CUMULATIVE FAITHFULNESS EFFECTS: OPAQUE OR TRANSPARENT?[*]

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Recent research has focused on the effects of cumulative markedness—that is, phonologies in which the violation of multiple lower-ranked markedness constraints can override the violation of a higher-ranked faithfulness constraint (e.g., Pater et al. 2007b). This paper explores the converse of the cumulative markedness problem: phonologies with cumulative faithfulness effects. In these languages, violations of multiple lower-ranked faithfulness constraints can "gang up" on a single higher-ranked constraint to eliminate outputs that are unfaithful in multiple ways, while allowing singly-unfaithful outputs to survive. Such effects are explored in the loanword phonologies of Fula and Hawaiian. Traditional optimality theory (Prince and Smolensky 1993/2004), even with local constraint conjunction (e.g., Smolensky 1995) is shown to have difficulties accounting for cumulative faithfulness effects; Harmonic Grammar is demonstrated to be a viable alternative. The question of whether these effects should be considered opaque or transparent is also addressed.

1. Introduction

Strict domination, which means that multiple violations of a lower-ranked constraint can never overcome a single violation of a higher-ranked constraint, is a well-known tenet of optimality theory (OT; Prince and Smolensky 1993/2004). A number of recent studies (e.g., Pater et al. 2007b), however, have focused on the cumulative effects of markedness constraints, showing that in some grammars, the multiple violations of low-ranked markedness constraints may eliminate a candidate in favor of one that only violates a single higher-ranked constraint. On the other hand, the cumulative effects of faithfulness constraints have not been explored in detail. Chain shifts, in which each member of a related set of segments moves one step up the chain under pressure of a high-ranked markedness constraint, exhibit a kind of cumulative faithfulness: each segment may only move *one* step in the chain, thereby violating only a single faithfulness constraint. There exists another type of cumulative faithfulness effect, however, which parallels the cumulative markedness effects described above. In these examples, the single violation of a faithfulness constraint is allowed, but when multiple faithfulness violations would be called for, the language instead chooses the least unfaithful route to unmarkedness: deletion of the offending segment.

Cumulative faithfulness effects are problematic for standard optimality theory precisely because of strict domination. Single violations of the relevant faithfulness constraints are allowed, so those constraints must be low-ranked, but there is no mechanism in place to allow for multiple low-ranked constraints to "gang up" on a higher-ranked constraint. Local constraint conjunction (LC; e.g., Kirchner 1996; Smolensky 1995) is an augmentation of standard optimality theory that has been proposed to deal with cumulative effects; two con-

straints can be conjoined such that violation of both conjuncts results in violation of the higher-ranked conjoined constraint. This allows the grammar to rule out just those structures that are too marked (with the conjunction of two or more markedness constraints) or too unfaithful (with the conjunction of two or more faithfulness constraints). Several valid criticisms of LC have been made, however. The domain of conjunction must be specified, and if the domain is too large, unattested grammars are predicted (for examples, see McCarthy 2003; Pater et al. 2007b). For instance, Pater and colleagues (2007b) note that the conjunction of NoCoda and *VoicedObstruent within a word can result in a grammar in which initial devoicing occurs only in the case that a word has a coda. This is a typologically unattested pattern. Moreover, the provenance of LC constraints is at issue; there is debate as to whether all constraints are conjoined (recursively or not) as part of Con, or whether Con simply includes an operation of local conjunction. These questions make an LC account of cumulativity effects problematic.

      Harmonic Grammar (HG; e.g., Legendre et al. 1990; Smolensky and Legendre 2006), a precursor to optimality theory, provides an alternative to LC. In short (and discussed in more detail below), HG consists of weighted, rather than ranked, constraints. A greater weight essentially parallels a higher ranking in optimality theory. In some cases, though, the combined weight of violations of two lower-weight constraints can "gang up" on a higher-weight constraint, allowing for exactly the type of cumulativity effects discussed above. Furthermore, as no domains are necessary in HG, the problem of defining the domain does not arise; likewise, HG does not predict the unlikely grammars mentioned above (Pater et al. 2007b).

    The question of whether cumulative faithfulness effects are opaque or transparent is also part of the focus of this paper. The standard definition of opacity is given in (1). Case a. is the underapplication case: it looks as though rule P failed to apply even though its structural description was met. Case b. is the overapplication case: it looks as though rule P applied even though its structural description was not met.

(1)   Opacity defined (Kiparsky 1973)

      Given a phonological rule P of the form A $\rightarrow$ B / C__D, P is opaque if there are surface forms
        a. A in the environment C__D
        b. B derived by P in environments other than C__D

As we will see below, from a rule-based point of view, cumulative faithfulness effects are transparent: the necessary rules are in a mutual bleeding order, and the output of the rules is not opaque in the counterfeeding or counterbleeding sense. However, cumulative faithfulness effects in many ways resemble another class of opacity effects: grandfather effects and non-derived environment blocking. In a grandfather effect, a marked sound is allowed to surface when underlying, but that same sound cannot be created by a phonological process. Thus the faithful sound is "grandfathered" in while the same sound is disallowed if it is unfaithful. This type of effect is similar to "non-derived environment blocking" (NDEB; Kiparsky 1976, 1993), in which a rule that eliminates a given marked structure is blocked from applying in a non-derived environment, thus allowing a marked segment or sequence to occur in a non-derived environment while that segment or sequence is modified when it arises

in a derived environment. Both of these types of effect are considered opaque by the underapplication subcase: in a grandfather effect, a rule fails to apply when it would create a marked form, and in NDEB, a rule that applies to derived forms fails to apply in non-derived forms. This type of opacity has nothing to do with rule ordering; the lack of process application is the result of some constraint on the grammar disallowing the creation of marked structure. Cumulative faithfulness effects have some of the same characteristics. In the examples that follow, a process can apply only insofar as it does not result in too unfaithful an output. One important difference between grandfather/NDEB effects and cumulative faithfulness effects is that in the former, certain segments or structures cannot be derived because they are too marked. In the latter, on the other hand, certain segments or structures cannot be derived because they are too unfaithful. The problem does not lie in the markedness of the structure, then, but in the degree of faithfulness. In any case, cumulative faithfulness effects resemble other cases of opacity, in spite of the fact that they produce transparent outputs. Moreover, standard optimality theory cannot account for cumulative faithfulness effects, and mechanisms that have traditionally been used to account for cases of opacity, like the local conjunction of faithfulness constraints, are necessary. Throughout the paper we will revisit the issue of whether cumulative faithfulness effects should be considered opaque or transparent.

The current paper details two examples of cumulative faithfulness effects in the adaptation of loanwords. By way of background, §2 introduces the cumulativity problem in more detail with an example of cumulative markedness effects from Pater et al. (2007b) and analyses within optimality theory and HG. §3 presents and analyzes cumulative faithfulness effects in loanword adaptation. Theoretical implications are discussed in §4, with a conclusion in §5.

2. The cumulativity problem

Pater et al. (2007b) present an example of cumulative markedness from loanword adaptation; this section outlines the data and analysis given in that paper in order to illustrate cumulativity effects, their problems for optimality theory, and their analysis in HG. In Japanese, a rule known as Lyman's Law allows a single voiced obstruent within a word, but bans two or more voiced obstruents.[1] Another restriction prohibits voiced geminates. Loanwords, however, may contain two voiced obstruents (as shown in (2a)), or they may contain voiced geminates (as shown in (2b)). Crucially, however, when a loanword contains *both* a voiced geminate and another voiced obstruent, the geminate is optionally devoiced, as shown in (2c). Here we will account only for the devoicing cases, because they show the cumulative interaction of two constraints that are relatively low-ranked in the loanword phonology; an account of the variation is left for future research.

