What constraint connectives should be permitted in OT?[*]

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1. Introduction

In Optimality Theory (Prince & Smolensky 2004 [1993]), the surface form of a given linguistic input is selected by determining which member of a set of candidate surface forms best satisfies a language-particular ranking of the universal constraint-set CON. Much (and quite possibly most) research within OT is concerned with what constraints are to be found in CON; that is, with the question of what constraints must be assumed to exist in order to properly account for language typology.

A related but distinct question is where the constraints in CON come from. Clearly at least some must be supplied by some mechanism outside of the linguistic system itself: constraints may be innate, or their existence may be inferred by the language learner from universal experiences that occur during acquisition, e.g. observing one's expenditures of articulatory effort during babbling (Hayes 1999) or one's errors in perceptually classifying speech sounds (Flack 2007a,b). Constraints that are supplied by the extra-grammatical world, either by the learner's genes or via the learner's inferences from observation of phonetic facts, can be referred to as *primitive*.[1] It is obvious that any version of OT must assume the existence of primitive constraints. However, it is not necessarily the case that *all* constraints available in OT grammars are primitive. It might be the case that learners also can create new constraints based upon two (or more) pre-existing constraints. Constraints which are constructed from other constraints can be referred to as *complex*.

The first and by far most widely used proposal for a device that creates complex constraints is Local Conjunction (or LC: Smolensky 1993, 1995, 1997). A locally conjoined constraint $[A\&B]_D$ is violated if and only if constraint A and constraint B are

[*] A portion of this work was previously circulated on the Rutgers Optimality Archive as 'A note on the construction of complex OT constraints by material implication'. Thanks are due to John McCarthy and Michael Becker for helpful feedback on several versions of this paper. All errors should be attributed to me.

[1] 'Primitive' is used here in a different sense than it is in Eisner (1999), which argues that CON is structured in such a way that all constraints are instantiations of one of two basic ('primitive') constraint schemas.

both violated within some domain D. LC has come to enjoy wide (though certainly not universal) acceptance among practitioners of OT, but relatively little attention has been paid to the possibility that other logical connectives with different semantics might be made available by the human language faculty.

Several connectives besides LC are proposed by Hewitt & Crowhurst (1996), Crowhurst & Hewitt (1997), Archangeli, Moll, & Ohno (1998), Crowhurst (1998), Downing (1998, 2000), and Balarí, Marin & Vallverdú (2000). However, these works do not exhaust the space of conceivable constraint connectives. Indeed, there are sixteen possible connectives which would take two constraints as arguments and yield a third constraint whose satisfaction or violation depended on the satisfaction or violation of the arguments. This is because, for any two constraints P and Q, there are four distinct situations in which a complex constraint P•Q formed by some connective • will be satisfied or violated:

(1) a. P is satisfied and Q is satisfied
b. P is satisfied and Q is violated
c. P is violated and Q is satisfied
d. P is violated and Q is violated

The complex constraint P•Q can have one of two values—violated or satisfied—in each of the four situations in (1). In the case of LC, the constraint [P&Q] is violated in situation (1)d, but satisfied in the other three. In principle, however, nothing prevents us from imagining (say) a constraint that was satisfied in situation (1)a, but violated otherwise, or which was violated in situations (1)b-c, and satisfied otherwise. The full space of imaginable constraint connectives is formed by letting P•Q take on each possible combination of being violated or satisfied in each of (1)a-d. Given these four situations and the two possible values that P•Q can have in each of them, there are $2^4 = 16$ possible constraint connectives.

Out of these sixteen options, LC has received by far the greatest amount of empirical attention, both pro and con, in the OT literature to date. Is this skew of attention justified? Is there a principled reason to suspect that Universal Grammar might make only LC, and no other connectives, available to natural languages? This paper will show that the following criterion comes very close to doing so:

(2) A logical connective • is available in natural-language OT grammars if and only if, for any two constraints A and B (each of which is either a markedness or a faithfulness constraint) A•B is either a markedness or a faithfulness constraint.

I will demonstrate that there are only four analytically interesting connectives that satisfy criterion (2), and that two of these cease to possess linguistic interest given assumptions about the locality of constraint coordination which are independently motivated by the need to restrain the typological predictions of LC itself (Łubowicz 2005). Of the remaining two connectives, one is LC, and the other is a connective which will create, from any two constraints, an instance of the economy constraint *STRUC (Prince & Smolensky 2004 [1993], Zoll 1993, 1996). *STRUC is itself controversial and may need to be excluded in principle from OT grammars (Gouskova 2003); if such a move were made, then LC would be left as the only connective standing.

The remainder of this paper is organized as follows: Section 2 lays out the empirical motivation for maintaining the null hypothesis that there are only markedness and faithfulness constraints, namely the fact that it correctly predicts the absence of circular or infinite chain shifts in natural-language grammars (Moreton 1999). Section 3 demonstrates the stakes involved in positing novel constraint connectives by showing an example of one proposed non-LC connective which is able to give rise to circular chain shifts. Section 4 then applies criterion (2) to the space of possible constraint connectives, showing that there are only five (out of a possible sixteen) which meet it, one of which is clearly analytically uninteresting because the complex constraints it creates never assign violation-marks to any candidate. Section 5 motivates the locality convention which strips two of the remaining four connectives of typological utility, and shows that the third will give rise to the independently-banned *STRUC, leaving LC as the only permitted connective. Section 6 concludes.

2. Reasons to think that there are only markedness and faithfulness constraints

Most work in OT adheres, explicitly or implicitly, to a null hypothesis that CON contains only two general types of constraints: markedness constraints and faithfulness constraints. These two constraint types may be formally defined in a manner proposed by Moreton (1999):

(3) a. A constraint C is a markedness constraint if, for any given candidate surface form [X], C always assigns the same number of violation-marks to [X], regardless of what the underlying form is.

b. A constraint C is a faithfulness constraint if it always assigns zero violation-marks to a candidate surface form that is identical to the underlying form.

Markedness constraints are responsible for disallowing marked structure in surface forms. The standard hypothesis about markedness constraints, as expressed in definition (3)a, is that they 'don't care' about the input. For example, a markedness constraint *ROUNDVOWEL will assign a single violation mark to a candidate surface form like [kop], irrespective of whether the [o] derives from an underlying round vowel, derives from an underlying non-round vowel, or is epenthetic.

Faithfulness constraints, on the other hand, demand that the surface form of some linguistic expression retain certain properties of the underlying form. This means, as expressed in definition (3)b, that a faithfulness constraint will never penalize a candidate surface form which retains *all* of the properties of the underlying form. Of course, not every faithfulness constraint will penalize a given unfaithful mapping. For instance, the anti-deletion constraint MAX will be entirely indifferent between a candidate where underlying /pat/ surfaces faithfully as [pat], and a candidate [pa.tə] which adds an epenthetic vowel. Crucially, though, there will be no faithfulness constraint which prefers [pa.tə] over [pat] as the realization of underlying /pat/. This is guaranteed if every faithfulness constraint always assigns zero marks to a fully-faithful candidate like /pat/ → [pat].

The null hypothesis that every constraint in Con is either markedness or faithfulness makes an empirical prediction about the kinds of input-output mappings that can be generated by an OT grammar. Specifically, Moreton (1999) gives a formal proof that an OT grammar with only markedness and faithfulness constraints cannot model circular or infinite chain shifts. The proof of the impossibility of circular chain shifts can be informally summarized as follows: faithfulness constraints will only be violated if doing so improves performance on some higher-ranked markedness constraint. This means that if underlying /X/ maps to surface [Y], [Y] must be less marked than its losing faithful competitor *[X] given the constraint hierarchy of the language. If this is so, then there is no rationale for underlying /Y/ to map unfaithfully to *[X], since this output will be both more marked *and* less faithful than [Y].

With respect to infinite chain shifts, the argument is similar. Suppose that underlying /X_1/ → [X_2], /X_2/ → [X_3], and so on *ad infinitum*. Since no faithfulness constraint can favor mapping an underlying form /X_n/ onto anything other than [X_n], each of the unfaithful mappings in the infinite chain shift would have to improve performance on the markedness constraints. That is, every [X_n] would have to be less marked than [X_{n-1}] with respect to the ranking of the markedness constraints which prevailed in the language in question. But this could not go on forever, since there is a lower bound on how marked a candidate can be, namely to receive no violation-marks from any markedness constraint. Psychological plasubility demands that there be only finitely many constraints and that candidates be of finite (even if unbounded) size. This means that every candidate surface form [X_n] receives a finite number of markedness violations: [X_n] contains only a finite number of structures, and there is only a finite number of markedness constraints that could potentially penalize each of those structures.[2] Every [X_n] is therefore worse than the immaculate surface form, with no markedness violations, by only a finite number of steps. As such, an OT grammar with only markedness and faithfulness constraints cannot model an infinitely long chain shift, since such a chain shift would involve an infinite number of markedness-reducing steps.[3]

This result is important, insofar as it is independent of any particular hypothesis about exactly what the markedness and faithfulness constraints in the universal constraint-set Con *are*. The exclusion of circular and infinite chain shifts is a formal

[2] This argument also involves the assumption that no markedness constraint assigns an infinite number of violation-marks to a single violating structure. This assumption is, needless to say, quite standard, and indeed it has been argued that OT constraints only ever assign one violation-mark to each structure that violates them (McCarthy 2003b).
[3] The role of the finitude of Con in ruling out unconditional augmentation is pointed out by McCarthy (2002: 186, fn. 24).

universal predicted by OT's theory of constraint interaction, coupled with the assumption that all of the relevant constraints are either markedness or faithfulness.

