

Current issues and directions in Optimality Theory — Constraints and their interaction

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1 Introduction

The first manuscripts on Optimality Theory (henceforth OT; Prince & Smolensky 1993/2004) were circulated in the early nineties, which is roughly a quarter of a century ago. For a theory, this is a long time, plenty of opportunity to develop, fracture, disintegrate or disappear into insignificance. As a quick look into the major journals of linguistics reveals, neither of the latter happened to OT. The majority of articles dealing with phonology in recent issues of the journals *Phonology*, *Linguistic Inquiry* and *Natural Language & Linguistic Theory* uses or discusses Optimality Theory. As far as *Linguistic Inquiry* is concerned one can even almost claim that phonology = OT, at least in the last four years. I found only one phonology-related article in LI in this period that didn't contain any reference to OT. The journal *Phonology*, however, provides a picture that is a bit more colourful, devoting substantial space to other theories/paradigms as well.

Seen from this perspective, we are thus dealing with the dominant paradigm in phonology these days. However, we will see in this article that the theory has fractured a bit into several competing models. There seems, however, to be a core of certain shared assumptions among the majority of scholars in the field — but there is also a vibrant debate and ongoing progress. To approach the question of current issues and directions in OT we will first have a quick look at the original basic assumptions to be able to better understand current debates (for a more detailed introduction, see Iosad, this volume). We will then look at which problems or challenges early OT caused or encountered and discuss which of these haven't been solved yet and which new problems have emerged with new developments. Given space constraints, the choice of topics that will be addressed here is necessarily limited and quite unlikely to be exhaustive (see as well Iosad, this volume, section 3, for discussion of some challenges to OT). Neither will it be possible to address any of these issues in great detail.

This chapter is structured as follows. Section 2 briefly recapitulates some of the basic tenets of OT to provide the background for the following discussions. Section 3 addresses the issue of the content or formalization of constraints, including functional grounding. Section 4 discusses constraint interaction. Here we will compare strict ranking with constraint weighting. The orthogonal matters of universal rankings versus more elaborate forms of constraint organisation, such as stringency relations and of constraint interaction by conjunction, i.e., the formation of complex constraints from more basic ones, will be discussed in section 5. The chapter ends with brief sketches of related topics in OT.

2 Basics

OT, as proposed by Prince & Smolensky (1993/2004), had a core of basic hypotheses that made it substantially different from other theories in phonology at the time. The

basic idea was that grammatical output representations in a given language are optimal in comparison to conceivable alternative forms when evaluated against the language's idiosyncratic ranking of universal violable constraints on surface wellformedness (Markedness, henceforth M constraints) and on input-output mapping (Faithfulness, henceforth F constraints). A Generator function (Gen) computes a (potentially infinite) set of output candidates of which the Evaluation function chooses the one that is best according to the language-specific ranking of constraints. Thus, OT was conceived as a generative theory of constraint interaction, rather than a theory of constraints or representations or processes. This condensed summary contains a few hypotheses that we will look at in more detail now.

2.1 Parallelism

All candidates are available for comparison at the same time and all but one of them are filtered out simultaneously.

Traditional generative phonology (based on Chomsky & Halle 1968) is derivational. An input representation is assumed, and successively applied operations (rules) change this representation into different representations, the last one of which is the output of the derivation. In OT, one assumes an input and then compares potential output matches to this input to pick the best. There are no intermediate stages or representations. This was only one potential conception of OT. Prince & Smolensky entertained a serial evaluation function as well and then opted for the parallelist model. As McCarthy (1996, 1999, 2000, 2003, 2005, 2007...) and many others pointed out, this caused a problem for the analysis of phonological opacity. Expressed in derivational terms, phonological opacity emerges when a later rule creates or removes the environment for a phonological process that has or was expected to apply earlier in the derivation (Kiparsky 1973). In more neutral terms, and under the default assumption that phonological processes apply whenever their conditions are present, we observe under- and overapplication, respectively. We can observe the result of the application of a process at the surface even though the environment for its application isn't present or we detect the environment for the application of a process, but it is blocked. There has been a range of proposals within OT to account for opacity or parts of the problem and related problems, such as Derived Environment Effects (DEE; or Non-Derived Environment Blocking, NDEB).

McCarthy (2007) discards all of them (including his own), some of them only on the grounds that they don't solve the whole problem 'en bloc', and reintroduces serial derivation into OT with his Candidate Chains Theory (OT-CC), which subsequently developed into Harmonic Serialism (McCarthy & Pater 2016 and references there). A less radical return to serialism was proposed with Lexical Phonology & Morphology OT (LPM-OT) by Kiparsky (2000, see as well Rubach 1997), later branded as Stratal OT (Bermúdez-Otero 2011, forthcoming, this volume; Ramsammy, this volume). The extreme serialism of McCarthy's approach faces various problems of both formal and empirical nature and developed back into harmonic serialism, a predecessor of OT. Another retrospective approach, van Oostendorp's Coloured Containment (van Oostendorp 2004, 2007a,b, 2017) retains parallelism but revives a repainted version of Prince & Smolensky's Containment model of Faithfulness. The original Containment model in OT was replaced by Correspondence Theory (McCarthy & Prince 1994, 1995, 1999), which can be considered the standard model of Faithfulness since the mid-nineties (see Iosad, this volume).

2.2 The Richness of the Base Hypothesis (RotB)

The heart of OT is summarized in the Richness of the Base Hypothesis, which states that all linguistic variation stems from the interaction of universal violable constraints rather than language-specific rules and restrictions on the lexicon. Since constraints are constraints on the output of evaluation and on the mapping between the input and the output, languages cannot differ by restrictions on the lexicon. Systematic differences between languages regarding their underlying representations have to be regarded as a side effect of the interaction of surface-oriented constraints. When we tease the RotB apart into sub-hypotheses we can isolate the following claims.

- (1) Richness of the Base Hypothesis
 - a) Surface patterns of languages are determined by constraints.
 - b) Constraints are potentially conflicting, and therefore violable and rankable.
 - c) Constraints are universal.

Despite McCarthy's (1993) proposal of a language-specific rule of r-insertion in Gen for an analysis of English intrusive *r*, sub-hypothesis (a) hasn't been challenged among proponents and users of OT. Also sub-hypothesis (b) enjoys widespread acceptance, though, see, e.g., Orgun & Sprouse (2010) for the proposal of inviolable constraints to model absolute ungrammaticality. Whether constraints are universal, though, is a constant matter of debate in one form or other. As we will see in section 3, whether constraints are universal or not also depends, at least for some constraints, on our interpretation of the term "universal" (for a non-universalist, emergentist viewpoint, see Archangeli & Pulleyblank 2015, this volume).

2.3 Constraints and their properties

OT didn't come with a fully articulated theory of constraints. The few things we can say about constraints are that they are either Markedness or Faithfulness constraints, and that they are violable, potentially conflicting, statements about output representations and about the mapping between correspondent representations at different levels (e.g., input and output – see Krämer 2012 for a discussion of the terms input and output in the context of OT), and that they are arranged in language-specific dominance hierarchies. Constraints that are proposed by an analyst to account for a certain phenomenon should be motivated, or grounded, either typologically or functionally, ideally in both ways. Typologically grounded constraints show dominance, i.e., a direct effect – rather than a residual effect – in some language. A constraint whose effect is only observed in one language and there only indirectly, i.e., the constraint is dominated by other conflicting constraints, is thus not a typologically well-motivated constraint. The poster children of typologically well-grounded constraints are ONSET and *CODA. Many languages don't allow syllables to start in a vowel and many languages don't display syllables closed by a consonant. In such languages these constraints are undominated. In other languages, though, they show residual effects. Intervocalic consonants are usually syllabified as syllable onsets (rather than codas) even in languages that allow onsetless syllables and closed syllables.

Constraints are functionally grounded if they are motivated by some observation about articulation, aerodynamics or perception (see Ramsammy's contribution on the

phonetics interface in OT, this volume, and, for example, Gordon's 2007 overview of functionalism in phonology). Certain segments are more difficult to articulate than others for reasons to be found in airstream mechanisms or in the vocal tract. Thus, a constraint against voiced obstruents, e.g., the Voiced Obstruent Prohibition (VOP, *[+voice], *Laryngeal) can be said to be functionally grounded, since vocal fold vibration is difficult to sustain if the outgoing airstream is blocked. Regarding the claim to universality, one could reasonably argue that functionally grounded constraints are good candidates for universal constraints since all humans share the same physical and mental capacities and limitations. However, being grounded this way, these constraints don't need to be hard-wired into the genome (i.e., not part of Universal Grammar), since they could be "discovered" by every individual through induction (see Hayes 1999 on inductive grounding).

Constraints that are only typologically grounded though, but crucially lack a functional motivation, can only be innate – in the sense that they are part of the genetically determined part of the language faculty. We will come back to this issue in section 3.

Discussing the formalization and properties of constraints in OT is a complex matter also because OT doesn't come with a theory of phonological representations. For example, while the majority of constraints referring to phonological features in Prince & Smolensky (1993/2004) and McCarthy & Prince (1995) makes reference to binary valued features (especially IO-Identity[±F] constraints), nothing hinges on this choice. OT has successfully been used with privative features, elements and even been combined with Exemplar Theory (see van de Weijer 2012 for the latter). However, the primitives the constraints refer to can be expected to make a difference for their formalization and their systemic properties.

