Typology in Optimality Theory

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Abstract

The mechanism of constraint re-ranking basis makes Optimality Theory a typologically oriented theory of phonology. By permuting the prioritization of constraints on a language specific basis a factorial typology of phonological patterns is generated. The factorial typology may be constrained by the incorporation of phonetically-driven constraint hierarchies that capture implicational distributions. Patterns generated by an Optimality-theoretic account can be compared to the set of attested patterns found in languages of the world to determine how well the analysis fits the observed typology. A particular challenge is presented by overgeneration, which may be pathologic, may reflect accidental gaps due to the paucity of a given phenomenon, or may be grounded in diachronic biases in speech perception.

1. Introduction

The primary responsibility of any phonological theory is to capture the range of variation observed in sound systems of the world's languages. While all theories take this goal seriously, the formalism of Optimality Theory (Prince and Smolensky 2004) is particularly well suited to making explicit typological predictions that can be rigorously tested by permuting the prioritization of a series of phonological constraints. The fundamental assumption of Optimality Theory that constraint ranking varies from language to language has provided fertile ground for typological research in phonology.

2. The formalism of Optimality Theory

Unlike earlier rule-based generative treatments of phonology, Optimality Theory (Prince and Smolensky 2004), abbreviated OT, in its original conception assumes a one step mapping between underlying and surface forms. The crucial element in this mapping operation is a set of hierarchically ranked constraints that evaluate a series of potential surface forms, or candidate forms, corresponding to the underlying form. These constraints are of two basic types. Some constraints are sensitive to the well-formedness of candidate forms, banning dispreferred or marked structures or requiring felicitous or unmarked properties. Other constraints are sensitive to the mapping, or correspondence, between underlying forms and candidate forms. Ideally all constraints find principled motivation in independent properties of speech production, perception, and processing. By imposing this grounding requirement on constraints, OT avoids a proliferation of unprincipled constraints and the unattested patterns they would generate (see section 7 for further discussion of generation in OT). The actual surface form is determined by evaluating how well the candidates satisfy the constraints, which, in many cases, impose competing demands. Crucially, the ranking of constraints varies from language to language, thereby accounting for cross-linguistic variation in surface forms.

To take an example of constraint evaluation and language specific constraint ranking, consider the case of syllable structure. Many languages, e.g. Hawai'ian, Cayuvava, only allow open syllables, whereas other languages also permit syllables closed by a consonant. The dispreference for closed syllables is attributed to a constraint against coda consonants, *CODA, where the asterisk indicates that a given structure is prohibited. A competing constraint, FAITHC, requires surface faithfulness to underlying consonants, i.e. requires that underlying consonants survive to the surface. Given an underlying string consisting of a consonant-final root followed by a consonant-initial prefix, i.e. CVC-CV, there are at least two possible candidates in competition to surface. One of the two intervocalic consonants could be deleted, a strategy that would satisfy the ban on coda consonants but that would run afoul of FAITHC due to its missing consonant. Alternatively, both members of the consonant cluster could be preserved, thereby honoring faithfulness but not the ban on coda consonants. The ranking of *CODA and FAITHC relative to each other in a given language determines that language's response to the potential consonant cluster. If *CODA outranks FAITHC, one of the consonants does not survive to the surface, whereas if FAITHC is ranked above *CODA, both intervocalic consonants emerge unscathed. These two outcomes are depicted in (1) by means of a tableau, the standard way of formalizing OT. First, in (1a), the ranking of *CODA above FAITHC is depicted, while in (1b), the ranking of the two constraints is reversed.

(1) Two rankings of CODA and FAITHC

(a) Coda deletion: *CODA >> FAITHC

/CVC-CV/	*CODA	FAITHC
☞ CVCV		*
CVCCV	*!	