This prediction is also almost certainly correct. There are a few reported examples of circular chain shifts that arise in morpheme realization, most famously in the Nilotic language DhoLuo, which is claimed to mark the plural and genitive (in part) by reversing the [voice] specification of the last consonant in the noun stem (Gergersen 1972, Okoth-Okombo 1982). However, a number of empirical doubts have been raised about whether the [voice] alternations in DhoLuo nouns are accurately described as an exchange process (Trommer 2005, Bye 2006, Pulleyblank 2006, Baerman 2007). Additionally, it is significant that the alleged DhoLuo exchange rule is a morphological mutation process. If a morpheme like the DhoLuo genitive has two listed allomorphs, one with a floating feature [+voice] and and one with a floating feature [-voice], then the selection of the allomorph that will produce a visible change when docked onto a stem segment can be achieved using only markedness and faithfulness constraints (de Lacy 2002, Wolf 2007). Nearly all other plausible cases of exchange rules arise in this same kind of morpheme-realization context (see Anderson & Browne 1973, McCawley 1974, Alderete 1999, Moreton 1999, Wolf 2007 for relevant discussion), and so would presumably be amenable to an analysis along the same lines.

The one other situation which supplies plausible examples of circular chain shifts is tone sandhi, with the most famous example being the four-step 'tone circle' in Taiwanese. For that language, it has been argued that the tone alternations are simply lexicalized listed allomorphy (Tsay & Myers 1996, Myers 2006). This conclusion is supported by an abundant body of experimental work which shows that at least some of the alternations making up the tone circle are not productive processes in the synchronic phonology of Taiwanese (Hsieh 1970, 1975, 1976, Lin 1988, Tseng 1995, Wang 1995, Peng 1998, Myers & Tsay 2002, Zhang, Lai & Turnbull-Sailor 2006).[4]

The evidence for infinite chain shifts in natural languages is even sparser than that for circular shifts. The only case I know of that has been characterized as possibly constituting one involves high tone spread in the Bantu language Chilungu; this process is the subject of a reanalysis (relying on only markedness and faithfulness) by Key & Bickmore (in prep.).

Because the exclusion of circular and infinite chain shifts is an empirically desirable result, we should be attentive to potential sources of novel constraint types—neither markedness nor faithfulness—which would subvert the assumption about CON which underlies Moreton's (1999) proof. In the most obvious cases, this possibility arises when a linguist explicitly proposes some new constraint type. For example, McCarthy's (2003a) Comparative Markedness constraints, and Łubowicz's (2003) Preserve-Contrast

[4] See Yue-Hashimoto (1986) for a survey of reported circular shifts in the tone sandhi systems of other Chinese languages. A three-step tone circle is also reported in Choapan Zapotec (Lyman & Lyman 1977), and two-step circles are reported in certain Hmongic languages (Mortensen 2004).

constraints are capable of generating circular chainshifts in input-output mappings.[5] (For Preserve-Contrast constraints, see Barrie 2006 for a demonstration of this). The other possible source of neither-markedness-nor-faithfulness constraints lies in the various novel logical connectives that have been proposed for combining two OT constraints into a larger complex constraint. The next section demonstrates how one proposed connective does just this.

3. Case study: Material implication

The constraint connective to be focused on in this section is independently proposed by Archangeli, Moll, & Ohno (1998) and Balari, Marín, and Vallverdú (2000), who view it as corresponding to the logical operator of material implication (→). To understand the connection with material implication, a small about of background discussion will be required. Crowhurst & Hewitt (1997) observe that, if constraint violation is viewed as corresponding to logical falsity and constraint satisfaction as corresponding to logical truth, then the semantics of LC are parallel to those of disjunction in classical propositional logic. A locally-conjoined constraint $[A\&B]_D$ is violated iff both of its arguments are violated in the domain D, but is not violated if one (but not both) of A or B is violated in D. Similarly, the disjunction $E \vee F$ of two propositions E and F is false iff E and F are both false; if one is false and the other true, $E \vee F$ is true.

Having observed this parallel, Crowhurst and Hewitt (1997) proceed to investigate whether other operators of propositional logic would be useful in OT. They argue that logical *con*junction (∧) and material implication (→) are needed. The classical semantics for material implication are given in the truth table below, together with the semantics of a complex constraint constructed by material implication, under the assumption that violation is equivalent to falsehood and satisfaction to truth:

(4)

P	Q	P→Q
0	0	1
1	0	0
0	1	1
1	1	1

P	Q	P→Q
*	*	✓
✓	*	*
*	✓	✓
✓	✓	✓

*(0 = falsity, 1 = truth; * = constraint violation, ✓ = constraint satisfaction)*

As shown, the material implication P→Q is false iff P is true and Q is false. Importantly, though, if P is false, P→Q is true regardless of whether Q is true or false. Likewise, a constraint P→Q will be violated only just in case constraint P is satisfied and constraint Q is violated. If constraint P is violated, P→Q will be satisfied irrespective of whether Q is violated or not.

[5] Transderivational antifaithfulness (Alderete 1999, 2001) and REALIZE-MORPHEME (Kurisu 2001) can also model circular and infinite chain shifts, but only ones which occur for the sake of marking a morphological category (like the alleged DhoLuo exchange rule). An input-output antifaithfulness constraint, which in principle could generate infinite chain shifts, is proposed in Baković (1996).

The semantics of Crowhurst & Hewitt's (1997) proposed material implication connective for OT in fact differ from this—they treat the constraint [A→B] as satisfied iff A and B are both satisfied. However, classical material implication as a tool for building complex constraints is proposed by Balari, Marín, & Vallverdú (2000), in reply to Crowhurst & Hewitt (1997); an apparently identical connective is also used by Archangeli, Moll, & Ohno (1998).[6] For these authors, a constraint [A→B] is always satisfied by a given candidate if that candidate violates constraint A, since a material implication, as mentioned, is always true if its antecedent is false.

If we augment OT with a constraint connective that has these semantics, circular chainshifts can be modeled by creating a constraint [A→B] in which A is a faithfulness constraint and B is a markedness constraint. To illustrate, suppose that we have the following constraint ranking:

(5)
IDENT[+round] » [IDENT[-tense] → *[+round]] » *[+tense] » IDENT[-tense], *[+round]

Constraint definitions:
IDENT[+round]: Assign a violation-mark if an input [+round] segment corresponds to an output [-round] segment.
IDENT[-tense]: Assign a violation-mark if an input [-tense] segment corresponds to an output [+tense] segment.
*[+tense]: Assign a violation-mark for every [+tense] segment in the output.
*[+round]: Assign a violation-mark for every [+round] segment in the output.

Given the ranking in (5), consider what happens to an input segment that is [+round, +tense][7]:

(6)

/y/	IDENT [+round]	[IDENT[-tense]→ *[+round]]	*[+tense]	IDENT [-tense]	*[+round]
a. [y]		*	*!		*
b. → [Y]		*			*
c. [i]	*!		*		
d. [I]	*!				

The undominated constraint IDENT[+round] rules out all candidates that change the input's [+round] to [-round]. This leaves [y] and [Y] as contenders. The complex

[6] A connective with the semantics of classical conjunction is also argued for in Hewitt & Crowhurst (1996) and Downing (1998, 2000). Łubowicz (2005) argues that material implication has a role to play in the semantics of LC, for the purpose of preventing LC from generating so-called markedness reversals (Ito & Mester 1998).
[7] In the following examples, [y] is [+tense, +round]; [Y] is [-tense, +round]; [i] is [+tense, -round], and [I] is [-tense, -round].

constraint [IDENT[-tense] → *[+round]] will not distinguish between these two candidates: first, since the input does not contain a feature specification [-tense], the antecedent IDENT[-tense] is vacuously satisfied by all candidates; and second, both of the remaining contenders are [+round], and therefore violate the consequent of the conditional. Hence, both of the remaining contenders equally violate [IDENT[-tense]→ *[+round]], by virtue of satisfying the antecedent while violating the consequent. The choice is then passed down to the markedness constraint *[+tense], which chooses lax [Y] over tense [y].