However, there are some properties each OT constraint should have. One of these is a clear definition of its violation profile, i.e., for any constraint it should be unambiguous which structures violate it and which satisfy it. And the violations of each constraint should be comparable to those of every other constraint. A property concerning violability constraints differ on is categoricity. Most constraint violations are categorical. Either a structure violates a constraint or it doesn't. In addition we can count the number of violations, i.e., we can quantify how bad a candidate fares with respect to a constraint and compare this with any other candidate's performance on the same constraint or any other. However, the only thing that matters is whether a candidate has the same or a different number of violations than a candidate it is compared with. "Quantification" thus necessitates counting only up to one. Constraints are gradiently violable if a single constraint violation can be more or less severe. This was considered a problem with Alignment constraints (alignment: McCarthy & Prince 1993; problem with non-categoricity of alignment: McCarthy 2003, Hyde 2012 and references cited there). While there is a categorical interpretation of alignment constraints, their violations have usually been assessed gradiently. One might think that it is an either-or question whether two edges coincide or not, however, the general practice established by McCarthy & Prince (1993) is that alignment constraints compute the distance between two edges in a candidate by referring to a third, the intervening, category. This was very useful in most cases, but also ran into the problem referred to as the "midpoint pathology" (an Alignment constraint places stress or the only foot at the centre of a string rather than at an edge) among other things.

2.4 Constraint interaction

As sketched above, constraint interaction is the source of cross-linguistic variation. The basic form of constraint interaction is considered to be ranking in a hierarchy. These dominance relations were hypothesized to be strict and transitive. They are strict in the sense that if constraint *A* dominates constraint *B*, candidate *a*, preferred by constraint *A* over candidate *b*, is considered more harmonic than candidate *b*, regardless of the number of violations candidate *a* incurs on constraint *B* in excess of those of candidate *b*. If candidate *a* satisfies constraint *A* and violates constraint *B* many times, while candidate *b* violates constraint *A* only once and even satisfies constraint *B*, the former candidate is still more harmonic than the latter, as illustrated in the tableau in (2). (In OT tableaux, each asterisk indicates a constraint violation and the pointing finger the preferred candidate. Constraints separated by a full line are ranked with respect to each other, with the constraint to the left dominating the constraint to its right.)

(2) Strictness of strict domination

<INSERT TABLEAU (2) AROUND HERE.>

Transitivity can be observed in ranking arguments. If constraint *A* can be argued to dominate constraint *B* and constraint *B* dominates constraint *C*, then constraint *C* is also dominated by constraint *A* by transitivity. No evidence/ranking argument is needed to establish the relation between constraint *A* and constraint *C*. If constraint *C* has to be assumed to dominate constraint *A* we are facing one type of ranking paradox. The most straightforward ranking paradox emerges when one piece of data requires *A* dominating *B*, while another piece of data in the same language requires the reverse ranking of the same constraints.

Constraints could also be ranked in a non-strict way. In such a model, every constraint carries a certain weight and violations of a constraint with lower weight could add up to outweigh the fewer violations of a constraint with more weight incurred by a competing candidate. Thus, the constraint with less weight potentially reverses the decision made by a constraint with more weight. Alternatively, rankings could be more flexible, with mobile constraints “inhabiting” potentially overlapping zones on a ranking scale. The latter two types of ranking have been proposed in Harmonic Grammar (Legendre, Miyata, and Smolensky 1990, Goldsmith 1990, Pater 2016) and Stochastic OT (Boersma 1998 et seq.), respectively. We will discuss the former, weighted constraints, in section 4.

Transitivity can potentially be circumvented, or relativized, if lower ranked constraints are allowed to team up against higher ranked constraints or if they can be cloned, with the resultant complex constraints or clones inhabiting higher strata in the hierarchy than the otherwise dominating conflicting constraints. After considering these options, Local Conjunction and positionally restricted constraints (positional faithfulness, positional markedness) as well as constraint indexation we will look at other modes of constraint interaction, universal rankings versus stringently organized constraints in section 5.

3 The motivation and formalization of constraints

3.1 Grounding

As sketched in the previous section, OT constraints are expected to be grounded either typologically or functionally, rather than just stipulated or descriptively convenient or a rephrasing of a generalisation or rule. There has been a considerable body of work investigating how the acoustic signal and the limits and biases of human perception shape phonological patterns and phonological computation (e.g., contributions in Hayes, Kirchner & Steriade 2008).

The hypothesis that phonology is grounded in phonetics could as easily be reversed into phonological grounding, that is, phonetics is grounded in phonology, since for the arguments brought up by functionalists we often can't tell which is the cause and which is the effect. Liljencrants & Lindblom's (1972) observation on the dispersion of vowel systems is a typical example. Why are vowels dispersed in the vowel space? The functionalist's answer is that this is the case to make perception easier. The thing is that what is made easier is the perception of phonological contrasts. If two phonetic exponents of phonological objects are intended to encode the contrast between the two they should be perceptually distinguishable. Contrast is a, if not THE, phonological function. Thus, the driving force here is not the phonetics (or perceptual difficulties) but the phonology.

Coming from this perspective, Krämer (2012), for example, argues for replacing phonetically defined features by a set of abstract contrastive features loaned from other cognitive modules (syntax, semantics), which get mapped to an articulation or signal that best corresponds to the semantics of the respective feature. Thus, the phonological content determines the phonetic shape of its exponent.

One can extend this kind of reasoning to the grounding of OT constraints. The prevalent greater diversity of segmental contrasts in onset or pre-sonorant position has been attributed to the availability of better phonetic cues for contrasts, e.g., voicing in obstruents (Steriade 2009). Steriade proposes the hierarchy of contexts favouring/disfavouring voicing contrast in obstruents given in (3). This contrast is found either nowhere in a language or only in pre-sonorant position or in pre-sonorant position and word-finally, or in these positions and after sonorants and so on.

- (3) Steriade's hierarchy of favourable environments for obstruent voicing contrast
nowhere - pre-sonorant - word-finally - post-sonorant - pre-obstruent - everywhere

Positionally restricted contrast can be analysed by recourse to positional Faithfulness constraints. In this situation the choice is between structurally determined abstract constraints, limiting the scope of the constraint by syllable position, i.e., Faithfulness to onsets and other positions, such as edges of certain domains, the morpheme or the prosodic word (e.g., Faith(F)/edgeX) or to define the constraints by their phonetic environment, i.e., Faith(F)/pre-sonorant. The latter approach runs into a minor empirical problem when the respective phonetic contexts are given but some more abstract structure makes them invisible or irrelevant for phonological computation. A language might have a certain contrast in obstruents in pre-sonorant position, but only if both the preceding obstruent and the sonorant fulfil additional conditions. Such conditions could be of morphological nature, i.e., that they belong to the same morpheme or word; or they could be of phonological nature, i.e., that the two involved segments belong to the same syllable or foot. Thus, languages with a voicing contrast might have final devoicing, but still devoice obstruents in some pre-sonorant positions because the following sonorant is not in the same word, morpheme, syllable, foot or phrase as the obstruent.

Northern varieties of German, for example, display final devoicing in pre-sonorant position only under certain conditions. The voiced stops devoice before tauto-morphemic nasals, but not before tauto-morphemic laterals. While a word like *Flug* ‘flight’ has a final [k] or [g̊], the plural form *Flüge* shows the underlying /g/. We find the same alternation in pairs like like *regnen* [ʀe:kən̩] ‘to rain’ which displays the voiceless or neutralized dorsal in pre-sonorant position and *Regen* [ʀe:gən] ‘rain’, which has a voiced dorsal stop. In an only slightly different context, though still in pre-sonorant position, namely before a lateral, as in *Regler* ‘modulator’, /g/ surfaces with its underlying voicing specification, though it doesn’t in *behaglich* ‘comfortable’. In the latter case the morpheme boundary is between the obstruent and the lateral, while in the former it follows the lateral (i.e., *behag-lich* versus *Regl-er*).

The situation becomes even more clear in varieties that also have g-spirantization. In such varieties we get *Flu[x]* – *Flü[g]e* and *Re[g]en* ‘rain’ – *re[ç]nen* ‘(to) rain’ but *Re[g]el* ‘rule’ – *Re[g]ler* ‘ruler, modulator’.¹

In the licensing by cue approach we would expect **re[g]nen* (which is licit in some varieties) and **beha[g]lich* or, alternatively, **Re[k]ler*. It is difficult to imagine an analysis that doesn’t make reference to syllable constituents. /g/ is devoiced and spirantized in the coda, and in words such as *regnen*, the *gn* sequence is syllabified in two syllables, i.e. [ʀe:ç.nən], rather than **[ʀe:g.nən]*, whereas *gl* in *Regler* is an onset, [ʀe:gl̩], as in words like *Glück* ‘happiness/luck’. While /gn/ is a licit syllable onset, as in *Gnom* ‘gnome’, this type of onset is very infrequent and seems to be marked (compare the historical fate of English stop + nasal onsets). Even without consulting a dictionary or frequency database one can safely say that words starting in *gl* are fairly unmarked.

However, the same generalizations on voicing neutralization hold for labial and coronal stops, and there are no words in German that start in the sequence /dl/. Surprisingly (for the syllable-based account, but not for the Licensing-by-cue approach), word- or morpheme-internally /d/ doesn’t devoice before a lateral, as in *Adler* ‘eagle’.

