiosáin and Padgett present detailed arguments for this position along with a review of previous supporting evidence. At the center of their discussion is an examination of Turkish vowel harmony, arguing that the spreading of vowel color features does not skip any segments and permeates consonants as well as vowels. In support of their analysis, they cite coarticulation studies which find that vocalic gestures normally overlap consonants (Öhman 1966). Placed within the context of a careful study of segment realization and contrast, Ní Chiosáin and Padgett argue that the perception of a consonant as 'transparent' to vowel harmony does not indicate that the spreading vocalic property is interrupted during the consonant; indeed, given the coarticulation research, the evidence suggests that the vocalic gesture is actually sustained during the consonant. Building on work in Dispersion Theory by Flemming (1995b), their independently-motivated explanation distinguishing contrast perception from articulation contributes to theoretical parsimony by eliminating any need for a transparency-specific representational configuration. They further argue that segmentally strict locality is needed in order to constrain the range of transparency effects found in language. A related line of research re-examines apparent transparency in coronal consonant harmonies (see especially Gafos 1996; also Ní Chiosáin & Padgett 1997, Flemming 1995a). These studies reveal that the spreading property of tongue tip shape or orientation can be maintained during so-called transparent segments—there is no need to regard them as 'skipped'.

The consequence of strict segmental locality for the analysis of nasal harmony is that spreading of [+nasal] may never skip a segment by linking across it, that is, all permeated segments must participate in nasal spreading. If nasalization of a particular segment cannot occur because of a nasal markedness constraint outranking spreading, the only possible outcome is that the segment block spreading. This agrees precisely with the analytical results driven by the typological generalizations of nasal harmony. I thus adopt convexity (from (13)) as the statement of phonological locality and take the participation of permeated segments to follow from this.

To review, two types of constraints have been established: the spreading imperative and the nasalized segment constraints. The family of nasalized segment constraints are scaled in a fixed hierarchy in relation to each other—a ranking grounded in phonetic factors. The view of spreading assumed is an elemental one: spreading simply involves the extension of a unitary and continuous featural gesture or property across segments—an understanding with a basis in functional and dynamic modelling, as well as case studies of long-distance phonological spreading. Together with the OT model, these constraints will be all that is needed to produce the core unified account of nasal harmony.

3.2 Typology from Factorial Constraint Ranking

Prince and Smolensky (1993) hypothesize that typologies are derived by factorial constraint ranking, that is, the set of possible languages will be given by the grammars produced by all of the possible constraint rankings. The previous section motivated nasal spreading and intrinsically-ranked nasal markedness constraints. Given factorial ranking, a typology should then be derived by all possible rankings of the spreading constraint in relation to the nasal markedness hierarchy.

The complete set of possible rankings is given in (15). These rankings match precisely with the hierarchical variation observed in the sets of permeable and blocking segments in nasal harmony (in (7)). Because of strict segmental locality, [+nasal] can never skip associating to a segment in the attempt to achieve nasal spreading. Since skipping is not an option in spreading, any nasalized segment constraint that dominates spreading will produce blocking, as it would be worse to form these nasalized segments than violate spreading. In contrast, nasalized segment constraints outranked by spreading will correspond to participating segments, as it is better to violate these constraints by forming the nasalized segments, than it is to violate spreading instead.

(15) ① *NASOBSSTOP » *NASFRIC » *NASLIQUID » *NASGLIDE » *NASV » SPREAD(+nas)
② *NASOBSSTOP » *NASFRIC » *NASLIQUID » *NASGLIDE » SPREAD(+nas) » *NASV
③ *NASOBSSTOP » *NASFRIC » *NASLIQUID » SPREAD(+nas) » *NASGLIDE » *NASV
④ *NASOBSSTOP » *NASFRIC » SPREAD(+nas) » *NASLIQUID » *NASGLIDE » *NASV
⑤ *NASOBSSTOP » SPREAD(+nas) » *NASFRIC » *NASLIQUID » *NASGLIDE » *NASV
⑥ SPREAD(+nas) » *NASOBSSTOP » *NASFRIC » *NASLIQUID » *NASGLIDE » *NASV
① *Spanish*, ② *Sundanese*, ③ *Malay*, ④ *Ijo*, ⑤ *Applecross Gaelic*, ⑥ *Tuyuca*

The overall ranking structure for the typology of nasal harmony is given in (16). A crucial feature of this pattern is that the ranking of nasalization constraints with respect to each other remains constant according to the intrinsically-ranked hierarchy in (9).