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[1] Lyman's Law is itself an example of a cumulative markedness effect: a single voiced obstruent is allowed (requiring the ranking IDENT[voice] >> *VOIOBS), but two voiced obstruents are not. Thus, the constraint *VOIOBS can be violated once in a native word, but its double violation is not tolerated.

(2)   Voicing bans in Japanese (data from Pater et al. 2007b)

a.   Lyman's Law violated in loanwords

[bagii]	'buggy'	[bagu]	'bug'
[bogii]	'bogey'	[dagu]	'Doug'
[bobu]	'Bob'	[giga]	'giga'

b.   Prohibition against voiced geminates violated in loanwords

[webbu]	'web'	[kiddo]	'kid'
[sunobbu]	'snob'	[reddo]	'red'
[habburu]	'Hubble'	[heddo]	'head'

c.   Optional devoicing of geminates only in words that contain another voiced obstruent

[guddo] ~ [gutto]	'good'	[doggu] ~ [dokku]	'dog'
[beddo] ~ [betto]	'bed'	[baggu] ~ [bakku]	'bag'
[doreddo] ~ [doretto]	'dredlocks'	[budda] ~ [butta]	'Buddha'
[baddo] ~ [batto]	'bad'	[doraggu] ~ [dorakku]	'drug'
[deibiddo] ~ [deibitto]	'David'	[biggu] ~ [bikku]	'big'

The constraints necessary to account for the Japanese data are in (3). It is clear that (at least for the loanword phonology) IDENT[voice] must be ranked above the markedness constraints *VOICEDGEMINATE and *2VOICE, which says that two voiced obstruents are disallowed within a word (Itô and Mester 1986), as each of these structures is allowed in loanwords. However, in the cases in which both of these structures would occur in the same word, the geminate devoices; this outcome would require ranking the faithfulness constraint below the markedness constraints, which presents a ranking paradox. LC, however, can account for the Japanese loanword data. To eliminate output candidates that contain both a voiced geminate and another voiced obstruent, we can conjoin the markedness constraints *VOICEDGEMINATE and *2VOICE.

(3)   Constraints and ranking for Japanese loans

a.   Markedness

*VOICEDGEMINATE: Voiced geminates are banned
*2VOICE: No more than one voiced obstruent is allowed per word

b.   Faithfulness

IDENT[voice]: Input and output segments have identical values for the feature voice

c. LC markedness constraint

> *VOIGEM&*2VOI: Local conjunction of *VOICEDGEMINATE and *2VOICE within a word

d. Ranking

> *VOIGEM&*2VOI >> IDENT[voice] >> *VOICEDGEMINATE, *2VOICE

The tableaux in (4) show the effects of the conjoined constraint. The winning candidates for the inputs 'bug' and 'web' each only violate one of the conjuncts of the locally conjoined constraint, and so that constraint is not relevant. The most faithful output for 'good', however, has both a voiced obstruent and a voiced geminate, and so the locally conjoined constraint eliminates that candidate (candidate a.). Candidate b., with a devoiced geminate, wins instead, in spite of its violation of IDENT[voice].

(4) LC markedness constraint eliminates doubly-marked candidates

/bagu/ 'bug'	*VOIGEM&*2VOI	IDENT[voice]	*VOICEDGEMINATE	*2VOICE
a. ☞ bagu				*
b. baku		*!		

/webbu/ 'web'	*VOIGEM&*2VOI	IDENT[voice]	*VOICEDGEMINATE	*2VOICE
a. ☞ webbu			*	
b. weppu		*!		

/guddo/ 'good'	*VOIGEM&*2VOI	IDENT[voice]	*VOICEDGEMINATE	*2VOICE
a. guddo	*!		*	*
b. ☞ gutto		*		

HG (Smolensky and Legendre 2006) can equally well account for the cumulative markedness effects in Japanese loanwords. First, some background on HG is necessary. HG is a precursor to OT and was originally intended to model connectionist networks. Each phonological input and output can be seen as a node in the grammar, with links between them symbolizing input-output pairs. Each link has a weight; the cumulative weight of all the links between an input and an output determines its activation. If heavier weights are given to more likely outputs, or more likely input-output pairs, then the resulting candidates are more likely to be activated in the grammar. HG was originally rejected in favor of OT because HG was argued to predict some grammars that do not seem to occur in the linguistic typology. More recently, though, HG has had a resurgence (e.g., Goldrick and Daland 2007; Jesney and Tessier 2007; Pater et al. 2007a, 2007b), and Pater et al. (2007b) have shown that HG actually predicts a more limited range of languages, particularly if restrictions are placed on the domain of evaluation of certain constraints.

HG differs from OT in that constraints are weighted rather than ranked. Constraints with higher weights would translate into higher-ranked constraints in OT, while low-

weighted constraints are similar to low-ranked constraints. The crucial difference between the two models is strict domination, a key feature of OT but not of HG (McCarthy 2002). Because of the symbolic nature of OT's constraints, a higher-ranked constraint strictly dominates a lower-ranked one—no number of violations of the lower-ranked constraint can overcome the violation of a higher-ranked constraint. On the other hand, in HG, multiple violations of low-weight constraints may, when added together, "gang up" on a higher-weighted constraint, allowing low-weight constraints to have more power than low-ranked constraints in OT.

Pater et al. (2007b) account for the Japanese loanword voicing problem in HG. By assigning each of the two markedness constraints a weight lower than the weight of the faithfulness constraint IDENT[voice], they assure that voiced geminates can appear in loanwords, as can multiple voiced obstruents. However, when a candidate violates both markedness constraints at the same time, their cumulative weight outweighs the faithfulness constraint, and that candidate loses. Weighting arguments for Japanese are given in (5). This display shows the weighting relationships among constraints necessary to achieve the desired outputs. The actual numerical weight of the constraints is somewhat arbitrary; what is important is the different relative weight among the constraints.

(5)　Necessary weightings for Japanese

Weighting	Result	
$W_{\text{ID[voi]}} > W_{*\text{2VOICE}}$	/bagu/	bagu > baku
$W_{\text{ID[voi]}} > W_{*\text{VOICEDGEMINATE}}$	/webbu/	webbu > webbu
$W_{\text{ID[voi]}} < W_{*\text{VOICEDGEMINATE}} + W_{*\text{2VOICE}}$	/guddo/	gutto > guddo

An HG tableau is given in (6); note that the weight of each constraint is shown above the constraint name, and the harmony (the cumulative weight of all constraints violated) is shown for each candidate in the rightmost column. Following convention, violations are shown with negative numbers; this means that the winning candidate is the one with the highest (closest to zero) harmony and, following Legendre et al. (2006), allows for the possibility of constraints which may reward candidates with positive violations rather than penalizing them with negative ones. In the tableau for the input 'bug', candidate b.'s violation of IDENT[voice] is sufficient to overcome candidate a.'s violation of *2VOICE, and in the tableau for 'web', candidate b.'s violation of IDENT[voice] is enough to overcome candidate a.'s violation of *VOICEDGEMINATE. In the tableau for 'good', however, the cumulative harmony of candidate a., which results from the addition of the violations of *VOICEDGEMINATE and *2VOICE, is heavy enough to overcome the single violation of IDENT[voice] in candidate b. Thus candidate b. has a higher harmony and is the winner.

