Constraint Conjunction and OTP[*]

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1. Introduction

From the beginning of modern linguistics, one of the primary issues in formulating a linguistic theory has been to make it *sufficiently* powerful without making it *too* powerful. Much attention, therefore, has been given to the power of Optimality Theory (OT; Prince and Smolensky 1993), and rightly so: unconstrained, OT could easily predict languages that intuitions about phonology rule out as impossible. Each time a new device is added to the theory, it must be scrutinized to ensure that the theory is not, as a result, capable of describing impossible languages. Generalized Alignment, Sympathy Theory, and Output-Output Faithfulness have all been subjected to criticisms concerning overgeneration and computability.

Local Constraint Conjunction (Smolensky 1995) has faced the same challenges. While some authors have adopted it without reservation, others have echoed the words of Féry (1998): "A possible drawback [to using conjunction] is the fact that the domain of the conjoined constraint has to be specified in the constraint itself, which leads to a certain amount of redundancy." Moreover, as researchers have developed the mechanism, disagreements have arisen over what forms of conjunction are and are not allowed.

In this paper, I adopt the framework of Primitive Optimality Theory as set forth in Eisner (1999), and explore how it can limit constraint conjunction, with the eventual goal of reassuring phonologists that not only can we eliminate the redundancy apparent in constraint conjunction, but that we can limit its power in order to prevent overgeneration. In doing so, I simultaneously offer evidence that conjunction is an acceptable device, and corroborate Eisner's claim that Primitive Optimality Theory is sufficiently powerful for the demands of phonology.

§2 discusses the mechanism of constraint conjunction, how it fits into the framework of OT and why it needs limitations. §3 introduces Primitive Optimality Theory, and discusses how it might represent conjunction. Finally, §4 covers the challenges left open by §3, with proposals for solving two kinds of problems not covered by the basic description.

2. What is Constraint Conjunction?

Since its earliest incarnations, Optimality Theory has undergone a number of revisions and extensions. Constraint conjunction is one such extension. The following sections describe the mechanism: §2.1 discusses the general architecture of OT, and §2.2 looks at various ways that the theory can incorporate constraint conjunction.

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[*] Or: How I Learned to Stop Worrying and Love the Ampersand. As this paper is my phonology generals, many thanks are due to my committee and to my classmates for helpful discussion; particular thanks go to Cheryl Zoll for frequent help and advice. The theory here is better for their input, but do not hold them responsible for any errors, which are wholly mine. This paper was written with the support of an NSF Graduate Fellowship.

2.1. The architecture of OT

OT is a particular instantiation of a more general theory, *Harmony Theory*. In its most austere form, harmony theory incorporates three components: *Con*, a set of constraints; *Gen*, a function that maps an input to a set of possible outputs; and *Eval*, an algorithm for applying the set created by *Gen* to the set *Con* to select the most harmonic, or optimal, member. Ideally, *Gen*, *Eval*, and the constraints in *Con* are universals, and in fact most research in OT takes them to be. The only language-specific elements are the ranking of the constraints in *Con* and the input forms.

In OT, *Eval* takes the constraints in *Con* in the order in which they are ranked, and for each constraint C eliminates from the set of possible outputs all candidates except those which violate C least. (Typically this means "which satisfy C," that is, "which do not violate C at all." It is possible, though, for no form to satisfy C.) When one candidate remains, the process ends and that form is chosen as "optimal."

Most OT research has focused on *Con*, both in specific languages and in language universals. Smolensky (1995) explores three ways in which *Con* is more than merely an ordered set of constraints. "Parametrized families" of constraints are ways of grouping constraints into families, in particular into faithfulness, structural and segmental markedness, and alignment constraints. "Harmony scales" are rankings derived from universal markedness hierarchies—following Prince and Smolensky (1993), a hierarchy such as the sonority scale *a* > *y* > *l* > *n* > *t* can be turned into a set of constraints *NUC(*t*) » … » *NUC(*a*), "avoid (*t*, …, *a*) in a syllable nucleus." The third extension is constraint conjunction.

2.2. Adding constraint conjunction

Smolensky (1993, 1995) notes that many language processes ban "the worst of the worst," forms that violate two constraints simultaneously. A classic case of this is German coda devoicing (discussed throughout the literature; the discussion here follows Itô and Mester (1999), who explain the data with conjunction, and a more complete discussion of their analysis appears in §4.2). German allows both voiced obstruents and codas ([gas] *Gas*, 'gas' exemplifies both), but does not allow voiced obstruents in codas, so that /taːg/ *Tag* 'day' surfaces as [taːk]. Constraints such as *CODA "segments should not be codas" and *VOIOBS "segments should not be voiced obstruents" are relatively low-ranked, but they are active when both are violated. Crucially, too, those violations must be in the same location: [gas] violates both, but in different segments.

To capture this intuition, Smolensky proposed allowing the *local conjunction* of two constraints A and B to be added to *Con* on a language-specific basis. His exact phrasing:

(1) a. **The Local Conjunction of C_1 and C_2 on domain *D***, $C_1 \&_l C_2$, is violated when there is some domain of type *D* in which both C_1 and C_2 are violated.

b. Universally, $C_1 \&_l C_2$ » C_1, C_2. (Smolensky 1995, (16d-e))

(Throughout this paper, I will use the notation $[C_1 \& C_2]_D$.) A partial *Con* for German would look like (2):

(2) [*VoiObs & *Coda]$_{Seg}$ » Max » Ident » *VoiObs, *Coda

The faithfulness constraint Max stops a segment from deleting entirely; similarly, the faithfulness constraint Ident prevents a segment from changing. The interaction can be seen clearly in the tableaux in (3). While candidate a in (3a) incurs violations of both *VoiObs and *Coda, the violations are in two separate segments: the conjoined constraint looks to see if both conjuncts are violated in a single segment, as in candidate a in (3b).

(3) Tableaux for German /gas/ *Gas*, ‘gas’ and /tag/ *Tag*, ‘day’

a.

/gas/	[*VoiObs & *Coda]$_{Seg}$	Max	Ident	*VoiObs	*Coda
☞ a. gas				g	s
b. kas			k!		s
c. ga		s!			

b.

/taːg/	[*VoiObs & *Coda]$_{Seg}$	Max	Ident	*VoiObs	*Coda
a. taːg	g!			g	g
☞ b. taːk			k		k
c. taː		g!			

The difference between (3a) and (3b) lies at the heart of constraint conjunction. If conjunction has no limitations, it predicts the possibility of a language like that in (4).

(4) Tableaux for Language X

a.

/gatɛpa/	*VoiObs & *Coda	Ident	*VoiObs	*Coda
☞ a. ga.tɛ.pa			g	
b. ka.tɛ.pa		k!		

b.

/gatɛpas/	*VoiObs & *Coda	Ident	*VoiObs	*Coda
a. ga.tɛ.pas	*!		g	s
☞ b. ka.tɛ.pas		k		

Because [gatɛpas] has both a voiced obstruent and a coda, the conjunction of the two constraints is violated. As a result, Language X can have voiced obstruents only in those words with only open syllables.

A language like Language X is not only unattested, it goes against all sensibilities of phonology. Certainly constraint conjunction, with no restrictions, will overgenerate; it is too powerful a device to add to OT. For this reason, Smolensky rightly limited conjunction to *local conjunction*: recall from (1) that conjunctions must apply in a specified domain, like the segment in (3). The conjunction in (4) has no domain set, giving it too much power. But this objection does not hold for long. The domain of conjunction (4) can be set to be a familiar prosodic domain, namely the word: [*VoiObs & *Coda]$_{Word}$. There is now a domain in which both C$_1$

and C_2 are violated, the definition of conjunction is satisfied, and yet constraint conjunction still overgenerates. More restriction on conjunction is needed.

2.3. Limiting Constraint Conjunction

Attempts to restrict conjunction have taken different approaches in the last few years. Most commonly, they come as answers to one of the questions in (5).[1]

(5) a . Do constraints need to be of the same “type” to conjoin?
b. Do constraints need to be of different “types” to conjoin?
c. Do constraints need a “common element” to conjoin?
d. What qualifies as “local” for local conjunction?

As suggested by the tableaux in (3)-(4), this paper is interested in questions of locality. For the sake of simplicity I will take the answers to (a)-(c) to be “no,” as these are the less restrictive assumptions.[2]

While all phonologists using constraint conjunction restrict it to local domains, for many authors the locality is something stipulated as part of the conjunction. Itô and Mester (1996) treat Rendaku effects in Japanese by conjoining *[+voi, -son] with itself in a domain specified as “the stem,” rather than, say, “the prosodic word” or “adjacent segments,” both of which are possible domains. But we have already seen what can go wrong when an insufficiently local domain is specified for a conjunction, with [*VoiObs & *Coda]$_{\text{Word}}$. If this approach is correct and specifying the domain of conjunction is part of conjoining two constraints, the theory needs a method to determine what domains can qualify as “local.” Without such a method, simple stipulation of the domain of conjunction will not be sufficiently constrained..

