Quantification in Structural Descriptions:
Attested and Unattested Patterns [1]

Charles Reiss

Abstract

This paper represents a contribution to the theory of 'substance free' phonology. The need for quantificational statements to express identity and nonidentity conditons in phonology entails the rejection of feature geometry. Feature geometric representation is insufficiently powerful, and must be replaced by an algebraic form of representation that allows the use of variables and indices for the purposes of identity checking. An attempt is made to explain apparent gaps in attestation of certain combinations of posited phonological primitives on phonetic grounds, instead of appealing to constraints on phonological computation. The paper challenges the empirical and conceptual validity of the Obligatory Contour Principle.

1. Introduction

This paper represents a contribution to the theory of 'substance free' phonology discussed by Hale and Reiss (2000ab), with antecedent and parallel suggestions by various scholars. The reader is referred to these works for fuller justification of this approach, since only a brief overview is provided in section 2. The claims of the present paper concerning the formal apparatus available to the phonological component of the human language faculty are not incompatible with other approaches to generative phonology, however, they illustrate the kinds of issues that substance free phonology treats as being of primary importance. The paper is further biased against models of phonology that rely on markedness constraints that evaluate the wellformedness of phonological representations. Again, the reader is referred elsewhere (Reiss 2002) for development of this viewpoint and its implications for a theory of Universal Grammar and language acquisition, although these topics will be touched upon briefly. The reader is thus asked to focus on a very narrow claim concerning the minimal computational apparatus needed by phonology.

2. Substance free phonology

The central claim of substance free phonology is that the symbol manipulating computations of the phonology have no access to the phonetic content (acoustics or physiological information) that corresponds to the features which make up phonological representations. Thus, for us, the mappings between the output of the grammar and the articulatory / perceptual systems are not part of phonology, by definition. Instead Hale and Reiss propose that they are to be accounted for by a pair of *transducers* or a pair of sets of transducers. Unlike the computations of the phonology, whose inputs and outputs are both described in the same representational alphabet, a transducer converts between different representational formats, or even between physical / neurological states and symbolic representations (see Pylyshyn 1984). The relevant mappings are shown in (1), where I is the input to the phonology, an underlying representation, and O is the output of the phonology, a surface representation:

(1) Relevant mappings (I and O are featural, symbolic representations):

- Grammar (Phonology): $I \leftrightarrow O$
- $\text{Transducer}_{auditory}$: $O \leftrightarrow AuditoryPercept$
- $\text{Transducer}_{articulatory}$: $O \leftrightarrow GesturalScore$

Note that this model obeys strict modularity—the Grammar can't 'see' inside the Transducers, and the Transducers can't see inside the Grammar or each other. Only the *output* of one module may be fed to another. This view allows us to take a new perspective on an old question: Are features articulatory or acoustic? The answer is that they are neither—features are just the symbolic arguments of the two transducers under consideration. Once we realize that the actual acoustics or articulation of speech can hardly be stored (there are no sound waves stored in our brains!) this conclusion is inevitable.

What is left for phonologists to work on once the substantive tendencies subsumed under markedness theory are excluded from consideration? The goal of this paper is to illustrate how much there is to do on the discovery of the formal properties of phonological systems. In particular, I attempt to develop the "adequate formal account of identity references" that Odden (1988) demonstrates is necessary for phonological theory. As Odden points out

> ... languages differ in what constitutes 'identical' segments. Biblical Hebrew identical consonant fusion requires reference to complete identity (including voicing). Syrian Arabic allows identity to ignore pharyngealization and voicing, Koya allows identity to ignore retroflexion, and Telugu Syncope requires only rough identity computed at the place of articulation, which ignores voicing and narrow place distinctions such as alveolar/retroflex/palatal (461).

We will look at some of this data below in section 3, which discusses the status of the Obligatory Contour Principle (OCP) from both an empirical and methodological perspective.

Again following Odden, I assume that "It is misguided to attribute every accidentally true statement about human language [or particular human languages—cr] to UG, for doing so trivializes the theory of UG itself"(461). Thus, linguistic theory should attempt to unify diverse phenomena by analysing them at an appropriately abstract level, instead of merely cataloging observations.[2] In this spirit, I follow up on Odden's groundbreaking work, and related observations by Archangeli and Pulleyblank (1994), to propose that phonological theory needs the power provided by the existential quantifier and the universal quantifier to express identity references as conditions within the structural description of rules. Section 5 develops the notion of identity and nonidentity conditions in rules, and in section 6 I propose and justify a new notation for expressing such conditions. This extension of Odden's work does not depend on the physical correlates of phonological features, but rather treats them as abstract mathematical entities. Thus this work helps us to discover the formal properties of phonological computation. Since the relationship of phonetic substance to phonological features is mediated by transduction, which, by definition, is not part of the phonology, the *only* properties the phonology has are *formal* properties.

Building on these results, I show that the need for quantificational statements entails the rejection of feature geometry in phonological representation. Feature geometric representation is insufficiently powerful, and must be replaced by an algebraic form of representation that allows the use of variables and indices for the purposes of identity checking.

3. Evaluating the OCP as a rule blocker

In various languages, vowels may appear to be exempted from a deletion process, just in case their deletion would cause identical consonants to be adjacent. For example, in Biblical Hebrew /ka:tab-u:/ → [ka:θvu:] but /sa:bab-u:/ → [sa:vavu:]. The vowel in [sa:vavu:] is said to survive because deletion would bring together the two underlying [b]'s (both of which are spirantized by an unrelated process).[3] McCarthy (1986) calls the 'failure' of the deletion rule to apply *antigemination*, since the rule is 'blocked' if its application would produce a geminate. McCarthy invokes the Obligatory Contour Principle (OCP), familiar from tonal phonology, as the constraint which blocks the rule from applying. In other words, the OCP causes the failure or the deletion rule to apply just in cases where the rule would result in a string of identical adjacent consonants.

Consider the following discussion of McCarthy's proposal from Yip (1988:67):

> If a language has a general phonological rule that is blocked just when the output would contain a sequence of identical feature matrices, we can conclude that the OCP is operating to constrain derivations ... The alternative is an ad hoc condition on such rules, as in [i]:
>
> [i] $A \rightarrow \emptyset / B\_\_C$

Condition: $B \neq C$

> Such a condition not only incurs an additional cost (whereas the OCP is taken to be universal) but also lacks explanatory power, particularly if contexts B and C are necessary only to state the ad hoc condition.

In other words, Yip argues that a theory with language specific rules and a universal OCP is a better theory than one with language specific rules that correctly encode where the rule applies, because adding the necessary conditions to the statement of such rules makes them more complex.

Note that the examples that Yip mentions conform to the first (2a) of the following three types of conditions on rule application, but Odden (1988) points out that in fact vowel syncope rules are found with all three of the following types of conditioning:

(2) Some conditions on vowel deletion rules (Odden 1988:462)

a. Delete a vowel unless flanking Cs are identical.

b. Delete a vowel blindly [whatever the flanking Cs are].

c. Delete a vowel only if flanking Cs are identical.

Condition (2a) can be restated as 'Delete a vowel if flanking Cs are *not* identical'. This is the condition described above, which Yip rejected: $B \neq C$. But note that Odden's type (2c) condition would be written as follows:

(3) Odden's Condition (2c) in the notation Yip rejects: $B = C$

In other words (2a) demands nonidentity and (2c) demands identity of segments in the structural description of a rule. Thus, there is no reason to propose, as McCarthy and Yip do, that rules that conform to condition (2a) illustrate a universal principle of markedness—condition (2c) is also a possible rule condition. A rule like (2c) *only* applies when it creates OCP violations—Odden refers to this phenomenon as *antiantigemination*. So a theory of UG must allow for both types. There is thus no good reason to claim that a universal principle, the OCP, *blocks* deletion in the (2a) cases, since deletion can also be *required* in cases that lead to apparent OCP violations when a rule with conditions (2b) or (2c) applies. Stated in McCarthy's terms (although he does not mention such cases), deletion can be blocked (in case 2c) if the rule will *not* generate an OCP violation. This point was clearly made by Odden, though it seems to have been ignored in most of the subsequent literature.[4]

To state things more bluntly, case (2c) is a counterexample to the claim that (a) reflects a phonological universal.[5] It is incoherent to attribute cases that happen to fit pattern (2a) to a universal principle and ignore cases that fit (2c). Suppose we examine some data concerning a certain phenomenon and find that all cases fall into two conflicting categories, x or y. If we present only cases of x and proclaim that we have found that x is always true, then our claim is not valid, *no matter how many positive examples of x we adduce.* The existence of (2c) cases, makes the existence of (2a) cases uninteresting on their own. The interesting problem is to account for all possible phonological systems—all of the patterns that Odden describes.

