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Opacity from Contrast: Neutral Segments in Harmony Systems

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Certain types of **derivational opacity** are known to be problematic for parallel theories of phonology like Optimality Theory (OT; Prince and Smolensky 1993/2002). Many proposed solutions within OT expand the power of the phonology to account for opacity (Inkelas and Orgun 1995, Kiparsky 1998, McCarthy 1999, Goldrick and Smolensky 1999, Wilson 2000, etc.). What's wrong with these solutions generally?

- **stipulative**: often not independently motivated nor useful for other phonological phenomena other than opacity
- **too powerful**: increased power over-predicts unnatural patterns besides attested instances of opacity
- **purely synchronic**: analyses ignore, yet 'coincidentally' mimic, historical ordering of diachronic sound changes, even when speakers would be unaware of the history
- **questionable status of opacity in phonology**: problematic cases of opacity are typically phonetically unnatural, language-specific, historically unstable, productive only in certain morphological environments, and/or only apply to a subset of the extant lexicon

In this talk, I argue that the behavior of neutral segments[1] in harmony systems (e.g., voiceless obstruents in Tuyuca nasal harmony (Barnes and Takagi de Silzer 1976, Walker 1998) is in fact a class of derivational opacity that is problematic for standard OT yet still needs to be given a synchronic, phonological analysis. Further, I argue that such an analysis is readily available by means of independently-motivated constraints governing the perceptual distinctiveness of contrasts within a language, as in Dispersion Theory (DT; Flemming 1995, etc.).

I begin in §1 with an overview of a typical harmony system containing neutral segments: nasality in Tuyuca. In §2, I demonstrate briefly why neutral segments are problematic for both standard OT and serial theories. I offer an analysis of harmony systems in §3 based upon ideas from DT, and in §4, I explain how neutral segments can be derived under the proposed analysis. Finally, in §5, I summarize the talk and explore some important consequences of this analysis.

1 Tuyuca nasal harmony

Segments in a word must be all oral or all nasal(ized) (modulo neutral segments; see (2)).

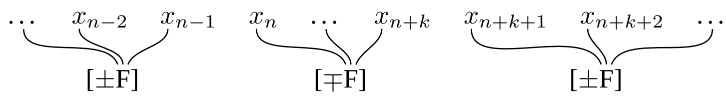
(1)	*all oral*	*gloss*	*all nasal*	*gloss*	*non-occurring disharmony*
	waa	'to go'	w̃ãã	'to illuminate'	*w̃aa, *w̃ãa, *wãã, …
	hoo	'banana'	h̃ɨ̃ɨ̃r̃ĩ	'watch out or you'll get burned!'	*h̃oo, *h̃ɨ̃ɨ̃ri, *hɨɨr̃ĩ, …
	wati	'dandruff'	j̃õr̃ẽ	'little chicken'	*w̃ati, *j̃õre, *jor̃ẽ, …

The generalization in (1) is derivationally opaque because its truth is obscured by the fact that voiceless obstruents are neutral segments: they do not nasalize, and they do not block nasal harmony, creating disharmonic words with two domains of harmony separated by a non-harmonizing neutral segment.

(2)	*disharmony*	*gloss*	*non-occurring harmony*	*non-occurring blocking*
	m̃ĩpĩ	'badger'	*m̃ĩp̃ĩ	*m̃ĩpi
	w̃ãtĩ	'demon'	*w̃ãt̃ĩ	*w̃ãti
	ãkã	'choke on a bone'	*ãk̃ã	*ãka
	j̃õsẽ	'bird'	*j̃õs̃ẽ	*j̃õse

[1] The segments in question are usually called 'transparent segments'. However, to avoid the confusion of transparent segments being derivationally opaque, I use 'neutral segments' instead.

The Tuyuca data is representative of a more general pattern of neutral segments in harmony systems, which produce the following type of local neutral structure centered around k neutral segments $x_n \ldots x_n + k$, where [±F] is the harmonizing feature (and $k \geq 1$):

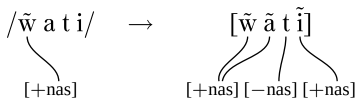
(3)


Other harmony systems with similar patterns (see also Ringen 1975, Baković 2000):

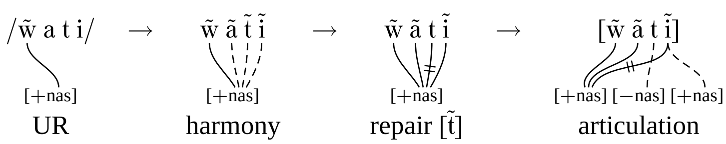
- Hungarian backness harmony (Vago 1976)
- Finnish backness harmony are neutral (Fudge 1967)
- Pasiego height harmony (Penny 1969)
- Wolof [RTR] harmony (Ka 1988)
- Nez Perce [ATR] harmony (Aoki 1966)

2 Difficulty in accounting for neutral segments

The surface alternation in [±F] is entirely predictable from the presence of exactly one value of [±F] in the underlying form, so it is not necessary to fully specify the values of [±F] in the underlying form. In fact, full underlying specification would not be desirable, since it fails to explain how harmony in borrowings and nonce forms obeys the behavior of neutral segments. (Cf. the 'richness of the base' hypothesis in OT.)