(16) Nasalized segment constraints >> SPREAD(+nasal) >> Nasalized segment constraints
blocking segments *spreading imperative* *participant segments*

The analysis is exemplified in (17-19). The tableau in (17) illustrates the ranking for Sundanese, with rightward spreading.[11] In this pattern, only vowels undergo harmony, so the spreading constraint outranks just the nasalized vowel constraint—other nasalization constraints dominate spreading. Nasalization in candidates is marked with a tilde and brackets are used to delimit spans of a [+nasal] feature, i.e. [nã] implies that one nasal feature is linked to two segments and [n][ã] signifies that there is a separate [+nasal] feature linked to each segment. In the optimal output (17a), spreading extends only as far as the adjacent vowel, since spreading further would violate a dominating nasalization constraint. In (17b), [+nasal] links to every segment, satisfying spreading, but this candidate loses since it violates the higher-ranked constraints against nasalized glides and obstruent stops. Candidate (c) shows a similar problem in spreading up to the obstruent stop. Candidate (d) nasalizes every vowel in the word, but it does not derive nasalization of the second vowel by multiple-linking of the first [+nasal] feature, rather it introduces a separate occurrence of [+nasal] into the structure. This candidate thus fails on the basis of spreading: it incurs three violations for the three segments appearing to the right of the first [+nasal] feature span and one violation for the segment to the right of the second [+nasal] feature span. In (17e), no spreading takes place, and this too loses on a spreading violation.[12]

(17) Sundanese

ŋajak	*Nas ObsStop	*Nas Fric	*Nas Liquid	*Nas Glide	Spread-R (+nasal)	*Nas Vowel
☞ a. [ŋã]jak					***	*
b. [ŋãj̃ãk̃]	*!			*		**
c. [ŋãj̃ã]k				*!	*	**
d. [ŋã]j[ã]k					****!	**
e. [ŋ]ajak					****!	

The variations in nasal harmony will differ from Sundanese only in the ranking of the spreading constraint. The tableau in (18) illustrates the case of Ijo, where vowels, glides, and liquids undergo nasalization. For this pattern, a leftward spreading constraint is situated between the constraint against nasalized fricatives and the constraint against nasalized liquids.

(18) Ijo

sɔɾɔ̃	*Nas ObsStop	*Nas Fric	Spread-L (+nasal)	*Nas Liquid	*Nas Glide	*Nas Vowel
☞ a. s[ɔ̃ɾ̃ɔ̃]			*	*		**
b. [s̃ɔ̃ɾ̃ɔ̃]		*!		*		**

When spreading dominates all nasalized segment constraints, all segments will participate in nasal harmony. This is how I propose to treat Tuyuca. (Note that the directionality restriction in spreading is removed in this example.)

(19) Tuyuca

wãti	Spread (+nasal)	*Nas ObsStop	*Nas Fric	*Nas Liquid	*Nas Glide	*Nas Vowel
☞ a. [w̃ãt̃ĩ]		*			*	**
b. [w̃ã]ti	*!*				*	*
c. w[ã]ti	*!**					*
d. [w̃ã]t[ĩ]	*!****				*	**

The optimal output selected on the basis of this ranking is (19a), in which all segments are nasalized, including the voiceless obstruent stop. This segment is actually described as oral, corresponding to a representation like that in (19d), with separate nasal feature spans on either side of the stop. However, comparing (19d) with (19b), where the stop blocks spreading, it is apparent that (19d) incurs a superset of the spreading and markedness constraint violations that (19b) does. Candidate (19d) can thus never be optimal under any ranking of these constraints. A candidate like (19a), with spreading to all segments, is the only one for which spreading can drive nasalization of the vowel following the stop. A grammar with this outcome is predicted by the factorial ranking hypothesis. Accordingly, I posit this as the basic analysis for languages with transparent segments in nasal harmony, and in the next section I explore how the optimal candidate in (19a) is mapped to the outcome in (19d) in an opaque constraint interaction.

We have now seen that exhaustive ranking of the spreading constraint in relation to the hierarchy of nasalized segment constraints derives precisely the hierarchical variation observed across languages. The unified typology is achieved through reduction to two basic kinds of constraints, spreading and nasal markedness, and two kinds of segment outcomes, permeated and blocking. A central claim underlying this typology is that descriptively transparent segments should be regarded along with targets as participants in nasal spreading. The analysis of transparent segments as participants is supported by the observations of crosslinguistic variation in nasal harmony on three fronts. First, the class of segments that may behave transparent are essentially in complementary distribution with those that may become nasalized in nasal harmony. Second, a system in which all segments including obstruents undergo nasalization is predicted under the factorial ranking hypothesis—positing transparent segments as participants fills this slot given by the hierarchy. Third, this analysis explains the generalization that whenever a segment behaves transparent to nasal spreading, all segments more compatible with nasalization are permeated by spreading—more compatible segments do not block. A more general grounding for the participation of transparent segments stems from the view that feature spreading is segmentally local. Section 4 focuses on a means of deriving the surface orality of transparent segments while maintaining the simple formulation of spreading and nasal markedness and the constrained view of strict segmental locality. In what follows I argue that transparent segments can be captured under the Sympathy approach to opaque constraint interaction (McCarthy 1997, with extensions by Itô and Mester 1997a), a mechanism with independent motivation in the theory.

4. Analysis of Transparency

A few different proposals have been made to preserve strict segmental locality for cases of apparent transparency, that is, where feature spreading appears to have skipped a segment. These proposals fall into two main directions. One line of research outlined above takes the position that in certain kinds of transparency, the relevant gesture is actually carried through the segment. I call this *false transparency*. This approach is taken by Ní Chiosáin & Padgett (1997, 1998) for transparent consonants in vowel harmony and by Gafos (1996) for transparency in coronal harmony (also Flemming 1995a; Ní Chiosáin & Padgett 1997). Further examples are discussed by McCarthy (1994), Padgett (1995a), and Walker & Pullum (1999). The false transparency accounts are unified by the claim that the spreading feature is compatible with the transparent segment.