4. Phonological 'pathology': The OCP as a rule trigger

According to Yip, the OCP not only *blocks* rule application as in McCarthy's antigemination cases, but also *triggers* it—it may be the case that a rule applies only to an input that violates the OCP. Instead of an argument based on formal simplicity in rule statements, as discussed above, Yip's discussion of the OCP as a rule trigger exemplifies the widely held notion that phonological processes are goal-oriented—they repair structures that are pathological or illformed or marked or disfavored: "The main contribution of the OCP is that it allows us to separate out condition and cure. The OCP is a trigger, a pressure for change" (74).

In Yip's model the 'cure' is effected by language specific rules. In OT models that make use of similar constraints the 'cure' emerges from the constraint ranking. Because of the violability of OT constraints, the winning candidate in an OT derivation is typically not fully 'cured'—certain marked structures may be present in the output form. One goal of this paper is to work towards removing the notion of ill-formedness from the generative component of the phonology. There are representations that are generated, or formed, by grammars; there are representations that are not generated—that is, not formed; but there is no reason to believe that anything a grammar actually generates is ill-formed. They are neither ill-formed, not well-formed—they are just formed (see Reiss 2002 for discussion).

Yip provides a range of examples that show how different solutions can be applied to OCP violations. They include deletion, dissimilation and assimilation rules (where assimilation represents multiple linking of a single node, and not identical adjacent nodes). One example of repair by deletion comes from Seri (Marlett and Stemberger 1983). This language has a rule that deletes a coda glottal stop in a syllable with a glottal stop in the onset:

(4) *Seri Glottal Stops*

a. ʔa-a:ʔ-sanx → ʔ-a:-sanx 'who was carried'

b. ʔi-ʔ-a:ʔ-kašni → ʔi-ʔ-a:-kašni 'my being bitten'

c. koʔpanšx 'run like him!'

Coda glottal stops can sometimes surface, as shown by (4c). The deletion rules only applies to a coda glottal stops, and not to those in onsets, so the second glottal stop in (4b) is not affected. The only glottal stop that is deleted is in (4a), since the preceding glottal stop is in the same syllable. Yip states that

> [we can] assume that the Laryngeal node is absent except for /ʔ/, and the entries for glottalization in [4ab] are thus adjacent and identical and violate the OCP. This violation triggers a rule that operates in the domain of the syllable, and the language chooses [one of the possibilities for repairing OCP violations,] deletion of one matrix (either [+constricted] or [Laryngeal]). The

actual rule has four parts, as shown in (5):

(5) *Glottal Degemination*

Domain: Syllable

Tier: Laryngeal

Trigger:

Change: Delete second

The environment is not stated, so the rule is unable to operate unless triggered "from the outside". The outside trigger is, of course, the OCP, a universal principle and thus free of charge.

For further illustration, Yip suggests that English uses epenthesis to 'cure' OCP violations of adjacent coronal stridents, thus accounting, for example, for the form of the plural morpheme after coronal stridents: *judges, couches, bushes, cases, etc.* In other words, if epenthesis did not apply, the adjacent coronal stridents would constitute an OCP violation. As Odden (1988) points out, the OCP is invoked rather opportunistically—note that it appears to be irrelevant to identity of adjacent [+voiced] specifications in words like *bins, rugs, hills, cars.* More seriously, Odden points out that there are rules that insert vowels only when doing so will specifically *not* repair an OCP violation. This is case (d) below. There are also rules that insert vowels regardless of the nature of the flanking consonants—case (e). And of course, there are rules that, like English epenthesis, depend on the total or partial identity of flanking segments—case (f).

(6) More conditions on vowel insertion rules (Odden 1988:462)

d. Insert a vowel unless flanking Cs are identical.

e. Insert a vowel blindly [whatever the flanking Cs are].

f. Insert a vowel only if flanking Cs are identical.

Parallel to (a), condition (d) can be restated as 'Insert a vowel if flanking Cs are *not* identical.' Thus there is no reason to see (f) as reflecting the OCP as a trigger when (d) shows that rules may be triggered if and only if they *fail* to fix OCP violations. The existence of rules with conditions (c) and (d) make it unlikely that appealing to the OCP as either a trigger or blocker of rules is a fruitful endeavor.[6]

5. Conditions on IDENTITY and NONIDENTITY

More of Odden's data will be presented below. For now, note that it is equally possible for a rule to generate OCP violations (c) as it is to repair them (f). And it is equally possible for a rule to be 'blocked' from generating OCP violations (a) as to be blocked from fixing them (d).[7] Since the goal of phonological theory should be to define the set of computationally possible human languages, Odden's observations provide an excellent opportunity to study the purely formal nature of linguistic rules. In the following discussion, we will concentrate on syncope rules as a matter of expository convenience, however, for completeness, we can mention a few insertion rules before proceeding.

Odden mentions Lynch's (1978) description of Lenakel, with insertion of schwa to break up geminates, and the Modern Hebrew insertion of [e] between stem final [d,t] and suffixal [t] (Bolozky 1977). These rules are examples of type (f)—they require an identity between the flanking consonants for epenthesis to apply. Odden (1988:459) also discusses a rule that inserts schwa into consonant clusters other than nasal plus obstruent in Tondano. Citing Sneddon (1975) Odden shows that the rule is blocked from applying between words if the adjoining consonants are identical:

(7) Epenthesis in Tondano

- **ŋaran ni tuama** → [**ŋaranːi tuama**] 'the man's name'
- **loit rintək** → [**loitərintək**] 'small change'

As Odden later points out (p. 462) this epenthesis rule appears to be optional between words, but is obligatory within words. Odden argues (his fn. 8) that the rule cannot be treated as a syncope rule, and he discusses two ways to handle the 'optional' *vs.* obligatory distinction. However, as he points out, "Either way, epenthesis in Tondano requires reference to identical consonants.' To be precise, the rule applies unless the consonants are identical—that is, only if they are nonidentical. This is a type (d) condition. This example also shows that the question of computing identity and nonidentity is logically independent of the question of real *vs.* fake geminates and morphological or syntactic conditioning.

As we work through the remaining examples, sticking to deletion rules, we will refer to a schematic representation C_1VC_2. Odden's conditions (a) and (c) can be restated as follows:

(8) The NONIDENTITY CONDITION on syncope rules (Version 1)

Delete a vowel if flanking Cs are *not* identical ($C_1 \neq C_2$).

(9) The IDENTITY CONDITION on syncope rules (Version 1)

Delete a vowel if flanking Cs are identical ($C_1 = C_2$).

The apparatus of phonological representation must be at least powerful enough to express the NONIDENTITY CONDITION and the IDENTITY CONDITION. This issue has implications for Feature Geometry as a model of phonological representation.[8]

There is an insightful discussion of the need for Identity Conditions in Archangeli and Pulleyblank (1994:368-373). These authors point out that "linked structures themselves are simply one type of configuration involving identity" (369). Archangeli and Pulleyblank present the 'Identity Predicate', a relation holding between two arguments, which "is important in a wide variety of phonological contexts" (369). In addition to the OCP cases, they cite the case of Tiv where [+round] spreads between vowels, if and only if they agree in height. Arguments against a linked structure analysis of identity conditions include cases where identity holds across a morpheme boundary—since the identical features belong to different lexical items, they cannot be stored as linked.

In the next section, I will formalize the identity condition and offer further arguments for the inadequacy of a 'linked structure' analysis of these conditions. Archangeli and Pulleyblank mention identity conditions holding of whole segments, as well as of individual features. We will see that it is also necessary to allow identity conditions over arbitrary subsets of the feature set. I will also show that linking is inadequate for the expression of nonidentity conditions.

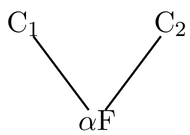
6. Feature algebra and conditions on rules

This section demonstrates that the notation of standard Autosegmental Representation (AR) is insufficiently powerful to represent the Nonidentity Condition and the Identity Condition. I propose a solution to this problem by incorporating basic quantificational logic into an algebraic system of phonological representation called feature algebra (FA). I will argue that this system of representation has all the expressive power of Feature Geometry, as well as additional power that allows us to state hitherto unformulated aspects of phonological UG. The concern of this section will be with stating the structural descriptions (SDs) of rules. In other words, we will concentrate on describing the representations to which a rule applies, and not on the statement of the structural changes effected by the rule.