Now consider what happens when the input is /Y/:

(7)

/Y/	IDENT [+round]	[IDENT[-tense]→ *[+round]]	*[+tense]	IDENT [-tense]	*[+round]
a. → [y]			*	*	*
b. [Y]		*!			*
c. [i]	*!		*	*	
d. [I]	*!				

As before, the undominated status of IDENT[+round] immediately reduces the set of contenders to [y] and [Y]. Moving down to the next highest-ranked constraint, we now encounter [IDENT[-tense] → *[+round]]. Unlike before, the input now contains a [-tense] specification, so it is no longer the case that all candidates vacuously satisfy the antecedent of the conditional.

The faithful candidate [Y] satisfies the antecedent (IDENT[-tense]) by virtue of preserving the input's [-tense] specification, but it violates the consequent (*[+round]) by virtue of having a [+round] specification. Because it satisfies the antecedent but violates the consequent, this candidate violates the material implication. By contrast, the unfaithful candidate [y] also violates the consequent *[+round], as it too has an output [+round] specification, but it differs from the faithful candidate in violating the antecedent constraint IDENT[-tense]. Because it violates the antecedent, [y] satisfies the material implication, and thus wins.

Building complex constraints by material implication thus allows us to model circular chain shifts in OT. In our example, input /y/ surfaces as [Y], while input /Y/ surfaces as [y]. The reason for this has to do with the fact that our complex constraint [IDENT[-tense] → *[+round]] has a faithfulness constraint as its antecedent and a markedness constraint as its consequent. Such a constraint rewards unfaithfulness, as can be seen in (7): [y] violates the antecedent by being unfaithful, and by so doing it is exempted from having to satisfy the consequent, whereas the faithful candidate [Y] satisfies the antecedent, and therefore would have to satisfy the consequent (which it doesn't) in order to satisfy the material implication. So, even though, for input /Y/, faithful [Y] and unfaithful [y] both violate *[+round], only the faithful candidate violates the material implication [IDENT[-tense] → *[+round]].

As mentioned, Moreton's (1999) proof that circular chain shifts cannot be modeled in OT rests on the assumption that OT grammars contain only markedness and faithfulness constraints. Inspection of tableaux (6)-(7) quickly reveals that [IDENT[-tense] → *[+round]] is neither a markedness constraint nor a faithfulness constraint, under the definitions employed by Moreton (1999) and presented in (3). It isn't a markedness constraint, since the candidate surface form [y] gets a violation from the complex constraint when the input is /y/, as in (6), but does not get a violation when the input is /Y/, as in (7). Nor is [IDENT[-tense] → *[+round]] a faithfulness constraint, since the fully-faithful candidates (6)a and (7)b both incur violations from it. Instead, given the appropriate circumstances in (7), [IDENT[-tense] → *[+round]] can serve as an input-output *anti*faithfulness constraint: it prefers an unfaithful candidate over a faithful one, because being unfaithful (violating the antecedent) exempts a candidate from a pressure to be unmarked (i.e., to obey the consequent).

This example prompts the very limited conclusion that proposals for a material-implication connective are probably best eschewed. More broadly, it poses the question of which possible connectives should be allowed in OT, and which should be excluded by virtue of violating criterion (2). In the next section, I show which five possible connectives pass that criterion.

4. Which connectives will yield only markedness and faithfulness?

4.1 Introduction

As described earlier in (1) with respect to OT constraints, if we have two propositions P and Q and a logical operator •, there are four situations in which P•Q can be either true or false:

(8) a. P is true and Q is true
b. P is true and Q is false
c. P is false and Q is true
d. P is false and Q is false

Because P•Q can be either true or false in each of these situations, there are $2^4 = 16$ possible two-place logical operators in a two-valued zeroth-order logic. With respect to the construction of complex OT constraints, the two relevant logical values at issue are constraint violation and constraint satisfaction (rather than truth and falsehood); in what follows I will use the symbols '*' and '✓', respectively, to denote violation and satisfaction.

The discussion in the following subsections will be based on a truth table (or, as we may call it, a 'violation table') of the following form:

(9)

C_1	✓	✓	*	*
C_2	✓	*	✓	*
$C_1 \bullet C_2$	1st	2nd	3rd	4th

When I speak of $C_1 \bullet C_2$ having a * or a ✓ in one of its 'positions', what I mean is that it is either violated or satisfied in each of the four combinations of violation or satisfaction of $Constraint_1$ and $Constraint_2$, which I number in ascending order from left to right, as in (9).

In order to determine which logical operators • could create a complex constraint $C_1 \bullet C_2$ that is neither markedness nor faithfulness, there are four situations that we have to consider with respect to the identities of C_1 and C_2: when C_1 is a markedness constraint and C_2 a faithfulness constraint; when C_1 is a faithfulness constraint and C_2 is a markedness constraint; when both are faithfulness constraints; and when both are markedness constraints. I now proceed to examine each of these in turn.

4.2 M•F

To begin, we look at the case where the first argument of • is a markedness constraint and the second a faithfulness constraint—that is, the case where we have the following violation table:

(10)

M	✓	✓	*	*
F	✓	*	✓	*
M•F	1st	2nd	3rd	4th

The following must hold in order for M•F to be either a markedness or a faithfulness constraint:

(11) a. In order to be a faithfulness constraint, M•F must not be violated when F is satisfied, since otherwise it would assign a violation-mark to the fully-faithful candidate. In the violation table used here, • must not have a * in the first or third positions.

b. In order to be a markedness constraint, whether or not M•F is violated must never depend on whether or not F is violated, since otherwise M•F would be sensitive to the input. In the notation used here, • must be identical in the first and second positions, and in the third and fourth positions.

As such, the operators that will yield a faithfulness constraint and those that will yield a markedness constraint when their first argument is markedness and their second faithfulness are those represented in the following violation tables:

(12) *Operators • for which M•F is faithfulness or markedness*

Faithfulness:

M	✓	✓	*	*
F	✓	*	✓	*
M•F	✓	✓	✓	✓

M	✓	✓	*	*
F	✓	*	✓	*
M•F	✓	*	✓	*

M	✓	✓	*	*
F	✓	*	✓	*
M•F	✓	✓	✓	*

M	✓	✓	*	*
F	✓	*	✓	*
M•F	✓	*	✓	✓

Markedness:

M	✓	✓	*	*
F	✓	*	✓	*
M•F	✓	✓	*	*

M	✓	✓	*	*
F	✓	*	✓	*
M•F	✓	✓	✓	✓

M	✓	✓	*	*
F	✓	*	✓	*
M•F	*	*	✓	✓

M	✓	✓	*	*
F	✓	*	✓	*
M•F	*	*	*	*

4.3 F•M

We now turn to identifying the class of operators • for which F•M will be either markedness or faithfulness. In this case, the violation table is as in (13):

(13)

F	✓	✓	*	*
M	✓	*	✓	*
F•M	1^{st}	2^{nd}	3^{rd}	4^{th}

In this case, the operators that satisfy (2) will have the following properties:

(14) a. In order for to be a faithfulness constraint, F•M must not be violated when F is satisfied, since otherwise F•M would assign a violation to the fully-faithful candidate. In terms of the violation table above, • must not have a * in either of the first two positions.

b. In order to be a markedness constraint, whether or not F•M is violated must never depend on whether or not F is violated, since otherwise F•M would be sensitive to the input. In the notation used here, • must be identical in the first and third positions, and also in the second and fourth positions.

The operators that satisfy one or the other of these criteria are:

(15) *Operators • for which F•M is faithfulness or markedness*

Faithfulness:

F	✓	✓	*	*
M	✓	*	✓	*
F•M	✓	✓	*	*

F	✓	✓	*	*
M	✓	*	✓	*
F•M	✓	✓	✓	*

F	✓	✓	*	*
M	✓	*	✓	*
F•M	✓	✓	*	✓

F	✓	✓	*	*
M	✓	*	✓	*
F•M	✓	✓	✓	✓

Markedness:

F	✓	✓	*	*
M	✓	*	✓	*
F•M	✓	*	✓	*

F	✓	✓	*	*
M	✓	*	✓	*
F•M	✓	✓	✓	✓

F	✓	✓	*	*
M	✓	*	✓	*
F•M	*	*	*	*

F	✓	✓	*	*
M	✓	*	✓	*
F•M	*	✓	*	✓

4.4 F•F

We now consider which operators will pass (2) when both of their arguments are faithfulness constraints. The violation table here is:

(16)

F_1	✓	✓	*	*
F_2	✓	*	✓	*
$F_1•F_2$	1^{st}	2^{nd}	3^{rd}	4^{th}

These are the conditions under which $F_1•F_2$ will yield a faithfulness or a markedness constraint:

(17) a. In order to be a faithfulness constraint, $F_1•F_2$ must not be violated when F_1 and F_2 are both satisfied, since otherwise $F_1•F_2$ would assign a violation-mark to the fully-faithful candidate. In terms of the notation used here, • must not have a * in the first position.

b. In order to be a markedness constraint, whether $F_1•F_2$ is violated must not depend on whether *either* argument is violated, since otherwise $F_1•F_2$ would be sensitive to the nature of the input. Notationally, this means that • must be identical in all four positions.