A more promising approach is taken by those authors (e.g. Łubowicz 1998) for whom “local” means “as local as possible,” so that the domain of any conjunction is exactly determined by the conjuncts. Even this approach is not without its unsolved problems, as two examples will illustrate. The first comes from Łubowicz’s description of Polish spirantization of palatalized ǰ (derived from underlying /g/). To explain the lack of derived ǰ, which is a legitimate surface segment of Polish when faithful to an underlying ǰ, Łubowicz conjoins *ǰ and Ident(coronal) in the domain of the segment.

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[1] This paper explores the nature of the constraints themselves; how they are ranked is a tangential issue. I will therefore only briefly mention here that Łubowicz (1998) and Itô and Mester (1999) discuss another possible restriction: limiting where in the hierarchy a conjunction can be ranked relative to its conjuncts. Łubowicz conjoins a markedness constraint M with a faithfulness constraint F to elevate the importance of M with respect to another faithfulness constraint F′, giving the ranking [M & F] » F′ » F, M. Itô and Mester discovered that the same cannot be done to promote over a markedness constraint: [M & F] » M′ » F, M leads to impossible languages. Whether this restriction must be stipulated, or whether it can result from other facts, is well outside the scope of this paper.

[2] Certainly, other authors have said the opposite. Fukazawa and Miglio (1998) and Fukazawa (1999) propose that constraints must be of the same “family” to conjoin (e.g. both OCP constraints), while Łubowicz (1998) postulates that only faithfulness-plus-markedness conjunctions exist (see footnote 1); Łubowicz and others (e.g. Baković (1999)) also claim that both constraints must refer to a common element.

Nothing discussed in this paper will provide evidence one way or the other. Nonetheless, if further research shows that the answer to any of (5a)-(5c) is “yes,” the theory developed in this paper will have the mechanisms necessarily to formalize those answers; see footnote 7.

(6) *ǰ: No surface voiced postalveolar affricate segments[3]
IDENT(coronal): Surface [coronal] segments are underlyingly [coronal]

[*ǰ & IDENT(coronal)]$_{\text{Seg}}$ No surface ǰ without underlying [coronal]

Taking the segment to be the smallest possible domain raises an immediate question. How can we be sure that the segment is chosen as the smallest domain? Or put another way, given that this domain should follow something, it must follow from the constraints themselves; how does it? Certainly the constraints as phrased in (6) both refer to only a single segment, but the smallest possible domain should not follow merely from metalinguistic phrasing.

A similar problem is raised by Tranel (2000), who gives evidence for conjoining ONSET and *CODA. Here, however, the question of the "smallest possible domain" is not as clear as it was in Łubowicz. Tranel argues an intermediate position between Itô and Mester's and Łubowicz's: the domain of conjunction must still be specified, but it must be as local as possible. Crucially, though, there may be a choice, as with ONSET and *CODA, so that we have both:

(7) a. [ONSET & *CODA]$_{\sigma}$ (Italian [and Dutch acquisition?])
"No violation of ONSET/*CODA in the same syllable," i.e. *[VC]$_{\sigma}$

b. [ONSET & *CODA]$_{\text{Adj-}\sigma}$ (French)
"No violation of ONSET/*CODA in adjacent syllables," i.e. *[…C]$_{\sigma}$ [V…]$_{\sigma}$

In some ways, this is a continuation of the question raised by the Polish spirantization constraints: is the "smallest possible domain" determined by the constraints? In this case the question is whether the smallest possible domain is *uniquely* determined.

McCarthy (1998:34) summarized the concerns expressed here as follows: "But the notion 'domain in which two (arbitrary) processes interact' has no formal status in OT or any other theory, nor can it, since it can only be determined on a post-hoc case-by-case basis, by trying to apply the processes to a particular form." What is needed is a general and deterministic method for conjoining constraints. To achieve that, we require a method for phrasing constraints themselves in a formal and clear manner. Having this method should provide a way to derive the domain of conjoined constraints. The next section details exactly this sort of formal language: Primitive Optimality Theory.

3. Primitive Optimality Theory

Eisner (1999) developed Primitive Optimality Theory (OTP) as a way of constraining OT. OTP formalizes the theory by allowing only two types of constraints, overlap and clash, which refer to features on a phonological timeline in a strictly local manner.

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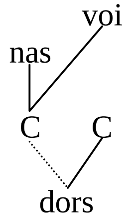
[3] That is to say, a combination of the features [-continuant], [coronal], [dorsal], and [+voice].

3.1. The representations

In OTP, constraints refer to *edges* and *interiors* of features. An underlying [nk] which surfaces as /ŋk/, often represented as in (8a) (adapted from Eisner, citing Goldsmith 1990), would be partially represented in OTP as (8b) (from Eisner's (15b)).

(8) a.



b.

$_{voi}[$	$]_{voi}$	
$_{nas}[$	$]_{nas}$	
$_{C}[$	I	$]_{C}$
$_{dors}[$		$]_{dors}$
	$_{\underline{dors}}[$	$]_{\underline{dors}}$

All features in OTP are privative; [-voice] in represented by a lack of a *voice* feature, as in on the /k/ above. These privative features comprise interiors and edges and lie on a continuous timeline; constraints refer to points on the timeline. The timeline can contain whatever features the phonology might need to refer to—for instance, autosegmental features such as *nasal* and *dorsal*; prosodic and morphological domains such as μ, σ, and Prosodic Word; stress marks; and so on. Features in underlying representations also appear on the timeline, represented by an underline (i.e. "underlyin'" representations). Other tiers besides input and output may be needed, such as a "base" tier aligned with the reduplicant; or tiers for inserted and deleted material (Albro 1998).

Many of the basic concepts of OT are preserved here. Correspondence, for instance, is simply overlap: the surface /k/ in (8b) would have a corresponding $_{\underline{C}}[\ldots]$ overlapping it across the same stretch of timeline. Representing the spreading of features does not require association lines; instead, the edges of the surface feature are placed to cover more of the timeline than the underlying feature does. In (8b), the *<u>dorsal</u>* feature spreads by having *dorsal* stretch over a longer section of timeline.

3.2. The constraints

Constraints in OTP refer to edges and interiors of features in one of two ways: *overlap* and *clash*, as formalized in (9) (Eisner's (19)).

(9) a. $\alpha \rightarrow \beta$: each α temporally overlaps some β.
(Each α without a β incurs one violation mark.)

b. $\alpha \perp \beta$: each α temporally overlaps no β.
(Each overlap incurs one violation mark.)

α and β can be interiors (for example, *nasal* or *voice*), edges ($]_{C}$ or $_{voi}[$), or conjunctions and disjunctions of a specific sort:[4]

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[4] Why these particular conjunctions and disjunctions and not, for instance, allowing *or* with ⊥, *or* in the first part of →, or *and* in the second part? Because such constraints would have more than one representation that violates them; the formulations in (10) do not, making them computationally tractable. As we will see, constraint conjunction

(10) a. $(\alpha_1 \text{ and } \alpha_2 \text{ and } \ldots) \rightarrow (\beta_1 \text{ or } \beta_2 \text{ or } \ldots)$
Violated once by each set of objects $\{A_1, A_2, \ldots\}$ of types $\alpha_1, \alpha_2, \ldots$ respectively that all overlap on the timeline and whose intersection does not overlap any object of type $\beta_1, \beta_2, \ldots$

b. $(\alpha_1 \text{ and } \alpha_2 \text{ and } \ldots) \perp (\beta_1 \text{ and } \beta_2 \text{ and } \ldots)$
Violated once by each set of objects $\{A_1, A_2, \ldots, B_1, B_2, \ldots\}$ of types $\alpha_1, \alpha_2, \ldots, \beta_1, \beta_2, \ldots$ respectively that all overlap on the timeline

(Because $\perp$ is associative and commutative, the latter is often written $\alpha_1 \perp \alpha_2 \perp \beta_1 \perp \beta_2 \perp \ldots$.)

Eisner demonstrates, through a review of constraints used in papers on the Rutgers Optimality Archive (http://ruccs.rutgers.edu/roa.html), that these templates will cover most constraints that have been proposed in the literature.[5] For instance, (11) re-expresses many of the constraints used above in OTP terms.

(11) a. *ǰ: (*coronal* and *dorsal* and *voice*) → *continuant*
"If coronal, dorsal, and voice coincide, they must overlap continuant" ≡
"Nothing can be coronal, dorsal, and [+voice], but [-continuant]"

b. IDENT(coronal): $\mathit{coronal} \rightarrow \underline{\mathit{coronal}}$
"Every surface [coronal] overlaps/corresponds with underlying [coronal]."

c. ONSET: ${}_{\sigma}[\rightarrow {}_{C}[$
"The left edge of a syllable must overlap the left edge of a consonant" ≡
"Syllables begin with consonants"

d. *CODA: $]_{\sigma} \perp]_{C}$
"Right edges of syllables cannot overlap right edges of a consonants" ≡
"Syllables do not end with consonants"

To see concretely how constraints works, consider the more complete but still partial timeline in (12). Here, numbers have been added along the bottom for reference. Note that the back-to-back brackets are intended to overlap, i.e. there is no space between the two syllables at point 5, nor between the two consonants at point 11.