6.1 Shared feature values

One of the advantages of autosegmental theory, including Feature Geometry, is that it provides us with a visual representation of a situation in which two segments share a single specification for a given feature F_n. Such a situation can be a condition on the application of a rule (or the relevance of a constraint):

(10) Two segments linked to the same valued feature



Suppose that instead of representing this situation geometrically we did it algebraically with indices. For example, let C_1 and C_2 be understood as abbreviations for feature matrices such as the following:

(11) Segments as feature matrices

$$C_1 = \begin{bmatrix} (\alpha F_1)_1 \\ (\beta F_2)_1 \\ (\gamma F_3)_1 \\ \vdots \end{bmatrix} \qquad C_2 = \begin{bmatrix} (\delta F_1)_2 \\ (\epsilon F_2)_2 \\ (\zeta F_3)_2 \\ \vdots \end{bmatrix}$$

F_i denotes a feature, such as [nasal] and Greek letter variables denote the value ($\pm$) that feature F_i has for a given segment.[9] The subscript outside of a pair of parentheses containing αF_i denotes the segment in question; thus, these subscripts are always 1 for C_1 and 2 for C_2.

If we want to express a state of affairs in which C_1 has the same value for some feature F_n as another segment C_2, we can express this as follows:

(12) Identical values for F_n using FA: $[(\alpha F_n)_1] = [(\beta F_n)_2]$

We thus express the fact that C_1 and C_2 have the same value for the feature mentioned. Perhaps we lose the visual metaphor of shared nodes, but the required *identity* condition on values is expressed by the equation. Obviously, this system can be extended to an arbitrary subset of the total set of features, even to the set of all features. We will do so below to formalize the Identity Condition, corresponding to Odden's condition (c).[10]

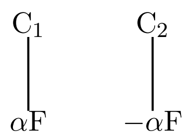
6.2 *Indifferent feature values*

An Autosegmental Representation may show two segments which are not linked with respect to a given feature. In such a case the standard interpretation is that such linking or lack thereof, is irrelevant to the application of the rule in question. The two segments *may* have identical values for a given feature, but this issue does not bear on the rule's applicability. This corresponds to Odden's condition (b). An example is a rule of schwa syncope in Hindi (Bhatia and Kenstowicz 1972). The form *daanəw+i* surfaces as *daanwi*, and *kaanən+i* surfaces as *kaanni*, showing that syncope is indifferent to identity or nonidentity of flanking consonants. The absence of association lines in the AR model is equivalent to the absence of an explicit algebraic statement of a relationship in our algebraic model. Since we constantly write rules which apply to *classes* of sounds in *classes* of environments, it is obvious that some feature values are irrelevant to the application of certain rules. For example, a rule that voices all stops between vowels does not refer to the various place of articulation features of the potential rule targets.

6.3 *Obligatorily different feature values*

Consider a rule which is only applied if two segments *disagree* with respect to some features. That is, consider rules conforming to Odden's conditions (a) and (d). For now let's consider a simple case where the two segments must disagree with respect to a single feature F_n. This can be represented trivially by overtly specifying the two segments, one as αF_n and the other as $-\alpha F_n$:

(13) Autosegmental representation of two segments with distinct values for a feature F



In algebraic terms this is easy to represent:

(14) Distinct values for F_n using FA: $[(\alpha \mathrm{F}_n)_1] \neq [(\beta \mathrm{F}_n)_2]$

The algebraic formulation (14) expresses the fact that C_1 and C_2 have the opposite value for the feature mentioned. Again, it is obvious that this system can be extended to an arbitrary subset of the total set of features. (It can be extended to the whole set, but appears not to be—see below.)

6.4 *The extra power of feature algebra with quantifiers*

Note, however, that there are examples of rule conditions (a) and (d), those that require that two segments be distinct, that cannot be expressed using just feature geometric association lines or feature algebra as sketched thus far. For example, imagine a requirement that C_1 and C_2 be different with respect to some arbitrary feature, that is any feature, or any feature out of a predefined subset of all the features. In other words, the two segments must *not be identical*, but it doesn't matter how they differ.

Let **F** be the set of all features. In order to express such a NONIDENTITY CONDITION we can make use of the existential quantifier:

(15) The NONIDENTITY CONDITION in FA (defined over all features)

$\exists\ F_i \in \mathbf{F}$ such that $[(\alpha F_i)_1] \neq [(\beta F_i)_2]$

There is at least one feature for which segment_1 and segment_2 have different values.

That is, there is some feature for which the two segments have a different value. Note that there is no way to represent NONIDENTITY using just Autosegmental Representation. This is because nonidentity can be due to a disagreement with respect to *any* arbitrary feature. The essence of autosegmental notation is the way in which it provides a geometric model of phonological structure. Being geometric, autosegmental represetation does not make use of variables. Therefore, autosegmental notation is not sufficiently powerful to express nonidentity conditions.

The requirement of difference can also be restricted to a subset of the features, $\mathbf{G} \subseteq \mathbf{F}$, for example, to the place of articulation features. Then, the more general version of the NONIDENTITY condition is the following:

(16) The NONIDENTITY CONDITION in FA (Final version)

$\exists\ F_i \in \mathbf{G}$ such that $[(\alpha F_i)_1] \neq [(\beta F_i)_2]$

For some specified subset of the features, there is at least one feature for which segment$_1$ and segment$_2$ have different values.

As we will see below, such a condition is necessary for the formulation of some well-known phonological processes.

Once we admit the necessity of quantificational statements in our phonology we can see that conditions of identity can be also be expressed in such a fashion. Total identity can be expressed as follows:

(17) The Identity Condition in FA (defined over all features)

$\forall\ F_i \in \mathbf{F}\ [(\alpha F_i)_1] = [(\beta F_i)_2]$

For all features, segment$_1$ and segment$_2$ have the same value.

whereas partial identity can be expressed by defining a subset of features, $\mathbf{G} \subseteq \mathbf{F}$ over which identity must hold. Total identity is just a special case of partial identity, where $\mathbf{G} = \mathbf{F}$.

(18) The Identity Condition in FA (Final version)

$\forall\ F_i \in \mathbf{G}\ [(\alpha F_i)_1] = [(\beta F_i)_2]$

For some specified subset of the features, segment$_1$ and segment$_2$ have the same values.

Again, we shall see that such conditions are part of phonology.

6.5. Examples of conditions on identity and nonidentity

Note that McCarthy's account of antigemination, which uses the OCP to block rule application, involves a 'lookahead' effect: the phonology must see what the outcome of the rule *would be* and then 'decide' whether or not the rule is to be applied. In effect the rule must be done and undone if the outcome is not satisfactory. An alternative to the rules-and-constraints lookahead solution is to build into the rule the conditions on its application. Note that this condition is just a part of the rule's Structural Description (SD), and a SD is needed in any event. In the case of antigemination, if the OCP is dispensed with, there is no lookahead, but instead a NONIDENTITY CONDITION is built into the rule. McCarthy's rule deletes a vowel in the environment $\#CVC_1\_\_C_2V$, unless it is blocked by the OCP. I propose replacing McCarthy's rule with one that deletes the vowel in the environment $\#CVC_1\_\_C_2V$ if $\exists\ F_i \in \mathbf{F}$ such that $[(\alpha F_i)_1] \neq [(\beta F_i)_2]$.

6.5.1. The NONIDENTITY CONDITION All the examples of OCP blocking cited by McCarthy, including the Biblical Hebrew case discussed above, can be restated as rules with a condition 'apply unless two segments are identical'. Again this is equivalent to 'apply only if two segments are different, that is, non identical'. So these rules all exemplify the NONIDENTITY CONDITION. Odden and McCarthy also provide an example of anti-gemination from Iraqi Arabic:

(19) Anti-gemination in Iraqi Arabic (from Odden 1988:452)

a.	xaabar	'he telephoned'	xaabr-at	'she telephoned'
	ħaajaj	'he argued'	ħaajij-at	'she argued'

b. *Syncope*

$$V \rightarrow \emptyset \ / \ V(C)C\_\_\_\_CV$$

The syncope rule applies normally in the form *xaabrat*, but is blocked, according to McCarthy, in *ħaajijat* to avoid generating an OCP violation.[11]

Under the theory developed here, rule application is not blocked by the OCP, but rather, the rule's SD includes a nonidentity condition. Rule 20 shows the necessary indexing of the consonants in the structural description:

(20) Revised Iraqi rule

$$V \rightarrow \emptyset \ / \ V(C)C_1\_\_\_\_C_2V$$

if $\exists\ F_i \in \mathbf{F}$ such that $[(\alpha F_i)_1] \neq [(\beta F_i)_2]$

To reiterate, the syncope rule is not written in an overgeneral form and *blocked* by the OCP, but instead the rule contains a condition (part of the structural description) which determines that the rule only applies when the consonants on either side of the vowel differ with respect to at least one feature. Since structural desciptions are obviously needed to determine where rules apply, there is no reason to decide arbitrarily that, say, the presence of flanking consonants should be part of the structural description, but that their identity or nonidentity should not be.