The operators that satisfy one or the other of these criteria are:

(18) *Operators • for which $F_1 \bullet F_2$ is either faithfulness or markedness*

Faithfulness:

F_1	✓	✓	*	*
F_2	✓	*	✓	*
$F_1 \bullet F_2$	✓	*	*	*

F_1	✓	✓	*	*
F_2	✓	*	✓	*
$F_1 \bullet F_2$	✓	✓	✓	*

F_1	✓	✓	*	*
F_2	✓	*	✓	*
$F_1 \bullet F_2$	✓	✓	*	*

F_1	✓	✓	*	*
F_2	✓	*	✓	*
$F_1 \bullet F_2$	✓	✓	*	✓

F_1	✓	✓	*	*
F_2	✓	*	✓	*
$F_1 \bullet F_2$	✓	*	✓	✓

F_1	✓	✓	*	*
F_2	✓	*	✓	*
$F_1 \bullet F_2$	✓	*	✓	✓

F_1	✓	✓	*	*
F_2	✓	*	✓	*
$F_1 \bullet F_2$	✓	*	*	✓

F_1	✓	✓	*	*
F_2	✓	*	✓	*
$F_1 \bullet F_2$	✓	✓	✓	✓

Markedness:

F_1	✓	✓	*	*
F_2	✓	*	✓	*
$F_1 \bullet F_2$	✓	✓	✓	✓

F_1	✓	✓	*	*
F_2	✓	*	✓	*
$F_1 \bullet F_2$	*	*	*	*

4.5 M•M

Lastly, we consider the operators that will pass (2) when both of their arguments are markedness constraints. Here, the relevant violation table is:

(19)

M_1	✓	✓	*	*
M_2	✓	*	✓	*
$M_1 \bullet M_2$	1^{st}	2^{nd}	3^{rd}	4^{th}

These are the conditions under which $M_1 \bullet M_2$ will yield a faithfulness or a markedness constraint:

(20) a. In order to be a faithfulness constraint, $M_1 \bullet M_2$ must never assign a violation-mark to a fully faithful candidate. Since, depending on the input, a fully-faithful candidate could satisfy or violate any markedness constraint, this is only guaranteed when $M_1 \bullet M_2$ is never violated, i.e. when • has a ✓ in every position.

b. In order to be a markedness constraint, there are no restrictions on •, since the assignment of violations by both of its arguments are insensitive to the properties of the input.

The operators that satisfy one or the other of these criteria are:

(21) *Operators • for which $M_1 \bullet M_2$ is either faithfulness or markedness*

Faithfulness:

M_1	✓	✓	*	*
M_2	✓	*	✓	*
$M_1 \bullet M_2$	✓	✓	✓	✓

Markedness: Anything

4.6 Summary

In order for an operator to be fully general and pass criterion (2), it must yield either a faithfulness or a markedness constraint regardless of whether each of its two arguments is faithfulness or markedness. That is, it must appear in the lists of potentially-valid operators adduced in each of the subsections 4.2-4.5. Inspection reveals that the following five operators are the only ones that appear in all four lists:

(22) *Operators which always yield markedness or faithfulness*

a.

C_1	✓	✓	*	*
C_2	✓	*	✓	*
$C_1 \bullet C_2$	*	*	*	*

b.

C_1	✓	✓	*	*
C_2	✓	*	✓	*
$C_1 \bullet C_2$	✓	✓	✓	✓

c.

C_1	✓	✓	*	*
C_2	✓	*	✓	*
$C_1 \bullet C_2$	✓	✓	*	*

d.

C_1	✓	✓	*	*
C_2	✓	*	✓	*
$C_1 \bullet C_2$	✓	*	✓	*

e.

C_1	✓	✓	*	*
C_2	✓	*	✓	*
$C_1 \bullet C_2$	✓	✓	✓	*

One of these operators, (22)e, is LC—it produces a complex constraint that is violated if and only if both of its arguments are violated. Of the remaining four, (22)b is clearly of no linguistic interest. Because the complex constraints that it produces are always satisfied, they always assign zero violation-marks to every candidate. These constraints therefore can never exert a preference between any two candidates, making them (and operator (22)b) completely inert with respect to linguistic typology. This leaves us with three further connectives to consider: (22)a and (22)c-d. Their status is not as immediately obvious, and will be explored in the next section.

5. Bingeing, locality, and *STRUC

5.1 The bingeing problem

Superficially, it may seem obvious that the operators (22)c-d are analytically uninteresting. (The same goes for (22)a, discussion of which will be deferred until the next subsection.) Operator (22)c simply returns a constraint $C_1 \bullet C_2$ that is violated or satisfied exactly when C_1 is violated or satisfied; likewise, (22)d returns a constraint $C_1 \bullet C_2$ that is violated or satisfied exactly when C_2 is violated or satisfied. One may therefore be tempted to think that these operators will simply yield up a constraint that is identical to either C_1 or C_2, and that they therefore can have no effect on linguistic typology, since they do nothing but produce a clone of an existing constraint.

However, it is not necessarily the case that the complex constraint returned by (22)c-d will be entirely identical to one or the other of its arguments. The point of difference arises if we consider cases where one of the constraints that serves as an argument of the connective is violated more than once. To illustrate, let's consider (22)c, and use the symbol ☆ to represent that logical connective; (22)d will behave in a parallel fashion. Suppose that we have a complex constraint $[\text{ONSET}☆\text{X}]_{\text{PWd}}$, where X is any constraint. As can be seen in (22)c, the violation or satisfaction of a complex constraint produced using ☆ is sensitive only to the violation or satisfaction of its first argument, so we can omit X from the violation table for $[\text{ONSET}☆\text{X}]_{\text{PWd}}$—it simply isn't relevant.

Given this constraint, let's now consider a candidate surface form like [ta.e.o], which contains more than one onsetless syllable. The domain of constraint coordination in $[\text{ONSET}☆\text{X}]_{\text{PWd}}$ is the prosodic word, so the logical computation in $[\text{ONSET}☆\text{X}]_{\text{PWd}}$'s violation table will be performed a single time for the entire PWd. The candidate word [ta.e.o] violates ONSET—twice in fact—but $[\text{ONSET}☆\text{X}]_{\text{PWd}}$ is violated only *once* by that candidate:

(23)

ONSET	✓	✓	**	**
X	✓	*	✓	*
ONSET☆X	✓	✓	*	*

The problem is that our constraint connectives know only two logical values: constraint violation and constraint satisfaction. (Making every numerical degree of violation a separate logical value is clearly absurd, since the logic of constraint coordination would then have infinitely many values.) The complex constraint $[\text{ONSET}☆\text{X}]_{\text{PWd}}$ simply says: 'if ONSET is violated somewhere in the prosodic word, assign a violation mark.' It doesn't matter whether a candidate prosodic word contains one, two, or a million onsetless syllables—$[\text{ONSET}☆\text{X}]_{\text{PWd}}$ will never assign more than one violation mark per prosodic word. [8]

[8] It is a standard assumption of the constraint-connective literature that things can work this way. In Hewitt & Crowhurst (1996) and Crowhurst & Hewitt (1997), the argument for a classical-conjunction operator

The problem with such a constraint is that it can produce implausible effects of a variety which we can refer to as *bingeing*.[9] Suppose that a language has the ranking [ONSET✫X]$_{PWd}$ » DEP. This language will employ epenthesis to achieve a state in which each prosodic word contains zero onsetless syllables, since that is the only circumstance in which [ONSET✫X]$_{PWd}$ is satisfied:

(24)

/taeo/	[ONSET✫X]$_{PWd}$	DEP
→ a. [ta.ʔe.ʔo]		**
b. [ta.ʔe.o]	*!	*
c. [ta.e.ʔo]	*!	*
d. [ta.e.o]	*!	

The fully-faithful candidate (24)d has two onsetless syllables, so it incurs one violation-mark from [ONSET✫X]$_{PWd}$. Candidates (24)b-c do no better on that constraint, since they each have one onsetless syllable per word. The winner, therefore, is (24)a, which has no onsetless syllables and therefore no violation of [ONSET✫X]$_{PWd}$.