A second kind of analysis addresses cases where the transparent segment seems to be realized with a feature specification truly opposing the spreading property. This type of transparency I will refer to as *antagonistic transparency* (after Archangeli & Pulleyblank 1994). Examples of this kind include certain transparent vowels in vowel harmony, for instance, nonlow front vowels transparent to [+back] harmony in Finnish (e.g. Ringen 1975, Kiparsky 1981). Transparent obstruents in nasal harmony also belong to this category—an instrumental study by Walker (1998) confirms the oral obstruent realization for voiceless stops that act transparent to nasal harmony in Guaraní. For cases of antagonistic transparency, it has been proposed that the transparent segments actually undergo spreading at some abstract level of phonological representation (see Clements 1976; Vago 1976; Piggott 1988; Walker 1996; Ní Chiosáin & Padgett 1997; among others). This abstract representation then forms the input to another level or rule at which point the transparent segment is changed to bear the opposite feature specification to the spreading one in order to resolve an incompatibility of feature specification.[13] This approach for nasal harmony is shown in (20), formalized in an SPE-style derivation for expositional simplicity.

(20)	Underlying representation (hypothetical form)	/ãrato/
	Nasal spreading (iterative): X → [+nasal]/[+nasal]__	ãr̃ãt̃õ
	Obstruent stop denasalization: [-son, -cont] → [-nasal]	ãr̃ãtõ
	Surface representation	ãr̃ãtõ

This kind of analysis calls on what has been called *derivational opacity* by Kiparsky (1973): the outcome of an early rule is reversed in the output—here the nasalization of the obstruent stop. As a result of the derivational opacity, a valid grammatical generalization in the language, namely that nasalization spreads through a continuous string of segments, is not surface-true. This approach differs from the false transparency proposals in two important ways. First, it assumes that in the output the transparent segment actually has a specification opposite to the spreading feature, i.e. it concedes transparency, and second, it makes use of an intermediate level of representation.

The previous proposals are not incompatible with each other, rather they have shown that apparent transparency may arise under two different sets of circumstances. Our concern lies with antagonistic transparency. I will argue that it is indeed correct that antagonistically transparent segments have a feature specification opposite to the spreading one in the actual output, but we need not call on a second level of input-output mapping or intermediate derivational step to achieve this result—it can be captured in a one-level framework by utilizing Sympathy theory.

4.1 *Transparency as a (Derivational) Opacity Effect*

An important result of the derivational opacity approach to segment transparency is that it preserves the strict segmental locality of spreading—the phenomenon of spreading carries a feature through a continuous sequence of segments. The discontinuity in the output comes about not through the satisfaction of spreading, but by an operation obscuring the outcome of spreading. In this it is consonant with a central finding of the unified typology of nasal harmony: transparent segments pattern with participants in nasal spreading.

The question we face is how to obtain this kind of derivational opacity effect in OT. It cannot be achieved by a simple ranking of the nasal spreading and markedness constraints, assuming a single level of input-output mapping. The problem is illustrated in (21) for a case of bidirectional spreading. The candidate in (21a) corresponds to the real outcome of a language with transparency (signalled by "☞"); however, it is not selected by this tableau. Instead, (21b), with blocking by the obstruent stop, is the one that is optimal according to this constraint ranking. (This wrong selected outcome is marked by "☹".) Under the reverse ranking of the constraints, (21c) would be the selected winner, with nasalization of all segments. Since (21a) incurs a superset of the violations incurred by (21b), no ranking of these constraints will select (21a) as optimal.

(21) Incorrect outcome for hypothetical form /ãrato/

	/ãrato/	*NASOBSSTOP	SPREAD(+nasal)
☞	a. [ãr̃ã]t[õ]		***!***
☹	b. [ãr̃ã]to		**
(❁)	c. [ãr̃ãt̃õ]	*!	

Candidates (21b) and (21c) represent more *derivationally transparent* alternatives—blocking or participation are the two basic outcomes for nasal harmony, as established in section 3. Note the overlap in descriptive terminology: derivational transparency vs. opacity describes whether valid grammatical generalizations are apparent in the output; segmental transparency vs. opacity (or blocking) describes different kinds of segmental behavior in harmony (as outlined in section 1).

It is of importance that derivational opacity effects exist independently in phonology and must be explained under any theory. In a study representing a significant advance in this area, McCarthy (1997) develops what is known as the 'Sympathy' approach to such phenomena in OT. The core idea underlying Sympathy is that faithfulness relations may exist between one candidate and another within a single candidate set. This co-candidate faithfulness relation establishes a correspondence mapping from a designated candidate in the evaluation set to a given output (see McCarthy & Prince 1995 on the model of the Correspondence Theory approach to faithfulness). Sympathetic faithfulness promotes an output form which resembles the designated candidate, that is, it favors an output which is in *sympathy* with a particular candidate. Importantly, only a single candidate set is utilized in determining the output, and so a single level of input-output mapping is maintained.[14] McCarthy shows that this strategy is capable of capturing a range of cases of derivational opacity that were previously problematic in OT. Examples of subsequent applications of sympathetic correspondence include Itô & Mester 1997, Davis 1997, Karvonen & Sherman 1997, Merchant 1997, Katayama 1998, de Lacy 1998, among others. (Itô & Mester also develop some extensions to McCarthy's original proposal that are discussed and utilized below.) I propose to draw on the Sympathy approach to explain antagonistic transparency, i.e. to achieve the derivational opacity in nasal harmony (and by extension to achieve antagonistic transparency in vowel harmony, though that will not be discussed here because of space limitations).