The Cushitic language Afar, dicussed by McCarthy (1986) and Yip (1988), based on data found in Bliese (1981) provides a similar case of antigemination which is sensitive to a nonidentity condition. Vowels which appear under stress in the left hand column of (21b) are deleted in the related forms to the right, since the stress has shifted. The unstressed vowels in (21c) do not delete. The rule is stated in (21a) with the relevant nonidentity condition, and the notation [-stress].

(21) *Syncope in Afar*

a. V $\rightarrow \emptyset$ / #CVC_1____C_2V if $\exists$ $F_i \in \mathbf{F}$ such that $[(\alpha F_i)_1] \neq [(\beta F_i)_2]$
[-stress]

b.

xamíla	xamlí	'swampgrass' (acc/nom-gen)
ʕagára	ʕagrí	'scabies' (acc/nom-gen)
digibté	digbé	'she/I married'
wagerné	wagré	'we/he reconciled'

c.

miđáđu	miđađí	'fruit' (acc/nom-gen)
xararé		'I, he burned'
danané		'I, he hurt'

The alternations in the (b) forms shows the deletion of unstressed vowels in open syllables. The first two lines show the relevance of stress— only unstressed vowels are deleted. The next two lines show that deletion does not occur when the syllable is closed. The (c) forms show that the rules does not apply when the flanking consonants are identical. In other words, the rule applies only between nonidentical consonants.

As noted above, there is no way to refer to nonidentity with respect to some arbitrary feature without making use of the existential quantifier. In the next subsection, I will show that the use of the universal quantifier is not only as good as a geometric representation to express identity conditions, but that in some cases, a geometric representation will be insufficient, so the quantificational formulation is the only one with sufficient power.

6.5.2. The IDENTITY CONDITION In this section, I repeat three of Odden's examples of deletion processes requiring identity between flanking segments. According to Odden, Sherwood (1983) motivates a rule in Maliseet-Passamaquoddy which deletes the short vowels /ə/ and /ă/ in doubly open syllables when flanking consonants are identical. Obviously, this identity condition must be stated so that it applies to the whole feature set (or at least to those relevant to consonants). The Hebrew syncope rule we began with deletes vowels unless the flanking consonants are identical. We have encoded the condition 'unless identical' as 'necessarily nonidentical', using the existential quantifier and negation of identity. In the Maliseet-Passamaquoddy rule, a vowel deletes only when the flanking consonants are identical. This requirement can be encoded using the universal quantifier and the identity relation.[12]

Other rules mentioned by Odden, such as one posited by Jensen (1977) in Yapese, demand only homorganicity between flanking consonants, and not identity of Laryngeal or manner features. The Yapese rule deletes a vowel flanked by homorganic consonants if the first consonant is postvocalic or word-initial:[13]

(22) Yapese: syncope between homorganic consonants

a. $V \rightarrow \emptyset$ /{V, #} C_1__# C_2

if $\forall F_i \in \{[\text{coronal}], [\text{labial}], [\text{dorsal}]\}\ [(\alpha F_i)_1] = [(\beta F_i)_2]$

	Underlying	Surface	Gloss
b.	ba puw	bpuw	‘it’s a bamboo’
	ni te:l	nte:l	‘take it’
	rada:n	rda:n	‘its width’

The Yapese data shows that we can use the universal quantifer to express identity. We now demonstrate that we should use the FA system with quantification, since Feature Geometry is insufficiently powerful.

6.5.3. Another failing of Feature Geometry Odden cites data from Koya (Taylor 1969:38) in which word final vowels are deleted if flanking consonants are identical, except that retroflexion is not used in the computation of identity. In other words, retroflex consonants group with plain coronals for the purposes of computing identity. The data and a FA formulation of the rule are given in (23).

(23) Koya: syncope between identical consonants—ignoring retroflexion

a. $V \rightarrow \emptyset$ /C_1__# C_2

if $\forall$ $F_i \in$

{[coronal], [labial], [dorsal], [spread glottis], [sonorant], [nasal], [lateral]}

$[(\alpha F_i)_1] = [(\beta F_i)_2]$

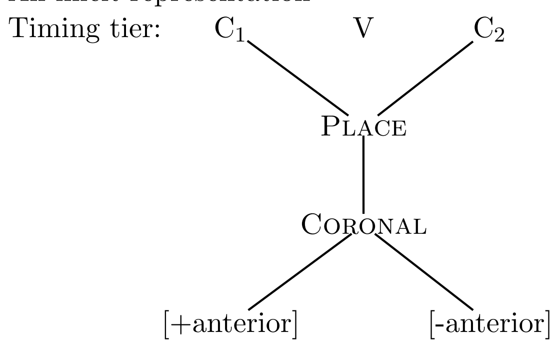
	Underlying	Surface	Gloss
b.	na:ki ka:va:li	na:kka:va:li	‘to me it is necessary’
	a:ru ru:pa:yku	a:rru:pa:yku	‘6 rupees’
	verka:ḍi digte	verka:ḍdigte	‘the cat got down’

Rule (23a) is not particularly pretty, but it is correct (insofar as the set of features listed as relevant to consonant identity, retroflexion excepted, is correct) as a formalization of Odden’s discussion.

It is extremely important to note that we have here further evidence for the inadequacy of Feature Geometry. As discussed above, Autosegmental Representation and Feature Geometry can be used to denote shared feature values, or even shared classes of features by a many to one mapping of segments (say, Root nodes) to feature structures. There are two implicit assumptions involved in using such representations. First, there is the assumption of locality: linked structures are adjacent in some sense, so that there are no intervening association lines to cross. In order to treat consonant identity across an intervening vowel as due to autosegmental linking, it is necessary to assume that the intervening vowel have no features which are shared with the two consonants. This assumption forces us to posit a different set of features for vowels and consonants, thus leading to the question of how the two types of segment can influence each other, or else it requires ad hoc segregation of vowels and consonants onto seperate tiers. See Archangeli and Pulleyblank (1994:368-70) for discussion.

Second, if nodes X and Y on a given tier both dominate a node A on a lower tier, then X and Y are assumed to be identically specified for node A (obviously) *and* any nodes that A dominates (by the transitivity of dominance). To illustrate, a structure like (24) is not well-formed since the [+anterior] and [-anterior] nodes are not ordered—temporal relations can only be determined with reference to the timing tier or Root tier.[14] In order to encode the ordering between these two specifications, one could mark them with an index to link them with C_1 and C_2 respectively. But in doing so, we have reverted to an algebraic notation.

(24) An illicit representation



But this view is incompatible with the situation in Koya where the retroflexion features are irrelevant to the computation of identity. Let's simplify matters and assume that the Koya vowels are not specified for Place features and thus flanking consonants can be considered adjacent. The syncope rule might then be assumed to apply when the flanking consonants share a Place node. However, the consonants should then be assumed to share all the dependents of the Place node. The Place node dominates the Coronal node and its dependents [anterior] and [distributed] in most models of Feature Geometry. However, the Koya rule applies even when the flanking consonants are not identically specified for these features. So, the rule cannot be stated using multiple linking of PLACE nodes or CORONAL nodes.

If we take this as evidence that [anterior] and [distributed] are not dominated by Coronal, but are perhaps directly dominated by the Root node, we are just claiming that Feature Geometry contains less structure, that is we are arguing against its usefulness as a representation of the organization of features, and we are heading back to a model of unorganized feature matrices, as in (11). FA, in contrast to Feature Geometry, allows us to list all and only those features which are relevant to the Koya identity condition. We thus see that even in certain cases of the identity condition, FG representation is insufficiently powerful. It does not allow us to *exclude* from consideration of identity computations those nodes whose dominating nodes are *included* in the computation.

In order to show that this is not an isolated example, consider an additional case concerning place assimilation in modern Irish (pointed out to me by Morris Halle, p.c., discussed by Ni Chiosán and Padgett (1993) and Halle, Vaux and Wolfe(2000)). In this language, "word-final coronal nasals assimilate the primary place of articulation of a following stop, but crucially do not assimilate the secondary articulation of the stop. Palatalized [n^j] assimilates the Dorsal articulation of a following [g], but not its contrastive [+back] specification. Nonpalatalized [n] assimilates the Dorsal articulation of following [g^j], but not its [-back] articulation. In other words, the secondary articulation feature [back] does not spread whenever its supposedly dominating node spreads. The authors cited offer different solutions to this problem, while still maintaining the basic FG model. I take the data instead to constitute evidence for the rejection of FG, as argued above.[15]

Odden also mentions several cases of insertion rules that rely on an identity condition. For example, in Lenakel (Lynch 1978) schwa is inserted between identical consonants. Yip's examples of rules that break up (partially) identical clusters of consonants, such as the English epenthesis between coronal sibilants, can all be restated in terms of rules constrained by identity conditions.