This much is typologically innocuous. The problem comes in if some higher-ranked constraint forces just one of the syllables to be onsetless. Consider now what happens if we have a ranking of ANCHOR-LEFT » [ONSET✫X]$_{PWd}$ » DEP, and an input /aeo/:

(25)

/aeo/	ANCHOR-LEFT	[ONSET✫X]$_{PWd}$	DEP
a. [ʔa.ʔe.ʔo]	*!		***
b. [a.ʔe.o]		*	*!
c. [a.ʔe.ʔo]		*	*!*
→ d. [a.e.o]		*	

The constraint ANCHOR-LEFT (McCarthty & Prince 1995) forbids, among other things, epenthesis at the left edge of the word. It therefore penalizes a candidate like (25)a which epenthesizes a consonant at the beginning of the word so as to prevent the syllable headed by [a] from lacking an onset. If ANCHOR-LEFT is top-ranked, it will rule out candidate (25)a, which is the only candidate that satisfies [ONSET✫X]$_{PWd}$, since it is the only candidate that has no onsetless syllables in its PWd.

The elimination of candidate (25)a means that all remaining viable candidates will contain at least one onsetless syllable (the initial one), and consequently will all get a

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rests, in part, on its ability to collapse the distinction between candidates that have different degrees of violation of some gradient constraint which serves as one of the arguments of the complex constraint.

[9] Credit for this terminology is due to John McCarthy.

single violation-mark from [ONSET☆X]$_{PWd}$, regardless of whether just one, both, or neither of the non-initial syllables are onsetless (as in (25)b-d respectively). Since [ONSET☆X]$_{PWd}$ is indifferent with respect to remaining candidates, the choice is passed down to DEP, which results in (25)d, with no epenthesis, emerging as the winner. Because [ONSET☆X]$_{PWd}$ can't distinguish between having three, two, or one onsetless syllables per PWd, in a situation like (25) where a higher-ranked constraint forces *one* of the syllables to be onsetless, the language will no longer use epenthesis to force *any* of the remaining syllables to have onsets. To speak metaphorically, if the language is compelled to have one onsetless syllable, it will lose all inhibitions and binge on onsetless syllables.

To my knowledge, no language exhibits a bingeing scenario like the one portrayed in (24)-(25). This means that the constraint connectives (22)b-c are not typologically inert, and in fact make *incorrect* predictions—provided that we allow the domain of constraint coordination to operate in the manner assumed in the discussion above. As it turns out, related domain issues arise with respect to LC, and an independently-motivated proposal about how to ensure the 'localness' of local conjunction will also serve to prevent bingeing scenarios, and render (22)b-c typologically inert. This proposal is the topic of the next subsection.

5.2 The solution: Locus-by-locus evaluation

The matter of the domain of conjunction poses overgeneration problems for LC as well (see McCarthy 1999, 2003a,b, Kawahara 2006 for discussion of this point). Consider, for example, a locally-conjoined constraint [*[nasal] & *VCDOBS]$_{PWd}$. This constraint will assign a violation-mark if a single PWd contains both a nasal segment and a voiced obstruent (which need not be one and the same segment). However, it will not assign a violation-mark if the PWd contains nasal segments, but no voiced obstruents; nor will it assign a violaton-mark if voiced obstruents, but no nasals, are to be found in the PWd. The constraint therefore is capable of giving rise to unattested situations like the following:

(26) *Overgeneration by local conjunction in the domain of the PWd*

a. Underlying nasals surface faithfully, if there are no voiced obstruents:

/na/	[*[nasal] & VCDOBS]$_{PWd}$	MAX	*[nasal]	VCDOBS
→ a. [na]			*	
b. [a]		*!		

b. Voiced obstruents surface faithfully, if there are no nasals:

/de/	[*[nasal] & VCDOBS]$_{PWd}$	MAX	*[nasal]	VCDOBS
→ a. [de]				*
b. [e]		*!		

c. With equal numbers of voiced obstruents and nasals in the input, the nasals are deleted…

/mod/	[*[nasal] & VCDOBS]$_{PWd}$	MAX	*[nasal]	VCDOBS
a. [mod]	*!		*	*
→ b. [od]		*		*
c. [mo]		*	*!	

d. …and if there is more of one than of the other, the least numerous type is eliminated:

/bamon/	[*[nasal] & VCDOBS]$_{PWd}$	MAX	*[nasal]	VCDOBS
a. [bamon]	*!		**	*
b. [ba.o]		**!		*
→ c. [a.mon]		*	**	

The conjoined constraint [*[nasal] & VCDOBS]$_{PWd}$ states that nasals and voiced obstruents cannot co-occur within a single PWd. Even if the conjoined constraint is ranked above faithfulness, words will be able to have nasals *or* voiced obstruents, provided that the markedness constraints against these types of segments are ranked below faithfulness, as seen in (26)a-b. However, a word cannot contain segments of both types, as seen in (26)c. More bizarrely yet, *which* of the two prohibited-from-co-occurring categories (nasals or voiced obstruents) is eliminated can depend on which one there is more of in the input, as seen in the contrast between (26)c and (26)d.

Certainly there is no attested language which allows nasals and voiced obstruents, but does not allow them to co-occur within a single word. The fact that LC is capable of banning the co-occurrence of any two given unrelated types of marked structure within any given prosodic domain suggests that there is something wrong with the original conception of local conjunction. The problem, intuitively, is that the structures that violate each half of the conjoined constraint do not have to have anything to do with one another, if we let the domain of conjunction be wide enough. Some locality restriction needs to be placed on LC in order to eliminate scenarios like the one depicted in (26), which might bring with it the elimination of the free variable of the domain of conjunction in the definition of a conjoined constraint.

One proposal of this sort is advanced by Łubowicz (2005). She proposes to constrain LC using the notion of *locus of violation* (McCarthy 2003a,b). The loci of violation of a constraint are simply the places in the output where it is violated. For markedness constraints, this notion is fairly easy to formalize. If every markedness constraint M has the form "For all output structures having property X, assign a violation-mark" (McCarthy 2003b), then the loci of violation of M are simply all of the pieces of structure[10] in the output satisfying description X. For faithfulness constraints, defining the locus of violation is a bit trickier, but we can intuitively think of the loci of

[10] By 'piece of structure' I mean the primitive representational units posited in whatever theory of representations might be assumed in a given analysis—features, root nodes, prosodic constituents like syllables and feet, etc.

violation of a faithfulness constraint F as being all of the pieces of structure in the output which differ from their input correspondents in the way forbidden by F; the reader is referred to Łubowicz (2005) for a more explicit formalization.

The notion of locus of violation provides us with coherent means to speak of a constraint being violated 'at' a particular piece of structure in the output. It also means that we can speak of a constraint being satisfied 'at' a specific piece of structure. A given piece of structure can be said to be a locus of satisfaction of a constraint C iff it is not a locus of violation of C. Thinking in these terms, we are equipped to generalize Łubowicz's (2005) proposal about locality in LC to apply to complex constraints created using an arbitrary logical operator:

(27) *Locality convention for interpretation of complex constraints*

Given a complex constraint A•B:

For every piece of structure S in the output:

i. Let a be the logical value (violation or satisfaction) of A at S.
ii. Let b be the logical value (violation or satisfaction) of B at S.
iii. Compute a•b using the violation table for •.
iv. If a•b = *, A•B assigns a violation-mark.

Let's now examine how this convention solves the locality problem for LC. A conjoined constraint [*[nasal] & *VCDOBS] will no longer be able to penalize a candidate surface form like [mod], as in (26)c, because there is no locus at which both of the conjuncts are violated. If we ignore autosegmental and prosodic structure (for the sake of simplifying the example), then the only three structural loci in [mod] are the three segments [m], [o], and [d]. The following table shows the logical value of each of the arguments of [*[nasal] & *VCDOBS] at each of those three loci:

(28) *Loci of violation and satisfaction in [mod]*

constraint	m	o	d
*[nasal]	*	✓	✓
*VCDOBS	✓	✓	*
[*[nasal] & *VCDOBS]	✓	✓	✓

As can be seen in (28), because the logical value of the conjoined constraint [*[nasal] & *VCDOBS] is computed independently at every locus in the output, it will not assign the logical value 'violated' to any locus in the candidate [mod]. This is because [mod] does not contain any locus at which *both* of the arguments *[nasal] and *VCDOBS have the logical value 'violated'. By only assigning marks when both of its conjuncts are violated at the same locus, convention (27)—which is a generalization of the proposal in Łubowicz (2005)—prevents LC from producing unattested long-distance co-occurrence restrictions on unrelated marked structures like those depicted in (26). What this means is that, even if we consider just LC, the notion 'domain of conjunction' makes incorrect predictions, furnishing a motivation to discard this element of LC and impose a locality convention like (27) on the interpretation of the logical operator.

