Towards a Typology of Disharmony

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We propose an OT-theoretic typology of vowel harmony systems based on a comparative study of front/back harmony. Its treatment of neutral vowels improves on those offered by sympathy, turbidity, and targeted constraints.

1 Harmony

1.1 Balto-Finnic vowel harmony

The scope of a harmony process in a language is determined by its phonological system.[1] Specifically, cross-linguistic analysis reveals two generalizations that connect vowel harmony processes to vowel inventories. The first generalization is that harmony spreads a feature to the fullest extent that the vowel system allows: morphological restrictions aside, *all* lexically contrastive vowels participate unless some constraint on the distribution of the harmonic feature prevents it. The second generalization is that *only* lexically contrastive vowels participate in vowel harmony, or, to put it another way, lexical harmony is typically *structure-preserving*, in the sense that it introduces no new vowel types.[2]

For example, the fact that *i* and *e* do not become **ɨ* and **õ* (back *i* and back *e*) in back harmony contexts in Finnish is connected with the fact that **ɨ* and **õ* are not phonemic in the language, as we can tell independently from the fact that they do not occur in initial syllables, which display the language's full set of vowel contrasts. Votic and South Estonian, closely related languages which do have *e*∼*õ* harmony, have phonemic /õ/, which is distinctive in initial syllables.

These two generalizations hold for all front/back harmony systems that we know of. All Balto-Finnic languages, at least, obey in principle the same front/back harmony constraint. Their actual harmony patterns vary quite widely, according to how they interact with other constraints. Wiik 1988 documents seven vowel systems in Estonian dialects, and harmony operates to the fullest extent in each. All seven of these vowel systems are also instantiated outside of Estonian in other Balto-Finnic languages, and in all of them too harmony operates to the fullest extent. The following table summarizes the data.

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[2]This second generalization has apparent exceptions. Some are clearly due to an overlay of postlexical harmony (Kiparsky 1985) or to local assimilation processes. For example, in Eastern Khanty **ɨ* and **õ* are not phonemic, and do not undergo vowel harmony, but they arise as allophones of /i/ and /e/ by assimilation in certain back contexts. Whether all apparent exceptions to the generalization can be explained away remains to be seen, of course.

[1]

Balto-Finnic	Estonian	Initial syllables	Non-initial syll.	Harmonic alternations
East Votic	N. Seto	*u o a ü ö ä i e õ ɨ*	*u o a ü ö ä i e õ*	*u∼ü, o∼ö, a∼ä, e∼õ*
Votic dial.	S. Seto	*u o a ü ö ä i e õ ɨ*	*u o a ü ä i e õ*	*u∼ü, a∼ä, e∼õ*
Finnish	N.E.	*u o a ü ö ä i e*	*u o a ü ö ä i e*	*u∼ü, o∼ö, a∼ä*
West Votic	N.Tarto	*u o a ü ö ä i e õ ɨ*	*u o a ä i e õ*	*a∼ä, e∼õ*
Enarve Veps	S.W.	*u o a ü ö ä i e õ*	*u a ü ä i e*	*u∼ü, a∼ä*
Veps dial.	Western	*u o a ü ö ä i e õ*	*u a ä i e*	*a∼ä*
Livonian	Northern	*u o a ü ö ä i e õ*	*u a i e*	---

At one extreme, Eastern Votic and the Northern Seto dialect of Estonian have the four harmonic pairs /a∼ä, õ∼e, o∼ö, u∼ü/ plus unpaired /i/ (Kiparsky and Pajusalu MS). At the other extreme are Livonian and Northern Estonian, with their restricted inventory of non-initial vowels, which permits no harmony whatever. As Wiik points out for Estonian, and is confirmed by the other Balto-Finnic languages, the intermediate inventories obey a partial hierarchy *ä* ≻ *ü/õ* ≻ *ö*: any dialect that has vowel harmony at all has at least *a∼ä* harmony; in addition possibly *u∼ü* and/or *e∼õ* harmony; and if one of these, then possibly *o∼ö* harmony. Wiik also observes that these implicational relationships reflect general markedness asymmetries. For example, the generalization that every front/back harmony system has at least *ä:a* harmony reflects the fact that frontness is more compatible with lowness than with rounding, so that *ä* is less marked than *ö, ü*.

Taken together, these two generalizations suggest that a harmony system can be understood as a resolution of the conflicting claims of a very general process which spreads a feature, and specific constraints which neutralize that feature.

The vowel inventory, and consequently vowel harmony, is determined by the interranking of neutralization constraints with antagonistic faithfulness constraints.

1.2 Neutral vowels

By definition, vowels (or more generally, segments) are NEUTRAL if they do not undergo harmony. A vowel fails to undergo harmony when its harmonic counterpart is prohibited, either in the inventory of phonemes (context-free neutralization) or by a distributional restriction (positional neutralization), e.g. the absence of non-initial *ɨ* in Southeastern Estonian.

Although the basic account of disharmony is quite simple, the behavior of neutral vowels shows some interesting complications, and these form the main topic of our investigation. Neutral vowels differ in how they combine with harmonic vowels. The fundamental division among neutral vowels is between OPAQUE vowels and TRANSPARENT vowels. Opaque vowels are defined as those which interrupt harmony and initiate a new harmonic domain, and transparent vowels are those which are "skipped" by harmony.[3] From a theoretical point of view, opaque vowels do not seem very problematic, for two reasons. In the first place, their behavior is quite uniform, and secondly, this behavior follows a pattern of minimizing harmony violations which can be readily characterized by almost any OT-based approach.

The very existence of transparent neutral vowels, on the other hand, immediately raises a theoretical puzzle: why should the doubly disharmonic *. . . a. . . i. . . a. . .* ever be preferable to

[3]Harmonic transparency and opacity in this sense should be distinguished from derivational transparency and opacity, arising from feeding/bleeding and non-feeding/non-bleeding interactions between constraints, respectively (as well as from other causes). Confusingly, harmonic transparency creates derivational opacity, and harmonic opacity creates derivational transparency, as we shall see directly below.

. . . a. . . i. . . ä. . ., which has just one disharmonic transition? The term “transparent” reflects the powerful intuition, which has guided many an analysis in different ways, that the effect of harmony somehow reaches “across” this kind of neutral vowel. But how can such apparent “action at a distance” be reconciled with the principle of locality on which so many fundamental results in phonology depend? This has been one of the central issues about vowel harmony from the beginning, and has become more urgent still with the advent of OT (Bakovic 2000, Ní Chiosáin and Padgett 2001).