7. Unattested Conditions

The previous section was really no more than a slight elaboration on Odden's important work on defining the range of possible conditions on rule application. In this section I suggest that the use of FA actually helps us discover that two types of rule condition are unattested in phonology.

Phonological theory needs at least the power of the NONIDENTITY CONDITION and the IDENTITY CONDITION. Interestingly, it appears not to need the power of the two conditions which are made by switching = and ≠ in the conditions already established. That is, no phonological rule appears to require what can be called the COMPLETE NONIDENTITY CONDITION (two segments must have opposite feature values for all of a given subset of features)[16] or the VARIABLE PARTIAL IDENTITY CONDITION (two segments must be identical with respect to one member of a given subset of features, but it doesn't matter which particular member it is).

(25) Unattested: COMPLETE NONIDENTITY CONDITION

$\forall \mathrm{F}_i \in \mathbf{G}\ [(\alpha \mathrm{F}_i)_1] \neq [(\beta \mathrm{F}_i)_2]$

For some specified subset of the features, $\mathrm{segment}_1$ and $\mathrm{segment}_2$ have different values.

(26) Unattested: VARIABLE PARTIAL IDENTITY CONDITION

$\exists$ $F_i \in \mathbf{G}$ such that $[(\alpha F_i)_1] = [(\beta F_i)_2]$

For some specified subset of the features, there is at least one feature for which segment$_1$ and segment$_2$ have the same value.

An example of the COMPLETE NONIDENTITY CONDITION would require that two segments have opposite values for, say, all place features, or even for *all* features. I know of no such case. For example, 'delete a vowel in the environment #CVC$_1$__C$_2$V if C_1 is [-anterior, -labial, +dorsal] and C_2 is [+anterior, +labial, -dorsal], or C_1 is [+anterior, -labial, +dorsal] and C_2 is [-anterior, +labial, -dorsal], *etc*'.

An example of the VARIABLE PARTIAL IDENTITY CONDITION would require that two segments have the same value for some feature in a given subset: 'delete a vowel in the environment #CVC$_1$__C$_2$V if C_1 and C_2 are both [αanterior], or [αlabial], or [αdorsal], *etc*'.

In other words, we can trivially construct a condition using the universal quantifier and a nonidentity relation, or the existential quantifier and an identity relation, but it seems that such conditions never are needed by the phonology. In section 7.2, I make a proposal concerning how this generalization should be treated by the theory.

7.1. Ambiguous cases

Obviously, there are rules for which the conditions on application *could* be expressed as an example of case (25) or (26), such as a rule requiring nonidentity for a single specific feature value. For example, Yiddish (Perlmutter 1988, Sapir 1915) has a rule that deletes the vowel in the plural suffix *-en* as long as the stem final consonant is not a nasal.[17] In terms of McCarthy's view of the OCP as a rule blocker, the rule fails to apply if it will bring two nasals into contact. Data appears in (27).

(27) Yiddish vowel deletion

	Sg	Pl
‘language’	šprax	špraxn
‘ear’	oyer	oyern
‘magazine’	žurnál	žurnáln
‘sea’	yam	yamen

Let’s assume that the only relevant feature in conditioning the rule is [nasal], and that, for example, [sonorant] and [voice] are not part of the rule’s structural description. Then, this rule *could* be stated in terms of a condition like (28), which is a highly restricted example of the COMPLETE NONIDENTITY CONDITION: the set of relevant features contains the single feature [nasal], and the rule has the added conditionn that the second consonant be [+nasal].

(28) Delete the vowel between an onset consonant C_1 and a nasal C_2
if $\forall\ F_i \in \{[\text{nasal}]\}[(\alpha F_i)_1] \neq [(\beta F_i)_2]$

However, this condition can be expressed as well as an example of the NONIDENTITY CONDITION, as follows:

(29) Delete the vowel between an onset consonant C_1 and a nasal C_2
if $\exists\ F_i \in \{[\text{nasal}]\}$ such that $[(\alpha F_i)_1] \neq [(\beta F_i)_2]$

So it is not *necessary* to combine the universal quantifier with a nonidentity requirement to express the correct condition. Thus the claim that the COMPLETE NONIDENTITY CONDITION and the VARIABLE PARTIAL IDENTITY CONDITION are unattested in phonological rules as necessary kinds of conditions remains valid.

Other potential cases of the COMPLETE IDENTITY CONDITION arise when segments have redundant values for certain features, values that can be predicted on the basis of other features. Suppose a language $\mathcal{L}$ has in its consonant inventory only voiceless obstruents and voiced sonorants. Then a rule in $\mathcal{L}$ which apparently demanded nonidentity of voicing between two consonants could have the condition shown in (30):

(30) $\exists\ \mathrm{F}_i \in \{[\text{voice}]\}$ such that $[(\alpha \mathrm{F}_i)_1] \neq [(\beta \mathrm{F}_i)_2]$

that is, $[(\alpha\text{voice})_1] \neq [(\beta\text{voice})_2]$

Alternatively, the correct (though extensionally equivalent) form of the condition might be one that referred to the feature [sonorant], as in (31)

(31) $\exists\ \mathrm{F}_i \in \{[\text{sonorant}]\}$ such that $[(\alpha \mathrm{F}_i)_1] \neq [(\beta \mathrm{F}_i)_2]$

that is, $[(\alpha\text{sonorant})_1] \neq [(\beta\text{sonorant})_2]$

Finally, the COMPLETE IDENTITY CONDITION in (32) is also extensionally equivalent to the two versions of the NONIDENTITY CONDITION just listed.

(32) $\forall\ \mathrm{F}_i \in \{[\text{sonorant}], [\text{voice}]\}[(\alpha \mathrm{F}_i)_1] \neq [(\beta \mathrm{F}_i)_2]$

that is, $[(\gamma\text{sonorant})_1] \neq [(\delta\text{sonorant})_2]$ AND $[(\epsilon\text{voice})_1] \neq [(\zeta\text{voice})_2]$

Again, since we do not need to use the formulation in (32), and since we have reasons to believe that we never need to use such conditions, we have a tool for choosing among extensionally equivalent grammars. The phonology of $\mathcal{L}$ potentially has the condition in (30) or the one in (31), but definitely not the one in (32). This is the kind of argument suggested by Chomsky (1986) in refuting the claim of Quine (1972) that it is futile to attempt to choose among extensionally equivalent grammars: “Because evidence from Japanese can evidently bear on the correctness of a theory of S_0, it can have indirect—but very powerful– bearing on the choice of the grammar that attempts to characterize the I-language attained by a speaker of English” (Chomsky 1986:38).

7.2. Towards an explanation for gaps in attestation

Assuming that the COMPLETE NONIDENTITY CONDITION and the VARIABLE PARTIAL IDENTITY CONDITION are really absent from human languages, how are we to treat this fact? One way to do so is to build the fact into UG as an explicit constraint against quantificational statements conforming to certain formats. This strikes me as the wrong way to approach the issue, if it merely consists of restating the descriptive observation as a principle of grammar and not being open to explanations outside of the realm of grammar. In this particular case, it may be possible to derive the gap, from the relationship between language change and phonetics. Note that this approach is in no way incompatible with a nativist perspective—the nativist position is just that some (not necessarily *all*) non-trivial aspects of the language faculty are innate.

Following work on the nature of sound change (Ohala 1990, Hale, forthcoming) and theoretical work in cognitive science (Pylyshyn 1984), Hale and Reiss (2000ab) argue that it is to be expected that attested patterns in the phonological systems of the world's languages reflect only a subset of what is computationally possible for the human phonological capacity.[18] In other words, all attested patterns must be generatable by the UG-given phonological capacity, but not all generatable patterns will arise, due to the nature of sound change and language acquisition. This point of view may be helpful in explaining why the Complete Nonidentity Condition and the Variable Partial Identity Condition are unattested.

In general, phonological processes arise diachronically from the reanalysis of sub-linguistic (gradient) phenomena as grammatical (categorical, feature-based) phenomena. Now note that there is at least a partial correspondence between phonetics and phonology—for example, features referring to place of articulation tend to correspond to the nature of formant transitions between vowels and consonants. Work on feature detectors and the like, though far from complete, reflects the belief that we can study the nature of the tranduction processes between phonetics (gradient phenomena) and feature-based phonology.[19] An identity condition defined over a subset of phonological features, therefore, will tend to be to some extent related to a 'natural class' of phonetic properties.

Similarly, a nonidentity condition on, say, segments in the environment of a rule implies identity of the segments in those environments in which the rule does *not* apply.

In other words, nonidentity entails the existence of identity in the complement set of environments. From the phonetic/diachronic perspective, then, these two conditions are the same. These two types of condition depend, at least at the point when they are phonologized by a learner, on clusters of phonetic properties. However, from a synchronic, phonological perspective, they are computationally distinct—one requires the equivalent of universal quantification and identity; the other, existential quantification and nonidentity.