We can now proceed to show that eliminating the domain of conjunction in favor of (27) also prevents (22)c-d from generating bingeing effects, and thereby strips (22)c-d of the ability to affect language typology. The bingeing problem, recall, arises from the fact that a constraint like [ONSET☆X]$_{PWd}$, where ☆ is (22)c, makes no distinction between a candidate like [a.ʔe.ʔo], with one onsetless syllable, and a candidate like [a.e.o], with three onsetless syllables. This was illustrated in tableau (25), which is repeated below as (29):

(29)

/aeo/	ANCHOR-LEFT	[ONSET☆X]$_{PWd}$	DEP
a. [ʔa.ʔe.ʔo]	*!		***
b. [a.ʔe.o]		*	*!
c. [a.ʔe.ʔo]		*	*!*
→ d. [a.e.o]		*	

Suppose now that we discarded the notion of 'domain of conjunction' from the interpretation of complex constraints, and instead assumed that convention (27) is at work. Doing so will now ensure that [ONSET☆X] will always assign one violation-mark for every onsetless syllable in the word—thus behaving no differently from ONSET in its distribution of marks. Assuming that the loci at which ONSET is potentially violated are syllables, then the locus-by-locus assignment of violation marks by [ONSET☆X] will be as in (30):

(30)

constraint	a	e	o
ONSET	*	*	*
X	?	?	?
[ONSET☆X]	*	*	*

constraint	a	ʔe	ʔo
ONSET	*	✓	✓
X	?	?	?
[ONSET☆X]	*	✓	✓

Since the violation or satisfaction of X is irrelevant to the violation or satisfaction of [ONSET☆X], its value at each locus can be ignored, and hence is given as a question mark. At each syllable in the output, [ONSET☆X] will be either violated or satisfied depending on whether ONSET is violated or satisfied. As can be seen in (30), this means that in [a.e.o], there are three loci at which [ONSET☆X] is violated, whereas in [a.ʔe.ʔo] there is only one locus where [ONSET☆X] is violated. Consequently, [a.e.o] gets three violation-marks from [ONSET☆X], and [a.ʔe.ʔo] gets only one violation mark. Because it distinguishes between these candidates, [ONSET☆X] can no longer produce the bingeing effect.

More generally, if the violation or satisfaction of [Y☆X] is independently computed for every locus in the output, [Y☆X] is guaranteed to exactly match the number of marks assigned by Y, provided that Y assigns only a single violation-mark per locus. That is to say, [Y✰X] will always assign to a given candidate exactly the same number of marks that Y does, provided that Y is *categorical* rather than *gradient*.

In OT, a constraint is said to evaluate *gradiently* if a single marked structure or unfaithful mapping can receive more than one violation-mark from the constraint. For instance, with respect to a candidate $[\text{pa.ta.(ra.ki)}_{\text{Ft}}]_{\text{PWd}}$, a gradient alignment constraint like ALIGN(foot, left, PWd, left)—for which see McCarthy & Prince (1993)—will assign two violation-marks, because the lone foot is two syllables away from the left edge of the prosodic word. The locus at which this constraint is violated is the candidate's lone foot, and two marks are assigned to this single locus.

McCarthy (2003b) has argued that gradient evaluation is both unnecessary and empirically undesirable. If we embrace this conclusion, then no constraint will assign more than one violation mark per locus. This means that [Y✰X] will always exactly reproduce the number of marks assigned by Y to every candidate, and that therefore [Y✰X] will have no effect on linguistic typology, since its preferences among candidates will be indistinguishable from those of Y.

To summarize, then: adopting criterion (2) means that only the five logical operators shown in (22) are available in natural-language OT grammars. Of these, (22)b is clearly analytically uninteresting. Operator (22)e is LC, and in order to restrain LC's typological predictions, a locality convention like (27) can be argued for. Convention (27), coupled with the (also independently-motivated) assumption that gradient evaluation is banned from OT, means that (22)c-d will produce constraints which are simply clones of one or the other of their arguments, leaving these operators as well without interest in the modeling of linguistic typology. This leaves us with one final operator to consider: (22)a.

5.3 Locus-by-locus evaluation and *STRUC

The violation table for operator (22)a is reproduced below:

(31)

C_1	✓	✓	*	*
C_2	✓	*	✓	*
$C_1 \bullet C_2$	*	*	*	*

Regardless of whether either of its arguments is violated or satisfied, a constraint produced using this operator is invariably violated. This does not mean, however, that such a constraint will be unable to distinguish between different members of the candidate set, since not all candidates will get the same number of violations from it. (For ease of illustration in what follows, I will employ the symbol ◈ for this connective.)

If we assume that the evaluation of candidates by complex constraints is governed by convention (27), then the violation or satisfaction of a complex constraint [A◈B] will be separately computed at every piece of structure in the output. Since the value of [A◈B] will always come out as 'violated', this means that [A◈B] will assign one violation-mark for every piece of structure in the output. Consequently, for any two constraints A and B, [A◈B] is equivalent to the following constraint introduced by Zoll (1993, 1996) and Prince & Smolensky (2004 [1993]):

(32) *STRUC
The output contains no structure.

Versions of *STRUC, both in the fully general form given in (32), and in specific subversions like *STRUC(σ), 'the output contains no syllables' (Zoll 1993, 1996) are posited to account for economy-of-structure effects. Because it prohibits *tout court* segments, syllables, feet, and any other type of structure, *STRUC ensures that such structures will emerge in the output only to the least extent required to satisfy higher-ranked constraints.

Unfortunately, positing the existence of *STRUC also leads to a number of highly implausible typological predictions, as extensively argued by Gouskova (2003). For just one example, a language with no consonants can be generated using the ranking shown in the following tableau:

(33)

/keta/	MAX-V	*STRUC(segment)	MAX-C	ONSET
a. [ke.ta]		***!*		
→ b. [e.a]		**	**	**
c. ∅	*!*		**	

The unattestedness of this and similar effects predicted by *STRUC suggests that this constraint—together with the connective ◈, which can create *STRUC from any pair of pre-existing constraints—does not exist. Moreover, *STRUC constraints arguably are not necessary. With suitable assumptions, attested economy effects can be derived from the interaction of ordinary markedness constraints which lack *STRUC's nihilistic character, meaning that economy-of-structure does not need to be posited as a grammatical principle in its own right. This is argued for Grimshaw (2003) for economy effects in syntax and by Gouskova (2003, to appear) for phonology; Trommer (2001) and Wolf (to appear) make similar points regarding morphology.

Where does this leave the theory of constraint connectives? By combining two independently-motivated assumptions—namely that only markedness and faithfulness constraints are allowed, and that the interpretation of complex constraints is subject to locality condition (27)—we can produce a situation in which OT grammars have only two analytically interesting constraint connectives at their disposal: local conjunction, and ◈, which creates *STRUC. Since LC and *STRUC are widely employed in OT analyses, this is a fortuitous situation, insofar as general principles are able to rule out 'exotic' constraint connectives like material implication in favor of those that are familiar. Still, familiarity is not to be confused with validity. As was argued above, there are convincing reasons to judge that *STRUC constraints are both superfluous and undesirable, and so we might find ourselves in a situation where we wanted to retain LC while dispensing with ◈. What might we add to criterion (2) to do this?

By way of a parallel with (2), one straightforward option would be to assume the additional criterion below:

(34) A constraint connective • is available in a natural-language OT grammar if and only if, for any two constraints A and B which are not * STRUC constraints, A•B is not a *STRUC constraint.

Clearly, this criterion will rule out ◈. The question that must then be asked is, will it also rule out LC?

To answer this question, we need to be explicit about what will count as a *STRUC constraint. More or less following Gouskova (2003), we may assume the following:

(35) A constraint C is a *STRUC constraint iff there is some markedness scale M = $a_n \succ a_{n+1} \succ \dots a_{m-1} \succ a_m$ such that C assigns a violation-mark to every non-∅ member of M.

What this means is that in any universal scale of phonological elements, there must always be at least one non-zero member that is fully unmarked with respect to some markedness constraint, in order for that constraint not to count as a *STRUC constraint.

Suppose now that there were some locally-conjoined constraint [A&B] which was a *STRUC constraint in the sense of (35). This would mean that there was some markedness scale M such that every non-null element in M violated [A&B]. Given the definition of LC, this would only obtain if every non-null element in M violated both constraint A and constraint B individually. That would mean that both A and B were themselves *STRUC constraints. Thus, LC cannot create *STRUC constraints in the sense of (35) unless it already has pre-existing *STRUC constraints available to serve as the arguments of the conjunction. If *STRUC constraints are banned in principle from the set of primitive markedness constraints in CON (Gouskova 2003), LC will never be able on its own to create a *STRUC constraint. LC passes criterion (34), while ◈ does not.