The application of sympathetic correspondence to segmental transparency is modeled in (22). The faithfulness of output candidates to the input are evaluated through Faith-IO (Input-Output) constraints. Here the input matches the underlying representation in the derivational approach in (20). Each representation produced at some stage of that derivation is included in the output candidate set. The candidate corresponding to the intermediate form with full spreading in (20) is designated as the sympathetic one in the evaluation set (marked by “❀”). Sympathetic faith constraints, abbreviated as Faith-❀O (after Itô & Mester 1997), enforce the resemblance of the actual output to this candidate. The actual output matches the surface representation in (20).

(22) Input: /ãrato/

FAITH-IO ⇗⇙ ⇖⇘

Output candidates: ã̃r̃ã̃t̃õ ⇔ ãr̃ãtõ

\\|// \|/ |

[+nas] [+nas] [+nas]

Sympathy candidate (❀) FAITH-❀O Actual output (☞)

In order for the sympathy candidate not to win itself, it must lose on the basis of some high-ranked constraint. This will be the constraint banning nasal obstruent stops, which plays the role of the obstruent stop denasalization rule in (20). The actual output is the candidate most closely resembling this candidate while still respecting *NASOBSSTOP.

It is important to note that all of the candidates being evaluated still respect locality, that is, a representation like that in (14), with gapping across a segment, is never generated or called on for comparison. The representation of the actual output has a separate [+nasal] feature specification on either side of the transparent obstruent. As observed in section 3, the actual output structure shown in (22) cannot be obtained directly from spreading. Spreading requires that each occurrence of a feature specification be linked to all segments in the word; it is not satisfied by candidates containing separate projected copies of that feature. The actual output is instead selected on the basis of its being the best possible match to the sympathetic candidate, with full nasal spreading.

Crucially, featural correspondence between the sympathetic fully nasalized candidate and the actual output is enforced by an IDENT[Feature] constraint, which requires not that features themselves have correspondents but that the featural properties of correspondent segments are identical (McCarthy & Prince 1995).

(23) IDENT-❀O[+nasal]
Let α be a segment in the sympathetic candidate and β be any correspondent of α in the output. If α is [+nasal], then β is [+nasal].

It is the IDENT-❀O correspondence relation for [+nasal] that produces the occurrence of separate [+nasal] features on either side of the transparent segment in the optimal output, that is, the optimality of the actual output in (22) is driven by its similarity in featural properties to the fully-spread sympathy candidate, even though the optimal output itself fares poorly with respect to spreading and involves introducing an extra [+nasal] feature. This result provides support for a view of featural faith mediated through segmental identity, given by the IDENT formulation.

An overview of the constraint ranking deriving segmental transparency through Sympathy is given in (24). The candidate with full nasal spreading (24a) is designated here as the sympathy candidate. This candidate loses in the contention for the optimal output, because it incurs a fatal violation of the constraint prohibiting nasalized obstruent stops. The next highest constraint is the sympathetic faith constraint requiring identity between the sympathy candidate (24a) and a given output in the [+nasal] property of segments. The form in (24c), which matches [+nasal] identity in all but [t], is the best of the candidates respecting *NASOBSSTOP on this faith constraint. The alternative in (24b) loses because in addition to [t], the next segment [o] is also oral. This extra IDENT-❀O faith violation is fatal, even though (24b) fares much better than (24c) on spreading.

(24) Overview of sympathy analysis of segmental transparency

	ãrato	*NASOBSSTOP	IDENT-❀O[+nasal]	SPREAD(+nasal)
❀	a. [ãr̃ãt̃õ]	*!		
	b. [ãr̃ã]to		**!	**
☞	c. [ãr̃ã]t[õ]		*	******

The tableau in (24) shows how sympathetic correspondence can achieve the effect of an opaque rule interaction of the type used to produce segmental transparency in spreading, while still maintaining a restrictive conception of locality, levels, and phonological constraints. Central to this account is the notion of a designated sympathy candidate. This will be the examined in the next section, which applies Sympathy to segmental transparency in Tuyuca.

4.2 Transparency in Tuyuca

Recall the interim result for Tuyuca from (19). SPREAD(+nasal) outranks all nasal markedness constraints to obtain permeability of all segments. The outcome of this ranking is repeated below.

