Variation as a Window into Opacity

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1 Introduction*

Opacity and variation are topics of considerable interest to contemporary phonologists because they present significant challenges for the dominant theoretical paradigm, Optimality Theory (OT; Prince & Smolensky, 1993). Opacity is problematic for OT, and all surface-based approaches to phonology (e.g. Natural Generative Phonology; Hooper [Bybee], 1976), because opacity results in generalizations not being surface-true. On the other hand, variation challenges the stipulated categorical nature of constraint interaction in OT and strict dominance hierarchies. Save a few notable exceptions (Anttila, 2007; Kawahara, 2002), these two phenomena have been studied independently. In this paper, I suggest that significant insight into opacity can be gained by looking at cases involving both.

The solution I propose begins by adopting an exemplar-based theory of phonology (Johnson, 1997) to account for variation. This approach relies on representations, rather than the grammar, as a solution by incorporating all variants into the UR. In contrast with approaches that place the locus of variation in the grammar (Anttila, 1997; Boersma & Hayes, 2001), an exemplar-based approach better accounts for the myriad factors known to condition variation. The consequence is a realization of variation through phonetic implementation (e.g. Keating, 1996). This can account for variation involving opacity as well as for cases of opacity that do not involve variation because of the similarity of primary linguistic data for these two empirical domains. This takes advantage of a primary tenet of exemplar-based phonology: that a morpheme's representation consists of the all of the heard tokens of that morpheme.

These points are argued for in the following manner: Section 2 illustrates why opacity is problematic for surface-based approaches to phonology and introduces the first case of the interaction of variation and opacity. In section 3, I present a number of other cases of opacity that reflect variation between opaque and transparent forms. In the course of doing so, I argue against the main approach that has been advanced to account for opacity and variation (Anttila, 2007). In section 4, I suggest an exemplar-based solution to variation and opacity that can account for the data in section 3 and I extend this approach to other cases of opacity involving paradigm uniformity. I conclude in section 5 by addressing some of the predictions this approach makes and some of its shortcomings.

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2 The Opacity Problem and Variation

Opacity has received significant attention as of late because of the problem it presents for OT. Consider, for example, one of the textbook cases of opaque rule-ordering, that of Sea Dayak (Scott, 1957; Kenstowicz & Kisseberth, 1977). Sea Dayak exhibits nasal harmony that is blocked by stops (1) and has a process of stop deletion that renders nasal harmony opaque (2).

(1) Sea Dayak Nasal Harmony
  a. mãta ‘an eye’
  b. mãjã ‘a season’
(2) Opaque interaction of nasal harmony and post-nasal stop deletion
  a. /naŋga/ nãŋa ‘set up a ladder’
  b. /ramboʔ/ ramoʔ 'a kind of flowering plant'

Constraint-based typologies of opacity (McCarthy, 1999) categorize this as under-application since harmony does not apply to the vowels it should apply to given their appearance after nasal segments in the surface form.

Under-application (see §3.1-2 on over-application) presents a problem for surface based approaches to phonology because the generalization of nasal harmony exhibited in (1) seems to not hold in (2). Accounting for both requires that the grammar exclude the harmony generalization demonstrated in the tableaux in (3) and (4) which show the correct evaluation of the transparent form juxtaposed with the incorrect evaluation of an opaque form.

(3)

	/naŋa/	*NV$_{ORAL}$	*ND	IDENT-V(NASAL)
	a. naŋa	*!*		
☞	b. nãŋã			**

(4)

	/naŋga/	*NV$_{ORAL}$	*ND	IDENT-V(NASAL)
☜	a. nãŋa	*¡		*
☹	b. nãŋã			**
	c. nãŋga		*!	

The *NV$_{oral}$ constraint (McCarthy, 2003) enforces harmony by incurring a violation for oral vowels that follow nasals. In the tableau in (4), the optimal, but incorrect, form (4b) reflects surface-true nasal harmony while a ranking for (4) that would produce the correct surface form (4a) would require that the constraint preserving input vowel nasality (IDENT-V[NASAL]) be ranked higher than the *NV$_{oral}$ markedness constraint, eradicating the harmony generalization from the grammar, thereby requiring /naŋa/ as the UR for (3).