The division of neutral vowels into opaque and transparent vowels, on the basis of whether they trigger harmony or not, only begins to scratch the surface. The harmonic permeability of neutral vowels is manifested in remarkably diverse ways. There are at least as many kinds of neutrality in phonology as there are in international relations. The boundary between them is complex, and various kinds of mixed behavior occur. Some vowels are neutral stem-internally but trigger harmony in morphologically derived environments, others do not. More subtly, some actually *prefer* disharmonic combinations, others prefer harmonic combinations, and which way the preference goes can itself depend on whether the environment is derived or not. Moreover, if there are several transparent vowels, they may diverge in respect to these properties.

All this variation is neither random nor simply a gradient matter of “degree of transparency”. We will present evidence for strict generalizations, both absolute and implicational, and propose explnations for them. One of the central results of OT phonology is that many categories previously posited as primitive emerge from the interaction of independently motivated constraints. The best-known example is the foot inventory previously postulated in the theory of stress and prosodic morphology, which has been argued to be derivable from constraints on prosodic form (see Kager 1999, Ch. 4 for a clear exposition). Similarly, we think that the complex patterns of disharmony follow from the same kind of interplay of faithfulness constraints with context-free and context-sensitive markedness constraints that governs harmony itself.

2 Disharmony

2.1 The typology of neutral vowels

Cross-linguistically, so-called transparent vowels may differ with respect to the context in which neutralization occurs. They may be context-freely neutral, or participate in harmony in some contexts while being neutral in others, or finally be idiosyncratically neutral. Contextual neutrality may be determined prosodically (for example, initial/stressed vs. non-initial/unstressed position) or by the harmonic context. For example, in Southern Vepsian (Wiik 1989) and in the South Estonian Mulgi dialect (Tanning 1961:33), *u* is neutral after vowels of unlike height ([. . . ä. . . u. . .] versus *[. . . ä. . . ü. . .]) but harmonic otherwise (*[. . . u. . . ü. . .], *[. . . ü. . . u. . .]), whereas *a* is always harmonic.[4] Because of such contextual neutralization, a vowel may be neutral even if it has a harmonic partner in the language’s inventory: the relevant notion of contrast is a *contextual* one.

On the basis of our study of front/back harmony, we propose three typological generalizations.

Unmarkedness. Neutral vowels bear an unmarked value of the harmonizing feature, in virtue of suppression of the contrast, either by a context-free feature co-occurrence constraint, or by a

[4] *i. . . a* is retained, as in *minnas* ‘go’ (cond.), except in the context of palatalized consonants (e.g. Transl.Pl. *iḽḽä-ksi* ‘quiet’); contrast *jää-nü* ‘stayed’ *müü-dä* ‘sell’.

prosodically or segmentally defined contextual neutralization. For example, the unmarked value of backness is [–Back] for unrounded nonlow vowels, and [+Back] for other vowels. For front/back harmony systems, therefore, neutral vowels can be one of *i, e, a, o, u*, but not *ɨ, õ, ä, ö, ü*. In Seto, we have already seen that *i, e, o* can be neutral vowels (and even its other two unmarked vowels *a, u* can be neutral in certain cases, as we shall see).

Uniformity. All neutral vowels with a given value [αF] of the harmonic feature will be either opaque or transparent. In Seto, for instance, the [–Back] neutral vowels are all transparent, and the [+Back] neutral vowels are all opaque, a generalization which will be confirmed as examine the whole system and find more instances of each type.

Asymmetry. Transparent vowels have a predictable feature value; in front/back harmony systems it [–Back].

In what follows we map out the space of variation and model it by an OT factorial typology, whose leading idea is that the category of "neutral segment" in all its variety arise from the competition between contextual constraints and feature co-occurrence constraints.

2.2 Markedness and faithfulness

The markedness constraints that govern harmony are of two types: *featural markedness constraints*, and context-sensitive *combinatoric* constraints. The ranking of these constraints with respect to faithfulness constraints determines the inventory in a particular position or context.

[2] Featural markedness constraints

a. $\begin{bmatrix}\text{–Lo}\\\text{–Rd}\end{bmatrix} \Rightarrow$ [–Bk]: If a vowel is nonlow and unrounded, it must be front. This constraint will be mnemonically referred to as **ɨ,*õ*.

b. [–Bk] $\Rightarrow \begin{bmatrix}\text{–Lo}\\\text{–Rd}\end{bmatrix}$: If a vowel is front, it must be nonlow and unrounded (mnemonically: **ä,*ö,*ü)*.

The implicational format in [2] is chosen over the simple co-occurrence format (such as *[–Lo,–Rd,+Bk], *[+Lo,–Bk], *[+Rd,–Bk]) in order to preclude satisfaction of the constraints by vowels that are simply underspecified for one of the features. In order to conform to the implicational constraints [2a,b], vowels must be positively specified for the required feature value. Of course, if other constraints or principles (such as the constraint SPECIFY proposed by Ringen and Heinämäki 1999) rule out underspecified vowels, we may reinstate the simple co-occurrence restrictions. Either way, the important point is that underspecification plays no role in our solution. Every underspecified output candidate succumbs to a more harmonic fully specified candidate, and for every underspecified input, the optimal output candidate is a fully specified well-formed possible word of the language. Let us add that this does not necessarily mean that we consider an underspecification analysis of harmony unfeasible, or undesirable. Our aim is simply to present a coherent account of vowel harmony without using underspecification, not to assess the complex issues raised by the alternative.

The featural markedness constraints in [2] should probably be further decomposed. As mentioned, *ä* is less marked than *ü, ö,* which suggests that [2b] conflates two constraints **ä* and **ö,*ü*, of which the latter universally ranks higher. Insofar as other constraints intervene between them, splits such as those noted above for Southern Vepsian and Mulgi will result.

The combinatoric markedness constraint that drives harmony is stated in [3].

[3] Combinatoric markedness constraint

AGR(F): Adjacent segments must have the same value of the feature [F] (Bakovic 2000:4, cf. Krämer 2000).

In the languages studied here, [F] = [Back], but the same constraint holds for any harmonic feature.
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We also require the two familiar faithfulness constraints in [4].