(6)　HG tableaux for Japanese

/bagu/ 'bug'	IDENT[voice] w=1.5	*VOICEDGEMINATE w=1	*2VOICE w=1	H
a. ☞　bagu			-1	-1
b.　　baku	-1			-1.5

/webbu/ 'web'	IDENT[voice] w=1.5	*VOICEDGEMINATE w=1	*2VOICE w=1	H
a. ☞ webbu		-1		-1
b. weppu	-1			-1.5

/guddo/ 'good'	IDENT[voice] w=1.5	*VOICEDGEMINATE w=1	*2VOICE w=1	H
a. guddo		-1	-1	-2
b. ☞ gutto	-1			-1.5

A great deal of recent research (e.g., Coetzee and Pater 2007; Jäger and Rosenbach 2006; Kager and Shatzman 2007; Keller 2005; Pater et al. 2007b, 2007b) has focused on the cumulative effects of markedness, which clearly present a problem for standard OT. Several proposals similar to HG exist in the literature: for instance, Graded Constraint Theory (McClelland 2007), the Split Additive Model (Albright et al. 2007), Linear Optimality Theory (Keller 2000), Maximum Entropy (Jäger 2003), and Stochastic OT (Boersma 1998). However, none of these researchers has discussed the cumulative effects of faithfulness; that is, cases in which a grammar allows outputs that are unfaithful in a single way, but not outputs that are doubly-unfaithful; instead of allowing doubly-unfaithful outputs, these grammars avoid marked segments or structures by deleting them. Such cases have elsewhere been referred to as "doubly-derived environment blocking" (Farris 2007) but here will be labeled cumulative faithfulness effects, or CFEs. The next section explores two examples of CFEs from the point of view of OT and HG, arguing that HG can better account for the CFEs. Examples of cumulative faithfulness can be found in fully developed languages, child acquisition, and loanword phonology (Farris-Trimble 2008); this paper focuses on the latter.

3. Cumulative faithfulness effects in loanwords

Before any analysis of loanwords can occur, it is necessary to state the set of assumptions being made here. Two competing theories are prevalent in the study of loanword adaptation (see LaCharite and Paradis 2005 for a detailed discussion). Under the phonetic approximation model, borrowers either misperceive or misinterpret source sounds or adapt them as they are (mis)perceived (e.g., Kenstowicz 2003; Silverman 1992; Yip 1993). On the other hand, in the phonological approximation model, borrowers are bilinguals and have full access to the phonologies of both the source and borrowing languages. For this reason, phonetic misperception is not expected (LaCharite and Paradis 2005; Paradis and LaCharite 1997, 2001; Paradis and Prunet 2000; Ulrich 1997). A dichotomy has been drawn between these two theories—few theories consider a midpoint analysis in which both phonetics and phonology influence loanword adaptation (c.f. Iverson and Lee 2004).

The phonetic model of loanword adaptation relies heavily on the perceptual abilities of borrowers. In this model, borrowers may misperceive sounds from the source language that do not exist in the borrowing language, or they may misinterpret the categorization of a sound, hearing a phonetic variant of a sound in the source language and interpreting it as phonemic. This analysis implies that speakers do not have any knowledge of the phonology of the source language—the perceived sounds are not interpreted at the phonological level of

the source. This theory does have some drawbacks. First, in the assumption that borrowing speakers do not have access to the phonology of the source language, the generalization that many of the speakers who initiate borrowings are bilinguals is glossed over. Likewise, La-Charite and Paradis (2005) point out that speakers consistently adapt a source sound as the *phonologically* most similar sound in the borrowing language, even if there is another sound that is phonetically more similar.

On the other hand, the phonological model of loanword adaptation, exemplified by the Theory of Constraints and Repair Strategies (TCRS, Paradis 1996) argues that borrowers (who are bilinguals in this model) adapt sounds based on their phonological representations in the source and borrowing languages. A prime example of this involves Spanish and English stops (example from LaCharite and Paradis 2005). English voiced stops, with VOTs of 0-30 msec, are phonetically similar to Spanish voiceless stops. Yet Spanish speakers borrow English voiced stops as Spanish voiced stops, matching the phoneme category of the source. There are problems with this model as well, however. For instance, many experiments have shown that the perceptual judgments of non-native speakers (even high-level bilinguals), are not identical to the perceptual judgments of native speakers of a language (e.g., Bohn and Flege 1997).

In the following examination of loanword adaptation, we will see that in both examples, certain sounds are deleted only when they arise in a multiply-marked environment (where their adaptation would require multiple processes). It is tempting to follow the phonetic model of loanword adaptation and claim that the borrowers simply did not perceive these sounds, and therefore did not produce them. However, this account fails to explain why the exact same sounds were adapted when they occurred in less marked environments (where their adaptation would require fewer processes). While it is true that the perceptibility of sounds is based in part on their context (e.g., Steriade 2001a, b), it seems too coincidental to claim that the contexts in which these sounds are least perceptible is also the context in which they would require the greatest number of adaptation processes. Thus we begin with the assumption that in the languages discussed below, the borrowing speakers correctly perceived the words they borrowed, and that their underlying representations match the outputs produced by speakers of the loaning language. That is, it is assumed that borrowers begin with a representation that is identical to the production of French words by French speakers (as for Fula in §3.1), or English words by English speakers (as for Hawaiian in §3.2). This means that all adaptations made were the result of the phonology of the borrowing speakers. However, this is a question that should be addressed in more detail before claims about loanword phonology can be completely justified.

3.1 Fula

Fula, a West African language, exhibits a number of CFEs in its adaptation of loanwords from French (Paradis 1995; Paradis and Beland 2002). Here we will focus on the adaptation of glides and consonant clusters. Fula's native phonology excludes the labio-palatal glide /ɥ/ and allows no onset or coda clusters. When it occurs in words borrowed from French, the labio-palatal glide is typically adapted as [w] (7a); onset or coda clusters in French borrowings are resyllabified with an epenthetic vowel between the two consonants (7b). Note that in the words in (7a), the restriction against onset and coda clusters requires that the word-medial segments be syllabified heterosyllabically. Thus the glide in these words is a single-

ton onset. The cases in which the labio-palatal glide occurs as the second member of an on-set cluster, however, are of particular interest; given individual repairs for the labio-palatal glide and for onset clusters, one might expect the clusters in (6c) to be adapted with both a change in glide place and epenthesis. Instead, the glide deletes in the output, also eliminating the consonant cluster.

(7) Fula (data from Paradis 1995)

a. French glide /ɥ/ adapted as [w]

/dəlɥil/   [dilwil]   'oil'
/minɥi/   [minwi]   'midnight'

b. French onset clusters repaired by epenthesis

/bwasɔ̃/	[buwasɔŋ]	'drink'	/plas/	[palas]	'place'
/kwafe/	[kuwaːfaːdɛ]	'coif (one's hair)'	/traktœr/	[taraktɔr]	'tractor'
/ljøtnã/	[lijetinaŋ]	'lieutenant'	/krɛjɔ̃/	[kɛrɛjɔŋ]	'pencil'

c. French onset+/ɥ/ clusters undergo deletion, rather than adaptation and epenthesis

/kɥivr/	[kiri]	'copper'	*[kuwiri]
/kɥizinje/	[kisiŋ^{ŋ}gɛ]	'cook'	*[kuwisiŋ^{ŋ}gɛ]
/biskɥi/	[biski]	'biscuit'	*[biskuwi]
/tɥijo/	[tijo]	'pipe'	*[tiwijo]

From a rule-based perspective, Fula requires three rules: a rule epenthesizing a vowel between members of a cluster (Epenthesis), a rule changing /ɥ/ to [w] (Glide Backing), and a rule deleting /ɥ/ when it is the second member of an underlying onset cluster (Glide Deletion). In order to achieve the outputs in (7c), the Glide Deletion rule must precede the Epenthesis and Glide Backing rules in a bleeding order. However, if Epenthesis and or Glide Backing preceded Glide Deletion, then Glide Deletion would be bled. The rules are thus in a mutual bleeding relationship. Mutual bleeding is typically considered a transparent interaction, as no rule appears to over- or underapply. This also is a sort of overlapping conspiracy (Kisseberth 1970): two rules are necessary to eliminate the labio-palatal glide, and two rules are necessary to eliminate consonant clusters. The Glide Deletion rule serves both ends and is thus part of both conspiracies. Conspiracies were one piece of evidence used to favor optimality theory over rule-based accounts. However, as we will see below, standard optimality theory cannot account for this particular conspiracy; it predicts that either deletion will be the repair for every marked structure, or that deletion will never be a good repair for any marked structure. Additionally, the Fula example greatly resembles the opaque blocking effects mentioned in §1. Glide Backing and Epenthesis can each apply alone, but they are blocked from applying when they would apply together. This does resemble opacity, as a set of processes can apply in some instances but not others.