This is, in fact, similar to the approach suggested by Mielke, Armstrong and Hume (2003) who argue that the generalization in Sea Dayak is not the negative generalization that oral vowels cannot follow nasal segments but rather the positive generalization that nasalized vowels can only follow nasal segments.

From a typological perspective this is questionable since there is significant cross-linguistic evidence for the *NV_{oral} constraint (McCarthy, 1995) whereas no cross-linguistic evidence is presented for *TV_{nasal}. More crucially, from a language-internal perspective, this approach is problematic because post-nasal consonant deletion is variable (5). The generalization missed by their analysis is that nasal harmony is rendered opaque precisely in those forms that exhibit variation whereas forms that do not exhibit variation are always transparent.

(5) Variation between opaque and transparent forms
 a. nãŋa ~ nãŋga 'set up a ladder'
 b. ramoʔ ~ ramboʔ 'a kind of flowering plant'

Instead of ignoring variation of this sort, the aim of this paper is to present an account of variation and opacity that takes advantage of it based on the idea that the transparent variant accounts and/or explains for why nasalization underapplies. The post-nasal obstruent in the UR, which is evident in the fully-faithful surface variant, blocks nasality from spreading in the other variant. This observation can be incorporated formally by providing access to both variants as part of the evaluation. Prior to exploring this approach in detail, a number of other cases of opacity that exhibit variation between opaque and transparent forms are presented in §3. Indeed, it is perhaps not a coincidence that there are many.

3 Variation and Opacity

In this section, I present data from three other languages – Shimakonde, Canadian French and Finnish – that exhibit variation between opaque and transparent forms. In the course of doing so, I argue against the approach to variation and opacity in Anttila (2007), which incorporates variably ranked constraints into stratal OT to account for data in Finnish. I show that this account is problematic because several cases of opacity have within-strata opacity contra the basic assumption of stratal OT that opacity arises only as a result of inter-strata process interaction. Furthermore, accounting for variation with variably ranked constraint ignores the observation that myriad factors condition variation and that it is not simply free. Also, variably ranked constraints introduce problems for deriving URs using lexicon optimization. This last problem foreshadows the approach advocated in §4: that variation and opacity can be accounted for with exemplar-based URs.

3.1 Shimakonde

Shimakonde (Bantu; Liphola, 2001; Ettlinger, 2008) exhibits canonical Bantu vowel height harmony (VHH; Hyman, 1999) (6) and also has a variable process of pre-tonic vowel reduction, the tonic being the lengthened penultimate syllable. Reduction targets mid vowels reducing them to *a* (7). When these processes interact, they do so opaquely. The mid vowels in the verb stem that trigger VHH in the suffixes are reduced to *a* so VHH over-applies (8).

(6) Shimakonde vowel height harmony (VHH)

		Applicative	Causative	Passive	
a.	kú-páát-a	kú-pat-ííl-a	ku-pat-iiy-a	ku-pat-igw-a	'to get'
	kú-píkíít-a	kú-píkíít-ííl-a	ku-pikit-iiy-a	ku-pikit-igw-a	'to play'
b.	kú-téléék-a	kú-télék-**éé**l-a	ku-telek-**ee**y-a	ku-telek-**ee**gw-a	'to cook'
	kú-tóót-a	ku-tot-**éé**l-a	ku-tot-**ee**y-a	ku-tot-**ee**gw-a	'to sew'

(7) Shimakonde Reduction

	UR	Reduced		Unreduced	
a.	/kú-pét-án-a/	kúpátáána	~	kúpétáána	'to sift each other'
b.	/kú-tót-án-a/	kútátáána	~	kútótáána	'to sow each other'

(8) Opaque interaction of VHH and reduction

		Reduced		Unreduced	
a.	/kú-tot-íl-a/	kútát**éé**la	~	kútét**éé**la	'they will sow for'
b.	/kú-ʃém-íl-a/	kúʃám**éé**la	~	kúʃém**éé**la	'they will call for'

(9)

	/kú-tót-il-a/	REDUCE	HARMONY	ID(HEIGHT)
☜	a. kútátééla		*!	**
	b. kútótééla	*!		*
☹	c. kútátííla			*

In contrast with under-application, as in Sea Dayak, over-application presents a slightly different constraint ranking problem for OT. Whereas in cases of under-application, opaque and transparent forms differ in terms of rankings, opaque forms resulting from under-application (9a) are harmonically bound by the transparent candidate (9c).[1] There is no possible constraint ranking that could select the opaque form, so the constraint ranking problem is independent of comparison to a transparent form.