[4] Faithfulness constraints

a. IDENT-σ_1(Back): An [αBack] input segment in a stem-initial syllable must not have a [$-\alpha$Back] output correspondent). (Positional Faithfulness, Beckman 1998).

b. IDENTSTEM(Back): An [αBack] input segment in a stem must not have a [$-\alpha$Back] output correspondent). (Note that this is an ordinary I/O faithfulness constraint, *not* the Output/Output constraint SA-IDENT(F) proposed by Bakovic 2000:23).

These faithfulness constraints become visible in a language when they dominate some markedness constraint, such as [3] AGR(Back). They determine two controlling ("triggering") environments in harmony systems. One is the *first* vowel of the harmonic domain, which is singled out by the constraint [4a] IDENT-σ_1(Back). The privileged status of the word-initial syllable established by IDENT-σ_1(Back) means two things: it is a trigger of harmony, and it is the position of maximal contrast (even independently of any harmony). The effects of this constraint are visible in all the languages that we are concerned with. Certain contrasts in the harmonic feature are suppressed in non-initial syllables, regardless of the morphological makeup of the word.

The second controlling environment is the STEM. The faithfulness constraint [4a] that ensures this is [4b] IDENTSTEM(Back). Like IDENT-σ_1(Back), IDENTSTEM(Back) has two functions. When stem and affix have distinct harmonic values, it causes the value of the stem to prevail. And it accounts for the "derived environment" asymmetries commonly seen in harmony systems. The overarching generalization here is that harmonic constraints are more severe in derived environments than stem-internally. For example, in Finnish, affixes are fronted after all-neutral stems: *si-nä* 'it (essive)' *viit-tä* 'five (abessive)'. But within simple stems, back and front harmonic vowels contrast after neutral vowels: *siä* 'you', *kina* 'squabble', *viitta* 'cloak', *riittä-* 'suffice'.[5]

In a suffixing language such as Finnish, the effects of the two constraints IDENTSTEM(Back) and IDENT-σ_1(Back) overlap significantly. Still, even though the privileged status of the initial syllable determined by IDENT-σ_1(Back) is normally not detectable, it can be seen in loanword adaptation, by a kind of Emergence of the Unmarked. The following data from Finnish show that the first vowel prevails:[6]

[5] Vocalic affixes after monosyllabic roots act like stem-internal vowels: *pes-u* 'washing', *tiet-o* 'knowledge', *el-o* 'living'.

[6] When the initial syllable is stressed, as in the languages considered here, the effect of IDENT-σ_1(Back) is indistinguishable from faithfulness to stressed syllables, which raises the question whether the former could be reduced to the latter. But Turkish, in spite of its word-final stress, shows the same special status of initial syllables, an indication that IDENT-σ_1(Back) is not reducible to faithfulness to stressed syllables.

[5] a. *Peugeot* → *pösö* (not **poso*)

b. *olympialaiset* → *olumpialaiset*, *trotyyli* → *rotuli*, *pulityyri* → *pulituuri*

2.3 Varieties of neutrality

Before completing the constraints let us review the typological space of neutral vowel behavior descriptively. To fix the behavior of an [αF] neutral vowel, we must know three things: whether it transmits [$-\alpha$F] harmony, whether it transmits [αF] harmony, and whether it triggers [αF] harmony on its own. None is entirely predictable from any of the others, but there are many implicational regularities. To schematize the typology for front/back harmony, we symbolize transparent vowels by *i*, back harmonic vowels by *a*, and front harmonic vowels by *ä*, and assume left-to-right harmony in virtue of [4], as in all the languages in our sample.

- *Transparency to back harmony.* Is . . . *a*. . . *i*. . . *ä*. . . excluded?
- *Transparency to front harmony.* Is . . . *ä*. . . *i*. . . *a*. . . excluded?
- *Triggering of front harmony.* Is . . . *i*. . . *a*. . . excluded?

The table in [6] maps out the different ways in which the Finno-Ugric languages treat these situations. There are eight logically possible combibations, of which the four represented by shaded rows are not instantiated.

[6] The differentiation of neutral vowels in derived environments:

	[[ä] a]	[[a] i]	[[a i] ä]	[[ä i] a]	[[i] a]
a. Finnish	*	✓	*	*	*
b. Uyghur, W Estonian	*	✓	*	*	✓
c. (Unattested)	*	✓	*	✓	*
d. Enarve Vepsian, Mulgi	*	✓	*	✓	✓
e. Khanty, NE Estonian	*	✓	✓	*	*
f. (Unattested)	*	✓	✓	*	✓
g. (Unattested)	*	✓	✓	✓	*
h. (Unattested)	*	✓	✓	✓	✓

Each column in the table represents a type of disharmony.[7] The stars in the first column diagnose harmony itself: if a language does not bar sequences of disharmonic vowels in adjacent syllables it does not have harmony at all. The check marks in the second column diagnose neutrality: if a language does not allow such sequences of syllables it does not have neutral vowels at all. The last three columns of [6] represent the three critical diagnostics just listed that establish the descriptive typology of neutral vowels. Since harmony is often suspended inside stems by the faithfulness constraint [4b] — to which we will return in a moment — we consider here the derived environment case (as shown by the brackets), in order to cast our net as wide as possible.[8]

[7]The table is based on Wiik 1988, 1989 plus the following: our interpretation of the data in Must 1995 (NE Estonian texts, see esp. p. 22), Juhkam & Sepp 2000 (Western Estonian texts), and Tanning 1961 (texts in the Mulgi dialect of South Estonian), the generative analyses of Uyghur vowel harmony by Lindblad 1990 and Vaux 2000, and the painstaking descriptive study of vowel harmony in Karjalainen's Eastern Khanty texts by Vertes 1977.

[8]In Seto, for example, front neutral vowels combine with back vowels within stems; the combination is starred in the last column of the table because *suffixal* vowels are always fronted after neutral-vowel stems.

In all the languages, the vowel *i* is neutral (unpaired); in some also *e* is neutral.[9] But these neutral vowel behave differently as shown. For example, Uyghur has back vowel endings in both *yol-imiz-Ka* 'our road-dat' and *sinip-ta* 'class-loc' (Vaux 2000), where Finnish treats the corresponding configurations differently, e.g. *sot-i-mis-ta* 'warring-part' versus *sinis-tä* 'blue-part'.