If one considers place features (PoA), one could easily come up with the conclusion that PoA in stops is better cued in postvocalic or postsonorant position, since we find the cues to the PoA of the stop in the formants of the vocoid in the transition from the vocoid to the closure of the stop. In the release phase on the other hand there can be the laryngeal burst of aspiration or the delayed VOT masking the transition of articulators from the stop’s PoA to that of the following vowel or sonorant consonant. In addition, that following sonorant consonant could have only weak formant structure compared to a vowel, which provides bad cuing. Also, there often is no release, i.e. at the end of a word/phrase/utterance or before another obstruent.

A typological observation that corroborates the idea of preemptive cuing (see as well Kochetov & So 2007) is nasal place assimilation (NPA). NPA is usually regressive (while **co[n]position* and **a[n]chor* don’t sound good in English, *apnoea* and *acknowledge* are fine). Postnasal stops tend to expand their PoA into preceding nasals. Progressive NPA, as in colloquial northern German (e.g., [ʔamp] *Amt* ‘office’ or [habm̩] *haben* ‘to have’) is much more exotic. This could be functionally grounded by concluding that, in comparison to a vowel, the transition from a nasal with its relatively weak formant structure provides a bad cueing ground for the place properties of a following stop. Hence, to increase perceptibility, the PoA of the stop is extended over the whole duration of the preceding nasal. This reasoning then also leads to the

¹ The choice of fricative surfacing for the /g/ is subject to the *ich-ach*-Laut alternation, which is irrelevant here.

conclusion that word-initial position is a bad place for PoA contrasts in stops/obstruents, since the stop starts with silence and the cues for the PoA emerge late and might be masked. Thus, PoA contrasts should typologically be more common in post-vocalic position than in post-sonorant position than in word-initial position. As it happens, PoA of obstruents is typically neutralized in coda, or pre-obstruent and pre-pause, position. In addition, many languages that have word-internal neutralisation of contrasts in coda/preconsonantal position do not neutralise PoA in word-final consonants, even though stops in this position often don't even have a release (see, e.g., some of the cases in Piggott 1999). West-Greenlandic neutralises PoA in word-initial fricatives by allowing only the alveolar or the laryngeal fricative, while the language displays fricatives at seven distinct PoA in other positions (Rischel 1974, Fortescue 1984). This pattern is surprising for two reasons. First, one would think that fricatives have intrinsic PoA cues and show PoA contrasts in more contexts than stops. Second, word-initial position is (in this language) necessarily pre-sonorant/prevocalic. If, then, (post-pausal) pre-vocalic PoA is less well-cued than PoA in post-vocalic, or intervocalic, position, the common tendency to display more PoA contrasts in word-initial or generally syllable onset position has to stem from another cause than licensing by cue. This other cause could be the nature of Faithfulness or Licensing constraints, i.e., the phonology.

Functional/phonetic grounding feeds the innateness debate. "Good" Markedness (henceforth M) constraints are those that are grounded in articulatory difficulty or complexity or in limits of perception etc. Since all human bodies are by and large the same in all relevant respects, one could say that M constraints then don't have to be universal, in the sense of innate (hard-wired in the genome), since every language learner can infer the constraints from the data, either by monitoring her own production (problems) or her own perception. Though the latter must be more of a challenge, given that learners tend to ignore overt correction, i.e., negative feedback.

In some of the functionally leaning literature constraints are therefore language-specific, learned in 1st language acquisition through overt evidence by exposure to the ambient language (Boersma 1998, Hayes 1999, Hayes & Wilson 2008). This stance raises two questions, one of which is how constraints are learned that are responsible for static phonotactic restrictions, the other is how constraints have been learned that only show effects in interlanguage, i.e., when adults learn a second language.

For simple M and related Faithfulness (F) constraints the situation is quite straightforward. A learner discovers a contrast, say, a minimal pair, such as *back* vs. *pack* in English, and infers that there must be a M constraint against the articulatory more marked member of the opposition, i.e., *[spread glottis] or *[voice] (depending on your favoured analysis of English), and a conflicting F constraint, e. g., IO-IDENT(laryngeal). The situation already gets difficult if the pattern involves positional neutralisation. There are functional argumentations for both positional faithfulness as well as positional licensing/markedness. Which choice does a learner make? Maybe she needs both, as one would for Dutch voice patterns (Grijzenhout & Krämer 2000), but if only one is needed, as for German, which displays final devoicing, but no voicing assimilation, there is no way of choosing (see also the discussion of positional restriction of constraints below).

When it comes to learning static phonotactic restrictions a learner actually needs negative evidence to induce constraints, which she doesn't get (see Prince & Tesar 2004, but also Hayes & Wilson 2008 for phonotactic learning in OT). Consider for example Beijing Chinese, which allows only nasals in postvocalic position (Blevins

1995), has only mono-syllabic words and hardly any morphology, and thus no relevant alternations. A learner who is expected to learn the Coda Condition of Beijing Chinese has a problem. She could figure out that there are perceptual and articulatory challenges in post-vocalic/pre-consonantal/pre-pausal obstruents and liquids if she had to perceive or produce any. Since she is never confronted with any challenge of this sort, she has no way of figuring out that there is a constraint that bans the liquid and the obstruents from the coda.

This result is challenged by data from L2 acquisition (Broselow et al. 1998). Chinese learners of English show strategies to avoid coda consonants, in words such as *bag* or *hammock*, that range from featural changes to deletion of the offensive coda consonants, or epenthesis of a vowel. The latter moves the consonant into onset position. First, such L2 processes can be seen as an argument for the superiority of constraint-based phonology over rule-based theories, since it is more plausible that such processes, such as devoicing of voiced coda consonants, can be explained straightforwardly as effects of constraints that are present in the Chinese grammar, but never show an effect since the Chinese lexicon doesn't contain any items that would create the context for the constraints to exert an influence on the choice of output candidate. Second, and more importantly for the discussion here, this implies that such constraints are present in the Chinese grammar, which is unexpected from the purely emergentist approach. The short response to this challenge is to assume that all constraints and representational building blocks (e.g., features or feet) are universal in the sense of being innate, i.e., hard-wired into the human genome (as assumed by Prince & Smolensky 1993/2004).

The less bold and slightly more complex stance refines the emergentist view: Constraints are universal in the sense that every human mind exposed to spoken (or signed) language can and does draw the same conclusions about representational options and about markedness (Hayes & Steriade 2004, see also Collins 2013 for a more refined discussion, and Archangeli & Pulleyblank, this volume).

3.2 Positional restrictions and the definition of constraints

A discussion completely different from the universality question, but strongly connected to the grounding issue, has been simmering for years. There are several proposals for the analysis of positional neutralization. The dispute boils down to the question whether positional neutralization should be regarded as a certain contrast being allowed only in a certain position or whether it is banned from the complementary position. The competing approaches, i.e., positional Faithfulness, positional Licensing and positional Markedness are all functionally grounded (claiming better or worse perceptual/articulatory conditions in the respective complementary environments).

The problem can easily be illustrated with final devoicing, already alluded to above. Many languages display a voicing or other laryngeal contrast only in obstruents in the syllable onset or pre-sonorant position. Often this interacts with voicing assimilation.

Positional Faithfulness (Beckman 1997, 2004, Lombardi 1999) assumes a clone of general Faithfulness to the laryngeal feature, restricted to obstruents in onset position, *IDENTITYONSETLAR*, which interacts with a simple markedness constraint, as illustrated in tableau (a) in (4). In most of the literature that uses final devoicing as a pet example to make some theoretical point, but which isn't interested in the typology of

voicing patterns, a positional M constraint is assumed that is violated by voiced obstruents in coda position, as in tableau (b) in (4) (see e.g. Pater's 2015 arguments against Local Constraint Conjunction, as well the discussion below in section 5).

(4) Positional Faithfulness or Positional Markedness

<INSERT TABLEAU (4) AROUND HERE.>

Consideration of voicing assimilation, which is usually regressive if the two members of an obstruent cluster are in separate syllables, settles the issue in favour of the positional F analysis. The Positional M analysis erroneously predicts progressive devoicing rather than regressive voicing for inputs with a voiced obstruent on the right. At this point one could also dismiss positional Licensing (Zoll 2004, Walker 2011), since positional F together with simple M does the job. Consider the next tableau, in which I added a Licensing constraint, which demands that laryngeal features be licensed by or linked to a segment in an onset.

(5) Positional Faithfulness and Positional Licensing

<INSERT TABLEAU (5) AROUND HERE.>

At first sight, the Licensing constraint and the positional M constraint seem indistinguishable. If we consider an assimilation situation in a language with final devoicing it becomes obvious that the Licensing approach is compatible with the typological observation when combined with positional Faithfulness. A voiced stop in non-onset position (i.e., coda) that shares the feature with a stop in onset position satisfies the Licensing constraint, but still violates the positional Markedness constraint. However, the Licensing constraint can't explain the directionality of assimilation. It needs positional Faithfulness.

(6) Positional Faithfulness and Positional Licensing in regressive assimilation

<INSERT TABLEAU (6) AROUND HERE.>

However, the situation is more intricate. Zoll (2004) provides examples in which also derived marked structures are allowed in certain prominent domains only, rather than only contrastive, i.e., underlying, marked features. This kind of positional restriction can't be captured by positional F alone, since positional F only caters for marked structures that are present in the input already. Walker (2011) argues that processes in which the trigger is in a weak position and the target in a prominent position (unstressed syllable and stressed syllable respectively) are an effect of licensing. The contrastive feature has to be licensed by a prominent position.