Furthermore, whereas the opacity in Sea Dayak involves an allophonic alternation in lexical forms and can be argued to be lexicalized (Meilke et al., 2003; Sanders, 2003), the opacity in Shimakonde is morphophonological. Therefore, it is not an option to suggest that the generalization is not part of the speaker's knowledge; in (9) the learner must select the correct applicative allomorph (*-il-* or *–el-*) and clearly she cannot do so based on surface forms alone.

3.2 Canadian French

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[1] The constraints HARMONY and REDUCE are used to stand in for any one of the potential formal analyses of these processes in Shimakonde (Liphola, 2001, Downing, 2006; Ettlinger 2008).

A third case of variation and opacity is found in Canadian French (CF; Poliquin, 2007) where vowels are generally lax in final closed syllables (10a) and tense in open syllables (10b). There are exceptions to these generalizations, however. First, there is a process of pre-fricative tensing, which requires that vowels in closed final syllables with fricative codas be tense and long (11a). Second, there is a variable process of regressive lax harmony targeting high vowels. This can result in lax vowels in open syllables, (11b). These two processes interact opaquely resulting in an over-application of harmony (12a).

(10) Canadian French open/closed vowel tensing and laxing:

a. Final closed syllable laxing: | b. Open Syllable Tensing

Tense	Lax		Tense	Lax
be.n**i**	e.l**ɪ**t	*l**i**t	m**i**.tɛn	*m**ɪ**.tɛn
kr**y**	a.n**ʏ**l	*n**y**l	k**y**.lɔt	*k**ʏ**.lɔt
de.g**u**	e.g**ʊ**t	*g**u**t	k**u**.te	*k**ʊ**.te

(11) Motivated exception to open-tense/closed-lax generalization

a. CF pre-fricative tensing

Tense	Lax
sa.li:v	*sa.lɪv
e.kly:z	*e.klʏz

b. CF Lax Harmony

Harmonized		Unharmonized
fɪ.lɪp	~	fi.lɪp
stʏ.pɪd	~	sty.pɪd

(12) Canadian French lax harmony opacity:

a. Pre-fricative tensing

Harmonized		Unharmonized
bʁʏ.l**y**:ʁ	~	bʁy.ly:ʁ
mɪ.s**i**:v	~	mi.si:v

b. Affixation-triggered opacity

Harmonized		Unharmonized
mʏ.zi.kɑl	~	my.zi.kɑl

In (12a), despite the surface realization of the closed final syllables vowels as tense, the open syllables are optionally lax, a condition only permitted by lax harmony. Affixation creates a similar opacity when a suffix resyllabifies a stem's coda creating an open syllable (12b). The stem-final vowel, now in an open syllable, is tense, yet the harmonized word-initial vowel remains lax.

These are similar to the case of Shimakonde where the trigger of harmony is eliminated, resulting in an over-application of harmony, except here the variable process is not the process rendierng harmony opaque, rather, harmony itself is variable.

3.3 Finnish & Stratal OT

Another instance of the interaction of variation and opacity is found in Finnish, which Anttila (2007) uses to argue for morphological level ordering. Finnish opacity involves the interaction of assibilation and apocope, where assibilation is variable and fricativizes *t* before *i* (13a), while apocope, also variable, deletes a short *i* in an unstressed syllable (13b).

(13) Opaque interaction of Finnish assibilation and apocope

a. Assibilation: *huut-i* → *huusi* ~ *huuti* 'shout-PAST'

b. Apocope: *makas-i* → *makasi* ~ *makas* 'lie-PAST'

c. /huut-i/ → huuti ~ huusi ~ huut ~ huus

When the two processes interact, four forms are possible because each process applies variably (13c). The crucial opaque form is *huus* where apocope and assibilation both apply; apocope counter-bleeds assibilation resulting in an over-application of assibilation.

Anttila's explanation for Finnish opacity and variation makes use of a combination of stratal OT (Kiparsky, 2000; Bermúdez-Otero, 1999) and variably ranked constraints (Anttila, 1997). Stratal OT posits three levels of evaluations with the output of the first serving as the input of the second, and so on, with each level corresponding to the different levels of lexical phonology (LP; Kiparsky, 1982). Opacity can arise from a serial ordering of phonological processes that correspond to the ordering of the different LP levels, but each individual level is supposed to be transparent. The strength of this approach for Finnish comes from the different domains of application of assibilation and apocope.