We will proceed on the assumption that the four unattested systems in [6] are systematic gaps, for two reasons. First, the attested types are predicted by constraints that are motivated independently of the workings of harmony systems, while the missing types would require additional otherwise unnecessary complications. Secondly, a similar typology seems to holds for ATR harmony. At least three of the four types that we find in back/front harmony occur also in ATR harmony, and none of the four types missing in back/front harmony are instantiated in ATR harmony, as far as we know. Wolof (Ka 1994, Archangeli & Pulleyblank 1994) is an analog to Finnish, and Turkana (Noske 1990) and Shilluk (Gilley 1992) are comparable to Uyghur and Eastern Khanty, respectively (in the relevant respects, of course).

We propose that the basic typology results from the intersection of two binary properties.

The first binary property distinguishes Finnish and Eastern Khanty from Uyghur and Vepsian. In Finnish and Eastern Khanty, all-neutral contexts trigger harmony (in derived environments), in Uyghur and Vepsian they do not. Alternative rankings of the two previously introduced constraints [2b] *ä, ü, ö* and [3] AGR(Back) generate this part of the typology. Uyghur and Vepsian prefer to avoid the marked vowels *ä, ü, ö*. In Finnish and Eastern Khanty, avoiding the marked vowels vowels *ä, ü, ö* is less important than eliminating even mildly disharmonic vowel combinations. In terms of constraint ranking:

[7] a. Finnish, Eastern Khanty: AGR(Back) ≫ **ä,*ö,*ü*

b. Uyghur and Vepsian: **ä,*ö,*ü* ≫ AGR(Back)

[8]

Finnish		…	AGR(Back)	**ä,*ö,*ü*	…
[i] a	i a		*		
☞	i ä			*	
[i] ä	i a		*		
☞	i ä			*	

[9]

Uyghur		…	**ä,*ö,*ü*	AGR(Back)	…
[i] a ☞	i a			*	
	i ä		*		
[i] ä ☞	i a			*	
	i ä		*		

This a very simple illustration of how the typology of neutral vowels reflects alternative resolutions of the conflict between syntagmatic constraints (such as AGR(Back)) and paradigmatic constraints (such as **ä,*ö,*ü*).

[9] Both languages present interesting complications which we set aside here. As mentioned, in Eastern Khanty, an optional postlexical local assimilation process creates back *ɨ, õ*, without interacting with harmony in any way. This is easily dealt with in Stratal OT (Kiparsky 2000, forthcoming) but problematic in parallel OT.

Of course, this cannot be the whole story by a long shot: stem-internally, Finnish welcomes combinations like *i a* with open arms, whereas it still excludes combinations like *ä a*. This fact tells us that there must be another, more selective constraint which is violated by *ä a* but not by *i a*. It also tells us that this more selective constraint dominates IDENTSTEM(Back) (since it treats stems and derived environments alike), which as we already know in turn dominates the more general harmony constraint AGR(Back). We propose that this new constraint forbids a harmony violation that involves marked vowels. The idea is that disharmony with marked vowels is both worse than disharmony alone, and worse than markedness alone. We need no new primitive constraints. Rather, we use local constraint conjunction (Smolensky 1993, Kager 1999:392-400) to combine the existing constraints AGR(Back) and **ä, *ö, *ü* into a new constraint MARKED HARMONY (MH):

[10] MARKED HARMONY (MH): [3] AGR(Back) & [2b,c] **ä, *ö, *ü*

A conjoined constraint is violated when both its conjuncts are violated. Example [11] will help make the general idea clear.

[11] Finnish disharmony within stems:

a. **a ä* — *ä* is both marked and disharmonic (violating the conjoined constraint)
b. ✓*i a* — *a* is disharmonic but unmarked (no violation of the conjoined constraint)
c. ✓*i ä* — *ä* is marked but harmonic (no violation of the conjoined constraint)

We must still account for the fact that sequences such as *ä i a* and *a i ä* are bad in Finnish and Uyghur, and good in the other languages, except of course where excluded by the constraint rankings already established (namely, in Eastern Khanty *ä i a* is rejected in favor of *ä i ä* by [7a], and in Enarve Vepsian *a i ä* is rejected in favor of *a i a* by [7b]). This is simply what we normally mean when we say that neutral vowels are *transparent* in Finnish and Uyghur. To account for it we need a constraint that militates against long-distance disharmony. When that constraint dominates the more general harmony constraint AGR(Back), transparency results.

Again, we need no new primitive constraints to get this result. As formulated in the literature so far (Kager 1999:393), the theory of constraint conjunction requires specification of some domain in which violations of conjoined constraints are assessed, such as a segment, a morpheme, or a word. Instead of embracing this full freedom, let us suppose that there are just two interpretations of conjoined constraints:

[12] a. CONSTRAINT CONJUNCTION (GENERALIZED CASE): A conjoined constraint C_1&C_2 is violated when C_1 and C_2 are violated.

b. CONSTRAINT CONJUNCTION (CORE CASE): A conjoined constraint C_1&C_2 is violated when C_1 and C_2 are violated and the minimal substrings that contain the violations overlap.

By specifying the domain of constraint evaluation in the two alternative ways in [12] we obtain two versions of the conjoined constraint [10] MH that precludes disharmony of marked vowels.

[13] a. GENERALIZED MH: domain may not contain both a vowel marked for F and a vowel disharmonic for F.

b. Core MH: a vowel may not be both marked for F and disharmonic for F.

For example, Core MH is violated by the sequences *a ä* and *ä a*, but not by the sequences *ä i a* or *a i ä*, whereas Generalized MH is violated by all of them. The sequence *ä o ä* has two violations of both constraints (one in the substring *ä o*, the other in the substring *o ä*). The sequence *ä i a i ä* has two violations of Generalized MH (namely *ä i a* and *a i ä*), but no violations of Core MH.

These constraints complete the desired factorial typology of neutrality. Neutral vowels are transparent if Generalized MH outranks some antagonistic constraint (be it faithfulness or markedness). The precise nature of the transparent behavior follows from the nature of the dominated constraint. In the languages under consideration, it is Agr(Back), which enforces local harmony, hence opacity rather than transparency.

[14] a. Transparency (Finnish and Uyghur): Generalized MH ≫ Agr(Back)

b. Opacity (Eastern Khanty and Vepsian): Agr(Back) ≫ Generalized MH

Note that this treatment of transparency requires that a conjoined constraint can outrank the conjuncts that compose it (contrary to what is usually assumed, Kager 1999:393).

