Synchronic Chain Shifts in Optimality Theory

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Synchronic chain shifts, whereby certain sounds are promoted (or demoted) stepwise along some phonetic scale in some context, are one of the classic cases of opaque rule interactions. If, for example, /a/ raises to [e], and /e/ raises to [i], it would appear that the /e/ → [i] raising must precede /a/ → [e] raising in the derivation, otherwise /a/ and /e/ would both neutralize to [i].[1] These cases therefore pose a challenge for non-serial theories of phonology, including strongly parallel versions of Optimality Theory (Prince and Smolensky 1993) (henceforth OT).[2] McCarthy (1993) and Orgun (1995) have given OT analyses of a particular chain shift, namely a→i→Ø reduction in Bedouin Hijazi Arabic; however, these solutions are limited to chain shifts with no more than two "steps," where one of the steps involves deletion. I show that a more general solution to the chain shift problem can be obtained using *local conjunction* (Smolensky 1995) of featural faithfulness constraints, the effect of which is to constrain the "distance" between input and output values along some phonetic scale. As an illustration, I analyze a three-step non-deletional chain shift in NzEbi (Guthrie 1968).

Let us begin with the previous treatments of vowel reduction in the Ḥarb dialect of Bedouin Hijazi Arabic (BHA) (Al-Mozainy 1981). In non-final open syllables, short /a/ raises to a high vowel (transcribed [i], realized as [i], [u], or [I] depending on adjacent consonants), while short /i/ syncopates (short /u/ is marginal, and in any case behaves like /i/ in this regard):

(1)	i→Ø	/?arif-at/	?arfat	'she knew'
		/kitil/	ktil	'he was killed'
		/kitil-at/	kitlat	'she was killed'
		/kitil-na/	ktilna	'we were killed'
		/yaskin-uun/	yasknuun	'they (m.) dwell'
		/yaskin-in/	yasknin	'they (f.) dwell'
	a→i	/katab/	kitab	'he wrote'
		/sami?/	simi?	'he heard'
		/rafaagah/	rifaagah	'companions'

In classic rule-based theories, such cases were handled by breaking the chain shift into distinct rules, one rule for each step, and imposing a counterfeeding order on the rule set.

(2) Rule 1: a → i / __ σ   Rule 2 precedes Rule 1

Rule 2: i → Ø / __ σ

However, as McCarthy (1993) observes, this shift constitutes a unified phenomenon of vowel reduction.[3] It should therefore not be decomposed into a set of formally unrelated rules. McCarthy attributes the vowel reduction to a constraint prohibiting place feature specifications in a short vowel in an open syllable, NO-V-PLACE. He further assumes the following faithfulness constraints:

(3) PARSE$_{hi}$: The feature [high] is parsed (by a vocalic root node).

PARSE$_{low}$: The feature [low] is parsed (by a vocalic root node).

PARSE$_{V}$: A vocalic root node is parsed (by a mora).

In this view of faithfulness, stray elements are automatically deleted post-phonologically, therefore failure to parse (indicated by angle brackets below) amounts to deletion.

(4)

		NO-V-PLACE	PARSE$_{hi}$	PARSE$_{V}$	PARSE$_{low}$
a.	/{V,low}/ → V | (= a) low	*!			
	/{V,low}/ → <V> | (= Ø) low			*!	
	☞ /{V,low}/ → V (= i) <low>				*
b.	/{V,hi}/ → V | (= i) hi	*!			
	☞ /{V,hi}/ → <V> | (= Ø) hi			*	
	/{V,hi}/ → V (= i) <hi>		*!		

(The restriction to non-final syllables is the result of interaction with alignment constraints, which are not relevant to this discussion.) Note that in the winner in (4b), PARSE$_{hi}$ is satisfied by linking the [high] feature to the root node, even though the root node itself is unparsed. As Orgun (1995) notes, this interpretation of featural faithfulness is problematic with respect to the phenomenon of autosegmental stability (Goldsmith 1976), e.g. Rotuman umlaut under deletion of a front vowel:

(5) COMPLETE INCOMPLETE

f u t i   f ü t < i >   ‘to pull’

| |

-back   -back

If PARSE$_{back}$ can be satisfied by linking the [-back] feature to the unparsed root node, it is unclear why [-back] reassociates to the preceding (parsed) vowel.