(25) Tuyuca ranking from (19) (fewer candidates shown)

	wãti	SPREAD (+nasal)	*NAS OBSSTOP	*NAS FRIC	*NAS LIQUID	*NAS GLIDE	*NAS VOWEL
☞	a. [w̃ãt̃ĩ]		*			*	**
	b. [w̃ã]ti	*!*				*	*
	c. [w̃ã]t[ĩ]	*!****				*	**

The winner in (25a) is actually phonetically impossible—a nasalized obstruent stop cannot be pronounced with simultaneous implementation of all its features (see note 13). This output is thus not one that could ever be heard and reproduced by a language learner. However, the accessibility of candidate (25a) in phonology is made evident by its influence in the selection of the actual output in (25c)—a form that cannot be selected under any transparent ranking of these constraints. The strategy of the Sympathy-based analysis is thus to designate (25a) as the sympathy candidate and select (25c) as optimal by virtue of its resemblance to (25a). Because of space limitations, I focus only on the transparency of voiceless stops here. A parallel account will achieve the transparency for fricatives, and on the nasal outcome for voiced stops in nasal morphemes, see Walker (1998).

In designation of the sympathy candidate I follow the model of *Harmonic Sympathy* (Walker 1998), aiming to develop and explicate the *Selector-Constraint* version of McCarthy (1997) and the extensions proposed by Itô and Mester. In McCarthy's approach, he suggests that the sympathetic candidate is identified by being the most harmonic of the set of candidates satisfying some designated 'selector constraint'. Opacity effects arise when the sympathetic candidate fails as the actual output by incurring a violation of some constraint dominating the selector constraint. Under this approach it is SPREAD(+nasal) that would be the selector constraint in Tuyuca harmony. SPREAD(+nasal) screens out all but the fully spread form (25a) for sympathy status. McCarthy proposes to limit derivational opacity effects by restricting the potential for selector status to faithfulness constraints. However, this limitation turns out to be too restrictive. In their work on opacity in German truncations, Itô & Mester (1997) argue that it is necessary to allow other constraints, besides faithfulness, to serve as the selector constraint (see also de Lacy 1998). Itô and Mester find that for German truncations, an alignment constraint must be granted the selector role. They further note that since assigning selector status to a constraint amounts to inducing a separate optimization in which that constraint is top-ranked, and ranking variation is a basic element of OT, then 'the logic of OT itself compels us to expect other constraints in [the selector] role as well' (1997: 126-7, n. 12). The derivational opacity effect of segmental transparency lends support to Itô and Mester's claim, since alignment (driving spreading) again plays a selecting role in designating the sympathetic candidate. This important extension of McCarthy's original proposal is thus assumed in the analysis of segmental transparency below.

Harmonic Sympathy seeks to bring a firmer understanding to what brings about opaque constraint interactions and the privilege that the selector constraint holds. This approach focuses on the connection between derivational opacity and the resolution of constraint conflict through ranking in a hierarchy—fundamental elements of OT. The puzzle presented by many cases of derivational opacity is that in the absence of sympathetic correspondence, the appropriate outcome cannot be achieved under the normal ranking resolution of two conflicting constraints. In (21), for example, we saw that no simple ranking of SPREAD(+nasal) and *NASOBSSTOP can achieve segment transparency

—the dominated constraint loses absolutely. If *NASOBSSTOP outranks SPREAD(+nasal), the candidate with segment blocking wins, even though it is quite different from the one that would have been selected by SPREAD(+nasal). The interaction between these two constraints is in fact more complex. The fully spread candidate fails because of its nasalized obstruent stop, but were SPREAD(+nasal) to have won the day, this would be the most harmonic form. The tableau in (24) above shows that the candidate that would have been chosen if spreading had won the conflict influences the selection of the optimal output. Under the Selector Constraint approach to Sympathy, this more complex kind of constraint interaction would be produced by designating SPREAD(+nasal) as selector; however, I propose to eliminate the need for introducing a ‘selector’ status as a property assigned to some constraint, and instead make this role emergent of a segmented constraint ranking structure. To achieve this, I propose that a second type of constraint conflict resolution is possible: a conflict between two constraints can be resolved by bifurcating the constraint hierarchy at the point of conflict into two ranked segments, P1 and P2, as illustrated in (26). P1 is the higher segment, and it contains the constraint that is actually respected in the optimal output, in this case *NASOBSSTOP. Within the lower segment, P2, the competing constraint, here SPREAD(+nasal), is top-ranked, and it dominates its competitor in this subhierarchy.

(26) P1 >> P2
*NASOBSSTOP SPREAD(+nasal) >> *NASOBSSTOP >> NASFRIC >> *NASLIQ ...

The above represents an opaque resolution of constraint conflict through *hierarchy partitioning*. As the constraint that belongs to the dominating P1 component, *NASOBSSTOP is the one that triumphs in the conflict—it is respected in actual outputs. The conflicting spreading constraint, loses by virtue of its domination by the P1 segment, but it gains recognition in another respect. I propose that the candidate that is most harmonic with respect to the P2 hierarchy is the sympathy candidate via an *embedded optimization*. The high-ranking status of SPREAD(+nasal) in P2 thus allows its force to be reflected in selection of the sympathy form.