On the other hand, positional Licensing doesn't account for directionality effects in assimilation processes, as we have just seen. For example, the difference between stress- or stem-controlled vowel harmony and metaphony, if assumed to be caused by Licensing constraints, has to be attributed to positional F constraints. In vowel harmony, all vowels in non-prominent positions assimilate to the vowel in the initial syllable, the stressed syllable or the next syllable in the stem (see, e.g., Krämer 2003a for an overview). In metaphony on the other hand, a word-final or unstressed vowel causes

the vowel in the stressed syllable to assimilate (see, e.g., Walker 2011 or the contributions in Torres-Tamarit et al. 2016). Vowel harmony systems require a high-ranking F constraint, restricted to a prominent position. Metaphony requires a highly ranked positional F constraint restricted to the last syllable (Walker 2011; see Krämer 2003a,b for a discussion of this type of edge Faithfulness). In the following tableaux, this constraint interaction is illustrated. Rearranging the two positional F constraints yields either the metaphony candidate (c), as in (7), or the vowel harmony candidate (b), as in (8), as optimal.

(7) Metaphony as licensing

<INSERT TABLEAU (7) AROUND HERE.>

(8) Harmony as licensing

<INSERT TABLEAU (8) AROUND HERE.>

The individual approaches undergenerate by not producing attested patterns and overgenerate certain unattested patterns. Admitting all options, i.e., positional F, positional Licensing, and positional M, accounts for attested patterns, but also produces undesired/unattested patterns.

Assimilation patterns, such as voicing assimilation, vowel harmony or metaphony, have been subject to analyses with a range of different constraints as the cause for the patterns, AGREE constraints, Syntagmatic Correspondence, ABC theory, positional and simple M, positional Licensing, different flavours of Alignment constraints (see Beckman 1997, Lombardi 1999, Baković 2000, Krämer 2003a, Walker 2005, 2011, Jurgec 2011) and it looks as if the issue is still far from settled.

The most appealing approach is of course the one that doesn't need a constraint that is only postulated to account for assimilation. Beckman (1997) attempts this. In her analysis of vowel harmony, only positional F and simple M constraints generate the pattern she discusses. The approach does not only run into the problems raised above, it also opens for another question: should M constraints also exist for the unmarked value of a feature? The problem is illustrated in the following tableau, which schematizes stress-controlled vowel harmony. Without the constraint referring to the unmarked value, candidates (a) and (b) can't be distinguished.

(9) Unmarkedness constraint

<INSERT TABLEAU (9) AROUND HERE.>

Parsimony demands that M constraints punishing unmarked structure should not be included in the constraint set, since they double the set of simple M constraints (at least those referring to features), and since the assumption of their existence requires a fixed ranking between M constraints referring to the marked value (*+F) and the corresponding M constraint referring to the unmarked value (*-F), which is *+F dominating *-F. The latter undermines the Free Ranking Hypothesis, which postulates that all constraints can be ranked freely (Prince & Smolensky 1993/2004). The Free Ranking Hypothesis was challenged already by Prince & Smolensky themselves in their discussion of harmonic alignment, sound patterns which apparently require universal

rankings of constraints that refer to a scale, such as the sonority hierarchy. The problem of fixed hierarchies will be taken up again in section 5.

Scalar well-formedness brings us to our next issue to be considered here, the nature of violability as binary. Constraint violation could be binary (or categorical), i.e., a statement on well-formedness is true for a certain representation or it isn't, or violation could have numerical or other scalar values, i.e., a representation occupies a certain rank on a scale of fitness. In the latter interpretation, constraints could be mildly violated by one representation and severely violated by another.

Prince & Smolensky (1993/2004) discuss syllable positions in this respect. An onset is more harmonic the lower it is on the sonority hierarchy, while a nucleus is the more harmonic the higher it is on the sonority hierarchy. Thus, Markedness constraints on these positions could assess a syllable position's value with regard to its distance from the highest or lowest class on the sonority hierarchy.

(10) Onset Harmony (H-ONS): The left edge of a syllable is more harmonic the lower it is on the sonority scale. Assign one violation mark for every step on the harmony scale an onset is away from the sonority of stops.

(11) Sonority and cumulative violation

<INSERT TABLE (11) AROUND HERE.>

In comparison, a constraint such as ONSET, which requires every syllable to start with a consonantal onset, can also be violated to various degrees by a single candidate, but then it is violated in different locations, i.e. by several syllables. Every syllable itself either satisfies or violates the constraint.

(12) ONSET: Assign a violation mark for every syllable that does not have a consonantal onset.

(13) Gradience versus categoriality

<INSERT TABLE (13) AROUND HERE.>

Languages use such scales in various ways, however, that are problematic for OT. One problem is that languages conflate or telescope the levels of such hierarchies, and the other is that they use seemingly random points on such scales as tolerance thresholds. E.g., while most languages tolerate only vowels as syllable nuclei, some also allow sonorant consonants and some display obstruents in nucleus position. However, with strict ranking, a constraint like H-NUC (the sister constraint of H-ONS, defining nucleus wellformedness) either dominates Faithfulness or it is dominated by Faithfulness constraints. It thus doesn't matter how bad a nucleus or onset is according to the respective scalar constraint unless each of these constraints is decomposed into binary sub-constraints that are rankable with respect to Faithfulness constraints.

(14) Scalar constraints decomposed I

H-ONS = {*[+vocalic]/Ons >> *[+liquid]/Ons >> *[+son]/Ons }

(15) Gradience versus categoriality

<INSERT TABLEAU (15) AROUND HERE.>

To keep the implicational result of the scalar constraint these constraint sets have to be in some kind of universal relation. Prince & Smolensky (1993/2004) propose a universal ranking. This undermines the Free Ranking Hypothesis, the assumption that all constraints can potentially be ranked in any order. We will take up other solutions to this problem in section 5.

A similar scalarity issue emerges with Alignment constraints (McCarthy 2003). Even though the definition requires mapping of two edges, as can be read from the definition in (16), the constraints are usually used to actually measure the difference between two edges by way of some intervening category. Thus the constraint violations are computed according to the clause in (17) (see discussion in McCarthy 2003, Hyde 2012).

(16) Generalized Alignment (McCarthy & Prince 1993)

ALIGN (Cat1 , Edge1 , Cat2 , Edge2)

The Edge1 of every ACat1 coincides with the Edge2 of some ACat2.

(17) Generalized Alignment, the third argument (McCarthy 2003)

Assess a violation mark for every Cat3 that intervenes between edges that fail to coincide.

To illustrate this we consider a constraint that requires all feet to be at the right edge of a word. (18) and (19) provide the usual gradient and a categorical definition, respectively. The tableau in (21) shows violation profiles for the two hypothesized constraints in a grammar that doesn't allow proper edge mapping by way of a higher ranked constraint, NON-FINALITY, which keeps the last syllable in the word extrametrical.

(18) ALLFTR (usual version): ALIGN(Foot, R, Wd, R) 'Align the right edge of every foot with the right edge of a Prosodic Word. Assign a violation mark for every syllable between each foot and the right edge of the word.'

(19) \forall FTR (oversimplified categorical version): 'Assign a violation mark for every foot that is not at the right edge of the word.'

(20) NON-FINALITY: The rightmost syllable in a Prosodic Word is not parsed in a foot.

(21) Edge magnetism and categoriality

<INSERT TABLEAU (21) AROUND HERE.>

The categorical version of the Alignment constraint doesn't distinguish candidates (b), (c), and (d). However, in real world cases like this, feet usually huddle up at the designated edge even if, due to a higher ranked constraint, alignment can't be perfect, compare candidates (e) and (f). Thus, the gradience of Alignment produces actually a desired result. It is other scalar constraints that are pointless or counter-productive in OT (see the discussion above, as well below in section 4).

Eisner (1997) observes the midpoint pathology produced by gradient Alignment constraints. Under certain circumstances, an Alignment constraint can drag a structure to the centre of a domain. Since phonological processes and structure building are usually edge oriented this is an undesired result. Feet and stress are usually oriented towards the left or right edge of the word, not the centre.

This midpoint pathology is illustrated in (22). The Alignment constraint requires the left edge of every syllable to align with the left edge of some foot. For some reason (higher ranked constraint) only one foot is allowed per word. Violation marks contributed by individual syllables are separated by commas, while violation marks associated with syllables preceding the foot, syllables inside the foot and syllables following the foot respectively are separated by semicolons. On the right I have given the total violation score (Σ) of each candidate for convenience, followed by violations incurred by syllables preceding the foot (p), contained within the foot (c) and following the foot (f).

(22) The midpoint pathology

<INSERT TABLEAU (22) AROUND HERE.>

As Hyde (2012) correctly points out, the problem here is not the gradient of Alignment alone, but only in connection with its relation-generalality. I.e., for assessment of violations it doesn't matter in which relation the two arguments, here syllable and foot, are, whether one is contained in the other or not. In tableau (22), one violation is incurred in all candidates by the second syllable within the foot. If one looks at the two other types of syllable, i.e., preceding and following the foot, one sees variation in the violation profiles.