Lastly, we can note that the argument for LC's surviving criterion (34) holds even if the definition of *STRUC constraints in (35) should prove incorrect. So long as a constraint would qualify as a *STRUC constraint by virtue of assigning a violation mark to some surface structure *X*, a locally-conjoined constraint would only be a *STRUC constraint if both of its conjuncts were also *STRUC constraints, since the conjoined constraint cannot penalize *X* unless both of its conjuncts independently penalize *X*.

6. Conclusion

Since the inception of OT, LC has been given vastly more empirical attention than other possible constraint connectives. The results that I have argued for in this paper mean that this skew of attention has been correct. The fifteen possible two-place connectives besides LC are either banned or rendered typologically inert by the following three assumptions:

(36) a. A logical connective is not allowed if it could produce a constraint that is neither markedness nor faithfulness, given arguments that are both either markedness or faithfulness. (=(2))

b. A logical connective is not allowed if it could produce a *STRUC constraint using arguments that are not * STRUC constraints. (=(34))

c. The violation or satisfaction of a complex constraint is separately computed at every structural locus in the output, with one violation-mark being assigned for every locus at which the complex constraint is violated. (=(27))

Each of these assumptions has an independent motivation involving language typology. Assumption (36)a is motivated by the need to exclude circular and infinite chain shifts, (36)b by the need to exclude the unattested predictions of *STRUC constraints, and (36)c by concerns about LC itself, namely the problematic effects of conjoining in overly-broad domains.

Together, the three assumptions in (36) provide a collective rationalization for assuming that LC is the only typologically-interesting logical operator available to natural-language OT grammars. The existence of a non-arbitrary motivation for excluding everything but LC does not, of course, entail that LC itself should be allowed. Even if the difficulties presented in (26) regarding the domain of conjunction are overcome by adopting a locality convention like (27), there remain a number of empirical objections that can be raised both against LC in general and against LC's usefulness for the various analytic purposes for which it has been employed.[11] One notable problem is LC's ability to create 'markedness reversals' (Ito & Mester 1998): a locally-conjoined constraint [IDENT(voice) & NOCODA] will be violated just in case a coda segment undergoes a change in its input voicing specification, making possible unattested languages which have a voicing contrast in codas but not in onsets. (For a proposed solution to this problem, see Łubowicz 2005). Regardless of the fate of LC, however, there do seem to be rational grounds for concluding that there are not any other logical connectives which OT analysts of natural languages need to consider.

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[11] To give just two representative examples, the application of LC to counterfeeding opacity (Kirchner 1996) is subject to objections raised by, among others, McCarthy (1999, 2003a, 2007), Padgett (2002), and Jesney (2005); the use of [M&F] conjunction to model derived environment effects (Łubowicz 2002, Kurisu 2006) is critiqued by Inkelas (2000), Blaho (2003), Blumenfeld (2003), McCarthy (2003a), Bradley (2007) and Anttila (to appear).

References

Alderete, John D. (1999). *Morphologically Governed Accent in Optimality Theory*. Ph.D. dissertation, University of Massachusetts, Amherst. [ROA-309]

Alderete, John D. (2001). Dominance effects as trans-derivational anti-faithfulness. *Phonology* **18**, pp. 201-253.

Anderson, Stephen R., and Wayles Browne (1973). On keeping exchange rules in Czech. *Papers in Linguistics* **6**, pp. 445-482.

Anttila, Arto (to appear). Derived environment effects in colloquial Helsinki Finnish. In Kristin Hanson and Sharon Inkelas (eds.), *The Nature of the Word: Essays in Honor of Paul Kiparsky*. Cambridge, MA: MIT Press.

Archangeli, Diana, Laura Moll, and Kazutoshi Ohno (1998). Why not *NÇ̥. In M. Catherine Guber, Derrick Higgins, Kenneth S. Olson, and Tamara Wysocki (eds.), *CLS 34, Part 1: The Main Session*. Chicago: CLS, pp. 1-26.

Baerman, Matthew (2007). Morphological reversals. *Journal of Linguistics* **43**, pp. 33-61.

Baković, Eric (1996). Foot harmony and quantitative adjustments. Ms., Rutgers University, New Brunswick, NJ. [ROA-168]

Balari, Sergio, Rafael Marín, and Teresa Vallverdú (2000). Implicational constraints, defaults, and markedness. GGT Report de Recerca GGT-00-8, Universitat Autònoma de Barcelona. [ROA-396]

Barrie, Michael (2006). Tone circles and contrast preservation. *Linguistic Inquiry* **37**, pp. 131-141.

Blaho, Sylvia (2003). Derived environment effects in Optimality Theory: The case of pre-sonorant voicing in Slovak. In Wayles Browne, Ji-yung Kim, Barbara H. Partee, and Robert A. Rothstein (eds.), *Annual Workshop on Formal Approaches to Slavic Linguistics: The Amherst Meeting 2002*. Ann Arbor: Michigan Slavic Publications, pp. 103-120.

Blumenfeld, Lev (2003). Russian palatalization and stratal OT: Morphology and [back]. In Wayles Browne, Ji-yung Kim, Barbara H. Partee, and Robert A. Rothstein (eds.), *Annual Workshop on Formal Approaches to Slavic Linguistics: The Amherst Meeting 2002*. Ann Arbor: Michigan Slavic Publications, pp. 141-158.

Bradley, Travis (2007). Morphological derived-environment effects in gestural coordination: A case study of Norwegian clusters. *Lingua* **117**, pp. 950-985. [ROA-834]

Bye, Patrik (2006). Eliminating exchange rules in Dholuo. Ms., Universitetet i Tromsø. [Available online at http://www.hum.uit.no/a/bye/Papers/dholuo-squib.pdf]

Crowhurst, Megan (1998). Conflicting directionality and tonal association in Carib of Surinam. Paper presented at 17th West Coast Conference on Formal Linguistics, University of British Columbia, Vancouver.

Crowhurst, Megan, and Mark Hewitt (1997). Boolean operations and constraint interactions in Optimality Theory. Ms., University of North Carolina, Chapel Hill, and Brandeis University, Waltham, MA. [ROA-229]

de Lacy, Paul (2002). Morpheme distinctiveness and feature exchange in DhoLuo. Talk presented at Phonology Group, University College London, 20 November.

Downing, Laura J. (1998). On the prosodic misalignment of onsetless syllables. *Natural Language and Linguistic Theory* **16**, pp. 1-52.
Downing, Laura J. (2000). Morphological and prosodic constraints on Kinande verbal reduplication. *Phonology* **17**, pp. 1-38.
Eisner, Jason (1999). Doing OT in a straitjacket. Colloquium presented at University of California, Los Angeles, June 14. [Handout available online at http://www.cs.jhu.edu/~jason/papers/eisner.ucla99.handout.large.pdf]
Flack, Kathryn (2007a). *The Sources of Phonological Markedness*. Ph.D. dissertation, University of Massachusetts Amherst.
Flack, Kathryn (2007b). Inducing functionally grounded constraints. Ms., University of Massachusetts Amherst. [ROA-920]
Gouskova, Maria (2003). *Deriving Economy: Syncope in Optimality Theory*. Ph.D. dissertation, University of Massachusetts Amherst. [ROA-610]
Gouskova, Maria (to appear). DEP: Beyond epenthesis. *Linguistic Inquiry* **38**.
Gregersen, Edgar (1972). Consonant polarity in Nilotic. In Erhard Voeltz (ed.), *Proceedings of the Third Annual Conference on African Linguistics*. Bloomington: Indiana University Press, pp. 105-109.
Grimshaw, Jane (2003). Economy of structure in OT. In Angela C. Carpenter, Paul de Lacy, and Andries W. Coetzee (eds.), *University of Massachusetts Occasional Papers in Linguistics* **26**: *Papers in Optimality Theory II*. Amherst: GLSA, pp. 81-120. [ROA-434]
Hayes, Bruce (1999). Phonetically driven phonology: The role of Optimality Theory and inductive grounding. In Michael Darnell, Frederick J. Newmeyer, Michael Noonan, Edith Moravcsik, and Kathleen Wheatley (eds.), *Functionalism and Formalism in Linguistics: Volume 1: General Papers*. Amsterdam: John Benjamins, pp. 243-285. [ROA-158]
Hewitt, Mark S., and Megan J. Crowhurst (1996). Conjunctive constraints and templates in Optimality Theory. In Kiyomi Kusumoto (ed.), *Proceedings of the North East Linguistic Society* **26**. Amherst: GLSA, pp. 101-116.
Hsieh, Hsin-I (1970). The psychological reality of tone sandhi rules in Taiwanese. In *Papers from the Sixth Regional Meeting, Chicago Linguistic Society*. Chicago: CLS, pp. 489-503.
Hsieh, Hsin-I (1975). How generative is phonology? In E.F.K. Koerner (ed.), *The Transformational-Generative Paradigm and Modern Linguistic Theory*. Amsterdam: John Benjamins, pp. 109-144.
Hsieh, Hsin-I (1976). On the unreality of some phonological rules. *Lingua* **38**, pp 1-19.
Inkelas, Sharon (2000). Phonotactic blocking through structural immunity. In Barbara Stiebels and Dieter Wunderlich (eds.), *Lexicon in Focus*. Berlin: Akademie Verlag, pp. 7-40. [ROA-366]
Ito, Junko, and Armin Mester (1998). Markedness and word structure: OCP effects in Japanese. Ms., University of California, Santa Cruz. [ROA-255]
Jesney, Karen (2005). *Chain Shift in Phonological Acquisition*. MA thesis, University of Calgary.
Kawahara, Shigeto (2006). A faithfulness ranking projected from a perceptibility scale: The case of [+voice] in Japanese. *Language* **82**, pp. 536-574.