The constraints necessary to account for Fula are given in (8). Markedness constraints banning labio-palatal glides as well as complex syllable margins are required; faithfulness constraints require identity in place and ban epenthesis and deletion.

(8)   Fula constraints and definitions

   a. Markedness

      *ɥ: The glide [ɥ] is banned
      *COMPLEX: Onset and coda clusters are banned

   b. Faithfulness

      DEP: Output segments must have input correspondents (no insertion)
      MAX: Input segments must have output correspondents (no deletion)
      IDENT[back]: Input and output segments have identical values for the feature
                        [back]

The tableaux in (9) demonstrate that a ranking paradox occurs: it is necessary to rank MAX above the other faithfulness constraints to allow for the outputs in (7a) and (7b) above, but MAX must be ranked below at least one of those faithfulness constraints to allow for the outputs in (7c). The ranking that accounts for the outputs in (7a) and (7b) incorrectly predicts both a change in place and epenthesis for the outputs in (7c).

(9)   Standard OT fails to account for Fula

/minɥi/ 'midnight'	*ɥ	*COMPLEX	MAX	ID[back]	DEP
a. min.ɥi	*!				
b. mi.nwi		*!			
c. ☞ min.wi				*	
d. mini			*!		

/bwasɔ̃/ 'drink'	*ɥ	*COMPLEX	MAX	ID[back]	DEP
a. bwasɔŋ		*!			
b. ☞ buwasɔŋ					*
c. basɔŋ			*!		

/tɥijo/ 'pipe'	*ɥ	*COMPLEX	MAX	ID[back]	DEP
a. tɥijo	*!	*			
b. ☜ tiwijo				*	*
c. ☞ tijo			*!		

LC can account for the range of Fula loanword adaptations; by conjoining IDENT[back] and DEP and ranking this conjunct above MAX, it is possible to eliminate outputs in which both epenthesis and place change have occurred in favor of outputs in which the glide is deleted. The LC constraint is not relevant if both conjuncts are not violated, and so the ranking of MAX above the individual conjuncts eliminates the deletion candidates in

those outputs in which only IDENT[back] or DEP is violated. The domain of conjunction of this constraint is an interesting question; the violations of IDENT[back] and DEP in an output like /tɥijo/ → [tiwijo] are not in the same syllable. As Paradis (1995; 2002) does not discuss the foot structure of Fula, the next smallest relevant domain of conjunction is the word. Thus the constraint in (10) conjoins IDENT[back] and DEP within the domain of a word. The tableaux in (11) show that the LC constraint eliminates the unattested doubly-derived output candidate for a word like 'pipe'. In the singly-derived words 'midnight' and 'drink', on the other hand, only one of the conjuncts of the constraint is violated, and so the locally conjoined constraint plays no role.

(10) Locally conjoined constraint

IDENT[back]&DEP_w: Local conjunction of IDENT[back] and DEP within a word

(11) LC accounts for Fula

/minɥi/ 'midnight'	ID[back]&DEP_w	*ɥ	*COMPLEX	MAX	ID[back]	DEP
a. min.ɥi		*!				
b. mi.nwi			*!			
c. ☞ min.wi					*	
d. mini				*!		

/bwasɔ̃/ 'drink'	ID[back]&DEP_w	*ɥ	*COMPLEX	MAX	ID[back]	DEP
a. bwasɔŋ			*!			
b. ☞ buwasɔŋ						*
c. basɔŋ				*!		

/tɥijo/ 'pipe'	ID[back]&DEP_w	*ɥ	*COMPLEX	MAX	ID[back]	DEP
a. tɥijo		*!	*			
b. tiwijo	*!				*	*
c. ☞ tijo				*		

We turn next to an account of the Fula borrowings in HG. The same constraints are necessary, with the exception of the LC constraint. Weighting arguments are shown in (12). By weighting IDENT[back] and DEP such that each weighs less than MAX, but their combined weight outweighs MAX, it is possible to achieve a grammar in which deletion is preferred over the violation of the other two faithfulness constraints.

(12) Fula weighting arguments

Weighting	Result	
$W_{*ɥ} > W_{ID[back]}$	/minɥi/	minwi > minɥi
$W_{*COMPLEX} > W_{DEP}$	/bwasɔ̃/	buwasɔ̃ > bwasɔ̃
$W_{MAX} > W_{ID[back]}$	/minɥi/	minwi > mini
$W_{MAX} > W_{DEP}$	/bwasɔ̃/	buwasɔ̃ > basɔ̃
$W_{MAX} < W_{ID[back]} + W_{DEP}$	/tɥijo/	tijo > tiwijo

HG tableaux are given in (13). Note that for the doubly-marked input 'pipe', both of the relevant competitors, that in which the labio-palatal glide is deleted and that in which both a change in place and epenthesis occur, are unmarked. This weighting of constraints chooses the least unfaithful unmarked output and allows for a grammar in which MAX is only violated if a single deletion can eliminate two markedness violations at once. For the singly-marked inputs 'midnight' and 'drink', deletion would eliminate only one marked structure and is thus too costly.

(13) HG accounts for Fula

/minɥi/ 'midnight'	*ɥ w=2	*COMPLEX w=2	MAX w=1.5	ID[back] w=1	DEP w=1	H
a. min.ɥi	-1					-2
b. ☞ min.wi				-1		-1
c. mini			-1			-1.5

/bwasɔ̃/ 'drink'	*ɥ w=2	*COMPLEX w=2	MAX w=1.5	ID[back] w=1	DEP w=1	H
a. bwasɔŋ		-1				-2
b. ☞ buwasɔŋ					-1	-1
c. basɔŋ			-1			-1.5

/tɥijo/ 'pipe'	*ɥ w=2	*COMPLEX w=2	MAX w=1.5	ID[back] w=1	DEP w=1	H
a. tɥijo	-1	-1				-4
b. tiwijo				-1	-1	-2
c. ☞ tijo			-1			-1.5

Though LC and HG can both account for the Fula CFE, they make different predictions about a set of words that occur in French but did not occur in Paradis' (1995; 2002) description of Fula loanwords. These words have onset clusters and the labio-palatal glide, but the glide does not occur as part of the onset cluster. Words of this structure, presented in (14), are quite common in French, and it is not a stretch to imagine that they may be borrowed into Fula.

(14) French words with unrelated onset clusters and labio-palatal glides

/gradɥe/	'graduate'	/spiritɥel/	'spiritual'
/gratɥi/	'free'	/statɥer/	'to hand down a ruling'
/prɔdɥi/	'produce'	/tradɥir/	'translate'

Because it was necessary to conjoin IDENT[back] and DEP in the domain of a word to account for the Fula CFE, this conjunction also predicts that words in which the glide is not part of the cluster will nevertheless undergo deletion of the glide. This is shown in (15).

(15) LC predicts deletion even when glide is not part of cluster

/gratɥi/ 'free'	ID[back]&DEPᵥᵥ	*ɥ	*COMPLEX	MAX	ID[back]	DEP
a. grat.ɥi		*!	*			
b. garat.wi	*!				*	*
c. ☞ garati				*		

HG, on the other hand, makes a different prediction. The inputs in (14) each violate two markedness constraints: *COMPLEX and *ɥ. Because these are high-ranked constraints, any successful output must repair both markedness violations. Deletion of the glide only repairs one violation, that of *ɥ. Thus the HG account, given in (16), predicts that when the labio-palatal glide is not part of a cluster, it will be adapted as [w] and the cluster will be repaired with epenthesis. This reinforces the point made earlier; the weighting of constraints necessary to account for CFEs entails that deletion is only an available strategy when it will repair multiple markedness violations at once. If deletion only repairs one markedness violation, and another markedness violation must be repaired with another strategy, deletion becomes too costly.