Anttila argues that assibilation is a stem-level process and apocope is post-lexical based on two factors. First, assibilation is only triggered by derivational or signature (number or tense) affixes whereas apocope applies across the board. Second, Finnish exhibits an OCP constraint against adjacent fricatives that operates at the stem-level, but not the word- or post-lexical levels since adjacent fricatives are present between words, at word-clitic boundaries, and across certain stem-affix boundaries. This OCP constraint blocks assibilation (/hiihtä-i/ → hiihti [*hiihsi] 'skied'), but not apocope (/piirtä-i-hän/→piirshän 'drew-clit.').

Anttila accounts for variation by positing that each stratum can have variably ranked constraints with each possible ranking corresponding to a different variant. For this Finnish data, the stem level has a variable ranking of *TI and IDENT(CONT) to account for variable assibilation while the post-lexical level has a variable ranking of *ɪ (no short i) and MAX to account for apocope.[2] At the stem level, MAX always outranks *ɪ so the *i* in /huuti/ is retained to transparently trigger assibilation. The output – *huusi* when assibilation applies and *huuti* when it does not – serves as input to the word, then post-lexical, levels so a fricativized coronal stop from the stem level remains fricativized in the post-lexical level independent of whether apocope occurs or not, yielding the four forms in (14).

[2] Anttila details a number of other constraints to account for other phonological facts conditioning these two processes accounting for the relative frequency of the four variants in different dialects.

Both aspects of this approach are problematic if we look at other languages, however.

3.3.1 The problem with a stratal approach

Stratal OT has been criticized for not being a restrictive enough formalism as it does not provide new insights into what types of opaque relationships can and cannot exist (McCarthy, 1999; Ito & Mester, 2003) and therefore predicts the existence of certain types of opacity that are not found. These charges of over-generation aside, in this section I focus on stratal OT's empirical inadequacy, i.e. its under-generation for cases of opacity which occur within a single stratum.[3]

First, in Sea Dayak, there is no evidence to suggest that nasal harmony and post-nasal stop deletion are anything other than word-level processes since they both apply to the whole word (2).

More definitive proof comes from Canadian French, which also has opaque process interaction within a single stratum as harmony and affix-triggered resyllabification both occur at the word level.

Final closed syllable laxing (CSL) must be word level based on words like [fin.mã] 'nicely' which can surface with a tense high vowel. Because open-syllable tensing is not applicable (the stem is closed), it must be the case that CSL did not apply to the bare stem /fin/, otherwise the surface form would have been required to be lax [fɪnmã]. Instead, CSL applies at the word level which feeds harmony (/mi.siv/→mɪ.si:v[4]), so harmony must also be at the word level.

Further evidence for harmony being word-level comes from the fact that harmony is triggered by certain suffixes ([–ɪsm] 'DOCT.', [-ɪst] 'ADJ.' and [-ʏl] 'DIM'). In a form like *illuminisme* [ɪ.lʏ.mɪ.nɪsm], the lax penultimate syllable is only possible because of harmony triggered by the lax vowel in the suffix.

However, based on opaque forms like *musical* [mʏ.si.kɑl], harmony must also apply prior to the affixation of derivational suffixes (*-al*). Suffixation triggers resyllabification resulting in the penultimate syllable being open, and therefore

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[3] A non-varying example of within-stratum opacity is found in Turkish, where opacity arises from the interaction of intervocalic velar deletion and cluster-epenthesis:

i) Turkish Opacity (Lewis, 1967)

(a) Epenthesis: /ip+n/→ipɯn 'your rope'
(b) Velar deletion: /bebek+i/→bebei 'baby-ACC'
(c) Opacity: /bebek+n/→bebeɯn 'your baby'

The form in (i.c) is opaque because the *k*, which conditions vowel epenthesis, is deleted intervocalically yielding an over-application of epenthesis. Velar deletion does not occur stem-internally ([jɑkɯ-n] 'your blister') nor between suffixes at a all levels ([bɑnkɑ-dɑ-ki] 'which is in the bank') suggesting it is word level. The possessive affix (i.a) is also argued to be at the word level (Inkelas & Orgun, 1995), the result being an opaque relationship within the word level.