[15]

Opaque /i/			. . .	Generalized MH	Agr(Back)	. . .
[ä i] a		ä i a		*	*	
	☞	ä i ä				
[a i] ä	☞	a i a			**	
		a i ä		*	*	

[16]

Transparent /i/			. . .	Agr(Back)	Generalized MH	. . .
[ä i] a		ä i a		*	*	
	☞	ä i ä				
[a i] ä		a i a		**		
	☞	a i ä		*	*	

If constraints which exclude marked configurations are never outranked by constraints which exclude unmarked configurations (this is really the definition of markedness), Core MH, which is subsumed by Generalized MH, would always be ranked at least as high as the latter. On these assumptions, the collated rankings discussed so far are as given in [17].[10]

[17] a. **Eastern Khanty:** *ɨ,*õ ≫ Ident-σ_1(Bk) ≫ Ident-σ_1(Back), Core MH ≫ Ident-Stem(Back) ≫ Agr(Back) ≫ Generalized MH, *ä,*ö,*ü,

b. **Vepsian:** *ɨ,*õ ≫ Ident-σ_1(Bk), Core MH ≫ IdentStem(Back) ≫ Generalized MH ≫ *ä,*ö,*ü, Agr(Back)

[10] The ranking of the two constraints Agr(Back) and IdentStem(Back), which determines whether sequences containing neutral-back vowel combinations act alike stem-internally and in derived forms, is not clear to us for all languages from the available data. In Finnish, the ranking is clearly as given above. It seems that this ranking is an independent language-specific matter which not have any further consequences for the rest of the system.

c. **Finnish:** **ɨ,*õ* ≫ IDENT-σ_1(Back), CORE MH, GENERALIZED MH ≫ IDENTSTEM(Back) ≫ GENERALIZED MH ≫ AGR(Back) ≫ **ä,*ö,*ü*

d. **Uyghur:** **ɨ,*õ* ≫ IDENT-σ_1(Back), CORE MH, GENERALIZED MH ≫ IDENTSTEM(Back) ≫ **ä,*ö,*ü* ≫ AGR(Back)

Illustrative tableaux for each of the four systems follow. Since we are considering only systems with neutral vowels, the two constraints [–Lo,–Rd] ⇒ [–Bk] IDENT-σ_1(Back) rank highest in all the languages considered here. Therefore the following types of combinations will be treated alike.

Input		**ɨ,*õ*	IDENT-σ_1(Back)	...
[a i]	☞ a i			
	a ɨ	*		
	ä i		*	
[a ɨ]	☞ a i			
	a ɨ	*		
	ä i		*	
[i]	☞ i			
	ɨ	*	*	
[ɨ]	☞ i			
	ɨ	*		
[ä i]	☞ ä i			
	ä ɨ	*		
	a i		*	
[ä ɨ]	☞ ä i			
	ä ɨ	*		
	a i		*	

In general, all candidates with back unrounded vowels will be excluded by undominated [–Lo,–Rd] ⇒ [–Bk], and will be omitted in what follows. The more interesting differences and similarities between the four systems are illustrated by the following combinations. Note the differentiation of stem-internal and derived environments due to IDENTSTEM(Back).

Input	Khanty	*ɨ, *õ	Id-σ_1(Bk)	Core MH	IdStem(Bk)	Agr(Bk)	Gen MH	*ä, *ö, *ü	Vepsian	*ɨ, *õ	Id-σ_1(Bk)	Core MH	IdStem(Bk)	Gen MH	*ä, *ö, *ü	Agr(Bk)
[a i] a	a i a					**			☞ a i a							**
	☞ a i ä					*	*	*	a i ä					*	*	*
	ä i ä		*		*			**	ä i ä		*		*		**	
[ä i] a	ä i a					*	*	*	ä i a					*	*	*
	☞ ä i ä							**	☞ ä i ä						**	
	a i a		*		*	**			a i a		*		*			**
ä i a	☞ ä i a					*	*	*	☞ ä i a					*	*	*
	ä i ä				*				ä i ä				*		**	
	a i a		*		*	**		**	a i a		*		*			**
[i] a	i a					*			☞ i a							*
	☞ i ä							*	i ä						*	
i a	☞ i a					*			☞ i a							*
	i ä				*			*	i ä				*		*	
i ä	i a				*	*			i a				*			*
	☞ i ä							*	☞ i ä						*	
ä a	ä a			*		*	*	*	ä a			*		*	*	*
	☞ ä ä				*			**	☞ ä ä				*		**	
	a a		*		*				a a		*		*			

	Finnish	*ɨ, *õ	Id-σ_1(Bk)	Core MH	Gen MH	IdStem(Bk)	Agr(Bk)	*ä, *ö, *ü	Uyghur	*ɨ, *õ	Id-σ_1(Bk)	Core MH	Gen MH	IdStem(Bk)	*ä, *ö, *ü	Agr(Bk)
[a i] a	☞ a i a						**		☞ a i a							**
	a i ä				*		*	*	a i ä				*		*	*
	ä i ä		*			*		**	ä i ä		*			*	**	
[ä i] a	ä i a				*		*	*	ä i a				*		*	*
	☞ ä i ä							**	☞ ä i ä						**	
	a i a		*			*	**		a i a		*			*		**
ä i a	ä i a				*		*	*	ä i a				*		*	*
	☞ ä i ä					*		**	☞ ä i ä					*	**	
	a i a		*			*	**		a i a		*			*		**
[i] a	i a						*		☞ i a							*
	☞ i ä							*	i ä						*	
i a	☞ i a						*		☞ i a							*
	i ä					*		*	i ä					*	*	
i ä	i a					*	*		i a					*		*
	☞ i ä							*	☞ i ä						*	
ä a	ä a			*	*		*	*	ä a			*	*		*	*
	☞ ä ä					*		**	☞ ä ä					*	**	
	a a		*			*			a a		*			*		

2.4 Deriving the typology

If correct, our analysis should derive the true typological generalizations about neutral vowels. Above we formulated three empirical generalizations, *unmarkedness*, *asymmetry*, and *uniformity*. These do follow from the factorial typology of the constraint system.