If one has a look at a range of Alignment constraints proposed in the literature a striking property they all share is that there is an implicit containment relation between arguments. For categories from the prosodic hierarchy it is usually intended that the constraint assesses violations only for those structures in which the lower category is contained within the higher one (e.g., feet contained within a PWd are aligned with an edge of this PWd and not a neighbouring one). Hyde (2012) redefines Alignment in a way that specifies the alignment categories, the separator categories and the (containment) relations between them, such that irrelevant categories (such as the neighbouring PWd) are excluded from the computation of violation marks. Since the intervening category is explicitly defined, the locus of each constraint violation can be identified as a different one, as considered a defining property of categorical violation by McCarthy (2003). Thus, even though the Relation-Specific Alignment constraints potentially still measure distance they are not gradient — at least not in the same way as those constraints discussed above, i.e., that the same item causes registration of more or less violation.

While some properties of constraints have dramatic consequences for OT computation regardless of assumptions on representations, others are crucially dependent on the theory of representation one adopts. However, even without commitment to a certain theory, we have seen here, a lot of fruitful discussion is possible on the more general properties of OT constraints and the discussion is an on-going one. We can expect new developments regarding the choices between different positional theories (Faithfulness, Markedness, Licensing) or their hybridization. A hybrid between Faithfulness and Alignment has also been proposed with Anchoring

constraints (McCarthy & Prince 1995). The above revisions to Alignment will surely have repercussions for Anchoring, which is commonly invoked in analyses of prosodic morphology (truncation, reduplication etc.).

4 Constraint interaction I: On the relative strictness of domination

As already alluded to in the introductory section, the standard ranking relation between constraints is strict domination. The number of violations on lower ranked constraints doesn't matter if a higher ranked constraint has forced a decision on two competitors, be these lower violations all violations of the same, or several constraints.

Instead of strict domination one could also consider candidates to be evaluated by overall score. I illustrate this with the constraint causing final devoicing, VOP/coda, its more general sister VOP (Voiced Obstruent Prohibition), and the conflicting one blocking it, i.e., IO-IDENT(voice), since they will become relevant again in the discussion of Pater's (2016) argument for Harmonic Grammar (HG) below. Constraint violations are indicated as negative numbers rather than asterisks in the following tableau for ease of interpretation.

- (23) Evaluation by total score, no prioritization (i.e., unranked/unweighted constraints)

<INSERT TABLEAU (23) AROUND HERE.>

Total scores alone are also too restrictive for typological theory since all candidates would score the same in all languages. We can combine the numerical values with ranking by giving constraints different weights, as proposed in HG. This results in potential typologies, as illustrated by the tableaux with different weightings of the same constraints.

- (24) HG – Contrast with weighted constraints

<INSERT TABLEAU (24) AROUND HERE.>

- (25) HG – Positional neutralization with weighted constraints

<INSERT TABLEAU (25) AROUND HERE.>

From a computational perspective, constraint weighting is more costly than strict domination, since it needs numerical calculation, while strict domination is digital in the sense that counting is needed only up to 1. (Either a candidate has one more violation of a constraint than a competitor or it doesn't.) Thus, one would expect a good argument for HG, which would be that it is either more restrictive than strict domination or it can account for patterns with which strict domination struggles. Pater (2016) claims gang-up effects to be the most convincing argument for weighted constraints. He provides an analysis of Lyman's Law effects in loanwords in Japanese (see Ito & Mester 2003, Kawahara 2011).

In recent Japanese loanwords, voiced geminates are allowed (while not attested in the native vocabulary) and only devoiced if they also violate Lyman's Law (no two

voiced obstruents within a word). The latter is also only enforced in these loanwords when a voiced geminate is involved (in addition to a second voiced obstruent). Pater proposes a very elegant analysis of these data utilizing weighted constraints. At the core of this analysis lies the cumulative violation of the Lyman's Law constraint (OCP-Voice in (26)) and the Markedness constraint against voiced geminates as more important than violation of a Faithfulness constraint that has a higher weight than each of the two Markedness constraints.

(26) HG analysis of Lyman's Law and OCP conspiracy (adapted from Pater 2016)

<INSERT TABLEAU (26) AROUND HERE.>

However, he also shows at length that gang-up effects are an expected result in HG. Let us investigate briefly what a gang-up effect is. With strict domination, candidate (b) wouldn't have won against candidate (a), since it violates the higher ranked IDENT-VOICE. Here it is assumed that the two constraints with less weight, OCP-VOICE and *VCE-GEM "gang up" against IDENT-VOICE. Their cumulative violations of candidate (a) outweigh the only relatively weighty violation of IDENT-VOICE incurred by candidate (b). In a gang-up, the violations of one or two less important constraints outweigh the violations of a higher ranked constraint. This kind of effect is also logically possible in other phonological phenomena. However, it is not attested. A gang-up could lead to inconsistency in final devoicing or other neutralisation patterns. Also in assimilation patterns one could logically expect that assimilation results in the shared feature value that is held by the majority of involved segments in the input, i.e., the "majority rules" (Baković 2000). I first consider voicing neutralization and assimilation and then turn to vowel harmony.

If we, for the moment, stick to obstruent voicing patterns, which also Pater (2016) uses in his argumentation for weighted constraints, final devoicing in interaction with voicing assimilation could be analysed as in the following tableau. The usual pattern, as found in Dutch, Russian, and many other languages, is regressive assimilation. Final devoicing is overridden by assimilation. In the following tableaux I will use the positional faithfulness approach of final devoicing, since that easily accounts for the regressive nature of assimilation in connection with final devoicing (Lombardi 1999; see, e.g., Krämer 2000 and Grijzenhout & Krämer 2000 for some discussion).

(27) HG analysis of regressive voicing assimilation and final devoicing

<INSERT TABLEAU (27) AROUND HERE.>

As the observant reader will have noticed, there is quite a safety distance in the weights of the top-weighted constraints. If we go for minimal weight differences the pattern turns out differently. In the following tableaux the weights are minimally different from each other and AGREE weighs heavier than IDENTONSET. The result is devoicing whenever at least one of the input segments is voiceless, which is quite an odd result typologically.

(28) Directionality switch dependent on underlying specification of one C

<INSERT TABLEAU (28) AROUND HERE.>

If we reverse the relation between the two top-weighted constraints, the pattern generated by this grammar displays free variation in cases in which the input contains a combination of a voiceless and a voiced obstruent, in that order (see sub-tableau (29ii)).

(29) Free variation dependent on underlying specification of Cs

<INSERT TABLEAU (29) AROUND HERE.>

Another problematic potential gang-up effect is that independent violations of a single constraint can add up to outweigh those of more weighty constraints in competing candidates. Legendre, Sorace & Smolensky (2006) refer to this as an unbounded trade-off. Here several items within a candidate “gang up” against another one rather than two or more constraints joining forces.

This is illustrated here with vowel harmony (VH; see Legendre, Sorace & Smolensky for an example involving stress placement). VH systems are often of the controlled type (as opposed to dominance of one feature value). In controlled systems a vowel in a prominent position, the stem, the first syllable, the stressed syllable or the rightmost syllable (see Baković 2000, Krämer 2003) causes all other vowels to assimilate. This is illustrated in (30) in sub-tableau (i). However, in such an HG analysis, if a form contains too many vowels, their cumulative unfaithfulness can reverse the pattern. The prominent position becomes unfaithful to avoid too much unfaithfulness among non-prominent vowels, as illustrated in tableau (ii) in (30).

(30) Majority rules in vowel harmony

<INSERT TABLEAU (30) AROUND HERE.>

HG predicts an infinite number of languages in which the majority takes over at different points, ranging from two to an infinity (minus one) of underprivileged vowels ganging up.

However easy these patterns are to model in HG, VH systems are either of the controlled (by the stem or stressed position) or the dominant type (Baković 2000). This “gang-up” or “majority rules” VH type is unattested.²

The conclusion thus has to be that either HG shows that certain language types are possible, but currently unattested by coincidence, or that HG needs further stipulations on the weighting of constraints, which makes the theory less attractive, given that cases like the Japanese conspiracy alluded to above can be analyzed with different means as well.

Pater (2016, as McCarthy 2007) argues against LCC (Local Constraint Conjunction; see below) by constructing weird LCCs and showing how the theory

² Admittedly, such gang-up effects caused by Faithfulness constraints are excluded in a serial version of HG by the restriction to one change (i.e., one violation of one F constraint) in the propagation from one representation to the next in an evaluation. However, for iterative assimilation patterns this theory then requires an analysis crucially relying on gradient Alignment (see the discussion here and in McCarthy 2003 and Hyde 2012 on why this is a problem and Jurgec 2011 why it isn't) as the driving force for vowel harmony and other unbounded assimilation processes, since, for AGREE constraints, a single change that doesn't necessarily increase harmony, e.g., the sequence of [+----] is as disharmonic as the sequence [+----] or [++++]. The grammar thus wouldn't be able to select an appropriate input for the next evaluation.

overgenerates and how weighted constraints don't overgenerate in the same way. Weighted constraints overgenerate in other ways. And, as indicated already in section 3, also other subtheories within OT lead to overgeneration. At the current stage the hard truth to face for phonologists is that the challenge lies in accounting for the attested rather than excluding the unattested. The OT tool of factorial typology (see Iosad, this volume), considered the litmus test for any proposed constraint set, requires the analyst to consider all possible rankings of a set of constraints. In the ideal case, the different rankings describe different patterns, and all predicted patterns are attested and each attested pattern is generated by at least one ranking. However, as proponents of substance-free phonology point out the set of currently known languages and patterns is not necessarily the same as the set of possible grammars or the set of grammars that a phonological theory is expected to account for (Hale & Reiss 2000, 2008, Reiss, this volume).