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when formalized in OTP produces constraints of the forms in (10), but no others, lending credence to the computationally friendly nature of conjunction in general and OTP conjunction in particular.

[5] Specifically, OTP cannot express generalized alignment constraints, which Eisner takes to be a positive result.

(12) OTP representation of hypothetical form [tapank] → /ta.baŋk/[6]

	t		a		b		a		ŋ		k	
[				][								]$_\sigma$
[		]$_C$		[		]$_C$		[		][		]$_C$
		[		]$_V$		[		]$_V$				
[		]$_{cor}$										
				[		]$_{lab}$						
								[				]$_{dors}$
		[								]$_{voi}$		
										[		]$_{\underline{dors}}$
		[		]$_{\underline{voi}}$		[				]$_{\underline{voi}}$		
1	2	3	4	5	6	7	8	9	10	11	12	13

The constraints in (13) are satisfied by this representation; the constraints in (14) are not.

(13) a. MAX(dorsal): $\underline{dors} \rightarrow dors$
"An underlying [dorsal] feature corresponds to surface [dorsal]"
($\underline{dors}$ occurs at 12; it overlaps *dors* there)

b. $C \neq V$: $C \perp V$
"Consonants and vowels are distinct"
(*C* and *V* never overlap; $]_C$ and ${}_V[$ overlap at 3 and 7, but that does not cause a violation here)

(14) a. *SPREAD(dorsal): $dors \perp {}_{\underline{dors}}[$
"The [dorsal] feature should not overlap its underlying left edge" ≡
"[dorsal] should not spread leftward"
(*dors* and ${}_{\underline{dors}}[$ overlap at 11)

b. *COMPLEX: $(\,]_C \text{ and } {}_C[\,) \perp \sigma$
"If the right and left edges of consonants meet, they should not overlap the interior of a syllable" ≡ "Syllables do not contain adjacent consonants"
(11 has the right and left edges of *C*, and is at the interior of a σ)

OTP constraints are powerful enough to express all of the constraints needed for OT, and expresses them in a formal and straightforward manner.[7]

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[6] Here and throughout, I use][as a typographical necessity to indicate the simultaneous ending and beginning of a feature. The brackets should be read as adjacent—i.e. with no gap between them.

[7] It can now be seen, as noted in footnote 2, that OTP contains the mechanisms to give restrictive answers to (5a)-(5c). FAITH constraints are those which refer to both surface and underlying features (e.g. $\underline{voi} \rightarrow voi$); MARK constraints refer only to surface features (e.g. $nas \rightarrow voi$). (OT constraints do not apply only to underlying representations.) A stipulation that only FAITH and FAITH and MARK and MARK can conjoin (cf. Itô and Mester (1998), Kirchner (1996)) is still a stipulation, but OTP allows it to be expressed clearly without having to additionally mark constraints as FAITH or MARK.

Similarly, if the answer to (5c) is the more restrictive "yes," it is clear what qualifies as "something in common," namely a feature common to both constraints—again, nothing will require the common element, but it can be stipulated. Formal clarity will prevent moves such as that of Łubowicz (1998): while her conjunctions

Before continuing to the proposal, there are a few points about OTP that bear mentioning. First, the use of privative features in the representations will not by and large limit what constraints can be expressed, because both overlap and clash are options. Take two features α and β where β was traditionally taken to be two-valued, say [dorsal] and [voice]. To express *[dorsal, +voice] "No voiced dorsals," OTP uses $dors \perp voi$; to express *[dorsal, -voice] "No voiceless dorsals," OTP uses $dors \rightarrow voi$, "dorsals must be voiced."[8] Similarly, consider *VoiObs "No voiced obstruents" expressed as "If [-sonorant], then [-voice]." It would seem that the OTP expression would be $\text{-}son \rightarrow \text{-}voi$, requiring non-privative features; but in fact the constraint can equally well be expressed as "If not [-voice] then not [-sonorant]," which is to say $voi \rightarrow son$.

Another point is that OTP does not dictate *which* constraints are good constraints, any more than OT itself did. Just as both Onset ("Syllables must have onsets") and *Onset ("Syllables must not have onsets") are writable in OT, both are expressible in OTP: Onset as in (11c), and *Onset analogously as ${}_{\sigma}[\perp {}_{C}[$, "The left edge of a syllable must *not* overlap the left edge of a consonant" or "Syllables must not start with consonants." The choice of which constraints are necessary is, as always, a separate question.

Finally, a point which we will revisit in various guises is that some constraints can be written in multiple ways in OTP, especially in relation to inviolable constraints. Again, take the familiar Onset; each constraint in (15) requires syllables to start with consonants.

(15) a. ${}_{\sigma}[\rightarrow {}_{C}[$ (= (11c))
b. ${}_{\sigma}[\perp {}_{V}[$ "No syllable starts with a vowel"
c. $\mu_s \rightarrow C$ "Strong moras overlap consonants"[9]

Technically these are different constraints. For instance, if ${}_{\sigma}[$, ${}_{C}[$, and ${}_{V}[$ all coincide, (15a) is satisfied but (15b) is violated. However, given an inviolable constraint $C \perp V$, that is, consonants and vowels do not overlap, such a representation would be ruled out. Similarly, an inviolable constraint ${}_{\sigma}[\rightarrow {}_{\mu\text{-}s}[$, "syllables must start with strong moras," will bring (15c) in line. In order to keep from being distracted by irrelevant concerns, I will assume that certain "common-sense" constraints (like "consonants are not vowels") are in fact inviolable, so that forms that violate them are not generated by *Gen*. (Alternately, see Orgun and Sprouse (1997), who argue for the existence of a *Control* component which holds inviolable constraints. Candidates created by *Gen* must satisfy all these constraints before being tested against *Con*. Orgun and Sprouse use this to derive ungrammaticality: if no candidate satisfies all of the constraints in *Control*, no output form exists. If this view is correct, *Gen* would generate these illicit forms, and *Control* would contain "common-sense" constraints such as $\mu_w \perp \mu_s$ and $C \perp V$, preventing such forms from being evaluated by *Con*. The ultimate effect is the same.)

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mostly have [coronal], [voice], or a long vowel as the "shared argument," the conjunction of *[dorsal][dorsal, coronal] and R-Anchor(Stem, σ), has only the "segment" as a shared argument. While the edges of stems and syllables are admittedly segments, to say that the constraint is genuinely about segments is somewhat counterintuitive. OTP allows a formal definition for "reference" to a feature without relying on intuitions about metalinguistic phrasings.

[8] These constraints are used for expository purposes; no claim is being made about their actual existence.

[9] "Strong mora" (μ_s) and "weak mora" (μ_w) are terms Eisner takes from Zec (1988). The strong mora of a syllable is the onset and nucleus; the weak mora is the coda, if any.

3.3. Constraint conjunction in OTP

OTP provides exactly what conjunction required if it was to be constrainable: a formal expression of constraints. Now we can put that formalism to work.

Primitive Optimality Theory is “primitive” not because it is any less developed than OT, but because it builds constraints from primitives. Constraint conjunction builds larger constraints from smaller ones. It stands to reason that if the conjunction is built from smaller constraints that are built from primitives, the conjunction must also be built from primitives. In this section I explore and formalize that reasoning.[10]

Consider two clash constraints, $a \perp b$ and $x \perp y$. The first says that *a* and *b* cannot overlap at any single point on the timeline; the latter, that *x* and *y* cannot overlap at any single point on the timeline. Suppose these constraints are conjoined. If the domain of conjunction is specified when the conjoined constraint is added to *Con*, a domain can be chosen which requires looking at more than one point on the timeline at once, giving non-local effects. Building the conjunction directly out of the primitives of its conjuncts will prevent this.

How would such a method work? Consider the representations that violate each constraint:

(16)	$a \perp b$	,	$x \perp y$	$\Rightarrow_{\text{conj}}$	$[a \perp b]$ & $[x \perp y]$
	$[\quad]_a$				$[\quad]_a$
	$[\quad]_b$				$[\quad]_b$
			$[\quad]_x$		$[\quad]_x$
			$[\quad]_y$		$[\quad]_y$

$a \perp b$ is violated if *a* and *b* overlap; $x \perp y$ is violated if *x* and *y* overlap. The conjunction should be violated if and only if both conjuncts are: that is, if *a* and *b* overlap and, overlapping them (i.e. at the same point—by necessity, given that OTP constraints can only consider a single point), *x* and *y* overlap, or in other words if all four overlap. OTP already has the language to express this: $a \perp b \perp x \perp y$ (see (10)). Two clash constraints can thus be conjoined to make a new unified constraint of OTP.