(b) Coda preservation: FAITHC >> *CODA

/CVC-CV/	FAITHC	*CODA
CVCV	*!	
☞ CVCCV		*

In tableaux, the underlying (or “input”) form customarily appears in the top left corner followed in the same column by competing candidate forms corresponding to that underlying form. After the first column, each constraint is given its own column where constraints to the left outrank those to their right. Each cell under a constraint name depicts the number of times the candidate in the corresponding row violates that constraint, where each violation is indicated by an asterisk. A candidate that commits one or more violations of a constraint is eliminated from contention, indicated by an asterisk after the fatal violation, if there is at least one other surviving candidate that commits fewer violations of that constraint. Candidates are gradually eliminated as constraint evaluation proceeds from higher to lower ranked constraints until there is only one candidate remaining. This winning candidate is the surface form, traditionally indicated by a pointing finger ☞. Crucially, once a candidate is weeded out due to a violation of a high ranked constraint, it cannot be redeemed no matter how well it satisfies lower ranked constraints. Cells that occur to the right of a fatal violation as well as cells occurring to the right of the constraint that has enabled determination of a unique winner are shaded to indicate their irrelevance to the process of selecting a winning candidate.

In (1a), the second candidate, the one containing both consonants in the cluster, is eliminated from contention due to its violation of the anti-coda constraint. This leaves the first candidate, the one in which a consonant has been deleted, as the winner even though it commits a violation of lowly ranked faithfulness. If the constraints are reversed, the faithful candidate with both intervocalic consonants emerges victorious, as shown in (1b).

Of course, other constraints come into play in the evaluation of additional candidate forms corresponding to the input. For example, in languages in which *CODA is ranked above FAITHC, another constraint must determine which of the intervocalic consonants is deleted in order to satisfy *CODA.

3. Reranking and typology in OT

Cross-linguistic variation in rankings is one of the cornerstones of Optimality Theory and makes the theory inherently well suited to tackle typological issues in phonology. An OT analysis of a given phenomenon can be evaluated on the basis of how closely the patterns predicted through constraint re-ranking, as in our syllabification example in 2, fit patterns attested in languages of the world. Ideally, the patterns generated through permutation of the constraint rankings exactly match the set of patterns found cross-linguistically. In reality, this ideal fit is seldom achieved. Rather, analyses typically overgenerate by predicting patterns that either do not occur cross-linguistically or at least have not been identified yet. Overgeneration is often difficult to assess critically, since unattested patterns predicted to occur by an analysis potentially reflect accidental gaps due to insufficient cross-linguistic data as opposed to pathologic patterns that could not reasonably be expected to occur. More seriously, analyses may undergenerate by failing to capture patterns that have been found in one or more languages. The issue of overgeneration and undergeneration in OT is discussed in section 7.