In contrast to these two cases, it is hard to imagine how either the COMPLETE NONIDENTITY CONDITION or the VARIABLE PARTIAL IDENTITY CONDITION could be derived from definable clusters of shared phonetic properties. For example, there is no phonetic unity to be found between segment transitions involving [± voiced] agreement and those involving [±coronal] agreement. But this is the kind of phonetic phenomena required to give rise to the VARIABLE PARTIAL IDENTITY CONDITION which requires agreement for an arbitrary feature among segments in a structural description.

It is also hard to imagine how having opposite values for a given set of features, as required by the COMPLETE NONIDENTITY CONDITION, could lead to a phonetically stable pattern. Recall that the relevant case would allow *every* pairing (of members of the relevant set **G**) of opposite feature values. Restricting the relevant set to the members A and B, each line of (33) would instantiate an environment for rule application under a COMPLETE NONIDENTITY CONDITION:

(33) Permutations of feature specification in the COMPLETE NONIDENTITY CONDITION

[+A +B] *vs.* [−A −B]

[−A +B] *vs.* [+A −B]

[+A −B] *vs.* [−A +B]

[−A +B] *vs.* [+A −B]

It is hard to imagine how such sets of representations could correspond to a phonetically natural grouping.

To summarize, the NONIDENTITY CONDITION and the IDENTITY CONDITION provide us with a lower limit on the computational resources of UG, whereas patterns of attestation reflect extragrammatical factors. I am not claiming that the two unattested conditions are in principle uncomputable by the phonological component of the mind, but rather that the nature of language transmission makes it unlikely that they will arise.

It is beyond the scope of this paper to provide a diachronic phonetic analysis of how, say, antigemination and antiantigemination arise, but we can indicate some directions for future research. Odden (1988:470) makes some suggestions related to the fact that the consonant closure gestures for nonidentical places of articulation can overlap in time, since they involve different articulators, whereas repeated, identical consonants cannot have overlapping gestures. We can imagine that vowels between identical consonants will be somewhat longer, and thus less susceptible to deletion diachronically than vowels between nonidentical consonants. If only the phonetically shorter vowels are deleted, the resulting grammar will manifest antigemination.

Antiantigemination could perhaps result from a sequence of reanalyses. First, consonant-to-consonant place transitions are reanalyzed as epenthetic vowels. The resulting grammar thus has epenthetic vowels between nonidentical consonants only. Next, *epenthesis* between nonidentical consonants is reanalyzed as *syncope* between identical consonants.

The first stage of this scenario results in a type (d) condition. Such rules appear to have arisen in various Oceanic languages such as Marshallese (Mark Hale, p.c.), Mokilese (Harrison 1976), Ulithian (Sohn and Bender 1973).[20]

Once we accept the existence of such epenthesis rules and the possibility of rule inversion we see that it is not surprising that antiantigemination can arise diachronically.

8. A difference between phonology and syntax

It seems clear that syntactic/semantic interpretation makes use of the existential and universal quantifiers—these are standard primitives of LF representational apparatus. A nice parallel to the phonological nonidentity condition can be found in the semantics of English *else*. In a construction like (34), *else* is an operator that restricts the set defined by *something* to all entities which disagree with the antecedent *chocolate cake* with respect to at least one property:

(34) John ate chocolate cake but Mary ate something else.

What Mary ate can be *an apple*, *carrot cake* or *chocolate ice cream*. Crucially, it cannot be *chocolate cake with frosting* or *chocolate cake à la mode*. In other words, *else* is a nonidentity operator that examines properties (chocolateness, cakehood, *etc.*) of entities at some level of representation (see Isac and Reiss 2003). [21]

In the following, I suggest that that the apparent gap of type COMPLETE NONIDENTITY (25) and VARIABLE PARTIAL IDENTITY (26) conditions in phonological rules is not paralleled in syntax.

The NONIDENTITY CONDITION, requiring that a set of features contain some differences, might be abbreviated thus (where k refers to a particular attribute or feature and x_k refers to the value that k has on segment x):

(35) $\exists k \; x_k \neq y_k$

But, of course, this is equivalent to the following

(36) $\neg \forall k \; x_k = y_k$

Similarly, the IDENTITY CONDITION can be abbreviated as follows:

(37) $\forall k \; x_k = y_k$

Of course this is equivalent to the following:

(38) $\neg \exists k \; x_k \neq y_k$

The two apparently unattested conditions can thus, also be given in two forms each. First is the Complete Nonidentity Condition:

(39) i. $\forall k \; x_k \neq y_k$

ii. $\neg\exists k \; x_k = y_k$

And the Variable Partial Identity Condition can be represented thus:

(40) i. $\exists k \; x_k = y_k$

ii. $\neg\forall k \; x_k \neq y_k$

Since each condition has two logically equivalent formulations, I will simplify the exposition by not using the negations of the quantifiers. So, this leaves us with the two quantifiers, used to quantify over the set of features, and the relation "=" and the negation of this relation. Now, let us rewrite the four conditions, replacing "=" with "R", to stand for an arbitrary relation:

(41) Four types of condition

A. $\exists k \; x_k \neg R y_k$

'Under some condition k, x is not in a given relationship with y.'

B. $\forall k \; x_k R y_k$

'Under all conditions k, x is in a given relationship with y.'

C. $\forall k \; x_k \neg R y_k$

'Under all conditions k, x is not in a given relationship with y.'

D. $\exists k \; x_k R y_k$

'Under some condition k, x is in a given relationship with y.'

A question to ask is whether conditions C (which encompasses the Complete Nonidentity Condition) and D (which encompasses the Variable Partial Identity Condition) are *ever* used by the language faculty, since they appear not to be used by the phonology. The answer seems to be that they, or their parallels, are used in the interpretation of binding relations.

Suppose we let the relation R be the *c-command* relation. So xRy means 'x c-commands y' and $x\neg Ry$ means 'x does not c-command y'. Epstein, *et al.* (1998:62) assume the following interpretive procedure in their derivational theory of syntax:

> The application of "disjoint" interpretive procedures occurs at every point in the derivation, whereas the application of "anaphoric" interpretive procedures occurs at any single point in the derivation.

Abstracting away from locality conditions, we can rephrase this generalization as follows.[22]

- A pronoun P is disjoint in reference from a category X if for all points in the derivation, X does not c-command P. (If X_i is category X at point i, then P is disjoint from X if $\forall i\ X_i \neg RP$—compare the COMPLETE NONIDENTITY CONDITION.)
- An anaphor A is anaphoric with a category X (whose features are compatible with A) if there is a point in the derivation where X c-commands A. (If X_i is category X at point i, then A is coreferential with X if $\exists i\ X_i RA$—compare the VARIABLE PARTIAL IDENTITY CONDITION.)

In other words, if we quantify over steps in a derivation (replacing the k in our phonological examples with the i in the binding examples, and replacing phonological identity with binding, we see that the interpretation of binding relations uses exactly those combinations of the quantifiers and a negated and un-negated relation that the phonology does not use. Syntactic operations like feature checking clearly involve the evaluation of identity relations—the features of a functional head only check *identical* features of lexical categories— so then there are types of conditions that are shared by syntax and phonology. Thus there is no simple complementarity between the types of conditions the two components make use of, nor is there any reason to expect there should be.[23]

9. Rose's (2000) account of antigemination

It may be a matter of faith whether the data cited by Odden demonstrates that the OCP is ill-founded as a principle of grammar or if, instead, it shows that OT constraint violability is central to an understanding of grammar. I have adopted the first alternative. Rose (2000) implicitly adopts the second, but I will now argue that her model is actually more unwieldy than indicated by the examples she discusses.

Rose achieves an analysis of antigemination by positing a constraint against gemination, No-Gem, and a constraint called OCP, which is violated by 'adjacent' (see below) identical segments. Actually, she posits a segmental OCP constraint (p.102) and a family of OCP constraints for different features, such as OCP/Coronal (p.97). She also makes the following crucial assumptions:

(42) Assumptions of Rose (2000)

a. Consonant adjacency: Two consonants in sequence are adjacent irrespective of intervening vowels (p.95).

b. A surface sequence C_iVC_i violates the OCP under consonant adjacency (p.101).

c. Any surface C_iC_i sequence in a given domain is a geminate and does not violate the OCP (p.101).

The first two of these assumptions are non-standard. Prior work on the OCP assumes that consonant adjacency is sensitive to strict linear ordering. The third assumption is consistent with earlier work such as Yip (1988) in that it assumes that surface sequences of identical consonants in fact reflect sequences of timing slots linked to a single feature bundle. Of course, this assumption is forced on an analysis, like Yip's, that takes the OCP to be inviolable. Since she is working in an OT framework, Rose could, in principle, take these sequences to violate the OCP.