The unmarkedness property follows from the leading idea that harmony reflects the interaction of general syntagmatic constraints (in this case AGR(Back)) with paradigmatic restrictions on vowel contrasts. There is no "harmony rule", therefore no stipulated contextual restrictions on the harmony process. Rather, neutrality is enforced by markedness constraints. We know that these constraints suppress feature distinctions in favor of the unmarked feature specifications. That is why neutral vowels show the unmarked values of the harmonic feature.

The uniformity property is a consequence of the generality of the featural markedness constraints [2]. The prediction here is weaker than in the preceding case, in that it depends on the substance of the actual constraints that we have posited. To the extent that there exist more specific markedness constraints that single out particular neutral vowels, non-uniformity should be possible.

The asymmetry property (in the case at hand, the generalization that back neutral vowels in front/back harmony systems are opaque rather than transparent) follows from the proposed analysis of transparency. Neutral vowels are transparent with respect to backness harmony when GENERALIZED MH (the conjunction of **ä,*ö,*ü* and AGR(Back)) ranks high. In [14] we saw that under the ranking GENERALIZED MH ≫ AGR(Back), *i* is transparent, and under the ranking AGR(Back) ≫ GENERALIZED MH, *i* is opaque. But, as the following tableaux show, *o* is opaque under *both* these rankings. In fact, the sequence *ä o a* is better than the sequence *ä o ä* with respect to front/back harmony on any ranking of the constraints we have (contrast [19] and [16]).

[18]

Transparent /o/		. . .	GENERALIZED MH	AGR(Back)	. . .
[ä o] a	☞ ä o a		*	*	
	ä o ä		**	**	
[ä o] ä	☞ ä o a		*	*	
	ä o ä		**	**	

[19]

Opaque /o/		. . .	AGR(Back)	GENERALIZED MH	. . .
[ä o] a	☞ ä o a		*	*	
	ä o ä		**	**	
[ä o] ä	☞ ä o a		*	*	
	ä o ä		**	**	

Under every ranking of the proposed constraints, neutral vowels are unmarked with respect to the harmonic feature, back neutral vowels are opaque (rather than transparent), and if even one front neutral vowel is transparent, all of them must be. Moreover, this prediction holds for all types of neutral vowels, whether context-free, contextual, or idiosyncratic.

In the instantiations of the conjoined constraint schema [13] considered so far, the conjunct that excludes the marked vowels is [2b] *(*ä,*ö,*ü)*. In principle all markedness constraints should conjoin with AGR(Back) both in the core mode and in the general mode.[11] Such conjoined constraints are in fact instantiated. For Turkish, Clements & Sezer 1983 propose the generalization that disharmonic words do not contain the marked vowels *ö, ü, ɨ* (but only the unmarked vowels *i, e, a, o, u*). This means that [3] also conjoins with [2a] into a constraint AGR(Back) & **ɨ,*õ*. The constraint ranking for Turkish would be as follows:

[20] **Turkish:** { AGR(Back) & **ɨ,õ* / AGR(Back) &**ä,*ö,*ü* } ≫ IDENTSTEM(Back) ≫ **ɨ,õ*, AGR(Back), **ä,*ö,*ü*

Turkish stem-internal (“non-derived environment”) disharmony as discussed by Clements and Sezer occurs because IDENTSTEM(Back) intervenes between the conjoined constraint barring marked disharmony and more general markedness constraints including the plain harmony constraint AGR(Back).

[21] Turkish stem disharmony:

a. **e ɨ* — *ɨ* is both marked and disharmonic (violating the conjoined constraint)
b. ✓*e u* — *u* is disharmonic but unmarked (no violation of the conjoined constraint)
c. ✓*e ü* — *ü* is marked but harmonic (no violation of the conjoined constraint)

3 Other approaches

Neutral vowels interfere with vowel harmony in one of two ways: either by creating islands of frontness in back harmonic domains (transparent vowels), or by introducing new back domains (opaque vowels). In the present section we argue that the devices previously proposed in OT for dealing with neutrality are not suitable. These include Sympathy, Extended Sympathy, Turbidity, and Targeted Constraints (see Kiparsky 2000 and forthcoming, for a more general critique of these devices).

3.1 Sympathy

For transparent vowels, a Sympathy solution of the type advocated by McCarthy might posit that harmony is outranked by a constraint which requires a vowel to have the same backness as a Sympathy candidate that does not undergo harmony. The Sympathy candidate (the “❀-candidate”) must be the optimal candidate that satisfies some Faithfulness constraint (with the understanding that all sympathy constraints are excluded from the selection process). In the derivation of Seto Estonian *kopima* ‘to grope’, the back vowel of the final syllable must harmonize with the preceding back vowel in **kopɨma*. This is the Sympathy candidate. The Faithfulness constraint that selects it must then be IDENT-I/O(Back).

McCarthy’s revised formulation of Sympathy theory (McCarthy 1999) posits two constraints, ❀CUMUL and ❀DIFF, universally ranked in that order. ❀CUMUL winnows out all candidates which are not CUMULATIVE, meaning that they do not have a superset of the ❀-Candidate’s faithfulness violations. Such “incommensurable” candidates can never be optimal. The sympathetic

[11] However, as Itô and Mester have noted, conjoined constraints should be mutually relevant, in some sense which remains to be precisely explicated.

candidate itself, therefore, does not violate ❁CUMUL, but, in the cases where sympathy does any work, it is rejected by some higher-ranking constraint. The function of ❁DIFF is to choose between remaining candidates, possibly in conjunction with other constraints of the system. ❁DIFF assigns one violation mark to every candidate for each unfaithful mapping that it does not share with the ❁-Candidate. Thus, it chooses the candidate that is most similar to the Sympathy candidate.

McCarthy's formulation of the constraints ❁CUMUL and ❁DIFF is reproduced in [22].

[22] Given a sympathetic candidate ❁-Cand, to evaluate a candidate E-Cand:

a. ❁CUMUL: E-Cand is cumulative with respect to ❁-Cand. That is, $U_{\text{❁-Cand}} \subseteq U_{\text{E-Cand}}$ (where U is the set of a candidate's faithfulness violations).

b. ❁DIFF: Every unfaithful mapping incurred by E-Cand is also incurred by ❁-Cand. That is, assign one violation mark for every member of the set $U_{\text{E-Cand}}$ which is not in $U_{\text{❁-Cand}}$.

c. ❁CUMUL $\gg$ ❁DIFF (universally).

