CONTRAST AND SIMILARITY IN CONSONANT HARMONY PROCESSES

by

Sara Mackenzie

A thesis submitted in conformity with the requirements
for the degree of Doctor of Philosophy

Graduate Department of Linguistics
University of Toronto

Contrast and Similarity in
Consonant Harmony Processes
Doctor of Philosophy 2009
Sara Mackenzie
Department of Linguistics
University of Toronto

This thesis deals with the nature and definition of phonological similarity and shows that, when similarity plays a role in the motivation of phonological processes, it is evaluated over abstract, phonological features and not purely phonetic properties. Empirical evidence for this position is drawn from the domain of consonant harmony. Typological studies of consonant harmony (Hansson 2001, Rose and Walker 2004) have argued that segments which interact in consonant harmony processes must be highly similar to one another. This thesis provides analyses of a range of consonant harmony processes and demonstrates that, in each case, the notion of similarity needed in order to determine participating segments is evaluated over contrastive feature specifications. Contrastive specifications are established according to language-specific feature hierarchies (Jackobson and Halle 1956, Dresher 2003, forthcoming) with some features taking scope over others. Languages analyzed in some detail include Bumo Izon, Kalabari Ijo, Hausa, Dholuo, Anywa, Tzutujil and Aymara.

Two definitions of similarity are proposed in order to account for two sets of cases. In one set of consonant harmony processes, interacting segments are similar in the sense that they constitute the natural class of segments contrastively specified in the harmonic feature. In another set of cases, participating segments must be similar according to the following definition; they must differ in only a single marked and contrastive feature specification.

TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION

1.1 Phonetic and Phonological Similarity

Much recent work in phonology has moved in a direction that increases the role of phonetics in accounting for phonological patterning (for discussion see Hayes et al. 2004, Gordon 2007). Phonetic similarity between segments is one aspect of phonetic structure that has been accorded greater importance in accounting for phonological processes. While the role of similarity avoidance in dissimilation processes and OCP constraints has long been recognized, recent work has emphasized phonetic and functional explanations for these phenomena citing challenges that proximal, similar segments pose for speech planning and perception (see e.g. Hansson 2001, Frisch et al. 2004, Rose and Walker 2004). In this thesis, I address the issue of similarity and argue that when similarity is crucial in shaping phonological patterns, it is evaluated over abstract, phonological properties and not purely phonetic ones. In doing so, I seek to address the following questions:

> What is the relationship between phonological similarity and phonetic similarity? Is similarity evaluated over phonetic properties or phonological ones?
>
> Are all phonological processes that make reference to similarity making reference to the same thing?
>
> I propose that the notion of similarity relevant for motivating phonological

processes is based on abstract phonological representations, not fine phonetic detail. These representations in turn are influenced by the contrasts in language-particular phonemic inventories. Thus, the relative phonological similarity of segments may differ

1

from language to language. More specifically, I argue that a theory of contrastive specifications in which features are hierarchically ordered (Jakobson and Halle 1956, Dresher 2003, forthcoming) is needed in order to derive representations that are able to determine relative similarity. While arguing for the importance of contrast in determining featural specifications, this thesis more generally argues for the importance of feature-based representations and against claims that universal, phonetic measures are able to account for the evaluation of similarity in the grammar.

Evidence for these claims comes from an investigation of consonant harmony patterns. In addition to showing that similarity is evaluated over contrastive feature specifications, I argue that distinct types of relationships between segments have been labeled as similarity. Even within the domain of consonant harmony processes, not all cases that have been argued to be motivated by similarity are motivated by the same thing. Two types of similarity advocated here are natural classes and global similarity measures based on shared contrastive and marked features. Other proposed cases of phonological generalizations determined by similarity are argued to be the result of diachronic and functional factors that need not be enforced by the phonological grammar.

1.2 Similarity and Harmony Processes

When similarity is shown to play a role in motivating phonological processes, it is something to be avoided. Dissimilation repairs sequences of similar segments by changing one segment in a sequence to another, less similar segment. The OCP functions as a morpheme structure constraint that bars similar segments from occurring within a domain. Cluster simplification processes function to avoid similarity by deleting one of a cluster of similar segments (Côté 2000, 2004). Similarity can be avoided by deletion of a

segment, as in cluster simplification, by changing the features of a segment, as in dissimilation, or by restrictions on the form of morphemes that ensure that combinations of similar segments never arise, as in the OCP.