[4] This analysis (Polliquin, 2007) suggests a Duke of York derivation (Pullum, 1976) is present where an underlying tense vowel changes to lax by word-final closed-syllable laxing triggering harmony in the initial syllable. Subsequent pre-fricative tensing (and lengthening) returns the vowel to its initial status of tenseness.

tense. Yet, the initial vowel is lax so it must be the target of harmony triggered by the lax vowel in the bare stem [mʏ.sɪk]. Therefore, at the word level, harmony and affixation interact opaquely and variably counter to the prediction of stratal OT that each stratum is transparent.

3.3.1 The problem with variable constraint ranking

In addition to stratal OT being an inappropriate solution for some of the cases of opacity presented here, the idea of using variably ranked constraints to account for variation is also problematic.

In Anttila (1997), a set of constraints are variably ranked with respect to each other and the frequency of occurrence of each variant will correlate with the number of grammars with strict constraint ranking that produce that particular variant. In a similar approach, Boersma & Hayes (2001) advocate numerically weighted constraints that vary with a Gaussian distribution. This noisy distribution results in some closely-ranked constraints being occasionally ranked in the opposite way, leading to variation. The constraint weights are based on a learning algorithm that is sensitive to frequency. Criticisms have been leveled against these approaches to variation (Keller & Asudeh, 2002), two of which are addressed here because they foreshadow the alternate proposal suggested in §4.

The first is that these proposals conflate grammatical competence and grammatical performance. Anttila's approach precludes different rates of variation within a single speaker but Schilling-Estes (2002) shows that there are significant differences in the rate of variation for a single speaker based on communicative context, while Bybee (2006) shows that frequency effects also play a role in rates of variation. Boersma & Hayes (2001) ameliorates this by incorporating frequency into the ranking of constraints, but they exclude communicative context, speaker-specific constraints (Mackenzie Beck, 1997) and sociolinguistic factors (Labov, 1994) from impacting variation. An alternative is to include all of these factors into the constraint ranking, but this would lead to an unwanted proliferation of constraints into the (universal) constraint set such as hypothetical *Vr/NYC-LOWER-CLASS (Labov, 1964) or *s/DRUNK constraints.

Second, variable constraint ranking creates problems for lexicon optimization. Lexicon optimization derives the underlying representations of surface forms based on the principle that the input most faithful to the output is selected as the UR. So, while /kæt/, /kʰæt/, /kætʰ/ and /kʰætʰ/ all map to [kʰæt] in English, /kʰæt/ is selected as the UR because it is most faithful to the output. For morphemes with multiple realizations, the UR selected is the one most harmonic to all realizations of the morpheme (Inkelas, 1995). Accounting for variation using variably ranked constraints results in multiple URs for any surface form, one for each of the different rankings.

For example, in the case of Sea Dayak, the two variants of /ramboʔ/ are [ramoʔ] and [ramboʔ] and can therefore both be URs. The constraint ranking does not disambiguate between the two, because the ranking of the constraints DEP and MAX are circularly based on the choice of UR. Thus, the UR /ramboʔ/ could generate [ramoʔ] with a *NC»Max ranking motivating deletion whereas /ramoʔ/ can generate [ramboʔ] with a *NV[oral]»Dep ranking motivating homorganic consonant epenthesis. So, implementing variation with variable constraint rankings create significant complications for lexicon optimization given that the UR selected is the one most faithful to the variants.

(14)

	SR	Dep	Max
a. /ramboʔ/	[ramboʔ]		
	[ramoʔ]		*
b. /ramoʔ/	[ramboʔ]	*	
	[ramoʔ]		

4 An Exemplar-based approach

To remedy the issue of accounting for variation with variable constraint ranking, I advocate, instead, for an exemplar-based approach to representations. First introduced in psychology as a theory of categorization (Medin, 1982), exemplar theory's application to linguistics is based on the idea that each morpheme is a category, which is represented by a cloud of the remembered tokens of that morpheme. Exemplar-models are motivated for use in phonology by experimental evidence that has shown that detailed information about heard speech is retained by listeners (Johnson, 1997). So, the category for the morpheme *write* might consist of a token representing the most recent time it was heard, in a carefully articulated lecture by a professor, another for when it was heard on the playground a year ago, uttered rapidly by a child and so on (15).