(4)


In a serial theory, the derivation of [w̃ãtĩ] seems to require massive structural reorganization in order for [ĩ] to be harmonically nasalized by assimilatory feature-spreading, for [t] to be denasalized, and for the right number and type of articulatory realizations of [±nas] to emerge in the pronunciation. (Other serial analyses are possible, but they come with their own drawbacks.)

(5)


OT doesn't fare much better. Assuming that HARMONY constraints require each harmonic domain to stretch from word edge to word edge and that IDENT_1 is a positional faithfulness constraint (Beckman 1998), then we see that it is impossible to derive a harmony system with neutral segments.

(6)

/w̃ati/	HARMONY-[nas]	*t̃	IDENT₁-[nas]	IDENT-[nas]	
✗ a. w̃ãtĩ	*****			**	no ranking works! bounded by b–d
✓b. w̃ãti	**			*	*t̃, IDENT_1 ≫ HARMONY ≫ IDENT
✓c. w̃ati	***				IDENT_1, IDENT, *t̃ ≫ HARMONY
✓d. wati			*	*	HARMONY, *t̃ ≫ IDENT_1, IDENT
✓e. w̃ãt̃ĩ		*		***	HARMONY, IDENT_1 ≫ *t̃ , IDENT

This is a classic problem in OT with this type of derivational opacity; the desired output simply cannot win under any constraint ranking because it is harmonically bounded by one or more other candidates — in this case, (6b–d).

As stated in §1, various solutions have been proposed, but they often rely on questionable theoretical devices.

3 Harmony as enhancement of perceptual contrast

Much work has been done in phonology, before OT (de Saussure 1959, Martinet 1964, Lindblom 1986, 1990, etc.) and since (Flemming 1995, Steriade 1995, Padgett 1997, Boersma 1998, etc.), that argues for an explicit phonological role for acoustic perception. By viewing language as a system of contrasting words, many seemingly arbitrary phonological patterns can be explained and predicted.

I adopt here a variant of Dispersion Theory (DT; Flemming 1995, modified in Padgett 1997, Ní Chiosáin and Padgett 2001, Sanders 2002, 2003). One of the key differences between between DT and standard OT is the existence of **dispersion constraints** or $\mathcal{D}$-constraints. I use the following definition:

(7) $\mathcal{D}_x$-[F] is violated for each pair of words which contrast only for feature [F] and which are perceptually closer than x% of the allowable perceptual distance for [F].

For each feature [F], there is a subhierarchy of $\mathcal{D}$-constraints, which require contrastive pairs of words to be farther and farther apart. For example, [mãɾ̃ã] and [maɾa] match in nasality for only 25% of the possible segments they could match for. Thus, they are spread apart from each other by 75% of the nasal perceptual space, a very good contrastive pair. In comparison, [mãɾ̃ã] and [mãɾã] match for 75%, a worse contrast that is more likely to be confused.

The following table gives constraint violations for these and other pairs (for clarity, with their nasality difference Δ listed. $\mathcal{D}_x$-[nas] is violated when $\Delta < x$.[2]

(8)

	[mãɾã] [baɾ̃a] $\Delta = 100$	[mãɾ̃ã] [maɾa] $\Delta = 75$	[mãɾã] [maɾa] $\Delta = 50$	[mãɾ̃ã] [mãɾã] $\Delta = 25$
$\mathcal{D}_{20}$-[nas]	✓	✓	✓	✓
$\mathcal{D}_{40}$-[nas]	✓	✓	✓	*
$\mathcal{D}_{60}$-[nas]	✓	✓	*	*
$\mathcal{D}_{80}$-[nas]	✓	*	*	*
$\mathcal{D}_{100}$-[nas]	✓	*	*	*

By inserting IDENT-[nas] in this subhierarchy, different levels of nasal contrast can be achieved. Ranking IDENT-[nas] high will prevent nasality from changing between input and output, which means a finer-grained contrast will be allowed (as in French for example, where each syllable of every word can in theory contain a nasal or oral onset and a nasal or oral vowel), whereas a lower ranking for IDENT-[nas] will result in languages like Tuyuca, which force words to harmonize for nasality.