Key, Michael, and Lee Bickmore (in prep.). Span binarity and overlap. Ms., University of Massachusetts Amherst and State University of New York, Albany.

Kirchner, Robert (1996). Synchronic chain shifts in Optimality Theory. *Linguistic Inquiry* **27**, pp. 341-350.

Kurisu, Kazutaka (2001). *The Phonology of Morpheme Realization*. Ph.D. dissertation, University of California, Santa Cruz. [ROA-490]

Kurisu, Kazutaka (2006). Weak derived environment effect. Paper presented at NELS 37, University of Illinois, Urbana-Champaign.

Lin, Hwei-Bing (1988). *Contextual Stability of Taiwanese Tones*. Ph.D. dissertation, University of Connecticut, Storrs.

Łubowicz, Anna (2002). Derived environment effects in Optimality Theory. *Lingua* **112**, pp. 243-280. [ROA-765]

Łubowicz, Anna (2003). *Contrast Preservation in Phonological Mappings*. Ph.D. dissertation, University of Massachusetts Amherst. [ROA-554]

Łubowicz, Anna (2005). Locality of conjunction. In John Alderete, Chung-hye Han, and Alexei Kochetov (eds), *Proceedings of the Twenty-Fourth West Coast Conference on Formal Linguistics*. Somerville, MA: Cascadilla Proceedings Project, pp. 254-262. [Lingref #1230; ROA-764]

Lyman, Larry, and Rosemary Lyman (1977). Choapan Zapotec phonology. In William R. Merrifield (ed.), *Studies in Otomanguean Phonology*. Dallas: Summer Institute of Linguistics/University of Texas at Austin, pp. 137-162.

McCarthy, John J. (1999). Sympathy and phonological opacity. *Phonology* **16**, pp. 331-399.

McCarthy, John J. (2002). *A Thematic Guide to Optimality Theory*. Cambridge: Cambridge University Press.

McCarthy, John J. (2003a). Comparative Markedness. *Theoretical Linguistics* **29**, pp. 1-51.

McCarthy, John J. (2003b). OT constraints are categorical. *Phonology* **20**, pp. 75-138.

McCarthy, John J. (2007). *Hidden Generalizations: Phonological Opacity in Optimality Theory*. London: Equinox.

McCarthy, John J., and Alan Prince (1993). Generalized Alignment. In Geert Booij and Jaap van Marle (eds.), *Yearbook of Morphology 1993*. Dordrecht: Kluwer, pp. 79-153. [ROA-7]

McCarthy, John J. and Alan Prince (1995). Faithfulness and reduplicative identity. In Jill N. Beckman, Laura Walsh Dickey, and Suzanne Urbanczyk (eds.), *University of Massachusetts Occasional Papers in Linguistics* **18**: *Papers in Optimality Theory*. Amherst: GLSA, pp. 249-384. [ROA-103]

McCawley, James D. (1974). [Review of *The Sound Pattern of English*]. *International Journal of American Linguistics* **40**, pp. 50-88.

Moreton, Elliot (1999). Non-computable functions in Optimality Theory. Ms., University of Massachusetts, Amherst. [ROA-364]

Mortensen, David (2004). Abstract scales in phonology. Ms., University of California, Berkeley. [ROA-667]

Myers, James (2006). Tone circles and chance. Ms., National Chung Cheng University, Min-Hsiung, Chia-Yi, Taiwan. [ROA-843]

Myers, James, and Jane Tsay (2002). Neutralization in Taiwanese tone sandhi. Ms., National Chung Cheng University, Min-Hsiung, Chia-Yi, Taiwan.

Okoth-Okombo, Duncan (1982). *DhoLuo Morphophonemics in a Generative Framework*. Berlin: Dietrich Reimer.

Padgett, Jaye (2002). Constraint conjunction versus grounded constraint subhierarchies in Optimality Theory. Ms., University of California, Santa Cruz. [ROA-530]

Peng, Shu-hui (1998). Evidence for a UR-free account of tone sandhi in Taiwanese. Poster presented at the Sixth Conference of Laboratory Phonology, University of York.

Prince, Alan, and Paul Smolensky (2004 [1993]). *Optimality Theory: Constraint Interaction in Generative Grammar*. Oxford: Blackwell. [ROA-537]

Pulleyblank, Douglas (2006). Minimizing UG: Constraints upon constraints. In Donald Baumer, David Montero, and Michael Scanlon (eds.), *Proceedings of the 25th West Coast Conference on Formal Linguistics*. Somerville, MA: Cascadilla Proceedings Project, pp. 15-39. [Lingref #1430]

Smolensky, Paul (1993). Harmony, markedness, and phonological activity. Talk presented at Rutgers Optimality Workshop I, New Brunswick, NJ. [Handout available as ROA-87]

Smolensky, Paul (1995). On the structure of the constraint component CON of UG. Talk presented at University of California, Los Angeles. [Handout available as ROA-86]

Smolensky, Paul (1997). Constraint interaction in generative grammar II: Local conjunction, or random rules in Universal Grammar. Talk presented at Hopkins Optimality Theory Workshop/Maryland Mayfest, Baltimore.

Trommer, Jochen (2001). *Distributed Optimality*. Doctoral dissertation, Universität Potsdam.

Trommer, Jochen (2005). Against antifaithfulness in Luo. Paper presented at 3rd Old World Conference in Phonology, Budapest. [Abstract available online at http://www.uni-leipzig.de/~jtrommer/05.pdf]

Tsay, Jane, and James Myers (1996). Taiwanese tone sandhi as allomorph selection. In Jan Johnson, Matthew L. Judge, and Jeri L. Moxley (eds.), *Proceedings of the 22nd Annual Meeting of the Berkeley Linguistics Society*. Berkeley: BLS, pp. 394-405.

Tseng, Chin-Chin (1995). *Taiwanese Prosody: An Integrated Analysis of Acoustic and Perceptual Data*. Ph.D. dissertation, University of Hawai'i, Mānoa.

Wang, Samuel Hsu (1995). *Experimental Studies in Taiwanese Phonology*. Taipei: Crane.

Wolf, Matthew (2007). For an autosegmental theory of mutation. In Leah Bateman, Adam Werle, Michael O'Keefe, and Ehren Reilly (eds.), *University of Massachusetts Occasional Papers in Linguistics* **32**: *Papers in Optimality Theory III*. Amherst: GLSA, pp. 315-404. [ROA-754]

Wolf, Matthew (to appear). Lexical insertion occurs in the phonological component. In Bernard Tranel (ed.), *Understanding Allomorphy: Perspectives from Optimality Theory*. London: Equinox. [ROA-912]

Yue-Hashiomoto, Anne O. (1986). Tonal flip-flop in Chinese dialects. *Journal of Chinese Linguistics* **14**, pp. 161-182.

Zhang, Jie, Yuwen Lai, and Craig Turnbull-Sailor (2006). Wug-testing the "tone circle" in Taiwanese. In Donald Baumer, David Montero, and Michael Scanlon (eds.), *Proceedings of the 25th West Coast Conference on Formal Linguistics*. Somerville, MA: Cascadilla Proceedings Project, pp. 453-461. [Lingref #1479]
Zoll, Cheryl (1993). Directionless syllabification and ghosts in Yawelmani. Ms., University of California, Berkeley. [ROA-28]
Zoll, Cheryl (1996). *Parsing Below the Segment in a Constraint-Based Framework.* Ph.D. dissertation, University of California, Berkeley. [ROA-143]

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