(16) HG predicts deletion *only* when it repairs multiple markedness violations

/gratɥi/ 'free'	*ɥ w=2	*COMPLEX w=2	MAX w=1.5	ID[back] w=1	DEP w=1	H
a. grat.ɥi	-1	-1				-4
b. ☞ garat.wi				-1	-1	-2
c. garati			-1		-1	-2.5

LC and HG make different predictions in the case of these words whose borrowed forms are not attested; it is thus an empirical question which is correct. It seems likely, however, that the output predicted by HG is the correct one, as it combines two unrelated repairs already found in Fula words. The large domain of the LC constraint makes the unexpected prediction. This has already been noted as a criticism of LC: conjunction in large domains makes the prediction that unrelated or non-local segments may affect one another (McCarthy 2003). Restrictions on the domain of conjunction have been proposed (Lubowicz 2005), and it is the case even in this example that one might think of alternative domains that would not cause unexpected predictions. For instance, we might consider conjoining DEP and IDENT[back] in the domain of adjacent segments, rather than the word. This also raises the question of what is a reasonable domain—do domains have to be prosodic constituents such as syllables, feet, or words, or can they be other local relationships, such as adjacent segments? In any case, HG does not have the domain problem. In the HG account in (13) above, determining the domain of application of any constraint or set of constraints was not necessary. This gives HG an advantage over LC.

3.2 Hawaiian

A somewhat more complex example of the cumulative effects of faithfulness constraints comes from the loanword phonology of a Hawaiian speaker discussed by Adler (2006). Speaker 2[2] exhibited a number of interesting patterns in his phonology of words borrowed from English. First, some background on the native language: Hawaiian has no coronal obstruents and no fricatives; there are no codas and no complex syllable margins. Speaker 2 complies with his native grammar in his adaptations of English loanwords. The English coronal stop /t/ merges with the velar stop /k/ in Speaker 2's grammar, as shown in (17a) and (17b). The English coronal fricative /s/ is also borrowed as the velar stop [k] when it appears prevocalically, as in (17c). Syllable-structure violations, both codas and clusters, are repaired with epenthesis, as is shown in (17d).

       Interestingly, though Speaker 2 borrows prevocalic /s/ as [k], and though typical syllable structure errors are repaired with epenthesis, an unexpected repair occurs for initial s-clusters. In these clusters, the [s] deletes, as in (17e), rather than being realized as [k] followed by an epenthetic vowel. The same repair occurs for coda /s/, as shown in (17f).

(17) Hawaiian (data from Adler 2006)

    a. English /k/ is borrowed as [k]

       [kolopi:]   'Colby'   [kakəpi:]   'cockpit'
       [ko:linə]   'corn'   [koinikə]   'zoink'

    b. English /t/ is borrowed as [k]

       [kake]   'task'   [kale:]   'trade'
       [mekikə]   'mystic'   [keike]   'taste'

    c. English prevocalic /s/ is borrowed as [k][3]

       [pelekine]   'blessing'   [paləkami]   'balsamic'

    d. English syllabic violations are repaired by epenthesis

       [kəlapi]   'clasp'   [kale:]   'trade'
       [ko:linə]   'corn'   [hapə]   'half'

    e. English onset s-clusters undergo deletion

       [pikə]   'speak'   [kaime]   'stymie'
       [kolə]   'score'   [lupe]   'sloop'
       [nika]   'snicker'

---

[2] Speaker 2 exhibited some variation; however, the patterns described here are robust. This paper does not attempt to account for any variation.

[3] Speaker 2 sometimes borrows English prevocalic /s/ as [h], which can be viewed as a one-step change. In a coda or a cluster, however, /s/ is always deleted.

f.   English coda [s] undergoes deletion

[kali:]	'crease'	[apəlinə]	'aspirin'
[wipə]	'whisper'	[maki]	'musky'
[pikə]	'beast'	[wa:pə]	'wasp'

At first glance, Speaker 2's adaptation patterns seem unsystematic; deletion and epenthesis are both active syllabic repairs, and the segment /s/ undergoes featural changes in some instances and is deleted in others. Upon closer examination, though, a clear pattern emerges. When a segmental or syllabic repair would involve the violation of three or more faithfulness constraints, deletion is chosen as an alternative. For instance, the change from /s/ to [k] violates two faithfulness constraints, one preserving manner features, the other preserving place features. When the /s/ is in preconsonantal or coda position, however, a third repair, vowel epenthesis, is necessary. This would constitute the violation of three faithfulness constraints; instead, /s/ is deleted in these cases, incurring a violation only of MAX. Note that it is clear that Speaker 2 allows any combination of repairs that are unfaithful in only one or two ways. The borrowing of prevocalic /s/ as [k] is unfaithful to manner and place; the adaptation of coda /t/ as [k] followed by an epenthetic vowel is unfaithful in both the change in place and the epenthesis. It is just the combination of all three of these faithfulness violations to repair a single ill-formed structure that is disallowed.

A rule-based approach to Speaker 2's grammar would require four rules. One rule, Velarization, would change all coronal stops to velars. A second rule, Stopping, would require that all fricatives be realized as stops. This rule would feed the Velarization rule in the case of input /s/.[4] A third rule would require epenthesis in order to fix syllabic violations like onset clusters or codas. And finally, a fourth rule, S-Deletion, would delete input /s/ when it appears as the first member of a cluster or as a coda. S-Deletion would bleed each of the other rules, and if ordered differently, any of the other rules would bleed S-Deletion. Thus this CFE can also be described as a mutual bleeding interaction. Again, a conspiracy is involved—in fact, two conspiracies are at work in this problem. One set of rules conspire to eliminate the sound [s]. Another set of rules conspire to eliminate bad syllable structure. It happens to be the case that one rule, S-Deletion, takes part in both conspiracies. However, just as for Fula, the Hawaiian conspiracy has some characteristics of an opacity effect. The Stopping, Velarization and Epenthesis rules can apply singly or in pairs, but they are blocked from applying when all three would apply together.

A formal optimality theoretic account of Speaker 2's loanword phonology involves the markedness and faithfulness constraints in (18). The markedness constraints against coronal obstruents, fricatives, codas, and clusters are all high-ranked in the grammar, as none of them is ever violated. (The constraint against fricatives, *FRIC, and the relevant candidates that would be eliminated by it, will be left out of the following tableaux for reasons of space.) The faithfulness constraints banning insertion and deletion and requiring identity in place and manner are each violated at some point, so they must all rank below the markedness constraints. What is at issue is the relative ranking of faithfulness constraints.

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[4] Alternatively, Velarization and Stopping could be combined into a single rule that requires that all input coronal obstruents be realized as velar stops. Because there is no restriction on how many featural changes can be made by a single rule, it is possible to eliminate both the marked features of /s/, the [coronal] and [+continuant] features, in one rule.