(9)

wa wã / w̃a w̃ã	$\mathcal{D}_{40}$	$\mathcal{D}_{60}$	IDENT	$\mathcal{D}_{80}$
a. wa wã / w̃a w̃ã		****!		****
b. wa / w̃a w̃ã		**!	*	**
✓c. wa / w̃ã			**	

Note that in DT, the input and the candidates are *sets* of words, not just individual words. This is a crucial consequence of encoding perceptual distinctiveness between words: if the words must be compared, then they must be present in the computation, and since every pair must be compared, every word must be present. Further, these words are not necessarily actual words, but rather, they are the possible contrastive words of the language. By the richness of the base hypothesis, the input is actually the set of all strings of all sounds!

[2] The actual number of and x-values for $\mathcal{D}_x$-[nas] constraints are unknown. Precise experimentation and typological comparison would be required to determine the exact set. I use a set that works for Tuyuca, with the understanding that this is not the only set that would work, and that ultimately, a single set should be found which works for all languages.

(10)

	$\mathcal{D}_{60}$	$\mathcal{D}_{80}$	IDENT	$\mathcal{D}_{100}$
jore jorẽ jor̃e jor̃ẽ jõre jõrẽ jõr̃e jõr̃ẽ j̃ore j̃orẽ j̃or̃e j̃or̃ẽ j̃õre j̃õrẽ j̃õr̃e j̃õr̃ẽ				
a. jore jorẽ jor̃e jor̃ẽ jõre jõrẽ jõr̃e jõr̃ẽ j̃ore j̃orẽ j̃or̃e j̃or̃ẽ j̃õre j̃õrẽ j̃õr̃e j̃õr̃ẽ	$*^{80}$!	$*^{112}$		$*^{112}$
b. jore jor̃ẽ jõrẽ jõr̃e j̃orẽ j̃or̃e j̃õre j̃õr̃ẽ	$*^{24}$!	$*^{24}$	$*^{8}$	$*^{24}$
✓c. jore j̃õr̃ẽ			$*^{20}$	

This ranking will further ensure that all words with four segments will be either all oral or all nasal. Even with longer words, this ranking might seem to allow some deviation from full nasal harmony, but the resulting languages are equally faithful as the fully harmonic language, so the tie gets broken by $\mathcal{D}_{100}$, which favors full harmony.

(In fact, it may only be necessary to have two $\mathcal{D}$-constraints: one that requires contrasts to be farther apart than 50%, and one that requires them to be at 100%. I have not yet been able to mathematically determine if the 50% threshold is sufficient to guarantee that any language which satisfies it must also be equally or less faithful than the full harmonic language.)

4 Neutral segments as imperfect perceptual contrast

The wrong candidate wins with the current ranking when neutral segments are added.

(11)

	$\mathcal{D}_{60}$	$\mathcal{D}_{80}$	IDENT	$\mathcal{D}_{100}$
jose josẽ jos̃e jos̃ẽ jõse jõsẽ jõs̃e jõs̃ẽ j̃ose j̃osẽ j̃os̃e j̃os̃ẽ j̃õse j̃õsẽ j̃õs̃e j̃õs̃ẽ				
a. jose j̃õse	*!	*		*
☹b. jose j̃õsẽ		*!	*	*
!! c. jose j̃õs̃ẽ			*	

(11c) should be worse because of the nasalized voiceless obstruent [s̃]. To account for the lack of nasalized voiceless obstruents, I assume a markedness constraint *NASVLSOBS which bans them. (It is also plausible that these sounds aren't perceptually distinct enough from their oral counterparts to sufficiently satisfy the relevant $\mathcal{D}$-constraints.)

(12)

jose josẽ jos̃e jos̃ẽ jõse jõsẽ jõs̃e jõs̃ẽ j̃ose j̃osẽ j̃os̃e j̃os̃ẽ j̃õse j̃õsẽ j̃õs̃e j̃õs̃ẽ	$\mathcal{D}_{60}$	*NasVlsObs	$\mathcal{D}_{80}$	Ident	$\mathcal{D}_{100}$
a. jose j̃õse	*!		*		*
✓b. jose j̃õsẽ			*	*	*
c. jose j̃õs̃ẽ		*!		*	

This analysis works fine for small words with few neutral segments. However, it is theoretically possible to have words like [põsẽtĩkã], which are only 50% nasal, below the allowable threshold.

As stated in §3, it may be mathematically possible to force full harmony with a threshold of 50%. If so, then words like [põsẽtĩkã] do not pose a problem. However, one can imagine a language with a nasal harmony pattern like Tuyuca's, but it also allows complex onsets and codas. Then we have problems with words like [stĩkspãpst], where the word is practically oral, only 20% nasal, certainly below any reasonable threshold for required nasal distinctiveness.

The question to be asked is: do we actually get harmony in such words? It's not clear that harmony does in fact spread through this many adjacent neutral segments. This analysis predicts that a sufficient number of neutral segments may block harmony or be required to participate. This is an empirical question that can be tested (and is, at the Arizona Phonological Imaging Lab, by Diana Archangeli, Robert Kennedy, Adam Baker, and Sumayya Racy; their preliminary findings seem to suggest that neutral segments actual harmonize 'somewhat'.)