Let us examine the resulting organization of the grammar in (27). This tableau shows the partitioning of the phonological constraint hierarchy into two segments, as induced by the opaque resolution of the conflict between *NASOBSSTOP and SPREAD(+nasal). To conserve space *NASOBS collapses the individual nasalized obstruent constraints in P2 and *NASSON collapses nasalized sonorant constraints. The P1 segment is shaded here to focus on selection of the sympathy candidate in P2. Because the spreading constraint is top-ranked in this segment, the sympathy candidate will be (27a)—the one with full spreading. The result of this subhierarchical optimization is marked by the flower at the left of the P2 segment.[15]

(27) Selecting the sympathetic candidate via embedded optimization

	P1		P2		
wãti	*NASOBSSTOP		SPREAD(+nas)	*NASOBS	*NASSON
a. [w̃ãt̃ĩ]	*	❁		*	***
b. [w̃ã]ti			*!*		**
c. [w̃ã]t[ĩ]			*!****		***

The full tableau selecting the (derivationally) opaque optimal output is exhibited in (28). Since the sympathy candidate violates *NASOBSSTOP, it falls out of the running for the optimal output early. Candidates (28b-c) survive *NASOBSSTOP and fall to IDENT-❁O[+nasal]. This chooses (28c) over (28b), because (28c) more closely resembles the sympathy candidate.[16]

(28) Transparency in Tuyuca:

		P1			P2		
	wãti	*NASOBSSTOP	IDENT-❁O[+nas]		SPREAD(+nas)	*NASOBS	*NASSON
	a. [w̃ãt̃ĩ]	*!		❁		*	***
	b. [w̃ã]ti		**!		**		**
☞	c.[w̃ã]t[ĩ]		*		*****		***

Descriptively speaking, the opaque resolution of constraint conflict means that the top-ranked constraint (*NASOBSSTOP) wins in selection of the actual output, but the losing constraint, SPREAD(+nasal), otherwise conditions selection such that the output resembles as closely as possible the candidate that would have been chosen if spreading were respected. The hierarchy partitioning is what enables selection of the sympathy candidate and it is the placement of sympathetic faith between the two opaquely interacting constraints that achieves the influence of the sympathy candidate in selection of the actual output. The organization that I assume locates sympathetic faith in P1. P2 then functions as an embedded optimizer for the sympathy candidate, and the P1 and P2 segments together compose the phonological grammar. It should be noted that the preliminary tableau in (27) is shown separately for expository purposes only; the tableau in (28) represents the complete evaluation. This evaluation involves two optimizations, an embedded one with respect to P2 and one with respect to the entire hierarchy.[17] Selection of the sympathy candidate and the optimal output is performed in parallel evaluation with a single input-output level.

Observe that in a nasal morpheme containing only sonorants, the actual output will incur no Faith-❀O violations. In forms of this type, the sympathetic candidate coincides with the actual output. This is illustrated in (29) for the Tuyuca form [j̃õr̃ẽ] 'little chicken'.

(29) Full spreading with no obstruents: sympathetic candidate is same as actual output

		P1			P2		
	jõre	*NASOBSSTOP	IDENT-❀O[+nas]		SPREAD[+nas]	*NASOBS	*NASSON
☞	a.[j̃õr̃ẽ]			❀			****
	b.[j̃õ]re		*!*		**		**
	c.j[õ]re		*!**		***		*
	d.[j̃õ]r[ẽ]		*!		*****		***

An important achievement of the account proposed here is that it does not make use of a transparency-specific configuration such as gapping to produce segmental transparency. It preserves the strict segmental locality of feature linking representations and obtains apparent skipping effects by calling on the notion of Sympathy, an approach to derivational opacity effects with extensive independent motivation in the theory. The analysis draws on the innovations of McCarthy's sympathetic correspondence relation and Selector Constraint model of sympathy along with developments by Itô and Mester, but makes some modifications in implementation. The hierarchy partitioning in the Harmonic Sympathy model essentially serves as a spell-out of what is entailed by selector constraint status. The two approaches share the idea that selection of the sympathy candidate involves an optimization corresponding to a constraint ranking differing in some respect from that selecting the actual output. Harmonic Sympathy casts insight on the basis of the sympathy optimization by making a direct connection with the structure of the strictly ranked constraint hierarchy—the sympathetic candidate is selected through an embedded optimization with respect to a contiguous segment of the constraint hierarchy—selector status itself is obviated in the theory. It is interesting to note that the principle of *base optimization* discussed by Alderete (1999) draws on some related mechanisms to those at work in the embedded optimization for Harmonic Sympathy. Base optimization chooses as the base for output-output (OO) correspondence the word which leads to the most harmonic base-output pair with respect to the constraint hierarchy. Both the OO base optimization and embedded sympathy optimization share the notion that the constraint hierarchy is used to identify the base for a correspondence relation. Base optimization calls on the entire hierarchy, while the embedded optimization draws on a partitioned segment.

Interestingly, the Harmonic Sympathy structure illuminates opaque constraint interactions involving implicational constraint hierarchies. Since selector status can in principle be assigned to any constraint (following Itô & Mester 1997), it is possible to lose the effect of fixed rankings in a constraint family by designating a lower ranked constraint as selector and inducing an optimization in which it is top-ranked in selection of the sympathy candidate. This clearly has the potential to produce undesirable results (see Walker 1998 for exemplification). On the other hand, in Harmonic Sympathy, the ranking for evaluating both the actual output and the sympathetic candidate is spelled out in the constraint hierarchy. Fixed rankings can thus be maintained if universal constraint hierarchies are interpreted as requiring that wherever a constraint is located in the hierarchy for a given grammar, it must be dominated by some occurrence of each of the constraints dominating it in a universal hierarchy. This offers a direct explanation of how the appropriate implications are to be maintained in opaque constraint interactions.