(18) Constraints and definitions

    a. Markedness

        *t: Coronal obstruents are banned
        *FRIC: Fricatives are banned
        NOCODA (NC): Syllable-final consonants are banned
        *COMPLEX: Onset and coda clusters are banned

    b. Faithfulness

        DEP: Output segments must have input correspondents (no insertion)
        MAX: Input segments must have output correspondents (no deletion)
        IDENT[place]: Input and output segments have identical place values
        IDENT[manner]: Input and output segments have identical manner values

The tableaux in (19) show that in standard OT, a ranking paradox between MAX and the other faithfulness constraints emerges. When the input /s/ is prevocalic, as in a word like 'blessing', a ranking of MAX over DEP, IDENT[place] and IDENT[manner] is necessary to ensure preservation of /s/ as [k]. On the other hand, when the /s/ is not prevocalic, in a word like 'speak', ranking MAX above the other faithfulness constraints results in an output in which the /s/ is incorrectly preserved. The correct generalization about Speaker 2's grammar is that deletion of /s/ is only an available repair when the alternative is an output that violates too many faithfulness constraints. That is, Speaker 2 only deletes /s/ when to preserve it would violate not only IDENT[place] and IDENT[manner], but DEP as well. This, then, is an example of cumulative faithfulness: the cumulative violation of IDENT[place], IDENT[manner] and DEP can be enough to overcome higher-ranked MAX and compel deletion. From another point of view, the Hawaiian example can be thought of as 'triply-derived environment blocking'. That is, an underlying /k/ is allowed, as is a [k] derived in one step (from /t/, which constitutes a place change) and a [k] derived in two steps (from prevocalic /s/, which constitutes a place and manner change). However, a [k] derived in three steps (from non-prevocalic /s/, which constitutes a place, manner, and syllabic change) is disallowed.

(19) Standard OT fails to account for Hawaiian

/blɛsɪŋ/ 'blessing'	*t	NOCODA	*COMPLEX	MAX	DEP	ID[place]	ID[manner]
a. blɛsɪŋ	*!	*	*				
b. ☞ pelekine					**	*	*
c. peleine				*!	**		

/spik/ 'speak'	*t	NOCODA	*COMPLEX	MAX	DEP	ID[place]	ID[manner]
a. spik	*!	*	*				
b. ☜ kəpikə					**	*	*
c. ☞ pikə				*!	*		

LC can account for this cumulative faithfulness effect, but to do so it is necessary to conjoin three constraints: DEP, IDENT[place], and IDENT[manner]. The constraints can be conjoined within the domain of a syllable. This constraint is defined in (20).

(20) Locally conjoined constraint

    LC: IDENT[place]&IDENT[manner]&DEP$_\sigma$: the conjunction of IDENT[place],
        IDENT[manner] and DEP within the domain of a syllable

By conjoining these constraints and ranking them above MAX, it is possible to rule out the triply-derived [k]. Ranking MAX above the other non-conjoined faithfulness constraints, however, preserves the /s/ as [k] in the case that it is prevocalic. The tableaux in (21) show this conjunction. Note that in the tableau for 'blessing', the winning candidate b. does not violate the LC constraint, even though the candidate does violate IDENT[manner], IDENT[place] and DEP. This is because the LC constraint operates solely within the domain of a syllable. The violations of DEP incurred by candidate b. are not in the same syllable as the violations of IDENT[place] and IDENT[manner], and so the LC constraint is not violated. This drives home the point that the deletion of /s/ is allowed only in the case that it avoids a three-step repair for that segment. Moreover, it is important to note that gratuitous violations of MAX are not allowed. Candidate d. in the tableau for 'speak' deletes not only the /s/, but also the coda /k/, which eliminates any need for either featural change or epenthesis. This candidate, however, incurs a gratuitous violation of MAX, which eliminates it, in spite of the fact that it violates no other constraint.

(21) LC account of Hawaiian

/blɛsɪŋ/ 'blessing'	LC	*t	NC	*COMP	MAX	DEP	ID[place]	ID[man]
a. blɛsɪŋ		*!	*	*				
b. ☞ pelekine						**	*	*
c. peleine					*!	**		

/spik/ 'speak'	LC	*t	NC	*COMP	MAX	DEP	ID[place]	ID[man]
a. spik		*!	*	*				
b. kəpikə	*!					**	*	*
c. ☞ pikə					*	*		
d. pi					**!			

While the LC constraint can sufficiently account for the data, it raises broader questions. Is it acceptable to conjoin three constraints? Are locally conjoined constraints part of Con, or are they created as needed by learners? If a triply-conjoined constraint exists in a grammar, do its doubly-conjoined counterparts exist as well? For instance, does Speaker 2's grammar also include the conjunction of IDENT[place] and IDENT[manner], or of DEP and IDENT[place], or DEP and IDENT[manner]? Note that each of these constraints must be ranked below the markedness constraints, because each would be violated by one of Speaker 2's outputs. These questions are not insurmountable; it may be that all possible conjunctions

of all constraints exist in Con. If this were the case, though, then even those conjunctions that predict implausible grammars must be assumed.

HG provides an alternative account of Speaker 2's adaptation pattern. Weighting arguments are given in (22). It is necessary to weight each of the constraints in the above account such that the violation of any one or two of the faithfulness constraints IDENT[place], IDENT[manner] and DEP will still be outweighed by a single violation of MAX, but the violation of all three of those constraints is enough to overcome MAX. Here the markedness constraints have all been assigned a weight of 3 (indicating, in a ranking-based account, their high ranking). MAX has a weight of 2.5, while the other three markedness constraints all have a weight of 1. The tableaux in (23) illustrate the HG account.

(22) Hawaiian weighting arguments

Weighting	Result	
$W_{*t} > W_{ID[place]}$	/tæsk/	k̲ake > t̲ake
$W_{*t} > W_{ID[place]} + W_{ID[manner]}$	/blesɪŋ/	pelek̲ine > peles̲ine
$W_{*COMP} > W_{DEP}$	/klæsp/	k̲əlapi > k̲lapi
$W_{NOCODA} > W_{DEP}$	/slup/	lupe > lup
$W_{MAX} > W_{ID[place]} + W_{DEP}$	/teist/	keik̲e > kei
$W_{MAX} > W_{ID[manner]} + W_{DEP}$	/hæf/	hapə > haf
$W_{MAX} > W_{ID[place]} + W_{ID[manner]}$	/blesɪŋ/	pelek̲ine > peleine
$W_{MAX} < W_{ID[place]} + W_{ID[manner]} + W_{DEP}$	/spik/	pikə > kəpikə

(23) HG account of Hawaiian

/blɛsɪŋ/ 'blessing'	*t w=3	NC w=3	*COMP w=3	MAX w=2.5	DEP w=1	ID[place] w=1	ID[man] w=1	H
a. blɛsɪŋ	-1	-1	-1					-9
b. ☞ pelekine					-2	-1	-1	-4
c. peleine				-1	-2			-4.5
d. lene				-3	-1			-8.5

/spik/ 'speak'	*t w=3	NC w=3	*COMP w=3	MAX w=2.5	DEP w=1	ID[place] w=1	ID[man] w=1	H
a. spik	-1	-1	-1					-9
b. kəpikə					-2	-1	-1	-4
c. ☞ pikə				-1	-1			-3.5
d. pi				-2				-5

Note that in the above examples, a violation of MAX is only allowed if a single deletion repairs multiple markedness violations. Each of the above inputs includes a variety of marked segments or structures. In the input for 'blessing', there is an onset cluster, a prevocalic /s/, and a coda consonant, so the fully-faithful candidate thus incurs violations of *t, *COMPLEX and NOCODA. Because of the high ranking of the markedness constraints, each of these marked structures must be repaired. Candidate b., the attested output, repairs both

the onset cluster and the coda with epenthesis and changes the prevocalic /s/ to a [k]. This, then, is an interesting example, as the winning output violates DEP (twice), IDENT[place] and IDENT[manner]. It might seem as though this set of violations should be disallowed, given the fact that the repair of a non-prevocalic /s/ by violations of exactly these three constraints is disallowed. If the multiple violations in 'blessing' are treated the same as the multiple violations in 'speak', then the deletion candidate should be a better alternative. This is not the case, however. If an input has multiple loci of markedness violations, then any deletion output candidate would have to have multiple loci of deletion. In the word 'blessing', no single deletion can avoid the violations of DEP, IDENT[place], and IDENT[manner]. It would take three deletions (as in candidate d.) to eliminate all the markedness violations. Because of the relatively high weight of MAX, these three deletions are not tolerated. Thus candidate b., in which DEP, IDENT[place], and IDENT[manner] are all violated, is the best candidate for this input. This drives home the point that in CFEs, a violation of the higher-weight faithfulness constraint (in this case, MAX) is only allowed if it will remove multiple marked structures, thereby avoiding the violation of multiple other faithfulness constraints. If a violation of MAX only resolves one marked structure, and thus only avoids the violation of one other faithfulness constraint, the violation of MAX is deemed too costly.