Each token is associated with speaker information and the discourse context of when it was heard, therefore this approach incorporates the factors ignored by variable constraint ranking by design. For example, the heard tokens of *write* (15) motivate the representation in (16). When the output of the phonological grammar – |ɹai{t/ɾ}| -- is fed to the phonetic realization, the intervocalic {t/ɾ} can then be realized as [ɾ] in the case of rapid speech in the phonetic context of a trochaic foot or as [t] in other contexts.

(15) Tokens of *writer*:

	wri[t]*e*	*wri*[t]*er*	*wri*[ɾ]*er*	*wri*[ɾ]*ing*	*wri*[t]*e*
Speech Style	hyper-art.	formal	casual	casual	casual
Phon Context	_#	(ˈV._V)	(ˈV._V)	(ˈV._V)	_#

(16) Phonological representation for *write*

hyper-articulate+(ˈV._V), _#
t
| ɹai{ }|
ɾ
regular+(V._V)

4.1 As applied to opacity involving variation

Applying a representation of the sort in (16) to the examples discussed in section 3 reveals that this augmented representation renders cases of opacity that involve variation transparent because both variants impact the evaluation.

Consider, for example, the case of Shimakonde (7, 8). The variants for the morpheme ‘sift’ (7) motivate the following underlying representation:

(17) Underlying Representation for ‘sift’:

$$/\mathrm{p}\left\{\genfrac{}{}{0pt}{}{\mathrm{e}}{\mathrm{a}}\right\}\mathrm{t}/$$

The key to a correct evaluation in the phonological grammar is the articulation of the harmony constraint. Myriad possibilities have been forwarded to account for the cross-linguistic diversity of harmony patterns (see Nevins, 2004; Van der Hulst, 1995 for overviews). In this example, as long as the harmony constraints is defined such that the suffix surfaces as a mid vowel if the stem *contains* a mid vowel or mid vowel features as part of its representation, then the exemplar-based UR produces the correct output since the stem contains both a low and mid vowel:

(18)

/ku-p{e/a}t-il-a/	HARMONY	ID(HEIGHT)
a. kup{e/a}tiila	*!	
☞ b. kup{e/a}teela		*

This approach works for Sea Dayak, as well. An exemplar-based UR would include both forms of the [ramoʔ]~[ramboʔ] variation (19). In the selection of harmonic outputs, the constraint on oral vowels yields the correct form because the union of the features of the post-nasal {b+ø} segment blocks nasalization (20). Then, the phonetic realization of the post-nasal stop in the output |ram{b/ø}oʔ|, is then based on the factors that condition variation.

(19) Phonological representation for [ramoʔ]~[ramboʔ]:

$$/\mathrm{ram}\left\{\genfrac{}{}{0pt}{}{\mathrm{b}}{\varnothing}\right\}\mathrm{o}ʔ/$$

(20)

/ram{b/ø}oʔ/	$*\mathrm{NV}_{\mathrm{ORAL}}$	IDENT-V(NASAL)
a. ram{b/ø}õʔ		*
☞ b. ram{b/ø}oʔ		

4.1.1 Contrast with underspecification

This approach is similar to under-specification (e.g. Kiparsky, 1993); indeed, in some of the above cases, an under-specification approach works just as well as an exemplar-based approach. However, the exemplar-based approach has greater empirical coverage and is necessary to account for all of the examples in §3.

Instead of a UR that has segments fully specified for all features, under-specification allows for some of the features to be undefined. For example, in Finnish, *i* triggers assibilation in coronals, changing *t* to *s* (21b). Not every *t* is subject to this alternation however (21a), and there is also an underlying *s* that does not exhibit alternation in any context (21c).

(21) Finnish t/s alternation

a.			koti	'home'
b.	halut-a	'want'	halus-i	'wanted'
c.	makas-a	'lie'	makas-i	'lied

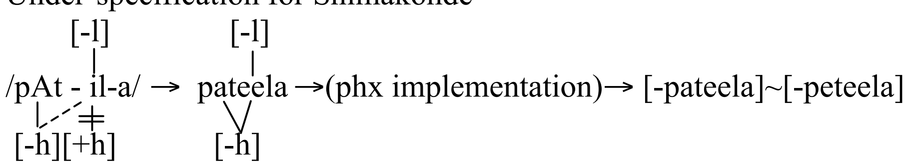
Thus there is a three-way contrast among coronal obstruents: those that alternate, those that are always fricatives and those that are always plosives. The theory of under-specification posits that this three-way contrast reflects a three-way contrast in featural representations with the fricative being [+cont], the non-alternating plosive [-cont] and the alternating plosive [0cont].