Antigemination, the failure to delete a vowel which otherwise should not surface between identical segments, derives from a ranking in which No-Gem outranks the relevant OCP constraint. The opposite ranking leads to deletion, since not deleting maintains an OCP violation—by (42a) identical consonants separated by vowels are adjacent.

Rose does not provide much of a model of phonological representation. For example, she does not tell us whether she is using binary or privative features, or if she is assuming some kind of feature geometric representation. This vagueness makes it somewhat difficult to state exactly what her model predicts in cases of partial identity conditions. However, it appears that we would have to endow her model with a much greater number of constraints than she discusses.

Consider the case of epenthetic vowels that appear between English coronal stridents, mentioned above. Note that this epenthesis cannot be driven in an OT model merely by adjacent coronal features. Following Rose's approach, the epenthetic vowel in, say, *bushes* would be due to the avoidance of a *partial* geminate consisting of string adjacent segments with linked nodes for the features which define coronal stridents—[+continuant, -sonorant, +coronal, +strident]. So we need a version of No-Gem that is violated by such partial feature sharing.

This cannot be accomplished merely by positing individual constraints for each feature, since epenthesis does not occur to avoid partial gemination with respect to certain subsets of these features. A form like *cliffs* has (in Rose's model) [+continuant] shared between the [f] and the [s]. A form like *bins* has a shared [+coronal] specification on the [n] and the [s], and so on. In other words, we cannot appeal to a constraint No-Gem-Coronal, banning linked coronal nodes, because this feature is relevant in driving epenthesis *only in the context of the other features that define coronal stridents.*

Therefore, Rose's model requires a separate No-Gem-type constraint for each combination of features that can group together in the structural description of a phonological pattern. As she acknowledges, she also needs separate OCP constraints, such as OCP/Coronal, for each feature.

In OT, such constraints are part of UG. My proposal instead endows UG with the necessary apparatus to construct rules (or constraints) in accordance with input from the target language. Again, I cite Odden (1988:461): "It is misguided to attribute every accidentally true statement about human language to UG".

The simplicity of the theoretical claims I am making can perhaps be appreciated with the following paraphrase: Phonological processes/alternations are context sensitive. One kind of information that can be used to define context is feature identity.

10. Conclusions

It is worthwhile to compare the extremely formalistic approach to phonology proposed here to that presented in an influential pre-OT paper by a phonologist who is one of the most important contributors to the success of OT. McCarthy (1988:84) states that "The goal of phonology is the construction of a theory in which cross-linguistically common and well-established processes emerge from very simple combinations of the descriptive parameters of the model". For example, "Assimilation is a common process because it is accomplished by an elementary operation of the theory—addition of an association line" (86). After attempting to motivate two operations and two constraints on well-formedness, McCarthy declares that "each operation and constraint is predicted to operate on each class node of the feature geometry in some reasonably well-attested linguistic phenomenon" (90).[24] The vagueness of terms like *common, well-established* and *reasonably well-attested* should alert us to the lack of rigor inherent in such an approach. A simpler, more explicit approach is to figure out what is the minimum amount of representational and computational machinery needed to generate attested patterns. With this goal in mind, phonology should not return to the rules-and-constraints models that predate Optimality Theory, but to a pure rule-based formalism. The nature of the types of rules needed by phonological theory thus becomes an empirical question that promises to yield answers if not prejudiced by preconceived notions of what rules 'should' look like.

It is also worth contrasting the approach advocated here with one of the founding documents of Optimality Theory, Prince and Smolensky 1993, which explicitly rejects the extreme formalist position:

> We urge a reassessment of this essentially formalist position. If phonology is separated from the principles of well-formedness (the 'laws') that drive it, the resulting loss of constraint and theoretical depth will mark a major defeat for the enterprise [Prince and Smolensky 1993: 198, see also p.3].

My view, in contrast, is that building into UG, by means of a universal constraint set, "every accidentally true statement about human language", as Rose (2000) and most OT work needs to do, surely "trivializes the theory of UG" by reducing it to an elaborate form of taxonomy.

I have argued that an algebraic formulation of phonological representation is necessary to allow the incorporation of quantificational logic into SD's. I have shown that well-known cases of Nonidentity conditions, referred to as 'antigemination' by McCarthy (1986), demonstrate the necessity of the existential quantifier (or its equivalent) in phonology.

Identity conditions that are not plausibly defined over linked structures provide one argument for the use of the universal quantifier. For example, there is little reason to believe that vowels and consonants are always located on different tiers, so consonant identity in a CVC structure cannot plausibly be represented by linked feature specifications. Stronger evidence for the universal quantifier comes from the cases of identity conditions that refer to arbitrary sets of features, sets that are not members of a class according to Feature Geometric models. Relevant examples include Koya syncope where identity computations ignore the features [anterior] and [distributed].

Since the Feature Algebraic notation is more powerful than Geometric notation, and since the Algebraic notation is necessary, the Geometric notation can be dispensed with. This is not surprising since we now understand the original motivation for Feature Geometry, to make it easy to express what happens often in the world's languages, to have been misguided.

In addition to the particular claims made in this paper, I would like to stress the programmatic aspects of the discussion. A deep understanding of human phonology can arise only by steering away from taxonomic, data-fitting models to a search for the basic cognitive apparatus needed for phonological computation. Even if the particular claims in this paper turn out to be empirically invalidated, I hope that such general goals can be maintained.

I have also attempted to explain why certain kinds of logically possible conditions such as the VARIABLE PARTIAL IDENTITY CONDITION and the COMPLETE NONIDENTITY CONDITION, though trivially formulable using necessary representational apparatus appear not to be attested in phonology. It is worth repeating that this gap in attestation is *not* to be explained as a property of UG.

There is a certain historical irony to be noted here. It has been claimed that the demise of rule-based phonology was due to a failure to formulate a theory of possible rules. Recall that Yip claimed that OCP 'effects' appear over and over again in phonological rules. She concludes that such conditions should therefore *not* be stated in structural descriptions. It should now be apparent that the opposite conclusion was warranted: by observing what type of conditions (for example, the IDENTITY and NONIDENTITY CONDITIONS) appear in structural descriptions, we approach a theory of what is a possible rule! This research program—investigation of the most important question in phonological theory: What is a possible rule?— made great progress in Archangeli and Pulleyblank (1994), but was stamped out by the advent of Optimality Theory.

One might be concerned that the view developed here must lead to the disturbing claim that 'phonological theory is empirically vacuous'. While I do not pretend to have a complete picture of how phonological theory should proceed, I do believe that the approach developed here is promising, and also is consistent with general scientific methodology. We are attempting to build a formal model of phonology. Note that some formal systems, like propositional logic, do not make use of quantifiers, and propositional logic does not have the expressive power of quantificational logic. I hope to have shown that phonology is more like quantificational logic than like propositional logic. This is a result in the same spirit as Chomsky's demonstration that Phrase Structure Grammars are insufficiently powerful to model human syntax. It is not a vacuous claim. Like Chomsky's demonstration, I am following standard methodology in my approach. The idea is to assume nothing and then demonstrate that the model must be enriched in certain ways. A fuller discussion of this approach appears in Reiss (2002). I argue there that UG should not be conceived of as a set of constraints, but rather as a definition of an inventory of representational and relational primitives. Thus, we are attempting to define the inventory of UG in positive terms—the child has a given 'toolbox' with which to analyze the PLD, and we are trying to characterize the contents of that toolbox.

A final philosophical issue arises from the results of this paper. Given that the use of quantification and identity are not specific to the language faculty, are we justified in labeling them as part of the language faculty, or as general cognitive mechanisms that the language faculty has access to?[25] Perhaps, the correct answer is that the use of quantification in logic and mathematics are somehow secondary manifestations, relatively recent in human hstory, of its use by the language faculty. Chomsky (2000: 3-4) has suggested that another property of the language faculty, the property of discrete infinity, is another such case. The answer to this question is probably not relevant for the purposes of self-contained phonological theorizing and modeling, but, consideration of such issues is necessary for an understanding of phonology in the context of cognitive science. Perhaps it is necessary to get a more complete picture of what phonology *is* before we attempt to state what it *is not*. Quantification and indexation of segments appear to be part of what it is.

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Notes

[1]Brendan Gillon, Daniela Isac, Mark Hale, Ida Toivonen and Ash Asudeh were all extremely helpful in getting me to clarify the ideas in this paper.Versions of this work have been presented at the *Fourth Utrecht Biannual Phonology Workshop* in 2000, the *2001 LSA Annual Meeting* in Chicago, the *Asymmetry Conference* at UQAM in 2001, the MIT Phonology Circle, and the McGill Linguistics Department. Audiences at each of these presentations made many useful comments. This work was partially supported by the SSHRC *Asymmetry Project* and the VRQ *Natural Language Processing* grants (Anna Maria di Sciullo, P.I.), as well as by several grants from Concordia University.