Orgun instead handles the BHA facts by splitting the faithfulness constraints into two distinct families: the CORRESPONDENCE constraints, which require the presence of corresponding segments in the input and output; and the MATCH constraints, which require corresponding input and output segments to be featurally identical.

(6) CORR(/a/): Every input /a/ has an output correspondent.

NO [a]:No [a] in open syllables.

NO V: No V in open syllables.

MATCH(V): Output correspondents of input V are featurally identical to it.

		CORR(/a/)	NO [a]	NO V	MATCH(V)
a.	/a/ → a		*!	*	
	/a/ → Ø	*!			
	☞ /a/ → i			*	*
b.	/i/ → i			*!	
	☞ /i/ → Ø				

Observe, however, that both McCarthy's and Orgun's analyses capture the chain shift effect by exploiting the distinction between failure to parse a feature and failure to parse a segment: McCarthy does this by treating the top-ranked faithfulness constraint, PARSE$_{hi}$, as satisfied in an unparsed segment; Orgun, by distinguishing a violation of CORRESPONDENCE (which is fatal in (6a)) from a violation of MATCH (non-fatal). For this reason, neither McCarthy's nor Orgun's approach can be extended to chain shifts which are richer than that found in BHA, namely chain shifts with more than two steps, or where none of the steps involve segment deletion.

A three-step non-deletional chain shift is found in NzEbi, a Bantu language spoken in Gabon (Guthrie 1968, Clements 1991):

(7)		UNRAISED	RAISED	
	i → i	bis	bis[-i]	'to refuse'
	u → u	suEm	suem[-i]	'to hide self'
	o → u, « → i	kol«n	kulin[-i]	'to go down'
	e → i	bet	bit[-i]	'to carry'
	E → e	BEEd	Beed[-i]	'to give'
	O → o	tOOd	tood[-i]	'to arrive'
	a → E	sal	sEl[-i]	'to work'

The raised form of the verb appears to be selected by certain tense and aspect affixes. The suffix *-i* in the raised form is omitted except in extremely careful speech; nor does there appear to be a general phonological process of vowel raising before a high vowel (cf. *banzix* 'oranges'); therefore it appears that the raising is morphologically rather than phonologically conditioned. Nevertheless, there exist other cases of non-deletional chain shifts which are clearly phonologically conditioned, e.g. Basque vowel raising under hiatus (Hualde 1991). Therefore, I believe that the NzEbi chain shift warrants a general phonological solution, albeit involving a morphologically conditioned constraint:

(8) RAISING: Maximize vowel height (in verbs when occurring with certain tense and aspect affixes).[4]

For the sake of concreteness, I assume the following vowel height features:

(9)

	low	high	ATR
i, u	-	+	+
e, o, «	-	-	+
E,	-	-	-
a	+	-	-

I further posit feature-specific faithfulness constraints, of the following form:

(10) PARSE$_F$: For all $\alpha \in \{+,-,0\}$, if feature F is specified α in the input, it is specified α in the output.

The obvious problem is that there appears to be no way to rank RAISING relative to the PARSE$_F$ constraints to permit raising of the non-high vowels without raising /a/ all the way to [i] (the ☞ here indicates the incorrectly predicted winner; the true winner appears in boldface):

(11) RAISING » PARSE$_{low}$ (otherwise no /a/ → [E] raising)
RAISING » PARSE$_{ATR}$ (otherwise no /E/ → [e] raising)
RAISING » PARSE$_{hi}$ (otherwise no /e/ → [i] raising)

	RAISING	PARSElow	PARSEATR	PARSEhi
a → a	*!**			
a → **E**	*!*	*		
a → e	*!	*	*	
☞ a → i		*	*	*

The crucial observation is that, to satisfy RAISING, the input-output mapping for a given vowel can violate any one vowel height faithfulness constraint, *but it cannot violate more than one*. This prohibition on outputs which contain compounded violations of a single constraint (or closely related constraints) within a single domain (in this case, within a given vowel), is not unique to this problem. To handle similar constraint interactions which enforce sonority distance requirements in syllabification, Smolensky (1995) posits an operation on the constraint set, local conjunction, whereby two or more constraints may be conjoined to form a derived constraint, which is violated just in case all the conjoined constraints are violated within the relevant domain.[5] Similarly, Donca Steriade (p.c.) observes that local conjunction is required to account for languages which permit stress clash but ban double-sided clash.