What about two overlap constraints? Take $a \rightarrow b$, $x \rightarrow y$, which are violated respectively only if there is an *a* that does not overlap a *b*, and an *x* that does not overlap a *y*. Taken together, we have a violation of both constraints if there is an *a* and an *x* overlapping, which do not overlap a *b* and do not overlap a *y*. In other words, (*a* and *x*) → (*b* or *y*), another legitimate OTP constraint.

Finally, consider an overlap and a clash, $a \rightarrow b$ and $x \perp y$. These are violated only if there is an *a* but no *b*, and only if there is an *x* and a *y*. Rearranging a little, both are violated only if there is an *x* and a *y* and an *a*, but no *b*: (*x* and *y* and *a*) → *b*. Any two OTP constraints can thus be conjoined, using one of the rules in (17).

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[10] In a sense, the reasoning here follows from Łubowicz (1998), who in the final sections of her paper speculates on the possiblity of “MARK-sub-FAITH,” constraints, markedness constraints that only apply in the segments that violate the corresponding faithfulness. OTP provides a clear method of formalizing this notion, as well as allowing it to extend to conjunctions of two markedness or two faithfulness constraints.

(17) Summary of conjunction in OTP
$a \rightarrow b, x \rightarrow y \quad \Rightarrow_{\text{conj}} \quad (a \text{ and } x) \rightarrow (b \text{ or } y)$
$a \rightarrow b, x \perp y \quad \Rightarrow_{\text{conj}} \quad (x \text{ and } y \text{ and } a) \rightarrow b$
$a \perp b, x \perp y \quad \Rightarrow_{\text{conj}} \quad a \perp b \perp x \perp y$

What do these rules say about the conjunctions used earlier in the paper? Let's see.

Consider the earlier evidence that conjunction needed to be local, German coda devoicing. The ranking in (2) included $[$*VoiObs & *Coda$]_{\text{Seg}}$, but $[$*VoiObs & *Coda$]_{\text{Wd}}$ was not a legitimate conjunction. Does an OTP conjunction of *VoiObs and *Coda give a constraint necessarily restricted to the segment (and not the word)?

(18) *VoiObs: $voi \rightarrow son$
*Coda: $C \perp \mu_w$

$voi \rightarrow son, C \perp \mu_w \quad \Rightarrow_{\text{conj}} \quad (C \text{ and } \mu_w \text{ and } voi) \rightarrow son$

Because of the limitation of OTP that constraints apply at single points, the conjunction in (18) will apply to a single segment, saying that if it is a consonant, in a coda, and voiced, it must be a sonorant. This is exactly the desired result; by the rules in (17), the constraints can conjoin in one and only one way, so that the conjunction applies to a single segment. OTP cannot produce a conjunction that applies to the entire prosodic word.

A similar result comes from conjoining *ǰ and Ident(coronal), repeated here in their formulations from (11).

(19) *ǰ: $(cor \text{ and } dors \text{ and } voi) \rightarrow cont$
Ident(coronal): $cor \rightarrow \underline{cor}$

$(cor \text{ and } dors \text{ and } voi) \rightarrow cont, cor \rightarrow \underline{cor} \quad \Rightarrow_{\text{conj}}$
$(cor \text{ and } dors \text{ and } voi) \rightarrow (cont \text{ or } \underline{cor})$

Again, the conjunction says that a single point which is coronal, dorsal, and voiced must either be continuant (in which case the surface phoneme is ž, satisfying *ǰ) or underlyingly coronal (in which case Ident(coronal) is satisfied—surface ǰ is allowed when corresponding to underlying ǰ). The question posed earlier has its answer: a single segment is indeed the smallest possible domain, and this fact does follow directly from the constraints themselves and not from metalinguistic phrasing.

A more challenging case is Onset and *Coda. Again from (11):

(20) Onset: ${}_{\sigma}[\rightarrow {}_{C}[$
*Coda: $]_{\sigma} \perp]_{C}$

${}_{\sigma}[\rightarrow {}_{C}[,]_{\sigma} \perp]_{C} \quad \Rightarrow_{\text{conj}} \quad ({}_{\sigma}[\text{ and }]_{\sigma} \text{ and }]_{C}) \rightarrow {}_{C}[$

In other words, "If there is a consonant ending where one syllable ends and the next begins, a new consonant must begin"—or, if one syllable violates *Coda, the next cannot violate Onset. Some sample forms are seen in (21) and (22).

(21) Syllable structure of hypothetical form /ta.ban/

	t		a		b		a		n	
[				][						$]_{\sigma}$
[				][				$]_{\mu\text{-s}}$		
								[		$]_{\mu\text{-w}}$
[		$]_{C}$		[		$]_{C}$		[		$]_{C}$
1	2	3	4	5	6	7	8	9	10	11

(22) Syllable structure of hypothetical form /tab.an/

	t		a		b		a		n	
[						][				$]_{\sigma}$
[				]		[		$]_{\mu\text{-s}}$		
				[		$]_{\mu\text{-w}}$		[		$]_{\mu\text{-w}}$
[		$]_{C}$		[		$]_{C}$		[		$]_{C}$
1	2	3	4	5	6	7	8	9	10	11

The word in (21) does not violate the constraint in (20), even though a single syllable has both an onset and a coda. ${}_{\sigma}[$ and $]_{\sigma}$ cooccur only at point 5, and there is no $]_{C}$ there, so there can be no point where all three overlap without a ${}_{C}[$, the configuration that violates [ONSET & *CODA]. In contrast, consider point 7 in (22). $]_{\sigma}$, ${}_{\sigma}[$, and $]_{C}$ do overlap, and there is no ${}_{C}[$, so the conjoined constraint is violated.

This constraint corresponds to the Adjacent-σ restriction of (7b), so that conjunction can be expressed in OTP. But it was noted before that OTP has a certain amount of optionality built into it. If the constraints are expressed in different ways, can a different domain result?

(23) ONSET: $\mu_s \rightarrow C$
*CODA: $\mu_w \perp C$

$\mu_s \rightarrow C,\ \mu_w \perp C \quad \Rightarrow_{\text{conj}} \quad (\mu_s \text{ and } \mu_w) \rightarrow C$

(23) says that if a strong mora and a weak mora overlap, they must overlap a consonant. As was discussed before, all languages by definition have an inviolable constraint, $\mu_w \perp \mu_s$, just as all language have an inviolable $C \perp V$ constraint by the definition of consonants and vowels. Compare the representations above, where strong and weak mora features never overlap. No representation created by *Gen* (or surviving *Control*, depending on the theory) will have overlapping strong and weak moras, and thus no candidate can ever violate the conjunction in (23).

4. Challenges for OTP Conjunction

In many ways, OTP is exactly the theory needed to ensure reasonable conjunctions. However, there are some conjunctions that it cannot express. We have already seen one of them, confirmed in the last section: [ONSET & *CODA]$_{\sigma}$ in (7a). How serious a problem is this for the proposal here? A survey of the Rutgers Optimality Archive shows that perhaps six percent of the papers there use constraint conjunction in one form or another.[11]

In fact, most of the conjunctions used in papers from the archive are local by OTP standards. This section examines two particular cases: Łubowicz (1998), whose conjunctions are strictly local and thus translatable into OTP, and Itô and Mester (1999), whose conjunctions are not, requiring a reanalysis of the data.

4.1. Expressible conjunctions

Łubowicz proposes five different conjunctions in her 1998 paper. One of them appears above in (19), repeated here:

(24) *ǰ & IDENT(coronal): (*cor* and *dors* and *voi*) → (*cont* or $\underline{\textit{cor}}$)

Recall that this results immediately from the OTP versions of the individual conjuncts. This is no surprise; as Łubowicz was applying the conjunction to a single segment, the OTP version should be straightforward, as indeed it was.

The same is true of [*VOICED/STOP & IDENT(voice)], which she uses in her analysis of Campadinian Sardinian. Again, each conjunct applies to a single segment, so the conjunction naturally does. *VOICED/STOP requires any voiced segment to be a continuant (in particular, /b/ violates it while /p/ and /β/ do not). IDENT(voice) is used to prevent voiceless segments from voicing—in other words, requiring any vocied segment to have been underlyingly voiced.[12] We thus have:

(25) *VOICED/STOP: *voi* → *cont*
IDENT(voice): *voi* → $\underline{\textit{voi}}$

[*VOICED/STOP & IDENT(voice)]: *voi* → (*cont* or $\underline{\textit{voi}}$)

In contexts which require /p/ to voice, it will spirantize as well (since there is no $\underline{\textit{voi}}$, there must be a *cont* feature), but underlying /b/ will not spirantize (the presence of $\underline{\textit{voi}}$ obviates the insertion of *cont*).