To make it clear how this idea works, we show the derivation in two stages. The first stage is represented in [23] and shows how ✯IDENT(Back) selects the sympathy candidate. For clarity, I omit ❁CUMUL and ❁DIFF from this tableau because the theory stipulates that they must be disregarded for this purpose. Assume first that the underlying form is /kopɨma/.

[23]

setotab	…	…	…	✯IDENT(Back)	…	…
Input: /kopɨma/						
a. ❁ kopɨma				✓		
b. kopima				*		
c. kopimä				**		
d. kopɨmä				*		

The most harmonic candidate that conforms to the selector constraint ✯IDENT(Back) is ❁*kopɨma*. The next tableau [24] shows how the actual output candidate is chosen by sympathy to ❁*kopɨma*, by *ɨ and ❁DIFF. Here we let AGR(Back) stand for whatever constraint or constraints drive vowel harmony.

[24]

setotabz	*ɨ	❁CUMUL	❁DIFF	AGR(Back)	✯IDENT(Back)	…
Input: /kopɨma/						
a. ❁ kopɨma	*					
b. ☞ kopima			*	**	*	
c. kopimä			**	*	**	
d. kopɨmä	*		*	*	*	

Since the Sympathy candidate (a) ❁*kopɨma* has no faithfulness violations relative to underlying /kopɨma/, all candidates have a superset of its faithfulness violations. The Sympathy candidate (a) *kopɨma* and candidate (d) are thrown out because they violate σ-WF (which has to dominate the Sympathy constraints ❁CUMUL and ❁DIFF if these are to have any effect). Of the remaining two candidates, (b) *kopima*, being closer to ❀*kopɨma*, better satisfies ❀DIFF. In this way Sympathy defeats AGR(Back), as desired.

The same result would be obtained if /kopima/ were chosen as the underlying form.

By Richness of the Base and Freedom of Analysis, we must allow any combination of front and back vowels in inputs, and, moreover, since frontness beyond the initial syllable is nondistinctive, the choice in those positions must converge on the same output. Suppose, then, we choose the input /kopimä/. ✭IDENT(Back) will now choose this input as the Sympathy candidate.

[25]

Seto	…	…	…	✭IDENT(Back)	…	…
Input: /kopimä/						
a. kopɨma				**		
b. kopima				*		
c. ❀ kopimä				✓		
d. kopɨmä				*		

Again all the candidates are commensurable with the Sympathy candidate (c) ❀*kopimä*, because each has a superset of the latter's faithfulness violation relative to underlying /kopimä/. Of the two candidates that survive σ-WF, it is the Sympathy candidate itself, identical to the underlying form, that best satisfies ❀DIFF.

[26]

Seto	*ɨ	❀CUMUL	❀DIFF	AGR(Back)	✭IDENT(Back)	…
Input: /kopimä/						
a. ☞ kopɨma	*		**			
b. kopima			*	**	*	
c. ☞❀ kopimä				*	*	
d. kopɨmä	*		*	*	*	

Therefore, under this choice of input form, Sympathy again fails to select the desired output. The output derived is, in fact, not a possible word of Finnish. We conclude that Sympathy subverts the fundamental OT assumptions of Richness of the Base and Freedom of Analysis.

3.2 Extended Sympathy

The argument so far has assumed that sympathy candidates must be selected by Faithfulness constraints. This stricture should not be given up in a casual way, because (as McCarthy shows) it is conceptually an essential part of the theory and has important empirical consequences. But problems like the one we have sketched out have nevertheless led several authors to propose that markedness constraints too can function as selector constraints (Itô and Mester 1997, Merchant 1997, De Lacy 1998, Walker 2000). The version of Sympathy Theory in which this is allowed is called EXTENDED SYMPATHY. Walker specifically argues that harmony is transmitted across intervening neutral vowels in local fashion via a Sympathy candidate in which neutral vowels covertly participate in the harmonic process.

Extended Sympathy fares better than original Sympathy in one respect: we can now force the desired Sympathy candidate *kopɨma* by using harmony as the selector. In this way the correct output would be derived here and in similar words. But using harmony as the selector has the unfortunate effect of making opaque vowels transparent. Let us develop this point with the example of the vowel /o/ in the Southern Seto dialect of Estonian, which is neutral in virtue of a constraint that prohibits *ö*. Dominated by IDENT-σ_1(Back), this constraint neutralizes the *o*:*ö* in non-initial syllables.

As discussed above, we correctly predict that *o*, like all back neutral vowels in front/back harmony systems, is opaque; cf. forms such as *lähko-lõ*, with a back vowel after the opaque *o*). How would this result be obtained under Extended Sympathy? The same harmony constraint is at stake, so the same sympathetic constraint should be visible. Under Extended Sympathy, the sympathy candidate for *lähko-lõ* has to be be the fully harmonic **lähkö-le*. On the basis of sympathetic harmony, we would then derive **lähko-le* instead of *lähko-lõ*. [27] shows the selection of the ❀-candidate under Extended Sympathy.

[27]

Seto	…	…	…	✯AGR(Back)	…	…
Input: /lähko-le/ (or /lähkö-le/, /lähko-lõ/, etc.)						
a. ❀ lähkö-le				✓		
b. lähko-lõ				*		
c. lähko-le				**		
d. lähkö-lõ				*		

The most harmonic candidate that conforms to the selector constraint is ❀*lähkö-le*. [28] shows how the incorrect output candidate **lähko-le* is chosen by sympathy to ❀*lähkö-le* on the assumption that the underlying form is /lähkö-le/. Any of the other underlying forms would give the same wrong result.

[28]

Seto	*ö	❀CUMUL	❀DIFF	AGR(Back)	✯IDENT(Back)	…
Input: /lähkö-le/						
a. ❀ lähkö-le	*					
b. lähko-lõ			**	*	**	
c. ☞ lähko-le			*	**	*	
d. lähkö-lõ	*		*	*	*	

Candidates (a) and (d) are thrown out because they violate **ö* (which, as before, has to dominate the Sympathy constraints in order for ❀CUM and ❀DIFF to have any effect at all). ❀DIFF then decides against the desired (b) *lähko-lõ* in favor of the unwanted (c) **lähko-le*. Extended Sympathy fails to predict the opacity of back neutral vowels in these harmony systems. Moreover (as far as we can tell) it even predicts that all neutral vowels of a language will either be transparent or opaque, which is falsified by Seto Estonian. We conclude that even the Extended Sympathy approach to opacity is inconsistent with OT's fundamental principles of Richness of the Base and Freedom of Analysis.