4. Conspiracies in OT

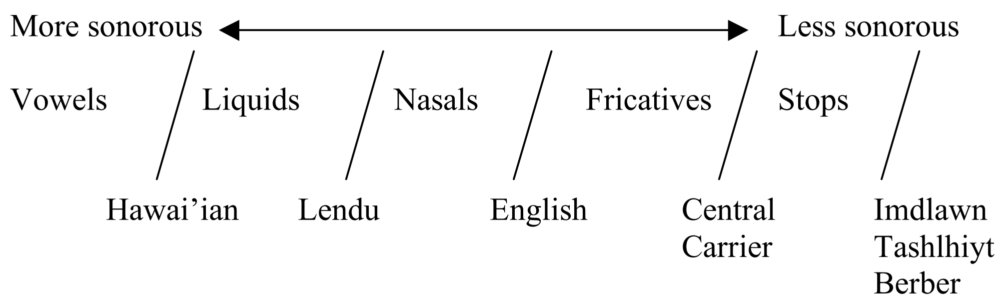
One of the virtues of Optimality Theory in the typological domain is its prediction of "conspiracies": instances where different languages employ diverse strategies that conspire to avoid the same ill-formed configuration. OT explicitly predicts the existence of such conspiracies due to its formal separation of constraints banning a particular structure from constraints sensitive to potential ways of eliminating that prohibited structure. For example, the constraint against coda consonants merely penalizes candidates that have a coda consonant without determining the path a language will take to avoid codas. There are several routes a language could take to avoid coda consonants ranging from deletion of the first consonant ($CVC_1C_2V \rightarrow CVC_2V$), to deletion of the second consonant ($CVC_1C_2V \rightarrow CVC_1V$), to insertion of an epenthetic vowel ($CVC_1C_2V \rightarrow CVC_1VC_2V$), to changing a consonant into a vowel ($CVC_1C_2V \rightarrow CVVC_2V$). The choice among these options is governed by the relative ranking of other constraints, e.g. an anti-epenthesis constraint banning vowels that are not present underlyingly, an anti-deletion constraint requiring that underlying consonants surface, a constraint banning the conversion of an underlying consonant to a vowel on the surface. A key feature of the OT analysis is its unification of these processes as strategies all serving the same goal driven by the same constraint against codas. This differs from traditional rule-based approaches that collapse the ill-formed configuration and the process eliminating the ill-formed structure into a single rule. The result is a series of formally distinct rules, each one capturing a different strategy for avoiding codas. Crucially the common goal uniting the various coda elimination processes is not transparent in the rule-based analysis and the set of possible rules predicted by the theory is not logically limited to those repairing ill-formed structures. For example, it is not clear what precludes the existence of a rule inserting a coda consonant intervocalically. In OT such an operation could only occur in order to satisfy a highly ranked constraint on syllable structure. If there were no constraint that penalized codaless syllables, the theory would never predict coda insertion. Crucially, such a constraint would be ungrounded, since there would be no phonetic or functional reason why a closed syllable would be preferred to an open syllable. In contrast, the constraint against coda consonants is motivated by perceptual considerations: coda consonants occur in an environment where they are less readily identifiable than onset consonants (see Jun 2004, Steriade 1999, 2001 for discussion in the context of OT).

5. Implicational hierarchies and OT

An important typological feature that must be handled by any phonological theory is the existence of implicational relationships. For example, the presence of closed syllables in a language implies the occurrence of open syllables in that language. Crucially, the converse implication is not true: there are many languages with open syllables that lack closed syllables. As we have seen, this particular implication is handled in OT by assuming a perceptually-driven constraint against coda consonants but not its ungrounded counterpart banning codaless syllables. Given this constraint inventory, only two possible patterns are generated: a language with no coda consonants, a pattern resulting from a highly ranked *CODA, and a language with both closed and open syllables, a distribution attributed to the prioritization of the constraint requiring that underlying consonants be preserved. It is impossible to generate a language that requires coda insertion since no constraint mandates that all syllables be closed.

Beyond this simple binary implication relationship holding of closed and open syllables, there are other more complex implications sensitive to hierarchies. For example, the selection of syllabic peaks adheres to a hierarchy that closely mirrors sonority scales (e.g. Steriade 1982, Selkirk 1984, Clements 1990, Parker 2002). All languages preferentially choose more sonorous segments as syllable nuclei than less sonorous sounds. Using a relatively coarse hierarchy like that depicted in (2), vowels are preferred as syllable peaks over liquids, liquids are preferred over nasals, which, in turn, are preferable to fricatives, which, in turn, make better peaks than stops. Languages differ in the cut-off point they impose between sounds that could potentially be syllable nuclei and those that are not permissible peaks, as shown in (2) (Blevins 1995).

(2) Implication hierarchy of syllabification of syllable peaks



For example, English tolerates vowels as peaks, liquids as peaks, e.g. in the second syllable of *little* and *butter*, and nasals as peaks, e.g. in the second syllable of *button* and *prism*. No syllable, however, may have a fricative or stop as a syllable nucleus in English. Hawai'ian is more restrictive in the segments that can serve as nuclei: only vowels may be syllable peaks. Imdlawn Tashlhiyt Berber, on the other hand, allows any type of sound, even stops, to be syllable nuclei. Crucially, there are no languages that tolerate less sonorous sounds as nuclei but disallow more sonorous nuclei. The occurrence of relatively non-sonorous syllable peaks thus implies the existence of more sonorous peaks in languages of the world.