This approach can successfully account for the data in Shimakonde. Given the representation of the five vowels in (22), vowels subject to reduction that alternate between mid and low can have an under-specified featural representation of [-high]. The UR of 'sift' would therefore be /pAt/ which can spread [-high] to the *-il-* suffix yielding *-el-* (23). Contra the approach outlined in Inkelas (1994), however, the output of the phonology would remain under-specified and would be resolved during phonetic implementation where the factors conditioning variation determine whether the *A* archiphoneme is realized as *a* [+low] or *e* [-low].

(22) Shimakonde Vowels:

	i	u	e	o	a
high	+	+	-	-	-
low	-	-	-	-	+
round	-	+	-	+	-

(23) Under-specification for Shimakonde



The contrast between under-specification and an exemplar-based approach, or hyper-specification (Scobbie, 1991), amounts to a difference in whether the intersection of the sets of features of the variants is adequate or whether a union of the features is required. In Shimakonde, the intersection is adequate since the alternating variants share the feature that happens to be active in vowel harmony.

The data in Sea Dayak, however, suggests that a union of the variants' features is required. The variant alternation in Sea Dayak is between a plosive and no segment, the intersection of which is the null set. This would yield the under-specified UR being /ramoʔ/ which, as shown above, is not an appropriate UR for the opaque interaction. So, exemplars are required since deletion requires that the UR reflect the union of features of the variants.

4.2 As applied to cases of paradigm uniformity

Interestingly, this approach can also account for cases of regular opacity that reflect paradigm uniformity (Benua, 1995). Consider the case of English vowel length before voiced segments. This is rendered opaque by flapping because both the voiced and voiceless coronal plosives are neutralized to a [+voice] (or [+sonorant]) flap, creating the conditioning environment for vowel lengthening (25). The vowel remains short (24b), however, which Benua (1995) argues is evidence for constraints enforcing identity (here, of vowel length) to the base (*bat*).

(24) Vowel-length/flapping opacity in English
  a. bæːd bæːɾɚ
  b. bæt bæɾɚ

An exemplar-based approach can similarly account for such cases of opacity. The variable tokens of *bat* motivate the representation /bæ{t/ɾ}/ and if the constraint on vowel length is formulated such that short vowels are prohibited before segments that lack the feature [-voice], then the appropriate surface form for *batter* |bæː{t/ɾ}ɚ| is optimal (25). The ultimate realization of the {t/ɾ} segment is determined by phonetic implementation where phonetic context and discourse and speaker-dependant factors are resolved. While in this particular case phonetic implementation corresponds with the post-lexical level (*hi*[ɾ] *Ann*) this is not always the case as CF and Shimakonde variation is word-level and Finnish is stem- and word-level.

(25)

/bæ{t/ɾ}ɚ/	*Vː C[-VOICE]	ID(LENGTH)
a. bæː{t/ɾ}ɚ	*!	
☞ b. bæ{t/ɾ}ɚ		*

4.3 Learnability

The reason an approach developed for cases of variation is appropriate for cases of paradigm uniformity is because of the striking similarity in primary linguistic data between the two. With transparent variation, there are two realizations of the same morpheme that reflect an apparent conflict in the ranking of constraints. So, for transparent variation in CF, the same morpheme can be realized as [sty.pɪd] or [stʏ.pɪd], which reflects conflicting constraint rankings (ID[ATR]»HARMONY and HARMONY»ID[ATR] respectively). For non-varying cases of paradigm-driven opacity, the same situation holds. In (25), one realization of the morpheme, [bæt] motivates *V:C[-VOICE] » ID(LENGTH), whereas the other, [bæɾɚ], motivates the opposite constraint ranking, ID(LENGTH) » *V:C[-VOICE].[5]

These examples contrast with normal cases of alternation where both alternates allow for the same constraint ranking. In Dutch, for example, both [hɔnt] 'dog' and [hɔndən] 'dogs' allow for the ranking of *VCDCODA over ID(VOICE) given the underlying form /hɔnd/.