Two of the three remaining conjunctions involve long vowels: [*HIGHLONG & WT-IDENT] and [*MIDLONG & WT-IDENT]. (I will use the former throughout the following discussion, as the same formalism will work for the latter.) Intuitively, these present no problem for OTP, as both conjuncts refer to the same segment, but here the formalization is less obvious:

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[11] This figure is a conservative estimate. The 95% which do not use conjunction includes some syntax and semantics papers, which almost never use conjunction, and some papers which are inaccessible. The actual figure may be somewhat higher.

[12] IDENT is typically a shorthand for a combination of DEP and MAX, so that IDENT(voice) would mean “a segment is voiced in the input if and only if it is voiced in the output” (often phrased “if a segment is voiced in the input, it is voiced in the output, and if a segment is voiceless in the input, it is voiceless in the output,” the second half being identical to the “only if” of the biconditional). This is, properly speaking, two different constraints, and only half—DEP(voice)—is represented in (25). This has no fundamental effect on the conjunction, because MAX(voice) and *VOICED/STOP cannot be simultaneously violated in the same segment: such a segment would need to be, on the one hand, voiced underlyingly and voiceless on the surface, and on the other, voiced and a stop on the surface. This is clearly impossible—no theory allows segments to be both voiced and voiceless.

what does it mean for a segment to be "a long vowel"? Here, we take a cue from Eisner (1999), who expresses a geminate as a single consonant feature overlapping a syllable boundary. Long vowels do not stretch across syllables, but they do stretch from the strong mora (i.e. the onset/nucleus) into the weak mora (the coda). Graphically:

(26) Syllable structure of /bi/ and /biː/

```
     b         i                   b         i         ː
[                   ]σ        [                            ]σ
[                   ]μ-s      [                  ]μ-s
                                                  [        ]μ-w
           [        ]V                  [                  ]V
```

It is now clear how to represent a restriction on the height of vowels. *HIGHLONG says that a point on the timeline cannot be both a high vowel and a long vowel: $hi \perp \mu_w$.

What about WT-IDENT? The relevant part of this constraint (see discussion in footnote 12) prevents an underlyingly short vowel from surfacing as a long vowel, which is to say that any vowel long on the surface is long underlyingly. The two constraints are thus:

(27) *HIGHLONG: $hi \perp \mu_w$
WT-IDENT: $(\text{V and } \mu_w) \rightarrow \underline{\mu_w}$

[*HIGHLONG & WT-IDENT]: $(hi \text{ and V and } \mu_w) \rightarrow \underline{\mu_w}$

This allows a high vowel to be part of a coda (i.e. long) only if it is underlyingly long.

The last conjunction in Łubowicz, *[dorsal][dorsal, coronal] & R-ANCHOR(Stem, σ), is used for Polish velar palatalization. It is less obviously local by OTP standards, as the first constraint refers to adjacent segments while the second refers to a single segment, namely the segment at the edge of the stem. Łubowicz sets the smallest possible domain as "adjacent segments," which would comprise two different points on an OTP timeline. But in fact, cast in OTP terms, both constraints refer to the border between two segments:

(28) *[dors][dors, cor]: $]_{dors} \perp {}_{dors}[\perp {}_{cor}[$
R-ANCHOR: $]_{\underline{Stem}} \rightarrow]_\sigma$

*[dorsal][dorsal, coronal] & R-ANCHOR(Stem, σ):
$( ]_{dors} \text{ and } {}_{dors}[\text{ and } {}_{cor}[\text{ and }]_{\underline{Stem}}) \rightarrow]_\sigma$

Again, these conjoin in the manner described in (17) without difficulty.

These five conjunctions are typical of the conjunctions that appear in the OTP literature. The next section examines one of the few proposed cases where two different constraints cannot be conjoined in OTP: Itô and Mester's (1999) account of German coda devoicing.

4.2. Inexpressible conjunctions

The relevant facts of German coda devoicing appear in (29), taken from Itô and Mester.

(29) German Coda Devoicing facts
  a. /taːg/ → taːk *Tag* ‘day’ cf. taːgə ‘days’
  b. /dɪŋg/ → dɪŋ *Ding* ‘thing’ cf. dɪŋgə ‘things’
  c. /hand/ → hant *Hand* ‘hand’ cf. handə ‘hands’
  d. /baŋk/ → baŋk *Bank* ‘bank’

Voiced obstruents devoice at the end of syllables, as we saw in (3); alternation with the plural form indicates that the final consonant in *Tag* is underlyingly voiced. However, when part of the coda /-ŋg/, the g deletes instead of devoicing. This is particular to g and not voiced consonants in general, as seen in (29c), and is not a constraint against surface [-ŋk], as seen in (29d). Informally, the generalization can be phrased: “No voiced obstruents in codas. Codas with dorsal plosives are acceptable, devoicing in complex codas is acceptable—but both together are not.”

This is the solution Itô and Mester propose, by conjoining the four constraints in (30).

(30) Constraints for German Coda Devoicing
  a. *Coda: no segment is part of a coda
  b. *DorsPlos: no dorsal plosives
  c. *Complex: no complex codas
  d. Ident(voi): corresponding input/output segments are identical for [±voice]

(30a) and (30b) taken together form the first half of the conjunction expressed informally above, ruling out dorsal plosives; (30c) and (30d) disallow complex codas where one segment is underlyingly voiced but voiceless on the surface. All four taken together, and ranked at the top of the constraint hierarchy, block complex codas with dorsal plosives only when devoicing has occurred.

On the surface, this presents a challenge for OTP. OTP, like OT, can conjoin more than two constraints; the problem here lies in the representations of the constraints. Individually they can be represented, but the conjunction fails. To see why, take the representations of *DorsPlos and *Complex in (31).

(31) *DorsPlos: $\mathit{dors} \rightarrow \mathit{cont}$ (“all dorsals are continuants”)
  *Complex: $\sigma \perp (\,]_{\mathrm{C}} \text{ and } {}_{\mathrm{C}}[\,)$

  $\mathit{dors} \rightarrow \mathit{cont},\ \sigma \perp (\,]_{\mathrm{C}} \text{ and } {}_{\mathrm{C}}[\,) \Rightarrow_{\mathrm{conj}} (\sigma \text{ and }]_{C} \text{ and } {}_{C}[\text{ and } \mathit{dors}) \rightarrow \mathit{cont}$

The conjunction in (31) claims that, where two consonants meet in a syllable, if there is a dorsal feature, there must be a continuant feature. This is a legitimate OTP constraint and is therefore local—but it is not the intended conjunction [*Complex & *DorsPlos], “Do not have a dorsal plosive in a complex onset/coda.”

What went wrong in (31), and is it salvable? The problem is that the intuitive conjunction, the one intended by Itô and Mester, says, “When *two adjacent segments* are a complex onset/coda, *neither one of them* can be a dorsal plosive." The OTP constraint formed by the conjunction rules, however, cannot refer to two adjacent segments, only to the border between segments. This is not a problem for *COMPLEX taken by itself, but when conjoined with a constraint that refers to the segments and not the border, the wrong results fall out. Moreover, rephrasing the constraints cannot help in this case; however they are phrased, *COMPLEX will necessarily refer to the border, and *DORSPLOS to the segments on either side.

One of two approaches will account for the impossibility of (31): we can revise OTP to allow simultaneous reference to edges and the segments on either side, or we can find another analysis. The former will lead to unraveling of the fundamentals of primitive Optimality Theory by weakening the strict locality requirements. Therefore, let us consider Itô and Mester's analysis more carefully.

What representations are ruled out when the constraints in (30) are conjoined? As noted before, a candidate violates the conjunction if it has an underlying voiced segment that surfaces as a voiceless dorsal plosive in a complex coda. This rules out /-ŋg/ → [-ŋk], and indeed any instance of /-Cg/ → [-Ck]. However, *CODA is violated by any segment in a coda role, not just the second segment of a complex coda. This analysis therefore predicts that /-gC/ should never surface as [-kC], as such a form would violate the high-ranked conjunction.

However, this does occur in German, which forms participles by circumfixing *ge…t* and which nominalizes some verbs with *-d*:[13]

(32) a. ge- + sag + -t → gesa[kt] 'said'
b. ge- + jag + -t → geja[kt] 'hunted'
c. ge- + frag + -t → gefra[kt] 'asked'

(33) ja/g/ + /d/ = ja[kt] 'hunt (n.)' cf. ja[k.d]en 'hunts (n.)'