This section has established how antagonistic transparency can be captured in OT via the model of Harmonic Sympathy. Importantly, the Harmonic Sympathy approach achieves this outcome while maintaining strict segmental locality as a universal of phonological representations. The final section recapitulates the typological results established earlier and addresses the issue of limiting factors in derivational opacity effects.

5. Conclusion and Further Issues

Let us review the results obtained by this account of nasal harmony. First, the account proposed here achieves a unified typology of nasal harmony while at the same time maintaining a very simple and constrained conception of the constraints and locality. Spreading is produced by the extension of a feature, representing a unitary and continuous property, across a sequence of segments. Blocking effects in spreading come about when a nasalized segment constraint outranks spreading, and in turn, permeation results when spreading dominates nasal markedness. An intrinsic ranking holding over the nasal markedness constraints captures the hierarchical implications across languages in the sets of segments permeated by or blocking nasal spreading. The typology of nasal harmony is achieved by factorial ranking of the spreading constraint (in P2) in relation to the fixed nasalized segment constraint hierarchy. For all but obstruent stops, evidence for the violability of the nasalized segment constraints is seen in the actual outputs of various languages with nasal harmony. In the case of obstruent stops, it is physically impossible to produce audible nasalization simultaneous with a burst; these segments thus must sacrifice some property in their output realization—they are either oral obstruents or nasal sonorant stops. As a consequence, when obstruent stops actually undergo nasal spreading, they must map to a pronounceable output—a mapping achieved through an opaque constraint interaction utilizing sympathetic correspondence. When a nasalized stop is mapped to an oral obstruent, the result is segmental transparency. This outcome is achieved through reference to a candidate where nasalization has spread to all segments, including obstruent stops. The approach thereby obviates any need for ad hoc transparency-specific representations and brings antagonistic transparency under the wing of widespread derivational opacity. Economy of analysis alone thus argues for treating true segmental transparency as a derivational opacity effect. Other considerations also support this move, such as the typological evidence of co-patterning between targets and transparent segments, the motivation from studies of other harmonies for strict segmental locality in feature linking, and a simple view of spreading as gesture extension.

At this point I turn to the matter of restricting the extent of derivational opacity effects. It is reasonable to question why transparent segments in nasal harmony are restricted to segments near the extreme of incompatibility with nasalization (i.e. obstruents). For example, what rules out a language in which only vowels are targeted and all consonants behave transparent? I suggest that acquisitional factors underlie the relatively rare outcome of segment transparency in contrast to blocking as well as the limitation of segment transparency to classes of segments near the extreme of incompatibility with nasalization. In his discussion of derivational opacity, Kiparsky (1971, 1973) proposes that opaque grammars are marked in the sense that they are harder to learn and the direction of language change will be towards derivational transparency. The sympathy account of derivational opacity lends insights to Kiparsky's claims: an opaque constraint interaction is more complex than a transparent one because it involves computing an extra optimization, namely, the embedded optimization selecting the sympathy candidate. This, in itself, predicts that segment blocking (arising from a transparent constraint interaction) will be more common than segment transparency (realized through an opaque interaction) in spreading, and this generally seems to be borne out.

In addition to representing the increased complexity of derivational opacity, sympathetic faith also gives us a means for evaluating the degree of difficulty for learning a particular opacity effect. I propose that the greater the gap between the sympathetic output and the actual output, the harder the language will be to learn, that is, grammars with more sympathetic faith violations are more difficult to acquire than ones with fewer violations. Coming back to nasal harmony, this means that grammars with fewer transparent segments will be easier to learn. A language in which all consonants behaved transparent would be difficult to acquire because of its much greater potential for difference between the sympathetic output and the actual output. This view provides explanation for the tendency for opaque interactions to occur with nasalized segment constraints ranked at the high end of the hierarchy. If P1 contains just one or two nasalized segment constraints, it will be those banning nasalized obstruents. As more nasalized segment constraints from the hierarchy are added to P1, the potential for sympathetic faith violations in the actual output increases, making the learning task more demanding. The possibility of a language with a larger set of transparent segments in nasal harmony is thus not excluded absolutely, but the probability of their occurrence is much reduced.[18] More generally, acquisitional factors will favor smaller P1 segments in grammars with opacity effects. These acquisitional dimensions of derivational opacity lend insight to the limited occurrence of segment transparency in the typology of nasal harmony. The acquisition of derivational opacity effects is undoubtedly deserving of more detailed study, and further research could productively be directed to investigating this area.

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1 The above analysts vary in their treatment of laryngeals. See Walker (1998) and Walker & Pullum (1999) for a review of the issues and a proposal to situate them near vocoids in the hierarchy (note also Boersma 1998).

2 Certain Bantu nasal alternations are not included (Ao 1991; Odden 1994; Hyman 1995; Piggott 1996). See Walker (1998) for arguments that these result from cooccurrence prohibitions, not spreading of [nasal].