Prince and Smolensky (2004) capture the distribution of syllable nuclei by positing a series of constraints governing the ability of different sound to be peaks. Constraints take the form *P/*x*, meaning that segment type *x* is prohibited as a nucleus, where *x* is a variable ranging over different sounds. Thus, if we collapse for the sake of illustration some of the distinctions made by Prince and Smolensky, one constraint, *P/V, prohibits vocalic nuclei, another constraint, *P/L, bans liquids from being peaks, yet another constraint, *P/N, penalizes nasals serving as syllable nuclei, while other constraints ban syllabic fricatives (*P/S) and syllabic stops (*P/T). In order to capture the implicational nature of the syllabicity hierarchy, Prince and Smolensky assume that the ranking of the peak constraints adheres to a universal hierarchy, where constraints banning less sonorous nuclei outrank constraints banning more sonorous nuclei, as in (3)

(3) Constraint hierarchy for syllabification of syllable peaks

Less sonorous nuclei ◄				► More sonorous nuclei
*P/T >>	*P/S >>	*P/N >>	*P/L >>	*P/V

They assume that the syllabicity hierarchy is ultimately projected from a scale of intrinsic prominence, which turns out to be most closely linked to the phonetic property of intensity (Ladefoged 1975, Parker 2002). Crucially, if one did not assume that the ranking of syllabicity constraints is fixed, we would incorrectly predict a number of unattested patterns. For example, if *P/V could be ranked above *P/T, we would generate a language in which stops could be syllable peaks but vowels could not be. Such a language is unattested and should thus not be predicted by an analysis to occur. Other competing constraints are interleaved with constraints on syllabicity thereby producing the observed cross-linguistic variation in syllable peak formation. For example, *CODA is often better satisfied in many positions by creating another syllable. Thus, the word-final string [kot] violates *CODA if the [t] is syllabified as a coda to the syllable headed by [o]. If, on the other hand, [t] is made into a nucleus, i.e. [ko.t], a violation of *P/T is incurred.

Several works in OT have posited universal constraint hierarchies for a number of phonological properties, e.g. , Kenstowicz (1997) on sonority-driven stress, De Lacy (2001) on tone-sensitive stress, Gordon (1998, 2001) and Zhang (2002, 2004) on tone, Jun (2004) and

Steriade (2001) on place assimilation, Steriade (1999) on laryngeal neutralization, Kirchner (2004) on consonant lenition. These hierarchies all seem to be grounded in phonetic and functional factors parallel to the constraints governing syllable peak formation.

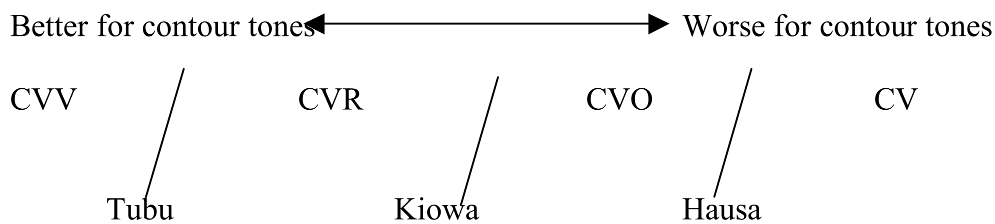
Let us consider two representative analyses of phonological hierarchies appealing to phonetically-driven scales: one governing the distribution of contour tones (Gordon 1998, 2001) and the other sensitive to the preservation of laryngeal contrasts (Steriade 1999).

5.1. Phonetic scales I: contour tones

Gordon (1998, 2001) posits a hierarchy of constraints capturing the ability of different syllable types to support contour tones (see also Zhang 2002, 2004 for a different scale of phonetically-driven constraints on tone). Syllables containing long vowels (CVV) are best suited to realizing contour tones, followed by syllables consisting of a short vowel followed by a sonorant coda (CVR), followed by syllables containing a short vowel plus obstruent coda (CVO), followed by open syllables containing a short vowel (CV).