Itô and Mester's analysis predicts that the /g/ should drop (here, *CDC is the conjunction of (30a-c), and *VC is *VOIOBS & *CODA):

(34) Tableaux for German *gesagt*, 'said' and *Jagd*, 'hunt (n.)'

a.

ge + sa/g/ + /t/	*VC	[*CDC & IDENT(voi)]	MAX	*CDC	IDENT(voi)
a. gesa[gt]	g!			g	
💣 b. gesa[t]			*		
☞ c. gesa[kt]		k!		k	k

b.

ja/g/ + /d/	*VC	[*CDC & IDENT(voi)]	MAX	*CDC	IDENT(voi)
a. ja[gd]	*!			g	
b. ja[gt]	*!			g	t
c. ja[kd]	*!	k		k	k
☞ d. ja[kt]		k!		k	kt
e. ja[d]	*!		g		
💣 f. ja[t]			g		t

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[13] I thank Michael Wagner for the data, as well as for discussions of Itô and Mester's analysis.

Demoting the conjunction [*CDC & IDENT(voi)] below MAX will get the right results for both words in (34), but will make the wrong prediction for words ending with /-ŋɡ/, namely that the /ɡ/ will devoice to [k].

This analysis of German fails because it does not capture the asymmetry between the two coda positions. Because *CODA, in their framework, is "violated by any segment bearing a coda role" (Itô and Mester 1999:4), the first and second segments of a complex coda necessarily act identically. To rescue this analysis, *CODA would need to be broken into *CODA$_1$ and *CODA$_2$, which would respectively ban segments from bearing the role of first coda or second coda. However, this would lead to massive and unexplained duplication in the constraints—for instance, both *VOICODA$_1$ and *VOICODA$_2$ would need to be at the top of the ranking, and the fact that both were would be accidental.

So the fact that the conjunction *CDC cannot be expressed in OTP is a welcome result—though only if another analysis is available. Fortunately, because OTP constrains representations on a linear timeline, the difference between the first and second coda positions can be captured naturally. The full constraint reads:

(35) $(\sigma \text{ and }]_{C} \text{ and } {}_{C}[\text{ and } {}_{dors}[\text{ and } {}_{\underline{voi}}[\ ) \rightarrow ({}_{cont}[\text{ or } {}_{voi}[\ )$[14]

Pieces of this are familiar from (30)—the first three features taken together form *COMPLEX, for instance. In fact, (35) can be seen as the conjunction of (36):

(36) a. *COMPLEX $\sigma \perp (\ ]_{C} \text{ and } {}_{C}[\ )$
b. MAX(voi)′ ${}_{\underline{voi}}[\rightarrow {}_{voi}[$
c. *DORSPLOS′ ${}_{dors}[\rightarrow {}_{cont}[$

Here, variations of the usual MAX and *DORSPLOS are used—compare (36c) with the version in (31). (35) derives from (36) if the variations in (36) exist; see the next section for discussion of this issue. The key fact here is that (35), whether derived or underived, will come into play at the boundary between two consonants, and the featural constraints that hold there will refer only to features in the timeline starting at that point, i.e. the second consonant in the coda. The forms in (32) and (33) will not violate this constraint, because a dorsal feature does not start at the point where two homosyllabic consonants meet—indeed, dorsal is ending and coronal beginning.[15]

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[14] ${}_{dors}[$ might need to be *dors*, if the dorsal feature is taken as spreading across the boundary between ŋ and k, as in the sample representation in (12). This is an orthogonal issue, and the discussion here is essentially neutral between the options; I chose one for exposition, but the other would work as well.

[15] Michael Wagner (p.c.) suggested that the data might instead be entirely reanalyzed: rather than having an underlying /ɡ/ that deletes, assume the underlying form is only /ŋ/, with constraints that insert a /ɡ/ as a homorganic stop where /ŋ/ would be an illicit onset. I have not pursued this approach primarily because Itô and Mester report a dialectal difference between Standard German, as described above, and Colloquial North German, in which *Ding* is pronounced [dɪŋk]. This approach would require postulating either different underlying forms for the same word in Standard German and Colloquial North German, or constraints that insert a consonant to create a complex coda under the proper circumstances. Neither alternative seemed appealing. I leave it to future researchers to see if there is a way to motivate a /ɡ/-insertion approach, or if there is another analysis entirely.

5. Self-conjunction

Self-conjunction (conjoining a constraint A with itself to form $[A \& A]_D$, often written A^2) is used almost entirely to derive the Obligatory Contour Principle (OCP). §5.1 discusses a few exceptions, and §5.2 covers the OCP and its expression in OTP.

5.1. Non-OCP uses of self-conjunction

One notable use of self-conjunction outside the OCP is found in Smolensky (1995). However, though it is one of the most frequently cited papers about conjunction, its use of conjunction is atypical. In particular, Smolensky uses ALIGN(${}_\sigma[$, ${}_C[$) as ONSET—not unlike OTP's ${}_\sigma[\rightarrow {}_C[$ —but by *C* he means one of a set of features {-sonorant, -approximant, -vocoid, -syllabic}. The universal ranking *ONS(liquid) » *ONS(nasal) is actually ONS^2 » ONS: ONS is violated once by a nasal onset, as [-sonorant] is not aligned to the syllable edge, but is violated twice by a liquid, for which [-sonorant] and [-approximant] are not aligned.

On the one hand, this usage is very idiosyncratic. Compare this to, for instance, Itô and Mester (1999), who suggest in a footnote that *COMPLEXCODA = *CODA^2_σ—using *CODA to apply to segments, not subsegmental features. Itô and Mester's use is more emblematic of the understanding of conjunction in the literature; cases like Smolensky's are rare at best. And, on the other hand, Smolensky's constraints are in fact expressible in OTP as four separate constraints about what must overlap the left edge of a syllable. The insight that these are all tied into ONSET is lost, but no representational power is.

Sanders (2000) is perhaps the only other exception to the observation that self-conjunction is used only for the OCP. He uses MAX^2 in his account of Icelandic truncation, to capture the fact that /j/ is usually deleted when word-final (/bylj/ → [byl] 'snowstorm'), but remains in nominalized forms created by truncation (/grenjɑ + τ/ → [grenj], *[gren]).

In fact, MAX^2 can be recast in OTP without using conjunction. Albro (1998) argues for a DEL tier to mark deleted segments, stretches of the timeline where there is underlying material but no surface material. Features on either side of a DEL feature are still considered adjacent. If such a tier is postulated, MAX^2 can be expressed as $]_{\text{DEL}} \perp {}_{\text{DEL}}[$, preventing two adjacent segments from deleting. Without a DEL tier, OTP can still express the same idea as

(37) MAX^2: $(\ ]_{\underline{x}} \text{ and } {}_{\underline{x}}[\ ) \rightarrow (\ ]_x \text{ or } {}_x[\ )$

where "x" stands in for segments/timing units, if they are part of OTP representations, or for C and V (in which case this is a family of related constraints). Regardless, the same intuition is captured: if two segments are adjacent underlyingly, at least one of them must surface. This has the additional advantage over the OT constraint MAX^2, of course, that the two segments must be adjacent; MAX^2 is violated by CVCCVC → CVCV, where two segments have deleted from different parts of the word.

Non-OCP uses of conjunction, rare as they are, can be expressed in OTP. What about the OCP?

5.2. The OCP and self-conjunction

The OCP prevents two alike elements from occurring adjacent to one another—for example, two consecutive syllables with high tones would violate the OCP. In some cases, “adjacent” is extended to “within a given domain,” so that Lyman’s Law in Japanese, “Stems do not have more than one voiced obstruent,” is treated as an OCP effect. It holds for stems in general, and in particular acts as an exception to Rendaku, which voices an initial obstruent in compound words.

(38) a. Rendaku in Japanese (Sequential Voicing)
/natsu + sora/ → natsu + zora ‘summer sky’
/kawa + hata/ → kawa + bata ‘river bank’
/otome + kokoro/ → otome + gokoro ‘maiden heart’

b. Lyman’s Law (blocking Rendaku)
/mori + soba/ → mori + soba *mori + zoba ‘soba serving’
/iwa + hada/ → iwa + hada *iwa + bada ‘rock surface’
/onna + kotoba/ → onna + kotoba *onna + gotoba ‘women’s speech’
(Itô and Mester 1996: (32), (34))

Itô and Mester (1996) recast this as a markedness effect by self-conjoining *[+voi, -son] in the domain of the stem (*[+voi, -son]$^{2}_{\text{Stem}}$), which I will take as a paradigmatic case of constraint self-conjunction used for the OCP.

Because a domain must be specified, this conjunction is not available in OTP. More generally, self-conjunction is not possible in OTP for any domain, because the constraint formed by conjoining any two constraints C_1 and C_2 involves evaluating C_1 and C_2 at the same point on the timeline; evaluating C_1 and C_1 at the same point on the timeline will be the same as evaluating C_1 alone.

5.2.1. Eisner’s (1999) solution to OCP

The Obligatory Contour Principle presents a challenge to OTP, because its effects often stretch across entire words and thus do not occur at local points on a timeline. Eisner (1999) offers a method of capturing the OCP, relating it to traditional autosegmental phonology. He expresses it informally as follows (his (56)):

(39) a. Every constraint has a set of relevant tiers.
b. The relevant tiers are those that participate directly in the constraint, plus any others mentioned on the side.
c. When evaluating a constraint, we **collapse** (ignore, skip over) any time intervals where nothing is happening on the relevant tiers.