Ultimately, this distinction can aid a learning algorithm in assessing whether the variable manifestations of a morpheme reflects variation and/or opacity and warrants an enhanced representation or whether the alternation simply reflects a phonologically conditioned alternation requiring only a simple phonemic representations:

(26) Juxtaposing alternation, variation and opacity

		SR	Constraints	UR
a.	Normal Alternation (Dutch):			
	i)	[hɔnt]	*[+voice] $]_\sigma$ >> Id(voice)	/d/
	ii)	[hɔndən]	*[+voice] $]_\sigma$ >> Id(voice)	/d/
b.	Transparent Variation (CF):			
	i)	[sty.pɪd]	ID[ATR]>>HARMONY	/{Y/y}..ɪ/
	ii)	[stʏ.pɪd]	HARMONY>>ID[ATR]	/{Y/y}..ɪ/
c.	Invariant opacity (English):			
	i)	[bæt]	*V:C[-VOICE]>>ID(LENGTH)	/æt/
	ii)	[bæɾ]	ID(LENGTH)>> *V:C[-VOICE]	/æ{ɾ/t}/

5 Conclusion

In addition to accounting for variation involving under-application (Sea Dayak) and over-application (CF, Shimakonde) this approach also makes a number of predictions. Some are borne out, whereas the incorrect predictions hint at further modifications that may expand this approach's empirical coverage.

The first correct prediction relates to how constraints must be reformulated to accommodate the change in representations. As discussed above, if the union of the variants' features is used in the representation, then constraints must be stated such that violations are incurred if the segment in question "contains" one of the relevant features. This predicts that phenomena like variable epenthesis should never yield an opaque interaction. Consider, for example, a hypothetical language, Sky Dayak with the UR /ramoʔ/ and a process of variable post-nasal homorganic epenthesis (instead of deletion). Nasalization would yield [ramõʔ] as the surface form. The question is whether epenthesis could yield an opaque [rambõʔ] variant. Another theory of variation, output-variant faithfulness (Kawahara, 2002) predicts this form could exist with a constraint enforcing identity of the nasal vowel

[5] Assuming a M>>F bias when the data is inconclusive (Gnanadesikan, 1996).

between an opaquevariant, [rambõʔ], and its transparent base, [ramõʔ]. This type of language is impossible in the approach presented here, however, because enhanced URs for Sea and Sky Dayaks would be the same. Thus, there is an asymmetry between epenthesis and deletion such that forms that are more fully specified are posited to be transparent, which seems to be the correct prediction.

Furthermore, in contrast with approaches such as constraint conjunction (Kirchner, 1996), comparative markedness (McCarthy, 2003) and contrast preservation (Lubowicz, 2003), this approach can also accommodate circular chain shifts, as attested in Xiamen tone sandhi (Chen, 1987). A basic chain shift involving the processes of A→B and B→C implies that C is more harmonic than A. In a circular-chain shift, these two processes are accompanied by a C→A change violating OTs principle of harmonic ascent. Eschewing the use of constraints for the resolution of alternates in favor of a post-lexical process allow these processes to be locally evaluated. Thus, the C→A change can be motivated by factors preferring A over C in that particular discourse/phonetic context irrespective of their global harmonic relationship.

The downside of this approach is that toggles, i.e. a A→B change accompanied by B→A change, are impossible because if the discourse/phonetic context favors one over the other, the same variant should be chosen irrespective of the UR.

A further shortcoming is that this approach cannot account for cases of opacity that are not in variation or the result of paradigm effects. Opacity at the lexical level, for example, would elude description in this framework (as well is in stratal-OT) whereas it is accommodated by other approaches to opacity. It is not completely clear, however, that these cases of opacity in the lexicon should be included in the phonological grammar (Sanders, 2003).

These two shortcomings can be resolved by assigning some priority to one variant/paradigm member over the other. Indeed, what makes this account successful is that it allows a transparent variant/paradigm member with greater faithfulness to the UR to impact the other, opaque and less faithful variant. A similar solution is to give the UR-variant special status and allow it to impact the opaque SR either through covert structure (Goldrick, 2002) or as an additional determiner of faithfulness (McCarthy, 1999; Ettlinger, 2008). The advantage of using exemplar-enhanced representations for cases of variation involving opacity, however, is that it also accommodates the extra-linguistic factors known to condition phonology and therefore incorporates a broader range of empirical data.

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