5 Summary and consequences

In this talk, I have provided a schema for analyzing neutral segments in harmony systems, which seem to behave in a derivationally opaque way. The present analysis focuses on **Tuyuca nasal harmony**, but can easily be converted to other harmony systems.

The analysis **depends on perceptual contrast**, which is already known to be required in phonology (in comparison, competing analyses of derivational opacity tend to be required only for opacity).

The analysis also **preserves the parallel nature of OT** by treating neutral segments in harmony systems as transparently derived from constraints on systemic perceptual contrast, rather than having to incorporate abstract intermediate forms to facilitate an opaque derivation.

Additionally, this analysis **predicts that neutral segments may block harmony** under certain circumstances. This prediction needs further research.

References

Aoki, Haruo. 1966. Nez Perce vowel harmony and Proto-Sahaptian vowels. *Language* 42:759–767.

Baković, Eric. 2000. *Harmony, Dominance and Control.* PhD dissertation, Rutgers University.

Barnes, Janet, and Sheryl Takagi de Silzer. 1976. Fonología del tuyuca. *Sistemas fonológicaos de idiomas colombianos* 3. Bogotá: Ministerio de Gobierno. 123–137.

Beckman, Jill. 1998. *Positional faithfulness.* PhD dissertation, University of Massachusetts, Amherst.

Boersma, Paul. 1998. *Functional phonology: Formalizing the interaction between articulatory and perceptual drives.* The Hague: Holland Academic Graphics.

de Saussure, Ferdinand. 1959. *Course in general linguistics.* New York: McGraw-Hill.

Flemming, Edward. 1995. *Auditory representations in phonology*. PhD dissertation, Stanford University.

Fudge, Eric C. 1967. The nature of phonological primes. *Journal of linguistics* 3:1–36.

Goldrick, Matthew, and Paul Smolensky. 1999. Opacity and turbid representations in Optimality Theory. Paper presented at the 35th meeting of the Chicago Linguistics Society, University of Chicago.

Inkelas, Sharon, and Orhan Orgun. 1995. Level ordering and economy in the lexical phonology of Turkish. *Language* 71:763–793.

Ka, Omar. 1988. *Wolof phonology and morphology: A non-linear approach.* PhD dissertation, University of Illinois at Urbana-Champaign.

Kiparsky, Paul. 1998. Paradigm effects and opacity. Ms., Stanford University.

Lindblom, Björn. 1986. Phonetic universals in vowel systems. In John J. Ohala and Jeri J. Jaeger, eds. *Experimental phonology*. Orlando: Academic Press. 13–44.

Lindblom, Björn. 1990. On the notion of 'possible speech sound'. *Journal of phonetics* 18:135–152.

Martinet, André. 1964. *Elements of general linguistics.* University of Chicago Press.

McCarthy, John. 1999. Sympathy and phonological opacity. *Phonology* 16:331–399.

Ní Chiosáin, Máire, and Jaye Padgett. 2001. Markedness, segment realization, and locality in spreading. In Linda Lombardi, ed. *Segmental phonology in Optimality Theory: Constraints and representations.* Cambridge University Press. 118–156.

Padgett 1997. Perceptual distance of contrast: Vowel height and nasality. In Rachel Walker, Daniel Karvonnen, and Motoko Katayama, eds. *Phonology at Santa Cruz* 5:63–78.

Penny, Ralph J. 1969. Vowel harmony in the speech of the Montes de Pas (Santander). *Orbis* 18:148–166.

Prince, Alan, and Paul Smolensky. 1993/2002. Constraint interaction in generative grammar. Ms., University of Colarado, Boulder, and Rutgers University.

Ringen, Catherine. 1975. *Vowel harmony: Theoretical implications.* PhD dissertation, Indiana University.

Sanders, Nathan. 2002. Dispersion in OT: Color contrast in Middle Polish nasal vowels. In Line Mikkelsen and Christopher Potts, eds. *WCCFL 21 proceedings.* Somerville, MA: Cascadilla Press. 415–428.

Sanders, Nathan. 2003. *Opacity and sound change in the Polish lexicon.* PhD dissertation, University of California, Santa Cruz.

Steriade, Donca. 1995. Positional neutralization. Ms., University of California, Los Angeles.

Vago, Robert M. 1976. Theoretical implications of Hungarian vowel harmony. *Linguistics inquiry* 7:243–263.

Walker, Rachel. 1998. *Nasalization, neutral segments, and opacity effects.* PhD dissertation, University of California, Santa Cruz.

Wilson, Colin. 2000. *Targeted constraints: An approach to contextual neutralization in Optimality Theory.* PhD dissertation, Johns Hopkins University.