In the tableau for 'speak', the fully-faithful candidate also violates exactly the same three markedness constraints that the fully-faithful candidate for 'blessing' violated: *COMPLEX because of the /sp/ cluster, *t because of the /s/, and NOCODA because of the /k/. The 'expected' repair, shown in candidate b., involves both epenthesis and the change from /s/ to [k] and would violate DEP (twice, once for the cluster and once for the coda), IDENT[place], and IDENT[manner]. Note that this is also exactly parallel to candidate b. in the tableau for 'blessing', the winning candidate. The crucial difference lies in the locus of violation of each of the faithfulness constraints. By deleting the /s/ in 'speak', candidate c. violates MAX but avoids violations of IDENT[place] and IDENT[manner] as well as one of the DEP violations (the other violation, for epenthesis after the coda /k/, is unrelated). Here, then, deletion is the preferred repair because a single deletion can eliminate multiple marked structures.

A careful observer will have noticed that several of the adaptations in (17) did violate three faithfulness constraints. It is not the case that Speaker 2's grammar disallows all outputs which are triply-unfaithful; some triply-unfaithful outputs are allowed, as in 'blessing' above, because the loci of the faithfulness violations do not intersect. Other triply-unfaithful mappings are allowed even when the loci of violations do intersect, indicating that not all of the low-weight faithfulness constraints have equal weight. An example from (17) is repeated in (24) along with details about which faithfulness constraints are violated.

(24) Some triply-derived repairs allowed

[koinikə]   'zoink'
/z/ → [k] violates IDENT[place], IDENT[manner], IDENT[voice]

Hawaiian does not have any voiced obstruents. In this example, the change from /z/ to [k] violates three identity faithfulness constraints; deletion of the /z/ would avoid these three violations, yet the deletion candidate is not the attested output. The optimal output for a prevocalic /z/ is the same as a prevocalic /s/. This implies that the additional faithfulness violation

incurred by the winning candidate for an input /z/, the violation of IDENT[voice], must have a very low weight, so low that the cumulative violation of IDENT[voice], IDENT[place], and IDENT[manner] cannot overcome the weight of MAX. The additional constraints necessary to account for this word and the relevant weighting argument are shown in (25).

(25) Additional constraints

    a. Markedness

       *VOIOBS: Voiced obstruents are banned

    b. Faithfulness

       IDENT[voice]: Input and output segments must have the same value for the feature [voice]

    c. Weighting argument

Weighting	Result
$W_{*MAX} < W_{ID[place]} + W_{ID[manner]} + W_{ID[voice]}$	/zɔɪŋk/ <u>koinikə</u> > oinikə

A tableau for 'zoink' is displayed in (26). Based on the weighting argument above, it is necessary for the combined weight of IDENT[place], IDENT[manner] and IDENT[voice] to be less than the weight of MAX. Given the previously established weights of IDENT[place], IDENT[manner], and MAX, it is simply necessary to assign IDENT[voice] a weight lower than 0.5. Here it is shown with a weight of 0.4. This allows the cumulative harmony of candidate b., the winning candidate, to be slightly higher than the cumulative harmony of candidate c., the deletion candidate.

(26) HG account of allowable triply-derived repairs

/zɔɪŋk/ 'zoink'	*t w=3	*VOIOBS w=3	MAX w=2.5	ID[place] w=1	ID[man] w=1	ID[voi] w=0.4	H
a. zɔɪŋk	-1	-1					-6
b. ☞ koinikə				-1	-1	-1	-2.4
c. oinikə			-1				-2.5

    In sum, Speaker 2's Hawaiian loanword adaptations show cumulative faithfulness effects. In his grammar, deletion is a repair strategy only when it would avoid the violation of multiple other faithfulness constraints whose weight can gang up on the weight of MAX. Otherwise, the relatively high weight of MAX renders it too costly a violation. While both LC and HG can account for Speaker 2's adaptation patterns, the LC account raises numerous questions about the conjunction of constraints. These questions are not problematic for the HG account, as the constraints do not have to be conjoined.

4. Theoretical implications

The goal of this paper has been to demonstrate that faithfulness interactions can show cumulativity effects just as markedness interactions can. In some languages, the best output is the one that avoids markedness in the way that violates the fewest faithfulness constraints. This shows an interesting interaction between markedness and faithfulness constraints: while languages may be under pressure to decrease markedness, they are also under pressure to be as faithful as possible. Here two of the topics of the paper are summarized and discussed: local constraint conjunction and the opacity/transparency of CFEs.

4.1 Local constraint conjunction versus Harmonic Grammar

The accounts of Fula and Hawaiian showed that both local constraint conjunction and harmonic grammar can account for CFEs. However, the conjunction of faithfulness constraints was shown to be subject to at least two of the same criticisms that arise in the discussion of the local conjunction of markedness constraints. First, the domain of conjunction must be specified; when the domain is too large, unlikely grammars are predicted. The domain of conjunction criticism has been discussed by McCarthy (2003), and restrictions on the domain have been proposed by Lubowicz (2005). Nevertheless, it is unclear whether the domain can be sufficiently restricted, and in any case HG does not share this problem. In LC, if the domain is too large, unattested results may obtain, but in HG, it was shown that with the proper weightings, CFEs were limited to structures whose markedness violations overlap, even without the specification of a domain. It seems, then, that by virtue of not having to specify a domain at all, HG has an advantage over LC.

    A second criticism of LC concerns whether conjoined constraints are part of Con or if constraint conjunction is an operation accessible to learners. Smolensky (1995) is silent on this issue. Baković (2000) and Ito and Mester (1998) have argued that locally conjoined constraints are universal, though Baković does state that conjunction is not recursive, as that would create an infinite number of constraints. This raises a further question: if conjunction is not recursive, how many constraints can be conjoined? It has been shown here that in some cases, three constraints must be conjoined; it is conceivable that there are grammars in which four or more constraints must be conjoined. If these constraints are universal, how many conjoined constraints exist? Moreover, Rice (2006) notes that if locally conjoined constraints are universal, they should play a greater role in grammars than they seem to. On the other hand, Ito and Mester (2003) and Smolensky (1997) argue that the operation of conjunction is part of Con, but that the locally conjoined constraints themselves are not necessarily universal—in fact, which locally conjoined constraints exist in a language is part of what makes each language different. Each of these arguments has its advantages, but which is the correct assumption is unclear. Again, HG is not plagued with the problem of universality or the provenance of constraints; it is the weighting of constraints that allows for CFEs, and the weighting is exactly what makes each grammar language-specific.

    Though HG is preferable to LC in the cases discussed here, HG does have its drawbacks. For some constraints that are violated gradiently, as many of the stress constraints are, HG has been claimed to make unattested predictions (e.g., Legendre et al. 2006). That is, HG has been criticized for being insufficiently restrictive (e.g., Legendre et al. 2006; Prince

and Smolensky 1993/2004, 1997). Pater and colleagues (2007b), however, successfully counter most of these arguments.