3.3 Turbidity

Goldrick (2000) attacks the problem of non-patent constraint interaction by introducing two types of input/output relations, an abstract, structural relation of PROJECTION, and an audible, surface relation of PRONUNCIATION. Normally the two relations coincide — what is projected is pronounced and vice versa. But because the two relations are subject to separate MAX and DEP constraints they can diverge under the pressure of structural markedness constraints.

Turbidity theory offers another way to achieve partial output visibility of neutralized underlying information. Any such solution runs into the same problem as sympathy, namely that the required underlying representations cannot be guaranteed where they are noncontrastive, as in the case at hand. Consequently turbidity makes the same false empirical predictions as sympathy.

3.4 Targeted constraints

Bakovic (2000) develops yet another approach to neutral vowels based on the notion of TARGETED CONSTRAINTS, which he credits to Colin Wilson. As Bakovic explains, the appealing intuition behind it is that "transparent-vowel candidates have more in common with the ideal, fully-harmonic candidate than opaque-vowel candidates do" (p. 272). Undoubtedly *kopima* sounds more like **kopɨma* than *kopimä* does. The question is whether targeted constraints cash in this intuition to explain how neutral vowels work.

Targeted constraints carry out *pairwise* (rather than global) constraint evaluations of candidates. Constraint evaluation proceeds by successive pairwise comparisons between candidates, whose outcomes are accumulated until the optimal candidate is found.

The targeted version of the constraint that rules out **ɨ* in Seto (a direct translation of a similar constraint of Bakovic's) would be:

[29] ⨀[–Back,–Round,+High]

Let *x* be any candidate and ζ be any [–Back,–Round,+High] vowel in *x*. If candidate *y* is exactly like *x* except that ζ is not [–Back,–Round,+High], then *y* is better than *x*.

Much depends on the right sequence of pairwise comparisons, for which Bakovic adopts the following principles formulated by Wilson:

[30] a. *Ordering.* Starting with the highest-ranked constraint in the hierarchy, if the current constraint asserts the ordering $x \succ y$, then add $x \succ y$ to the cumulative ordering *O*, except when the opposite ordering (i.e. $y \succ x$) is in *O*. Repeat for the next highest-ranked constraint in the hierarchy. [To which Bakovic adds: The order in which the relative orderings among candidates that a given constraint asserts are added to *O* is given by the absolute ranking which that constraint establishes among the candidates.]

b. *Transitive closure.* For any candidates *x*, *y*, and *z*, if both $x \succ y$ and $y \succ z$ are in the cumulative ordering *O*, then $x \succ z$ is also in *O* (i.e. $x \succ y$ & $y \succ z \Rightarrow x \succ z$).

c. *Optimality.* A candidate is **optimal** if and only if it is not worse than any other candidate in the first cumulative ordering (i.e. when the loop in (a) ends).

Still cleaving to Bakovic's exposition, we consider the derivation of *kopima* from /kopi-ma/. This time we need not worry about the backness of the non-initial input vowels, for targeted constraints do not rely on faithfulness to underlying representations. Ignoring all but the four most interesting candidates, we obtain the tableau in [31], where the desired output form is the winner.

[31]

Candidates		⊙[+Back,–Round,+High]	AGR(Back)
Input: /kopi-ma/			
a.	kopɨma	$d \succ a$!	
b.	kopimä		$a \succ b$!
c.	kopɨmä	$b \succ c$!	
d. ☞	kopima		$a, b, c \succ d$
Cum. ordering:		$d \succ a, b \succ c$	$d \succ a \succ b \succ c$

Crucially, both [+Back,–Round,+High] and AGR(Back) must be targeted constraints, evaluated in the pairwise fashion stipulated in [30].

Now consider the vowel *o*. On our proposal, the desired opaque behavior follows from ranking the neutralization constraint **ö* above AGR(Back) (but below IDENT-σ_1(Back), since *ö* is distinctive in initial syllables). Moreover, we showed that a hypothetical dialect where *o* is transparent (rather than opaque) could not be dealt with in our framework, a good result because the data show that back vowels *must* be opaque with respect to front/back harmony.

Under targeted constraints this is not the case. There is no reason why *o* would not be transparent like *i*. The tableau in [32] is exactly parallel to the one in [31], differing only in that the markedness constraint excludes ö rather than ɨ. The predicted output is **lähko-le* instead of correct *lähko-lõ*.

[32]

Candidates		⊙[–Back,+Round,–High]	AGR(Back)
Input: /lähko-le/			
a.	lähkö-le	$d \succ a$!	
b. ✓	lähko-lõ		$a \succ b$!
c.	lähkö-lõ	$b \succ c$!	
d. ☛	lähko-le		$a, b, c \succ d$
Cum. ordering:		$d \succ a, b \succ c$	$d \succ a \succ b \succ c$

Plainly, targeted constraints give the wrong result for opaque vowels. It seems that this treatment of neutral vowels would require a mix of targeted constraints (for transparent vowels) and ordinary constraints (for opaque vowels) within one constraint system, a formally undesirable outcome because the two kinds of constraints are evaluated in completely different ways. Absent priciples that determine when a constraint is targeted and when it is not targeted, we again lose the prediction that back neutral vowels are opaque while front neutral vowels can be transparent.

4 Conclusions

We have presented a tentative typology of front/back vowel harmony systems, concentrating on disharmony phenomena. Disharmonic vowels are either opaque or transparent, and the latter show cross-linguistically very diverse behavior. The leading idea of our analysis is that disharmony arises when a general harmony constraint that imposes feature agreement on neighboring vowels is dominated by markedness constraints that govern vowel inventories and by faithfulness constraints. We showed that the empirically attested typology of disharmony is derivable from these assumptions on the basis of uncontroversial constraints. The only novelty was to make use of two modes of local constraint conjunction, which however are already implicit in the theory. Far from being a weakening of the theory, our proposal is In this respect more restrictive than the heretofore countenanced alternative of allowing the domain of local conjunction to be freely stipulated. In a concluding argument which complements Kiparsky 2000 and forthcoming, we showed that our analysis compares favorably to those based on sympathy and related approaches to opaque constraint interactions.

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