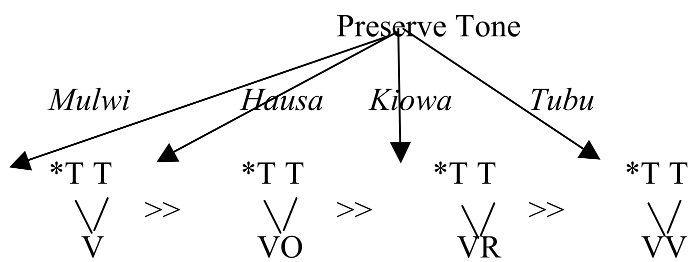
The hierarchy of contour tones is a function of the ability of different segment types to support tonal information. Vowels are best suited to carrying tones followed by sonorant consonants, and then obstruents. Long vowels are best for supporting contour tones since they provide the longest backdrop of maximal sonority for realizing the full tonal excursion associated with a contour. Many languages, 25 in Gordon's (2001) survey, thus only allow contour tones on CVV syllables. CVR syllables provide the next best docking site for a tonal transition. Accordingly, many languages (29 in Gordon's study) tolerate contours on both CVV and on CVR but not on other syllable types. CVO is considerably less effective for realizing contour tones, only slightly better than CV. It is thus not surprising that very few languages (only 3 in Gordon's survey) preferentially allow contour tones on CVO but not on CV. As predicted by the phonetic considerations guiding the realization of tonal contours, no languages preferentially allow contour tones on syllables that are relatively poor conveyors of tone but disallow contours on syllable types better suited to realizing tone. The hierarchy of contour tone bearing ability and the resulting phonological patterns corresponding to different cut-off points in the hierarchy are given in (4).

(4) Implicational hierarchy of contour tones



A series of constraints accounts for the implicational scale of contour tones. A constraint against contour tones on open syllables with short vowels is at the top of the constraint hierarchy, followed in turn by a constraint banning contour tones on short voweled syllables closed by an obstruent, then a constraint prohibiting contours on short voweled syllables closed by a sonorant, and finally a constraint against contours on syllables containing a long vowel. Interlanguage variation in the cut-off points in the hierarchy between syllables that allow contours and those that do not is attributed to competing faithfulness constraints that act to preserve underlying contour tones. Depending on the ranking of faithfulness relative to the contour tone well-formedness constraints, different patterns are generated. For example, if faithfulness is outranked by all the constraints against contour tones, contours are not permissible on any syllable types. If faithfulness is prioritized over only the constraint against contours on CV, a language with contour tones on all syllable types except CV is generated. If faithfulness outranks both the constraint against contours on CV and the constraint banning contours on CVO, the resulting pattern permits contours on CVV and CVR but not on CVO or CV. If faithfulness takes precedence over all anti-contour constraints except the one referring to CVV, we get a language that tolerates contours only on CVV. Finally, if faithfulness is ranked above all anti-contour tone constraints, contours are permitted on all syllable types. The schematic ranking of faithfulness relative to constraints governing tone-to-syllable associations and the resulting tonal patterns are shown in (5).

(5) Interaction of faithfulness with contour tone restrictions



5.2. Phonetic scales II: laryngeal neutralization

Steriade (1999) explores the distribution of laryngeal contrasts in obstruents, i.e. contrasts involving voicing, aspiration, or glottalization. She develops an account of the neutralization of laryngeal contrasts grounded in perceptibility factors. Laryngeal contrasts are more likely to be lost where the contrast is less likely to be clearly audible. For example, contrasts between voiced and voiceless obstruents are less likely preceding another obstruent than before a sonorant, since a following sonorant provides a far better backdrop for the salient realization of important right edge cues to an obstruent's laryngeal features, e.g. voice-onset time, burst amplitude, fundamental frequency, first formant frequency, than a following obstruent. Steriade documents a perceptibility hierarchy which mirrors an implicational hierarchy in the distribution of laryngeal contrasts cross-linguistically: laryngeal contrasts are only preserved in a given context if they are also preserved in other contexts in which the contrast is perceptually more viable. This hierarchy is sensitive both to the sound preceding and following the laryngeal contrast and whether the contrast occurs at the left or right edge of a word. Crucially, for most obstruents, the following sound is more important in determining the perceptual robustness of a contrast, since the more decisive cues to an obstruent's identity reside at the release of an obstruent rather than during the transition from a preceding sound. The perceptibility scale is thus primarily a function of the right edge context in which the obstruent occurs. Steriade posits a series of constraints banning laryngeal contrasts in environment *x*, where x varies according to the contexts in (6). Languages draw different cut-off points between permissible and impermissible contexts for voicing contrasts. Contrasts are allowed in all contexts to the left of the demarcation point.