4.2 Opaque or transparent?

A final question that has come up throughout this paper is whether CFEs are transparent or opaque. Valid arguments exist for each side of the debate. CFEs are always mutual bleeding interactions, which are typically considered transparent because no rule appears to have under- or overapplied in the surface form. The outputs of each of the CFEs discussed here are transparent: for instance in the Hawaiian form [pikə] 'speak', the s-deletion rule has properly applied, and the surface form does not contain any element that one of the rules should have eliminated. Moreover, CFEs can easily be accounted for with HG, which cannot account for other types of opacity effects. Finally, CFEs can be analyzed as conspiracies (Kisseberth 1970). Multiple processes are working together to eliminate a single marked output. As conspiracies are always transparent, CFEs must be transparent as well.

On the other hand, CFEs are reminiscent of grandfather/NDEB effects in that a given structure is allowed in some environments but not in others. In a grandfather effect, a rule is blocked if it would create a marked structure. In CFEs, a rule is blocked only in the event that another rule would also have to apply. For instance, in Fula, Glide Backing and Epenthesis can each apply individually, but when both would apply together, their application is blocked. In addition, the conjunction of faithfulness constraints can be used to account for CFEs, though the only previous use of such conjunction was to deal with chain shifts, a kind of underapplication opacity.

Intuitively, it seems as though CFEs involve underapplication opacity effects. In Fula, for instance, given an underlying representation like /tɥijo/ and the Glide Backing and Epenthesis rules, it appears that those rules underapply. In fact, they are bled by the ɥ-deletion rule. Bleeding is normally not a type of underapplication, but the bleeding interaction evidenced in CFEs is unusual. In a standard bleeding relationship, there is independent motivation for each of two rules. When the structural description of both rules is met, one rule applies first and the resulting intermediate representation no longer meets the structural description of the second rule. In CFEs, on the other hand, the deletion rule that bleeds the other rules (here ɥ-deletion) is not independently motivated. The only time deletion ever occurs is when it is used to avoid a doubly-unfaithful output. It is as if the phonology is aware that without deletion, the output will be doubly-derived. In order to avoid such unfaithfulness, a deletion rule is invoked. This same deletion rule is never invoked in a singly-derived case, however.

In order to view CFEs as a type of underapplication opacity, we need a way in which a derivation or a process can have access to what the output would be if the process did not apply. That is, we need to be able to make a statement like "Deletion applies only in those cases in which otherwise both of two other rules would have applied." Baković (2007), in presenting a number of overapplication opacity effects that have not previously been discussed, provides just such a mechanism. One of his new opacity effects, which he terms 'cross-derivational feeding', occurs when the grammar compares an actual derivation with a counterfactual derivation, that is, a logically possible derivation that is not the attested output. To understand his argument, we will briefly summarize the Lithuanian example he uses. In Lithuanian, an obstruent assimilates in voicing and palatalization to a following obstruent, as

in (27a). A second process, Epenthesis, applies when two adjacent obstruents are identical or only differ in terms of voicing or palatalization, as in (27b).

(27) Lithuanian (examples from Baković 2007)

    a. Voicing/palatalization assimilation

        [at-ko:pʲtʲi]   'to rise, climb up'
        [ad-gautʲi]   'to get back'
        [atʲ-pʲautʲi]   'to cut off'
        [adʲ-bʲekʲtʲi]   'to run up'

    b. Epenthesis

        [atʲi-taikʲi:tʲi]   'to make fit well'
        [atʲi-tʲeisʲtʲi]   'to adjudicate'
        [atʲi-duotʲi]   'to give back, return'
        [atʲi-dʲetʲi]   'to delay, postpone'

Baković claims that the correct analysis for the Epenthesis rule is that it applies only between adjacent identical consonants. Note that in (26b), epenthesis is applying in exactly those cases in which Assimilation otherwise would have created identical adjacent consonants. This "would have" case is known as the counterfactual derivation. In cross-derivational feeding, the counterfactual derivation instead "feeds" the actual derivation. By applying Epenthesis before Assimilation, the grammar can result in outputs that are surface-true (note that in the counterfactual derivation, Assimilation would have created the environment for Epenthesis, resulting in counterbleeding opacity). In short, one rule applies because it can look across derivations and see what the output would have been if a different rule had applied instead. According to Baković, this is a type of overapplication opacity; Epenthesis overapplies to non-identical adjacent consonants if it is fed by the counterfactual derivation.

       If we apply the same sort of reasoning to the CFE examples discussed here, we can compare the actual and the counterfactual derivations for Fula. The rules necessary to account for Fula are given in (28).

(28) Fula rules

        ɥ-deletion   ɥ → Ø / .C__
        Glide Backing   ɥ → w
        Epenthesis   Ø → V / .C__C

The ɥ-deletion rule states that the glide ɥ is deleted in a very specific environment: when it is the second member of an onset cluster. The Glide Backing rule is a context free rule representing the elsewhere condition: in all other environments, ɥ is realized as [w]. Finally, the epenthesis rule requires a vowel to be inserted between two members of an onset cluster. Given these rules, the actual derivation is shown in (29a), with the counterfactual derivation in (29b).

(29) Fula derivations

    a. Actual derivation   b. Counterfactual derivation

	/tɥijo/		/tɥijo/
ɥ-deletion	tijo	Glide Backing	twijo
Glide Backing	---	Epenthesis	tiwijo
Epenthesis	---	ɥ-deletion	---
	[tijo]		[tiwijo]

Each of these derivations constitutes a bleeding relationship: in (27a), ɥ-deletion bleeds Glide Backing and Epenthesis; in (27b), Glide Backing and/or Epenthesis bleed ɥ-deletion. As the ɥ-deletion and Glide backing rules are written, they are in a special-general relationship. In a special environment, the glide ɥ is deleted; in all other environments, the same glide is backed and realized as [w]. If we imagine that an actual derivation could also see the counterfactual derivation, however, we might also imagine a different definition of ɥ-deletion, such that it would apply only when a word's counterfactual derivation would result in multiple unfaithfulness. It is as if the grammar can look at the counterfactual derivation and realize that it would produce a doubly-unfaithful output. When this would occur, ɥ-deletion is invoked to bleed the other rules. In the Baković case, the output of the counterfactual derivation actually feeds the other derivation. Here, it seems simply that the grammar must have access to the counterfactual derivation. The doubly-unfaithful output of the counterfactual derivation informs the grammar that deletion is necessary.

      So, are CFEs opaque? The answer to this question is not obvious. They are clearly not opaque in any traditional sense. Nevertheless, they do not completely resemble transparent bleeding interactions either. They might instead be thought of as "opaque bleeding" interactions. Deletion is invoked to force the underapplication of other rules only in the case that the output would have been too unfaithful.

5. Conclusion

This paper has presented a kind of cumulativity not previously discussed: cumulative faithfulness. Loanword phonology was found to be a rich source for CFEs because in loanword adaptations there are likely to be marked segments or structures that must be eliminated by the borrowing phonology. In each of the loanword examples discussed here, deletion applies only when it will eliminate a segment or structure that violates multiple markedness constraints. In Fula, the glide [ɥ] is deleted when it coincides with a syllable-structure violation. In Hawaiian, [s] is also deleted when it coincides with a syllable-structure violation. In fact, in many CFEs, a segmental markedness violation coincides with a syllable-structure violation. Deletion of the segment solves both problems.

      It was shown that CFEs cannot be accounted for in standard optimality theory. While the local conjunction of faithfulness constraints can solve the problem, the Fula and Hawaiian examples show that the local conjunction account has some undesirable results. Instead, the weighted constraints of Harmonic Grammar were invoked. By differentially weighting the faithfulness constraints, we can arrive at a grammar in which single unfaithful mappings are allowed, but candidates that are too unfaithful are eliminated.

Finally, the question of whether CFEs are transparent or opaque was examined. While these effects are not opaque in a traditional sense, they were found to share certain characteristics with opacity effects. A compromise between the two sides might be found in the idea of "opaque bleeding": an effect in which the output is transparent, but nevertheless it seems as though some rules have been forced to underapply because of the application of a deletion rule.

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