For instance, the OCP for high tones, stating that two high tones cannot be adjacent in the same word (that is, if two high tones are adjacent, there is a word boundary there), is expressed as in (40), his (57).

(40) OCP(H): ( ]$_H$ and $_H$[ ) → $_{PrWd}$[(L)

The relevant tiers for the constraint in (40) are H, L, and PrWd. As a result, (41) is treated as if it were (42) (adapted from Eisner's (58) and (59)).

(41) Partial OTP representation of búdúgòtí nó

```
  b   u   d   u   g   o   t   i   n   o
 [                              ][      ]PrWd
     [  ]H   [  ]H           [  ]H  [   ]H
                     [  ]L
 [  ]C    [  ]C   [  ]C   [  ]C   [  ]C
```

(42) Relevant tiers of (41)

```
    [                          ][     ]PrWd
    [     ][      ]H     [      ][     ]H
                 [      ]L

    1  2  3   4  5   6  7   8  9   10 11
```

Point 3 in (42) is an OCP violation, because the consonant (and other features) that appear between the two high tones are not relevant for evaluating the constraint. Point 9 is not, because a prosodic word does begin at the point where one high tone ends and another begins. Finally, the high tones at 4 and 8 are not adjacent, because there is intervening material on a relevant tier, namely L.

While appealing, this account has two problems, one theoretical and the other empirical. On the theoretical side, suppose this same account is applied to vowel harmony. Given two languages, one in which /a/ is transparent to rounding harmony and one in which it blocks it, two different constraints will be needed, one in which *low* is a relevant tier and one in which it is not. Alternate accounts (see the following section for a discussion of Albro (1998)) capture the difference between such languages through the more conventional method of constraint interaction, and the mechanism introduced by such accounts is sufficient to handle the OCP.

A more serious challenge comes from the Japanese Rendaku and Lyman's Law effects discussed in (38). Eisner's account requires a constraint like (43).

(43) OCP(voice): ( ]$_{voi}$ and $_{voi}$[ ) → ( ]$_{Stem}$ or]$_{son}$ or $_{son}$[ )

That is to say, two consecutive voiced segments need to be in different stems, or else one must be a sonorant. But unlike the OCP for high and low tones, where no intervening material bears a tone, here the intervening material does have a feature on a relevant tier—that is to say, vowels are voiced and sonorant, so two voiced obstruents will never be adjacent, even using Eisner's "collapsing" representations.

Moreover, more than vowels may intervene; nasal consonants, also voiced sonorants, do not block Lyman's Law. So *nama* + *kome* → *nama gome* 'raw rice,' but *nama* + *tamago* → *nama tamago* 'raw egg.'[16] Even somehow skipping vowels will not capture the facts in

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[16] From the Japanese tongue twister *nama mugi, nama gome, nama tamago* 'raw wheat, raw rice, raw egg'.

Japanese, since the *d* and *g* in **nama damago* are not adjacent consonants, nor do they display adjacent instances of voicing on consonants.

Collapsing representations are neither theoretically nor empirically adequate; another solution must be found.

5.2.2. Optimal Domains and the OCP

OTP representations are tier-based. Each feature is on its own tier, and consideration of different processes has added new tiers to the theory before. Eisner (1999) suggests that reduplication requires a separate tier holding a copy of the base, and overlapping with (and thus corresponding to) the reduplicant; Albro (1998) points out the need for DEL and INS tiers to keep track of syncopated and epenthesized material. Even more strikingly, Albro uses Cole and Kisseberth's (1994) Optimal Domains Theory to explain vowel harmony.

According to Cole and Kisseberth, a domain corresponding to some process—[ATR] harmony, for instance—is added to the representation of each candidate, with constraints mediating how far the domain extends and to what extent segments covered by the domain must undergo the process it represents. For instance, a language with [ATR] harmony would use "basic alignment" constraints that align the ATR-domain with the vowel that projects the domain, "wide scope alignment" constraints that attempt to spread the domain to the full word, and EXPRESS(ATR) to ensure that anything in the domain carries the [ATR] feature. Since low vowels cannot have [ATR], an additional constraint, CLASH(Low, ATR) rules out low ATR vowels. The interaction of these constraints will capture various types of harmony: if low vowels block harmony, EXPRESS(ATR) will rank above the ALIGN constraints, but if low vowels are transparent, the reverse ranking holds.

These constraints are easy to express in OTP—perhaps unsurprisingly, as Eisner's "representation is inspired by Optimal Domains Theory" (Eisner 1999:4). With the addition of a tier, ATR-dom, we have

(44) a. CLASH: $low \perp ATR$
b. Basic Alignment: ${}_{\underline{ATR}}[\rightarrow {}_{ATR\text{-}dom}[\ ,\ ]_{\underline{ATR}} \rightarrow\ ]_{ATR\text{-}dom}$
c. Wide Scope: ${}_{ATR\text{-}dom}[\rightarrow {}_{Word}[\ ,\ ]_{ATR\text{-}dom} \rightarrow\ ]_{Word}$
d. EXPRESS(ATR): $(\text{V and } ATR\text{-}dom) \rightarrow ATR$

(44b) and (44c) will vary according to the details of spreading in the language—what blocks it, how far it occurs. (44d) is at the heart of the theory: anything within the domain must be [ATR] (as long as it would not violate a higher-ranked CLASH constraint). Albro works this out in detail for Turkish, and the reader is referred to his paper for further detail.

An analogous procedure will work for OCP constraints. Suppose, to use Lyman's Law as an illustration, that there is a domain in Japanese in which the OCP applies to voiced obstruents; postulate an OCP-dom tier. Then take the constraint in (45).

(45) *VOIOBS-IN-OCP: $(OCP\text{-}dom \text{ and } voi) \rightarrow son$

Any point on the timeline which is in the OCP-domain and which is voiced must be sonorant. The remaining constraints would to do the *opposite* as those in (44b), and would ensure that the OCP domain does *not* include the underlying voiced obstruent.

(46) Alignment I: ${}_{voi}[\rightarrow ({}_{son}[\text{ or }]_{OCP\text{-}dom})$
Alignment II: ${}_{OCP\text{-}dom}[\rightarrow {}_{Stem}[$

According to the first constraint, if there is underlying voicing starting at a point, either there is also sonorance starting there (in which case this is not a voiced obstruent), or the OCP-domain ends there, which would mean that there is an OCP-domain to the left. The second simply says that the domain starts with the beginning of the stem.

To take a specific example, consider *soba* from (38b). According to Alignment I, each time a voiced segment starts, either it must be sonorant, or an OCP domain ends there. Since *b* is a voiced segment that isn't sonorant, an OCP domain must end where the *b* starts. *Gen* requires brackets to match, so the OCP domain must start somewhere. According to Alignment II, the start must overlap the start of the stem. As a result, an OCP domain will stretch across the first two segments of the stem. The constraint in (45) will then ensure that any segment which is voiced and which overlaps the OCP domain must be sonorant. The *o* satisfies this constraint by being voiced and sonorant; the *s* satisfies it by being voiceless. However, because these constraints outrank the constraints forcing Rendaku, the *s* cannot voice to *z*. The only legitimate representation for *soba* will be the one in (47).[17]

(47) OTP representation of Japanese *soba* 'soba'

	s		o		b		a	
[								$]_{Stem}$
[		$]_C$		[		$]_C$		
		[		$]_V$		[		$]_V$
		[		][		][		$]_{voi}$
		[		$]_{son}$		[		$]_{son}$
[				$]_{OCP\text{-}dom}$				

Thus, ranking (45) and (46) above the constraints responsible for Rendaku will ensure that only the rightmost obstruent is voiced. In forms like *zora* in (38a), that will be the first obstruent; in forms like *soba* in (38b), it will be a later obstruent.

5.2.3. Lingering issues resolved

The OCP domain has been categorized as being "to the left of" a voiced obstruent. Does this mean that another voiced obstruent can appear to the right of that voiced obstruent—in other words, will OTP allow OCP effects to hold for only part of the word? Take a word, /kabat/, from a hypothetical family of languages. If setting up OCP domains to the left allows OCP effects only to the left of the voiced consonant but not to the right, then /kabad/ should be possible output.

But this does not happen at all Consider the tableau in (49), showing various outputs for /kabat/. The tableau uses the constraints in (48a), repeated from above, and the pseudo-constraint in (48b) that stands in for a process that voices consonants. The constraints are left unranked, so that any possibly ranking can be considered.

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[17] This will also, of course, require other faithfulness constraints to prevent, e.g., the *s* from becoming sonorant.