For NzEbi, the correct result is obtained by conjoining the faithfulness constraints as follows:

(12) PARSElow & PARSEATR (violated iff PARSElow and PARSEATR are violated with respect to a given vowel)

PARSEhi & PARSEATR (violated iff PARSEhi and PARSEATR are violated with respect to a given V)

	PARSE$_{low}$&PARSE$_{ATR}$	PARSE$_{hi}$&PARSE$_{ATR}$	RAISING
a → a			***!
☞ a → E	(only PARSE$_{low}$)		**
a → e	*!		*
a → i	*!	*	
E → a	(only PARSE$_{low}$)		**!*
E → E			**!
☞ E → e	(only PARSE$_{ATR}$)	(only PARSE$_{ATR}$)	*
E → i		*!	
e → a	*!		****
e → E	(only PARSE$_{ATR}$)	(only PARSE$_{ATR}$)	*!*
e → e			*!
☞ e → i		(only PARSE$_{hi}$)	
i → a	*!		***
i → E		*!	**
i → e		(only PARSE$_{hi}$)	*!
☞ i →			

An alternative approach is to build the stepwise condition into the raising constraint itself, by allowing the constraint to refer to the underlying height of the vowel (i.e. "Raise a vowel one step from its underlying height value"). Note, however, that vowel raising in Basaa (Guthrie 1953) is essentially identical to NzEbi, except that /a/ and /E/ both raise to [e]. Under the "built-in stepwise" approach, Basaa would require a distinct raising constraint which is neutralizing with respect to /a/ and /E/ but stepwise with respect to the other vowels. If this approach is extended to chain shift phenomena generally, we must, for example, posit distinct constraints for stepwise vs. neutralizing applications (or combinations thereof) of vowel reduction, thereby losing a unified treatment of vowel reduction phenomena; likewise for all other phonological processes which can apply in chain shift fashion. Under the local conjunction approach however, the Basaa facts can be handled straightforwardly, *pace* Schmidt (1994), using the same constraint hierarchy as in NzEbi, modulo the ranking of PARSE$_{low}$ (and any conjoined constraints containing PARSE$_{low}$) below RAISING.[6]

The local conjunction approach can readily be extended to handle the BHA facts as well. I posit the following vowel reduction constraint:

(13) REDUCE: Minimize duration of a short vowel in open syllable.

High vowels are phonetically shorter than low vowels (Lehiste 1970), and of course Ø has zero duration. As demonstrated in Kirchner (1995ab), such sub-phonemic durational distinctions are relevant in conditioning various phonological phenomena, and must therefore be represented. For the sake of concreteness, I will assume the following (privative) durational features for BHA.[7]

(14)

	[duration > 0 msec]	[duration > 150 msec]
a	+	+
i	+	
Ø		

Thus, [a] incurs a greater violation of REDUCE than [i], and Ø incurs no violation at all. The conjunction of the corresponding faithfulness constraints, ranked above REDUCE, yields the correct results for BHA.

(15)

	PARSE$_{dur>0}$&PARSE$_{dur>150}$	REDUCE
a → a		**!
☞ a → i	(only PARSE$_{dur>150}$)	*
a → Ø	*!	
i → a	(only PARSE$_{dur>150}$)	*!*
i → i		*!
☞ i → Ø	(only PARSE$_{dur>0}$)	

More generally, for any constraint that militates in favor of maximal (or minimal) values of features with respect to some phonetic dimension, that constraint applies in chain shift fashion just in case it is outranked by locally conjoined PARSE constraints for features in that dimension. More generally still, for any case previously characterized as a rule application of "counterfeeding in the focus" (Kenstowicz and Kisseberth 1977) (whether or not the counterfeeding rules appear to constitute a unified phenomenon, cf. fn. 3), the counterfeeding effect falls out from domination of the constraints which give rise to the alternations by some conjunction of PARSE constraints.[8]

A remaining question concerns the class of constraints that may be conjoined with one another. Unrestricted local conjunction would appear to result in excessive descriptive power. For example, if it is possible to conjoin a constraint on complex onsets with a constraint on heavy syllables, we wrongly predict sound systems in which only light syllables may have complex onsets. While it is certainly premature to attempt to formulate restrictions on local conjunction, I tentatively observe that the cases motivating local conjunction appear to be limited to conjunction of a constraint with itself, e.g. self-conjoined *CLASH to ban double-sided stress clash; or with closely related constraints, e.g. faithfulness constraints for features within the same phonetic dimension, in the chain shift cases.[9]