We thus need different evaluation metrics for competing theories or apply those we have in a different way. For example, while LCC is a logical option within the formal apparatus of OT, weighted constraints are a completely different hypothesis about constraint interaction, i.e., an entirely different conceptualization of ranking, which comes with its own set of additional stipulations (such as exponential increase in constraint weight).

At the start of this section I showed a tableau with unweighted constraints in which several candidates tie. One can interpret this as a result, i.e., the top-scoring candidates are in free variation. There has been a considerable amount of research on phonological variation in the sense of optionality in recent years, which resulted in various revisions to the theory of constraint interaction. Some phonological processes apply only optionally, such as final *t* deletion in English or Gorgia Toscana, the spirantization of voiceless stops in postvocalic position in Tuscan Italian (see Iosad, this volume, and Ramsammy, this volume for more details). In the original version of OT, free variation is excluded, since every constraint ranking has to be exhaustive. For constraints for which a language doesn't provide a ranking argument, a random or default ranking has to be assumed (e.g., M above F or specific above general). With a total ranking and every candidate supplied by Gen minimally differing from every other candidate by one violation mark, this results in one and only one winner in each evaluation.

There are several competing proposals to account for free variation in OT. The most straightforward approach is Partially Ordered Grammars Theory (Anttila 1997, 2004, 2007). Anttila still assumes exhaustive ranking. Though, this is enforced only temporarily. Constraints that are unranked with respect to each other assume a random order in every evaluation. Thus, considering two unranked constraints, A and B, the probability of constraint A dominating constraint B in an evaluation is 0.5. If each of the involved constraints favours a different of two candidates which otherwise tie, the chances of one or the other winning are 50%. Add a third constraint C, which favours the same candidate as constraint A, the chances of this candidate to be chosen as optimal increase to 66%. In this way, free variation can be described, as well as frequency biases. The tableaux in (31) illustrate this schematically. Tableau (i) shows the unordered constraints and the subsequent tableaux the factorial typology that emerges with spontaneous rankings. In this scenario candidate *a* wins in four out of six possible rankings, *b* in two and *c* never. Thus, *a* and *b* are in free variation, with a higher likelihood of realization for *a*.

(31) Partially ordered constraints

<INSERT TABLEAU (31) AROUND HERE.>

The same results can be achieved with Stochastic OT (Boersma 1998) and Maximum Entropy Grammar (Hayes & Wilson 2008) or Noisy Harmonic Grammar (Coetzee & Pater 2008), only with more complex maths involved in the computation.

A very different kind of softening up of the strictness of domination comes with the relation between constraints in content. At its most extreme, two constraints have the same content, which is only restricted to a subset of environments in one of them. This is the special-general relationship between constraints. This relation comes in various incarnations, which (probably) all can be summarized as constraint cloning. This will be discussed in slightly more detail in the next section, but see as well section 3 above.

5 Constraint interaction II: Organization beyond ranking

In section 3, the problem with gradient or scalar constraints was introduced. The pointlessness of gradient violation under the strict ranking hypothesis did not only lead to proposals of different approaches to ranking but also to universal (strict dominance) rankings as well as to organizational relations between constraints beyond simple ranking, such as de Lacy's (2006) stringency relations. Gradience however, is not the only problem that sparked the development of more sophisticated modes of constraint interaction and coordination or conjunction, and not the actual problem, which are universal implicational (markedness) hierarchies. Other types of interaction are found in constraint duplication or cloning.

There are three ways of cloning constraints. Pater (2007) introduces the term in connection with lexical indexation of constraints. Constraints can be indexed and the copy of the constraint with the index is ranked higher in a hierarchy than its unranked original. Some lexical items are also indexed, and it is only the output candidates of these inputs that are sensitive to the higher ranked indexed constraint clone. Positional Faithfulness can be understood as one type of cloning and indexing: There is a general Faithfulness constraint and a more restricted version that is only active in a certain environment. There are two differences between the two forms of indexing. First, positional restriction is not arbitrary, as lexical indexing can be. It refers to well-defined positions or classes, such as stressed syllables (i.e., prosodically defined) or stems (i.e., morphologically defined). The boundary between the two types of indexing already becomes blurry in the latter case. For prosodically defined positions one could say that positional Faithfulness is defined over surface categories, while indexing is defined over input properties. A morphologically defined category, such as "stem", however, is clearly a property of the underlying form or input.³

The third cloning option is Local Constraint Conjunction (LCC; Prince & Smolensky 1993/2004, Smolensky 1996, 2006, Lubowicz 2002, 2005). Two (or more) constraints join forces in a domain (e.g., the segment) and every instance of that domain in which each of the two constraints is violated constitutes a violation of the local

³ Especially so if one embraces strict modularity and all syntactic, semantic and morphological, that is, non-phonological, information is considered inaccessible in the phonological computation.

conjunction of the two (or more) constraints. The LCC only has an effect on output forms if it dominates at least one of the two constraints involved. However, indexation of an LCC with an arbitrary index or a general grammatical category (e.g., lexical vs. functional or major lexical class, as for positional F or indexation) is an option.

5.1 Implicational hierarchies, gradience, and constraint coordination

Freely ranked nuclear constraints seem to be badly suited to account for universal implicational relations or hierarchies. A famous exception is the relation between the constraints ONSET and *CODA, which expresses a typological observation about syllable inventories (languages with syllables that have codas also have syllables with onsets, but not vice versa). This relation is captured in the respective positive and negative formulation of the constraints.

PoA in consonants shows a structurally comparable asymmetry. The three major PoAs are labial, coronal and dorsal. However, if a language has only two PoA, one usually finds a labial and a dorsal. Furthermore, many phonological processes indicate that coronal is the least marked of the three PoA, or even underspecified (see de Lacy 2006 and references given there), and glottal is even less marked than coronal, since it is the output of debuccalization and consonant epenthesis.

De Lacy (2006), based on previous work by Lombardi and many others, proposes the markedness hierarchy for PoA given in (32). These markedness relations between the different PoAs should be reflected in the constraint hierarchy, as in (b) or in the definition of the constraint set, as in (c). The constraints in (c) are in a stringency relation (de Lacy 2006). {*Dorsal/*Labial}, for example is violated by any segment that is either dorsal or labial.⁴

- (32) Markedness of Place of Articulation
- a. Dorsal > labial > coronal > glottal
 - b. Universally ranked M constraints: *Dorsal » *Labial » *Coronal
 - c. Stringent constraint sets:
 - c'. *Dorsal, {*Dorsal/*Labial}, {*Dorsal/*Labial/*Coronal}
 - c''. Faith(dors), Faith(dors/lab), Faith(dors/lab/cor), Faith(d/l/c/glottal)

These stringently related constraints can be freely ranked and still express the markedness imbalance. Any dorsal in a candidate violates three M constraints, while a labial violates only two and so on.

The scalar behaviour discussed above relates to the sonority hierarchy. The problem there was that languages use different levels on the hierarchy as cut-off points for various processes. Prince & Smolensky (1993/2004) discuss syllable nuclei in this respect. While some languages allow only vowels, others allow sonorant consonants or even obstruents as syllable nuclei. However, every language always also allows the classes higher on the sonority hierarchy than the lowest one that is acceptable as a syllable nucleus in the respective language. Accordingly Prince & Smolensky decompose the gradient constraint H-NUC into a universally fixed hierarchy of categorical

⁴ Iroquoian languages that don't have any labial consonants in their inventory, such as Seneca (Chafe 1996), are potentially difficult for Dispersion Theory (Flemming 2004), though easily accounted for with de Lacy's constraints on PoA.

Markedness constraints. For a constraint on nuclear harmony one could assume the following gradient violation profile.

(33) Sonority and cumulative violation of H-Nuc

<INSERT TABLEAU (33) AROUND HERE.>

However, no amount of violations of H-Nuc will ever trigger vowel epenthesis to provide a better nucleus for a syllable as long as the anti-epenthesis constraint DEP is ranked above H-NUC.

(34) H-Nuc decomposed

*STOP/NUC >> *FRIC/NUC >> *NAS/NUC >> *LIQ/NUC

DEP can now be ranked somewhere in between these constraints and block vowel epenthesis in forms in which any of the classes referred to lower down in the hierarchy is syllabified as a nucleus. The universal ranking of these constraints undermines the free ranking hypothesis and it thus would be desirable to reformulate the same insight with freely rankable categorical constraints in the same way as the constraints on the major PoAs.

(35) H-NUC stringently decomposed

*STOP/NUC

*{STOP∨FRIC}/NUC

*{STOP∨FRIC∨NAS}/NUC

*{STOP∨FRIC∨NAS∨LIQ}/NUC

Similar issues are identifiable with Faithfulness in chain shifts. In many lenition processes consonants only move up one step on the sonority hierarchy. Likewise, vowel raising often moves the vowel up only one step in the height dimension, e.g., low vowels raise to lax mid, lax mid raise to tense mid and tense mid raise to high, as in metaphony in Romance languages (see e.g., Gnanadesikan 1997, Moreton & Smolensky for an overview of chain shifts, Iosad 2010 on mutations, Calabrese 2011 or Krämer 2016 on metaphonic raising). One solution that has been proposed relies crucially on Local Constraint Conjunction (e.g., Kirchner 1996, Moreton & Smolensky 2002).