3 Nasal harmony in Applecross Gaelic presents further complexities that are not relevant to the basic typological categorization here. For fuller discussion, see Ternes (1973), van der Hulst & Smith (1982), and Walker (1998).

4 The transcriptions in (5) follow Ternes, who asserts that fricatives become nasalized in nasal spreading and remain fricated. For a review of the evidence for nasalized fricatives, see Cohn (1993a), Ohala & Ohala (1993), Walker (1998, §2.4), and references cited therein.

5 Independent evidence for initial syllable privilege in Tucanoan languages comes from a dialect of Orejon (Arnaiz 1988 cited by Pulleyblank 1989), where nasality in vowels clearly originates in the first syllable.

6 Aspects of the variable dependency approach are further developed and modified by Piggott (1996, 1999) and Piggott & van der Hulst (1997) in connection with a proposal that harmony with transparent segments involves [nasal] spreading at the level of the syllable rather than the segment. However, the central drawbacks for this line of explanation remain: it retains the assumption of variable dependency and fails to achieve a unified account for the complementary patterns. Boersma (1999) proposes a different approach to Piggott's "Type A" and "Type B" harmonies, but his account still analyzes the patterns with transparency as a separate type of nasal harmony.

7 I characterize the feature [nasal] as binary, but whether it is treated as privative or binary does not signify here.

8 Note that liquids such as [l] or trilled [r] might arguably be treated as [-continuant]; however, these would be distinguished from the oral counterparts of nasal stops in the manner feature characterizing the liquid.

9 The relatively high placement of laryngeals [h, ʔ] in the nasal compatibility scale (see note 1) also signals a difference between the scales, since laryngeals might well be considered to have a low sonority. See Boersma (1998, 1999) for discussion on this point (also Walker 1998).

10 Walker (1998) notes some language-particular variability in the ranking of voiceless fricatives and voiced stops in the nasalization hierarchy that seems to mirror variability in the sonority scale (Hooper 1972; Steriade 1982). This parallelism also might reasonably have a common basis: both continuancy and voicing increase sonority in obstruents and favor nasality; languages appear to vary in judging which property makes a greater contribution.

11 The following tableaux show the evaluation of candidates for a plausible input form. The input that corresponds to the actual underlying representation is determined by Lexicon Optimization (Prince & Smolensky 1993).

12 The tableaux displayed here show the core constraints interacting in the propagation of nasal harmony. There are, of course, other constraints that contribute to the selection of an overall well-formedness of the optimal output. For example, faithfulness for the feature [nasal] (IDENT(+nasal)) prevents nasality from being eliminated altogether from the input nasal stop (or vowel).

13 In vowel harmony, the spreading feature is crosslinguistically dispreferred when realized in combination with the segments behaving transparent (e.g. in Finnish transparency avoids realizing [ɯ], [ɤ]). In nasal harmony it is clear that transparency of stops is driven by the extreme incompatibility of nasalization with obstruents. While analysts differ to some extent on the precise characterization of the property defining an obstruent stop, all agree that at least in buccal segments (those articulated forward of the place where the velic valve joins the nasal and oral cavities) it is incompatible with a velic opening (see, e.g., Chomsky & Halle 1968; Ohala & Ohala 1993; Steriade 1993).

14 Cf. Walker (1996) and Ní Chiosáin & Padgett (1997), who propose a second level of input-output mapping with

generation of a second evaluation set. The Sympathy approach eliminates the need for this second level.

15 Since fricatives also act transparent, *NASFRIC will also appear in P1, but I abstract away from that detail here.

16 Because of space limitations, attention is restricted here to only a few candidates. I assume that the alternative [w̃ãni] loses on IDENT-❁O[±voice] and [w̃ãn̥i] is ruled out by a constraint against voiceless nasals that is undominated in Tuyuca. More generally across languages the nonoptimality of these candidates can be understood (at least in part) in terms of their significant weakening/loss of contrast between the series of stops (for some further discussion on this point see Walker 1998: 115-6). Note that in some languages an alternation between voiceless obstruent stops and nasals can occur to a limited extent in functional morphemes, which are typically more susceptible to neutralization of contrast. Robboy (1987) reports that in Guaraní nasal harmony a dative clitic postposition exhibits an alternation between [-pe] and [-mẽ]. This type of alternation does not take place, however, in roots of the language.

17 Note that the occurrence of *NASOBSSTOP in P2 is not crucial in this particular form; however, in various derivational opacity effects it is evident that the winning constraint (the one in P1) contributes to selection of the sympathy candidate, although in this it is dominated by the conflicting constraint top-ranked in P2 (see e.g. Itô & Mester 1997, Walker 1998). An equivalent result is achieved under McCarthy's Selector Constraint model. Evidence from nasal harmony is discussed in a study of nasalization spreading across morpheme boundaries in Tuyuca (Walker 1998). In cross-morpheme spreading, obstruents act as blockers and sonorants become nasalized. *NASOBSSTOP thus contributes to selection of sympathy candidate in morphologically complex forms; it is dominated by the constraint driving morpheme-internal spreading but in turn outranks cross-morpheme spreading.

18 See also Walker (1998:156) for an argument that a grammar with transparent approximants is also difficult to acquire for perceptual reasons.

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