(6) Implicational hierarchy of environments for laryngeal neutralization

Voicing contrasts preferred ◄────────► Voicing contrasts dispreferred

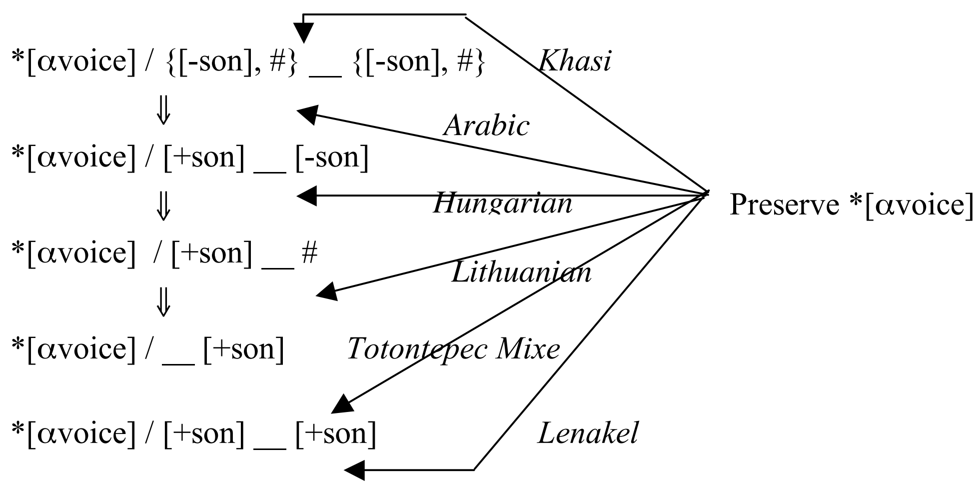
Nowhere / intersonorant / presonorant / word-finally / preobstruent / everywhere /

Lenakel / Totontepec Mixe / Lithuanian / Hungarian / Arabic / Khasi

The laryngeal well-formedness constraints obey a universal hierarchy corresponding to the perceptibility scale in (6). A competing constraint, Preserve *[αvoice], requires faithfulness to underlying contrasts. Steriade characterizes the faithfulness constraint in terms of [αF], where F stands for the relevant laryngeal feature, in this case [voice], and α indicates both positively and negatively specified voicing values. This notation captures the fact that the perceptibility of the contrast between voiced and voiceless sounds is at stake rather than the perception of just one or the other. The result of contrast loss is a stop which lacks its own voicing target gesture and instead receives its surface realization as a function of its environment: voiced when adjacent to voiced sounds, voiceless when adjacent to voiceless ones and in final position, where aerodynamic factors encourage devoicing.

By varying the ranking of the faithfulness constraint relative to the constraints banning contrasts, different laryngeal neutralization patterns corresponding to the hierarchy in (6) are produced, as shown in (7).

(7) Ranking of constraints governing voicing contrasts



6. Computer generated factorial typology in OT

The constraint-based formalism of OT coupled with recent advances in computational power has allowed for rigorous evaluation of the typological coverage of analyses using computer software. For example, OTSoft (Hayes et al. 2000) takes a set of user entered constraints and generates the set of output patterns, the factorial typology, resulting from all possible ranking permutations of the constraints. Employing software for calculating the factorial typology generated by an analysis represents an important advance since even an analysis with a relatively small set of constraints outstrips the human's ability to thoroughly assess the predictions of an analysis. An analysis employing even six constraints has 720 possible ranking permutations (6!), while one with 10 constraints has 3,628,800 rankings! It is often only through computer aided factorial typology generation that undesirable predictions of an analysis become apparent.