In a LCC two (or more) constraints team up and can be ranked higher than the individual constraints themselves.

(36) Local Constraint Conjunction (Smolensky 2006)

*A&_D*B is violated if and only if a violation of *A and a (distinct) violation of *B both occur within a single domain of type *D*.

Cooccurrence constraints, such as the constraint responsible for the observation that high lax vowels are typologically marked are pretty complex constraints if conceived as primitive constraints. Decomposing them as a LCC of two primitive constraints yields a more elegant constraint set. I.e., high vowels violate the simple constraint *[+high] and lax vowels violate the constraint *[Retracted Tongue Root] (or *[-Advanced Tongue Root]). While high vowels are typologically very common and vowels with retracted

tongue root are very common as well, the combination of both in one segment is marked. This is captured in the LCC $\{*[high]\&_{segment}*[RTR]\}$.

Kirchner (1996) proposes to handle chain shifts with LCCs of Faithfulness constraints (see as well Krämer 2016, Walker 2011). A chain shift grammar tolerates violation of one Faithfulness constraint, i.e., a change of one feature in one segment, but not two (or more) violations, i.e., two feature changes in the same segment. An issue that arises here is the formalization of the triggering M constraint, since often the goal of markedness reduction is not accomplished, it is only approached by one step.

LCC has repeatedly been criticized for being too powerful, allowing all kinds of undesired constraint interactions (see Pater 2016 for the latest assault), especially if one allows all sorts of domains beyond that of the segment, despite the proven usefulness and explanatory adequacy of LCCs in the analysis of a wide range of phonological phenomena (see, e.g., Kirchner 1996, Moreton & Smolensky 2002, Smolensky 2006, Collins 2013).

Furthermore, as pointed out already by Crowhurst & Hewitt (1997) conjunction is only one logical operation available for the coordination of constraints. De Lacy's (2006) stringently organized constraints for example can be analysed as local disjunctions, i.e. a single segment should not violate either constraint A or constraint B, e.g., either *Labial *or* *Dorsal. Implicational constraints of the type "if x then also y" have also been proposed in various forms by Krämer (2003a:86), Smith (2005) as well as Levelt & van Oostendorp (2007).

5.2 Exceptionality and constraint indexation

Phonological processes often only apply to restricted lexical classes or to arbitrarily selected individual lexical items or morphemes. In many languages, loanwords also form a separate phonological class in which different, often more loose, restrictions hold than in the native vocabulary (though, see Jurgec 2010 for the contrary). The phenomenon of exceptionality and loanword phonology have first been handled with co-phonologies, i.e., the duplication of the complete constraint hierarchy, or the duplication and reranking of a substring of the hierarchy (Anttila 2002) or with prespecification (exceptional processes only apply to arbitrarily underspecified morphemes; Inkelas, Orgun & Zoll 1997 et seq.).

A more restrictive and more insightful theory of exceptions is constraint indexation (Ito & Mester 1999). A constraint is cloned, tagged with an index, and placed higher up in the hierarchy than the original constraint. The indexed constraint is only visible, or only registers violation marks, for morphemes that are tagged with the same index. These morphemes can be loanwords, lexical categories, or random groups of morphemes or single morphemes. If both M and F constraints can be indexed, as in Pater's (2009) version, the approach produces three welcome results. Not only does it distinguish loanwords from the native vocabulary (by associating certain F constraints and all loanwords with an index), it accounts for the observation that exceptionality is morphophonologically local (though see Jurgec 2014), and it distinguishes between exceptional blocking and exceptional application of a phonological process.

If two morphemes from different classes combine, it is not clear under the co-phonology approach which constraint ranking should be used. Furthermore, the presence of one morpheme from a co-phonology P', causes the whole form to be subdued to the constraint ranking of P'. Lexically indexed constraints are activated by the corresponding lexically indexed morphemes and only apply to these morphemes.

That is, different co-phonologies can be active within one morphologically complex form.

Whether the activity concerns the exceptional blocking or the exceptional application of a process depends on whether the indexed constraint is a F constraint or a M constraint, respectively.

- (37) Indexation and exceptionality
- | | |
|-----------------------------|-------------------|
| a. Exceptional process: | $M_I \gg F \gg M$ |
| b. Exception to process: | $F_I \gg M \gg F$ |
| c. Loanword exceptionality: | $F_L \gg M \gg F$ |

Lexical indices are of course simple diacritics and therefore this is not a phonological solution to the challenge. Morpheme-specific processes and blocking analyses relying on under-/pre-specification or floating features seem to be more attractive since they don't have to rely on arbitrary diacritics. If, however, loanword phonology and lexical class-specific phonology also require indexation it is tempting to apply a uniform analysis to all forms of exceptionality.

6 Related topics and future directions

Unfortunately this chapter comes with a severe flaw: restricted space. While we covered some ground, this overview of current issues and new developments is far from exhaustive and I use the final section to draw attention to some additional issues and trends.

Overgeneration has been touched in passing, even though it would have deserved its own section (see Iosad, this volume, for more discussion). Constraint interaction has been shown repeatedly to show undesired results. For example, Steriade (2009) notes that nasalization is not an attested repair strategy in response to a constraint like VOP/coda (the Final Devoicing constraint). However, a mapping of /tab/ to [tam] is easily produced with the respective ranking of common OT constraints. The too many solutions or too many repairs problem has been discussed in various places with very divergent results (Blumenfeld 2006, de Lacy 2006, Baković 2007a, van Oostendorp 2007b, Blaho & Rice 2014).

Overgeneration, in some sense, is tightly connected with computability, which has barely been mentioned so far. The infinite set of output candidates and their parallel evaluation poses a potential challenge which has been met with some scholars' move to a serialist version of OT or HG (though, see Iosad, this volume). In serial OT only one change can be made at a time to the input, and evaluation is repeated until there are no minimal changes left that would improve the output with respect to the constraint ranking. On the one hand this results in a potentially long chain of evaluations, on the other it restricts the set of output candidates in each evaluation round dramatically. However, Magri (2013) raises serious doubts about the computational advantage of HG over OT. Bane & Riggle (2012) point out that HG generates much larger factorial typologies than standard OT. Kaplan (2011) and Kazutaka (2012) argue that Harmonic Serialism is problematic because it can't (straightforwardly) account for patterns that are elegantly taken care of with parallel OT. See as well Hyde (2012) for a critical stance on serial OT.

The adoption of a serial version of OT has its motivation in OT's problem with opaque interactions of phonological processes, which has sparked a firework of

theoretical proposals. McCarthy (2007) gives an overview of the state of the discussion at that time. The issue is far from resolved, as subsequent contributions show, for example Padgett's (2010) reductionist approach, Baković's (2007b, 2011) reassessment of the phenomenon or van Oostendorp's (2004, 2017) return to the original Containment model of Faithfulness with slight modifications, Coloured Containment. See as well Bermúdez-Otero (this volume).

The functional move that came with OT has led to the inclusion of phonetic detail for example in the definition of constraints, such as formant frequencies, and the ambition to explain a much greater amount of variation than discussed above, i.e., phonetic variation. This raises the question whether OT is actually a theory of competence or performance (in the Chomskyan sense) or of both.

The inclusion of phonetic detail (rather than abstract categorical features) in phonological constraints is also relevant for another discussion that is orthogonal to OT-internal discussions, the nature of underlying representations. While traditional generative phonology endorses abstract categorical phonological representations there has been an on-going discussion, especially since the nineties of the last century, concerning the degree of abstractness and economy in underlying or lexical representations, i.e., the mental representation of phonological objects, or, in a wider view, speech (see summarizing discussion and references in Krämer 2012). The debate (within OT) was sparked already in Prince & Smolensky (1994/2004) by their discussion of Lexicon Optimization and its undesired results and has led to a range of proposals (for more recent contributions see Krämer 2012, Tesar 2013, van Oostendorp 2014).

In conclusion, it seems there are not many of the basic assumptions of OT that are not under debate and it is going to be interesting to see how the framework will develop in the future.

Further reading

While learnability was a central issue from the beginning on, and considered one of the strong arguments in favour of OT, it is still a hotly debated issue, spawning new proposals, e.g., Brasoveanu & Prince (2012), Tesar (2013), Tessier & Jesney (2014), Rasin & Katzir (2016).

The most recent trend in OT has turned to a more fine-grained investigation of the typological properties of systems of rankable constraints, e.g., Alber et al. (2016), Brasoveanu & Prince (2011) or McManus (2016) and the assumed candidate sets, e.g., Bane & Riggle (2012). With these projects research in OT has explicitly turned its focus from phonological phenomena, such as opacity or gradience, to the theory itself and its properties, as the subject of investigation.

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Current issues and directions in Optimality Theory —
Constraints and their interaction

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Tables and tableaux

(2) Strictness of strict domination

	A	B
☞ a		*****
b	*!	