[2]A reviewer comments: "[This] addition to Odden's statement, 'or particular human languages' introduces an absurd strawman theory ('Every true statement about particular human languages is part of UG') which, to the best of my knowledge, has never been seriously proposed by any linguist. Why does the author even mention it?" In fact, the universal constraint set of Optimality Theory, and the claim that all crosslinguistic variation is due to constraint ranking *requires* that every alternation, for example, be somewhat directly encoded in UG. For example, the effects of Rendaku in Japanese, are attributed, in numerous OT analyses, to universal constraints.

[3]It has been brought to my attention that vowel length in the Hebrew is actually difficult to determine. However, this issue is irrelevant to the point under discussion—any example of 'antigemination' will do and additional ones are provided below.

[4]For example, Keer's (1999) recent OT thesis on the OCP, lists Odden's papers in the bibliography, but contains no discussion in the text of the challenges they raise, even in sections discussing antigemination.

[5]Providing a principled response to the reader who finds this discussion to constitute an argument for the violable constraints of Optimality Theory is beyond the scope of

this paper, or perhaps even impossible, reducing to a question of faith.

[6]Hayes' (1986) work on inalterability and integrity, Schein and Steriade's work on geminates and many other sources are relevant to much of the data discussed in this paper. Hayes (1986), for example, is built on "independently motivated principles of CV phonology: (a) the Obligatory Contour Principle, (b) the ban on crossing association lines, and (c) the statement of assimilation as spreading" (328). Coleman and Local (1994) have demonstrated that the line crossing constraint is vacuous. In my opinion, Odden (1986, 1988) shows that the OCP is not part of UG. Finally, assimilation as spreading can be restated in terms of the Feature Algebra proposed here, but working out the details is a project for the future. In other words, Hayes' excellent article surely contains many insights that will survive a reframing, but since this paper starts from such different assumptions than such earlier work, those findings cannot be discussed in full here. Also note that whether or not morphological conditioning and the true/fake geminate contrast is relevant to the data under consideration, it remains the case that identity and nonidentity must be expressible. Morphological conditioning just adds *additional* representational demands.

[7]Of course, (b) also potentially generates OCP violations, and (e) potentially repairs OCP violations.

[8]The necessity for such conditions has been known for a long time. For example, Kenstowicz and Pyle (1973:40) contains a nonidentity condition for a metathesis rule of Tunisian Arabic, as well as a discussion of a nonidentity condition in Kasem, proposed in *SPE* (Chomsky and Halle 1968:361). My point is that the implications of such conditions on rules have not be sufficiently appreciated.

[9]I continue to refer to segments for expository convenience, however, the valued features belonging to a given segment are more accurately characterized as the valued

features sharing an index. These indices, in turn are best understood as denoting association to elements of an X-slot or CV timing tier—valued features with identical indices are linked to identical elements of the timing tier.

[10]I refer to Halle (1975:532) for discussion of the importance of explicit, careful formalization: "[D]etailed concern for the formal machinery of phonology has led to significant insights into the relationship between superficially disparate facts ... [I]t has paid off in terms of a deeper grasp of the significance of certain empirical facts." My debt to Odden is, I assume, obvious.

[11]Since McCarthy treats this as a case of anti-gemination, that is a failure of syncope to apply, he appears to be treating the vowel *i* as underlyingly present in the feminine form. It is not inserted by rule, and there is also nothing in his discussion to suggest that the vowel is derived by raising the *a* found in the masculine.

[12]We can remind the reader here that, as is always the case, only one of the two quantifiers is necessary, since they can each be derived from the other *via* negation. For example, '$\forall x, x = y$' is equivalent to '$\neg\exists x$ such that $x \neq y$'; and ' $\exists x$ such that $x \neq y$' is equivalent to '$\neg\forall x, x = y$'. I continue to make use of both quantifiers for ease of exposiion.

[13]Presumably the correct generalization is that the first consonant is in an onset.

[14]Such representations have been proposed for affricates–with a single Root node dominating both a [+continuant] and a [-continuant] specification. In such cases, one might propose that a default ordering principle ensures that the [-continuant] specification be ordered first, since that is how they are ordered in affricates. Such a strategy will not work in the present case, since the order of the features is not fixed in Koya.

[15]A reviewer grants that "the claim that Feature Geometry lacks [the necessary]

expressive power may be empirically justified" but is bothered by the rejection of Feature Geometry: "Is there still any place in substance free phonology for formal universal conditions on representations? Similarly, is there any place in phonology for the notion of 'natural class'?" The answer to the first question is that there are obviously *formal* conditions on representations in substance free phonology; there just are not conditions that are grounded in phonetic substance. The answer to the second question is that the notion of natural class has the same status in the theory advocated here as it has in all other phonological theories. A natural class of segments is a class definable by a representation that subsumes (contains a subset of the information in) all and only its members. Even in Feature Geometric models, a natural class has a formal definition.

[16]That is 'complete' refers to all members of the given subset, not in general, to the whole feature set.

[17]The rule is also sensitive to syllable structure in a way that is irrelevant to the point under consideration, so I have given only examples of stems that end in a single consonant. Other data makes it clear that this is not a rule of epenthesis: *tate* 'father', *(dem) tatn* DATIVE.

[18]This point is too obvious to be credited to Hale and Reiss or anyone else, for that matter. However, it seems to be ignored in OT arguments which suppose that the factorial typology, the set of possible ranking of a constraint set, should reflect *attested* languages. Obviously, the factorial typology must generate all attested patters, but it is clear that some may not be attested, for reasons that have nothing to do with phonology.

[19]See Harnad 1987 for critical discussion of feature detector theory. Current work that attempts to incorporate phonetic description (acoustic parameters, trajectory of

articulators, *etc.*) into the phonology represents an overly naive approach—one that essentially equates physical partameters with representational constants.

[20]It is beyond the scope of this paper to provide full analyses of these processes. It is clear, however, that they involve complex chains of diachronic events. Here are some typical descriptions:

- "Consonant clusters are often broken up by the insertion of a vowel ... An excrescent vowel is never inserted betweeen identical consonants, as in *kodda* above. Clusters consisting of a [nasal and a stop, a liquid and a stop, or a fricative and a stop] are not broken up by an execrescent vowel when the two consonants have the same place of articulation. ... [W]here the two consonants have different points of articulation ... excrescent vowel insertion appears to be optional" (Harrison 1976:42-3)
- "Clusters are allowed in medial position ... in which case an excrescent vowel optionally intervenes if the members of a cluster are not in the same position of articulation and if the first consonant is not one of **l**, **n** and **g** [the velar nasal—cr]" Sohn and Bender (1973:38).
- "In order to maintain the phonetic and structural equilibrium, such forces as compensatory lengthening, excrescent vowel insertion, vowel reduction, etc. are constantly in operation. The above rule deals with vowel reduction ... When the single vowel to be reduced is preceded by nasal or **l**, the reduction seems almost complete. In the case of non-nasal and non-**l**, the reduction, which is incomplete [to the high central vowel [ɨ]—cr] is applicable only where the neighbouring vowels are dissimilar" Sohn and Bender (1973:67).

[21]The formal nature of such properties in conceptual structure is poorly understood, leading to some unclarity in the exact nature of the nonidentity condition. Perhaps

it is best stated as an exclusion of entities whose descriptions are subsumed by the antecedent.

[22]It must be noted that this discussion slightly simplifies that of Epstein, *et al.*, since for them c-command is also derivable from the nature of *Merge*.

[23]At least one other explanation is available, namely that the binding conditions suggested are not, in fact, those of natural language, and that their dependence on the kinds of conditions that are unattested in the phonology is further evidence of this fact.

[24]The following sentence is much closer to a coherent proposal: "In other words, we should be able to freely combine the predicates of our theory of representations and our theory of operations and constraints and, in each case, come up with some real rule that languages have." See, however, Hale and Reiss (2000ab) for arguments that the set of actually attested languages is expected to be only a subset of the set of computationally possible human languages allowed by UG. If taken literally McCarthy's statement leads to the absurd conclusion that our theory of UG should be just a catalog of attested or extant patterns.

[25]See Kempson (1986) for related discussion.

keywords:

quantification, Obligatory Contour Principle, antigemination, identity, feature geometry, features, substance free phonology, constraints, feature algebra

languages:

Arabic (Tunisian, Syrian, Iraqi), Koya, Hebrew (Modern, Biblical), Seri, English, Lenakel, Tondano, Tiv, Afar, Maliseet-Pasamoquoddy, Yapese, Irish, Yiddish, Marshallese, Mokilese, Ulithian