Gordon (2002) provides an example of computer generated factorial typology in the area of metrical stress theory. He focuses on weight-insensitive stress systems in which the location of stress is predictable on phonological grounds without reference to the internal structure, or weight, of syllables. Some examples of weight-insensitive stress patterns include languages that place stress on the initial syllable of words, e.g. Chitimacha, those that stress the penultimate syllable, e.g. Nahuatl, those with second syllable stress, Koryak, and those with final stress, Atayal. Also falling under the heading of weight-insensitive systems are languages with two stresses per word, e.g. initial and penultimate (e.g. Lower Sorbian), and languages which stress alternating syllables counting from either the right or left edge of words, e.g. stress odd-numbered syllables counting from the left (e.g. Maranungku) or stress even-numbered syllables counting from the right (e.g. Cavineña)

Gordon posits a set of 12 constraints designed to account for all known species of weight-insensitive stress. Permuting the constraints such that all of the 479,001,600 possible rankings were tested would have been an intractable task without the aid of a computer. Submitting the 12 constraints to the factorial typology component of OTSoft generates a total of 79 patterns, a small subset of the nearly 11 trillion logically possible stress systems for words containing between 1 and 8 syllables. Crucially, all of the stress patterns found in an extensive cross-linguistic survey of weight-insensitive stress systems are generated by Gordon's analysis. The account also generates a number of apparently unattested in languages of the world, though most of the non-existent systems contain elements that are found in other languages but not in the exact combination observed in the unattested systems. For example, one generated pattern situates stress on both the second and the final syllable of the word, conflating two stress locations observed in isolation.

7. The evaluation of overgeneration in an OT analysis

While the failure of an analysis to offer complete empirical coverage of the attested phonological patterns is clearly a shortcoming of that analysis, it is more difficult to evaluate the generation of unattested patterns that is virtually guaranteed to occur in any exhaustive treatment of a phenomenon. One possibility is that unattested patterns merely reflect accidental gaps due either to lacunae in our typological knowledge of a phenomenon or to a paucity of languages providing probative distributional data for the examined property.

An example of the former type of accidental gap is plausibly provided by secondary stress patterns. Gordon's (2002) account of stress predicts a number of systems with secondary stresses that appear to be unattested. However, many grammars report only on the location of primary stress, the perceptually most prominent type of stress. It is thus conceivable that further study of many of the languages described in those grammars will reveal the existence of secondary stress in addition to primary stress and that the patterns discovered in these languages will fill some of the gaps in the factorial typology generated by Gordon's constraint set.

For many phenomena, discrepancies between attested patterns and predicted patterns might simply be due to the rarity of a phenomenon. For example, although Steriade (1999) fully fleshes out the typology generated by varying the ranking of faithfulness relative to a constraint banning voicing contrasts, her account also extends to neutralization of the contrast between voiceless stops and ejectives. We may thus assume a parallel set of constraints banning contrasts between voiceless stops and ejective stops since this contrast also relies heavily on the stop release and thus the following context. As expected, typological inspection of ejectives suggests a hierarchy of sites in which ejective and voiceless stops are contrasted. Thus, Kabardian tolerates ejectives in a full range of environments including before obstruents, word-finally, and before sonorants. Hupa, on the other hand, restricts ejectives to word-final and presonorant position. Navajo only permits ejectives in presonorant position. Kabardian, Hupa, and Navajo thus instantiate three patterns in the continuum of perceptibility established through evaluation of voicing. I am not aware, however, of any languages that only tolerate ejectives between sonorants, the ejective analog to the Totontepec Mixe voicing pattern in (6). Nor am I aware of any languages that tolerate ejectives before another obstruent but only if the ejective is preceded by a sonorant, a distribution parallel to that observed for voicing in Arabic. Furthermore, I am not aware of any languages in which the syllabic nature of a following sonorant consonant influences ejective contrasts, the ejective analog to a pattern found in Russian, whereby a syllabic sonorant consonant before another consonant optionally blocks voicing neutralization in a preceding obstruent while a non-syllabic sonorant in preconsonantal position fails to block neutralization in a preceding obstruent. (Steriade attributes the Russian pattern to the greater length of syllabic sonorants, which allow for a longer and thus more salient realization of transitional cues to voicing.)