It is unclear whether the approach proposed here will be sufficient for the reanalysis of all phenomena previously characterized as opaque rule interactions. Cole and Kisseberth (1995), for example, account for the counterbleeding/counterfeeding interaction of Yawelmani vowel lowering and harmony in terms of the notion of feature domains, and the distinction between existence of a domain and its featural expression. To handle other opacity cases, McCarthy (1995) tentatively abandons the condition that well-formedness constraints are exclusively stated over output representations. I have shown, however, that a substantial class of opaque rule interactions, namely synchronic chain shifts, can be handled insightfully within a strongly parallel theory of phonology, using local conjunction of faithfulness constraints.

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[1]In *diachronic* chain shifts, of course, this is not a problem, since the ordering of the sound changes presumably corresponds to distinct historical stages.

[2]This assumes the standard conception wherein well-formedness constraints are stated exclusively over output representations, and only the faithfulness constraints can refer to underlying properties (this conception is implicit in McCarthy and Prince 1995, and explicit in Orgun 1995). As an anonymous reviewer notes, opacity phenomena pose no formal problem if structural descriptions of well-formedness constraints can refer to underlying as well as surface environments (see McCarthy 1995); though the resulting theory is much less restrictive.

[3]An anonymous reviewer points out that in a similar chain shift in Kashgar Uighur (Orgun 1994), the environment for deletion is more restricted than the environment for raising, and concludes from this that deletion and raising really *are* two unrelated phenomena. Whether or not this conclusion is warranted, for Uighur or BHA, McCarthy's general point is clearly valid for numerous other chain shifts, including the NzEbi vowel raising examined below.

[4]For an explicit treatment of the notion of a phonetic dimension, such as vowel height, see Flemming 1995a.

[5]This operation was originally proposed in Smolensky 1993. Note that Hewitt and Crowhurst (1995) have proposed a similar operation, which they also call conjunction, whereby the derived constraint is violated just in case *any* of the component constraints is violated. See also Suzuki 1995.

[6]Flemming (1995b) gives yet another OT analysis of NzEbi, relying on constraints which refer directly to the preservation of contrasts within a given phonetic dimension. That is, the raising is constrained by the need to maintain at least two vowel height contrasts. However, the MAINTAIN CONTRAST constraints say nothing about the mapping between particular vowels in the unraised and raised forms. To rule out mappings such as i→E,{a,e}→i, →Ee, local conjunction of faithfulness constraints is required. But as shown herein, locally conjoined faithfulness constraints are sufficient to account for chain shifts (whether or not the MAINTAIN CONTRAST constraints are motivated by other phenomena).

[7]If this feature were not privative, i → Ø would violate $\text{PARSE}_{dur>150}$ (-dur>150 → 0dur>150), and so would violate the conjoined constraint, yielding the wrong result in tableau (15).

[8]It is not immediately apparent how to handle circular chain shifts such as Xiamen tone sandhi (Chen 1987, wherein a 53 contour tone lowers to 44, 44 → 22, 22 → 21, but 21 raises all the way to 53) in this or any other approach. Perhaps a solution lies in the idea that the points at opposite extremes of a phonetic dimension are in some sense perceptually closer to each other than to the intermediate points; i.e. the perceptual "space" is curved. If this idea is feasible, the 21 →53 alternation would traverse *less* perceptual distance than 21 →44, thereby falling into line with the distance-based effects attributed to conjoined faithfulness constraints above.

[9]Paul Smolensky (p.c.) suggests that local conjunction, even in the chain shift cases, can be formally reduced to self-conjunction, by allowing faithfulness constraints to refer to "feature classes" (Padgett 1995). Thus, assuming that the vowel height features ([high], [low], [ATR]) constitute a class, the active conjoined constraint in NzEbi is $\text{PARSE}_{\text{V-height}}$ & $\text{PARSE}_{\text{V-height}}$, or in Smolensky's notation, $\text{PARSE}_{\text{V-height}}^2$. However, this approach cannot handle the Basaa chain shift, without invoking an ad hoc class of vowel height features which excludes [low].