(4) Positional Faithfulness or Positional Markedness

a. /bad/	IDENTOnset	*LAR	IDENT	b. *LAR/coda	IDENT	*LAR
i. bad		**!		*!		*
ii. pat	*!		**		**!	
iii. pad	*!	*	*	*!	*	**
☞ iv. bat		*	*		*	*

(5) Positional Faithfulness and Positional Licensing

/bad/	IDENTOnset	*LAR	IDENT	LIC(lar)/onset	*LAR/coda
i. bad		**!		*	*
ii. pat	*!		**		
iii. pad	*!	*	*	*	*
☞ iv. bat		*	*		

(6) Positional Faithfulness and Positional Licensing in regressive assimilation

/...pd.../	AGREE	IDENTOnset	*LAR	IDENT	LIC(lar)/onset	*LAR/coda
☞ i. b.d			**!	*	✓	*
ii. p.t		*!		*		
iii. p.d	*!		*			

(7) Metaphony as licensing

$\begin{array}{c} -F \quad +F \\ \quad \\ /CV'CVVCVCV/ \end{array}$	LIC(F)/P	IDENT(F)/R	IDENT(F)/Px	IDENT(F)
$\begin{array}{c} -F \quad +F \\ \quad \\ \text{a. } CV'CVVCVCV \end{array}$	*!			
$\begin{array}{c} -F \\ / \quad / \quad / \\ \text{b. } CV'CVVCVCV \end{array}$		*!		***
$\begin{array}{c} +F \\ / \quad / \\ \text{c. } CV'CVVCVCV \end{array}$			*	**
$\begin{array}{c} +F \\ / \quad / \quad / \\ \text{d. } CV'CVVCVCV \end{array}$			*	***

(8) Harmony as licensing

$\begin{array}{c} -F \quad +F \\ \quad \\ /CV'CVVCVCV/ \end{array}$	LIC(F)/P	IDENT(F)/Px	IDENT(F)/R	IDENT(F)
$\begin{array}{c} -F \quad +F \\ \quad \\ \text{a. } CV'CVVCVCV \end{array}$	*!			
$\begin{array}{c} -F \\ / \quad / \quad / \\ \text{b. } CV'CVVCVCV \end{array}$			*	***
$\begin{array}{c} +F \\ / \quad / \\ \text{c. } CV'CVVCVCV \end{array}$		*!		**
$\begin{array}{c} +F \\ / \quad / \quad / \\ \text{d. } CV'CVVCVCV \end{array}$		*!		***

(9) Unmarkedness constraint

$\begin{array}{cccc} -F & +F & -F & -F \\ & & & \\ /CV'CVVCVCV/ \end{array}$	IDENT(F)/Px	*+F	*-F
$\begin{array}{cccc} -F & +F & -F & -F \\ & & & \\ \text{a. } CV'CVVCVCV \end{array}$		*	*!***
$\begin{array}{c} +F \\ \swarrow \downarrow \searrow \\ \text{b. } CV'CVVCVCV \end{array}$		*	
$\begin{array}{cccc} -F & -F & -F & -F \\ & & & \\ \text{c. } CV'CVVCVCV \end{array}$	*!		****
$\begin{array}{c} -F \\ \swarrow \downarrow \searrow \\ \text{d. } CV'CVVCVCV \end{array}$	*!		*

(11) Sonority and cumulative violation

vowel	liquid	nasal	fricative	stop
****	***	**	*	√

(13) Gradience versus categoriality

		ONSET	H-ONS
a.	.æ.æ.æ.	1+1+1	4+4+4
b.	.æ.æ.	1+1	4+4
c.	.æ.	1	4
d.	.læ.		3
e.	.næ.		2
f.	.hæ.		1
g.	.ʔæ.		0

(15) Gradience versus categoriality

		H-ONS	*[+voc]/Ons	*[+liquid]/Ons	*[+son]/Ons
c.	.æ.	4	*		*
d.	.læ.	3	*	*	*
e.	.næ.	2			*
f.	.ʔæ.	1			

(21) Edge magnetism and categoriality

	NON-FINAL	∇FTR	ALLFTR
a. {σσσσ(σσ)}	*		
∇/A b. {σσσ(σσ)σ}		*	*
∇ c. {σσ(σσ)σσ}		*	**
∇ d. {(σσ)σσσσ}		*	***
e. {σ(σσ)(σσ)σ}		*, *	***, *
f. {(σσ)σ(σσ)σ}		*, *	****, *

(22) The midpoint pathology

	ALIGN(σ, L, Ft, L)	Σ	p	c	f
a. σσσ(σσ)	***, **, *, *	7	6	1	0
b. (σσ)σσσ	*, **, ***, ****	10	0	1	9
☞ c. σσ(σσ)σ	** , *, *, **	6	3	1	2
d. σ(σσ)σσ	*, *, **, ***	7	1	1	5

(23) Evaluation by total score, no prioritization (i.e., unranked/unweighted constraints)

/bagdabgad/	IO-IDENT(voice)	VOP/coda	VOP	Σ
a. bagdabgad		-3	-6	-9
b. bakdabgad	-1	-2	-5	-8
c. bakdapgad	-2	-1	-4	-7
☞ d. bakdapgat	-3		-3	-6
☞ e. bakdapkat	-4		-2	-6
☞ f. baktapkat	-5		-1	-6
☞ g. paktapkat	-6			-6
h. pagtabkad	-3	-3	-3	-9

(24) HG - Contrast with weighted constraints

	IO-IDENT(vce)x3	VOP/Codax1	VOPx1	Σ
☞ /pad/ - pad		-1	-1	-2
/pad/ - pat	-1			-3
☞ /bad/ - bad		-1	-2	-3
/bad/ - bat	-1		-1	-4

(25) HG - Positional neutralization with weighted constraints

	IO-IDENT(vce)x2	VOP/Codax3	VOPx1	Σ
/pad/ - pad		-1	-1	-4
☞ /pad/ - pat	-1			-2
/bad/ - bad		-1	-2	-5
☞ /bad/ - bat	-1		-1	-3

- (26) HG analysis of Lyman's Law and OCP conspiracy (adapted from Pater 2016)

	/dog:u/	IDENT-VOICE 3	OCP-VOICE 2	*VCE-GEM 2	Σ
a.	dog:u		-1	-1	-4
☞ b.	dok:u	-1			-3
c.	tog:u	-1		-1	-5
d.	tok:u	-2			-6

- (27) HG analysis of regressive voicing assimilation and final devoicing

i. /abga/	AGREE 4	IDENTONS 5	VOP 2	IDENT 1	Σ
☞ abga			-2		-4
apga	-1		-1	-1	-7
apka		-1	0	-2	-7

ii. /apga/	AGREE 4	IDENTONS 5	VOP 2	IDENT 1	Σ
☞ abga			-2	-1	-5
apga	-1		-1		-6
apka		-1	0	-1	-6

iii. /abka/	AGREE 4	IDENTONS 5	VOP 2	IDENT 1	Σ
abga		-1	-2		-9
apga	-1	-1	-1	-1	-14
☞ apka				-1	-1

- (28) Directionality switch dependent on underlying specification of one C

i. /abga/	AGREE 4	IDENTONS 3	VOP 2	IDENT 1	Σ
☞ abga			-2		-4
apga	-1		-1	-1	-7
apka		-1		-2	-5

ii. /apga/	AGREE 4	IDENTONS 3	VOP 2	IDENT 1	Σ
abga			-2	-1	-5
apga	-1		-1		-6
☞ apka		-1	0	-1	-4

iii. /abka/	AGREE 4	IDENTONS 3	VOP 2	IDENT 1	Σ
abga		-1	-2		-7
apga	-1	-1	-1	-1	-10
☞ apka				-1	-1

(29) Free variation dependent on underlying specification of Cs

i. /abga/	AGREE 3	IDENTONS 4	VOP 2	IDENT 1	Σ
☞ abga			-2		-4
apga	-1		-1	-1	-6
apka		-1		-2	-6

ii. /apga/	AGREE 3	IDENTONS 4	VOP 2	IDENT 1	Σ
☞ abga			-2	-1	-5
☞ apga	-1		-1		-5
☞ apka		-1		-1	-5

iii. /abka/	AGREE 3	IDENTONS 4	VOP 2	IDENT 1	Σ
abga		-1	-2		-8
apga	-1	-1	-1	-1	-10
☞ apka				-1	-1

(30) Majority rules in vowel harmony

+ --	AGREE 10	FAITH/P 3	FAITH 1	Σ
i. /V _p VV/				
+ -- V _p VV	-1			-10
+ ++ ☞ V _p VV			-2	-2
- -- V _p VV		-1	-1	-4

+ - - - -	AGREE 10	FAITH/P 3	FAITH 1	Σ
ii. /V _p VVVVV/				
+ - - - - V _p VVVVV	-1			-10
+ + + + + V _p VVVVV			-5	-5
- - - - - ☞ V _p VVVVV		-1	-1	-4

(31) Partially ordered constraints

i.		A	B	C
☞	a			*
☞	b	*	*	
	c	*	*	*

ii.	A	B	C
☞			*
	*!	*	
	*!	*	*

iii.	A	C	B
☞		*	
	*!		*
	*!	*	

iv.	B	A	C
☞			*
	*!	*	
	*!	*	*

v.		B	C	A
☞	a		*	
	b	*!		*
	c	*!	*	*

vi.	C	A	B
	*!		
☞		*	*
	*!	*	*

vii.	C	B	A
	*!		
☞		*	*
	*!	*	*

(33) Sonority and cumulative violation of H-Nuc

vowel	liquid	nasal	fricative	stop
√	*	**	***	****