Even if such patterns turn out to be unattested for ejectives, these gaps arguably could merely be an artifact of the independent rarity of languages with ejective stops. Thus, only 16.4% of the languages in Maddieson's (1984) survey of 317 languages possess ejectives compared to 66.9% that possess voiced stops. Given the relative paucity of ejectives cross-linguistically, there are a priori fewer chances to instantiate all patterns generated by an analysis. Overgeneration in the case of ejectives is thus less likely to reflect a weakness in the theory than overgeneration in the case of voiced stops. Steriade also develops a perceptually-driven account of preaspirated stops, in which the preceding context plays the primary role in determining their distribution. However, fewer divisions along the perceptibility hierarchy appear to be exploited by languages for preaspiration than for voicing. This also is probably not surprising in light of the independent rarity of preaspiration in languages of the world.

8. Typology as a diachronic phenomenon

There is another possible interpretation of overgeneration in factorial typology. Myers (2002) suggests that certain patterns predicted to occur by an analysis may reflect systematic gaps attributed to phonetic biases against such patterns. Under this view, which is consistent with work by Ohala (1981), Hyman (2001), Blevins and Garrett (2004) and others, the phonetic basis for well-formedness constraints is diachronic rather than synchronic resulting from misapprehensions of patterns intended by the speaker. According to Myers (2002), unattested patterns predicted to occur by an analysis may be absent because they are unlikely to arise phonetically. For example, Myers discusses gaps in the typology of strategies for avoiding nasal plus voiceless obstruent clusters, which are phonetically dispreferred because aerodynamic conditions favor voicing following nasals (Hayes 1999). Pater (199) shows that several ways of avoiding nasal plus voiceless obstruent clusters are attested cross-linguistically, including voicing of postnasal obstruents, deletion of the nasal, deletion of the voiceless obstruent, and replacement of the nasal with a voiceless obstruent. Pater develops an OT analysis of these strategies in which a well-formedness constraint against nasal plus voiceless obstruent clusters drives the elimination of these clusters while various faithfulness constraints determine which strategy for eliminating the ill-formed structures is adopted in a given language. In addition to predicting the attested strategies for resolving nasal plus voiceless obstruent clusters, Pater's analysis also predicts a number of unattested strategies, including lenition of the obstruent to a sonorant, epenthesis of a vowel between members of the cluster, and metathesis of the consonants. Myers suggests that the attested patterns are attributed to historical changes resulting from phonetically plausible misapprehensions on the part of listeners. For example, the overlap of perseverative voicing from the nasal with the voiceless obstruent could easily lead to the obstruent being perceived as voiced. Conversely coarticulatory overlap could be regressive in which case the nasal might become devoiced. Over time, the devoiced nasal might either fail to be perceived as distinct from the following obstruent, in which case the result would either be deletion of the nasal or reinterpretation of the nasal as the first half of a voiceless geminate. Alternatively, the velum lowering gesture associated with the nasal could overlap rightward onto the following obstruent making the obstruent less perceptible and thus likely to delete. The unattested patterns, on the other hand, are less likely to arise as misapprehensions on the part of the listener. Although it is possible for an intrusive vowel to occur upon release of a stop, including a nasal stop, this vowel should occur before both voiceless and voiced obstruents since it is not conditioned by voicing but rather by manner of articulation. Similarly, lenition of the voiceless obstruent is also unlikely to be sensitive to voicing of the preceding nasal. Myers argues that it is not incumbent upon an OT analysis to fail to generate the unattested patterns since such patterns are precluded on phonetic grounds. In support of the view that the role of phonetics in phonology is diachronic rather than synchronic, Hyman (2001) shows that not all constraints are phonetically natural. Rather, a series of historical events, each of which might itself be phonetically natural, might conspire to create a phonetically unnatural synchronic pattern, such as postnasal *devoicing*. The role of phonetics as a diachronic vs. synchronic factor in sound systems is an ongoing debate in phonological theory (see papers in Hayes et al 2004 for discussion).

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