(48) a. Familiar constraints
*VOIOBS-IN-OCP: (*OCP-dom* and *voi*) → *son*
Alignment I: $_{voi}[\rightarrow (_{son}[\text{ or }]_{OCP\text{-}dom})$
Alignment II: $_{OCP\text{-}dom}[\rightarrow {}_{Stem}[$
MAX(voice): $\underline{voi} \rightarrow voi$

b. Pseudo-constraints
VOICE-OBS: (voice obstruents)

(49) Tableau for /kabat/, showing only consonants

<u>k</u> <u>b</u> <u>t</u> [ ] <u>voi</u>	Align I	Align II	*VO IN OCP	MAX (voice)	VOICE OBS
a. k b t [ ] voi [ ] OCP-dom					tk
b. g p t [ ] voi | OCP-dom				p	t
c. k p d [ ] voi [ ] OCP-dom				p	k
d. k b d [ ] [ ] voi [ ] OCP-dom	*		b		k
e. k b d [ ] [ ] voi [ ] [ ] OCP-dom		*			k
f. g b d [ ] [ ] [ ] voi [ ] OCP-dom	**		gb		
g. g b d [ ] [ ] [ ] voi | [ ] [ ] OCP-dom		**			

In a language with OCP effects, one of the first three candidates will win. If MAX(voice) outranks the voicing process, of course, the word will surface faithfully and (a) will win; if the VOICE-OBS process outranks MAX(voice), other constraints will decide between (b) and (c). In contrast, [gabad] will surface if VOICE-OBS is ranked above any of the OCP constraints, since (f) and (g) alone satisfy it. Crucially, [kabad] can never win. Candidate (d) violates Alignment I and *VOIOBS-IN-OCP, which (a) satisfies, and VOICE-C, which (f) satisfies; therefore any ranking of the three constraints will prefer either (a) or (f) over (d). An identical argument holds for (e) in relation to (a) and (g).

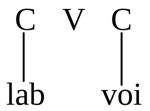
In short, if a language has OCP effects, the constraints to align the OCP will be ranked high, and the effects will hold in the entire word; if the aligning constraints are low-ranked, the language will simply not have OCP effects. No language is predicted to show mixed effects, however.

What happens in a language that has, instead of the constraints in (48), the ones in (50)?

(50) Alignment I: $_{voi}[\rightarrow (_{son}[\text{ or }]_{OCP\text{-}dom})$
Alignment II: $_{OCP\text{-}dom}[\rightarrow {}_{Stem}[$
*LABIAL-IN-OCP: *OCP-dom* ⊥ *lab*

OCP domains will occur in the same circumstances they do in Japanese—starting at the beginning of the word, stretching until the first voiced obstruent—but instead of disallowing voiced obstruents in the domain, the language disallows labials. The effect would be the same as one of the constraints in (51).

(51) a.



b. $[\text{*VOIOBS \& *LABIAL}]_{Stem}$

This is naturally undesirable. However, this is not a problem unique to the OCP effects described here, or even to OTP.

On the one hand, the same problem arises with ATR domains as described above: once an ATR vowel has created an ATR-domain, what prevents there from being a constraint (V and *ATR-dom*) → *hi*, so that an ATR vowel in a word causes all other vowels to be high vowels (instead of [+ATR] vowels). The solution is to say that there is a conncetion between the kind of domain something is and the features it can refer to, so that ATR vowels project ATR domains, and ATR domains require ATR vowels within them. The same is true here: what has been called an "OCP-domain" in shorthand is properly an "OCP-voiced-obstruent" domain, projected by a voiced obstruent and only able to restrict other voiced obstruents. This is a constraint on what constraints can be formed in OTP—no different from the restrictions on *Con* that set up *hi* and *lo* as opposites, or H and L (high and low tones), so that *hi* ⊥ *lo* and H ⊥ L are universal restrictions on representations, but *hi* ⊥ H is not.

And on the other hand, the exact same restrictions must be placed on a theory of OT that does not use OTP or Optimal Domains, exactly to rule out the constraints in (51), which are otherwise expressible. In a sense, OTP has merely inherited the problems of its ancestors, but is therefore no worse off than any other related theory.

The approach outlined in these sections demonstrate how OCP effects can be explained without using conjunction at all, by using strictly local constraints.

6. Conclusions and Future Topics for Research

6.1. Locality with and without OTP

OTP is a useful tool for ensuring that conjunction is kept strictly local. The claims about the locality of conjunction made throughout this paper, however, are independent of the formalism of OTP. If strict adherence to the principles of OTP should prove after further research to be impossible, the conclusions about locality nevertheless hold.

In OTP, the locality follows from other facts, as we have seen. Translated into general Optimality Theory, the locality condition on conjunction is as follows.

(52) **The Local Conjunction of C_1 and C_2**, C_1 & C_2, is violated either when a single segment violates both C_1 and C_2, or when the meeting of two segments violates both C_1 and C_2.

Compare this to the definition in (1a). Instead of a domain needing to be defined, the domain of conjunction is necessarily the smallest possible domain, in a strict and non-optional sense of "smallest." A similar conclusion is reached in Łubowicz (1998) using "Mark-sub-Faith," though without the same formalism behind it as OTP provides here; (52) also extends to conjunctions of two markedness or two faithfulness constraints.

6.2. Concluding observations

I have argued in this paper that Local Constraint Conjunction is not too powerful a device to add to Optimality Theory, insofar as it can be restricted through use of the formal machinery of primitive constraints. OTP brings the additional advantage of simplifying the grammar by not requiring the domain of conjunction to be specified, but having it instead follow from the constraints themselves. Moreover, limiting constraint conjunction by using OTP will still allow the majority of conjunctions used in the OT literature, and those conjunctions inexpressible in OTP can nevertheless be treated by means of a different analysis.

Needless to say, this paper does not resolve all issues in constraint conjunction. The questions raised in (5) about what constraints can conjoin are still open questions. Using OTP raises new questions as well. For instance, what constraints are basic in the system, if any? Or, phrased another way, what constraints are universal, and what constraints must be built by the language learner? Given a set of features and the $\rightarrow$ and $\perp$ relations, learners could build all constraints without having any given. However, as discussed in §3.2, Eisner noted that OTP expresses Onset and *Onset (${}_{\sigma}[\rightarrow {}_{C}[$ or ${}_{\sigma}[\rightarrow {}_{V}[$ respectively) with equal ease; something must still determine what constraints are used.

This question extends to constraints that use *and* and *or*, which Eisner called "dispreferred" due to their additional computational complexity. If constraints that use *and* and *or* are conjunctions of constraints that do not, this makes sense: they are dispreferred because they must be postulated and formed on a language-specific basis. However, it is not clear that this is true. Consider *Complex, which throughout this paper has been expressed in OTP as "$\sigma \perp$ ($]_{C}$ and ${}_{C}[$)," which is to say "$\sigma \perp\ ]_{C} \perp {}_{C}[$." If this is a conjunction, the conjoined constraints are two of the following three:

(53) a. $\sigma \perp\ ]_{C}$ Consonants may not end mid-syllable
b. $\sigma \perp {}_{C}[$ Consonants may not begin mid-syllable
c. $]_{C} \perp {}_{C}[$ Consonants may not adjoin

(53a) is violated by any consonant that does not end when the syllable does: the first part of a coda or any onset consonant, complex or not. Similarly, (53b) is violated by any consonant in a coda or any onset consonant after the first. (53c) rules out complex onsets, complex codas, and codas followed by onsets. None of these seem like very natural constraints, insofar as they refer to heterogeneous classes of consonants; but two of them would need to be universal constraints if all instances of “and” and “or” derived from conjunction.

If, on the other hand, $\sigma \perp ( ]_C \text{ and } {}_C[ )$ is a universal constraint, nothing prevents (35), repeated here, from being one as well.

(35) $(\sigma \text{ and }]_C \text{ and } {}_C[\text{ and } {}_{dors}[\text{ and } {}_{\underline{voi}}[ ) \rightarrow ({}_{cont}[\text{ or } {}_{voi}[ )$

Of course, this is not entirely a new problem: OT does not inherently rule out constraints of the form “CODACONDITION: no voiceless dorsal plosives in complex codas that are underlyingly voiced.” Indeed, while I have argued against the specifics here, I believe Itô and Mester to be thinking along the right lines when they attempt to derive the OCP or from self-conjunction or *COMPLEX from *CODA$^2_\sigma$. Breaking complex constraints into their component parts, and determining what constitutes a component part, is vital to our understanding of phonology. Here again the formalism of OTP can help, as it is clear whether an OTP constraint is built from smaller parts, and less clear whether an informally-written constraint description does.

While these questions may remain open, it is my hope that OTP provides a framework to enable discussion of these questions to proceed in clear and unambiguous terms. Indeed, without a formal restriction on constraints and on conjunctions, many of these questions cannot be phrased at all. I have confidence that further research will solve these unresolved issues.

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