All of the these processes prevent occurrences of similar segments by changing some segment to be more distinct from another or by preventing similar sequences altogether through deletion or avoidance. Another possible repair to an unwanted level of similarity, however, is to make the relevant segments more similar to one another. Similarity is distinct from identity and some processes motivated by similarity function to make segments that are merely similar, identical, either completely or with respect to some feature specification.

Processes that function in this way include vowel harmony systems in which vowels undergoing harmony must already agree in some feature specifications (see Cole and Trigo 1989, Krämer 2003 for discussion). For example, in the Northern Turkic language Kachin Khakass (Korn 1969) rounding harmony takes place only between vowels which share the specification [+high]. Local assimilation processes are also more common between segments that already share a number of feature specifications and may function to make sequences of segments that are merely similar, identical. This is the case in Sudanese Arabic where stops assimilate to the manner of a following fricative only if both segments have the same place of articulation. This is illustrated in the data below.

(1)   Sudanese Arabic   (Rice 2007 from Kenstowicz 1989)

     a.   kitaa[b]   'book'
            kitaa[f] fathi   'Fathi's book'
            kitaa[p] samiir   'Samiir's book'

     b.   bi[t]   'girl'
            bi[t] farid   'Farid's girl'
            bi[s] saamya   'Saamya's girl'

The above discussion shows that segments that share some degree of similarity are more likely to interact, both in dissimilatory processes and in assimilatory ones. Typological studies of consonant harmony processes (Hansson 2001, Rose and Walker 2004) have provided particularly compelling evidence for the role of similarity in motivating assimilatory processes. Consonant harmony processes involve the assimilation of consonants at a distance without affecting intervening segments. An example of consonant harmony in Chumash is given below.

(2)   Consonant harmony in Chumash   (Applegate 1972)

     a.   k-sunon-us   'I obey him'
            k-ʃunon-ʃ   'I am obedient.'
     b.   uʃla   'with the hand'
            usla-siq   'to press firmly by hand'
     c.   ha-s-xintila   'his Indian name'
            ha-ʃ-xintila-waʃ 'his former Indian name'

In this example, all sibilants in a form must share the same specification for the feature [anterior]. The rightmost sibilant determines the anterior value for all sibilants within a word.

Consonant harmony is typologically rare in comparison to vowel harmony and local assimilation processes. Nonetheless, consonant harmony has garnered substantial attention in the phonological literature due to the issues that these processes raise for theories of locality and feature organization (see for example Shaw 1991, Odden 1994,

Gafos 1999). Recent typological studies (Hansson 2001, Rose and Walker 2004) have contributed greatly to our knowledge and understanding of consonant harmony, giving evidence of the variety of harmonic features that are possible in consonant harmony processes and the ways in which consonant harmony patterns differently from both vowel harmony and local assimilations. Central to the claims of both these works is the idea that consonants participating in harmony processes must be highly similar to one another.

Hansson (2001) and Rose and Walker (2004) show that targets and triggers in harmony processes generally share major stricture features such as [sonorant] and [continuant]. Many processes also require interacting segments to share major place features. When the segments participating in a harmony process are restricted to a small set they are likely to be those segments which are most similar to one another. Harmony results in greater similarity, or often identity, between interacting segments by requiring agreement in the harmonic feature. In the Chumash example above, the only segments participating in harmony are the sibilants /s/ and /ʃ/. Potential cooccurrence of these similar segments is prevented by the effects of anterior harmony which requires all sibilants to be identical.

I follow Hansson (2001) and Rose and Walker (2004) in considering consonant harmony processes that result in alternations, like Chumash, and consonant harmony patterns that consist of static morpheme structure constraints as a unified phenomenon motivated by the same factors and enforced via the same mechanisms. Hansson's (2001) comprehensive typology of consonant harmony systems includes 120 cases, many of which are realized only as morpheme structure constraints. One of several arguments that Hansson provides for considering morpheme structure constraints within the set of

consonant harmony systems is found in comparative-historical data. In some cases where related languages have consonant harmony, in some languages harmony extends to affixes resulting in alternations and in others harmony is limited to the root and realized only as a static morpheme structure constraint. For example, in Nilotic languages like Dholuo and Anywa, dental harmony bars the cooccurrence of dentals and alveolars in roots. In the related language Mayak, harmony optionally extends beyond the root, leading to alternations in the form of affixes. This is shown in the data in (3a) where we see Dholuo roots in which coronals agree in dentality. In the Mayak data in (3b), the underlying form of the suffix contains a dental stop and the suffix is realized as such when there are no coronals in the stem. If the stem contains an alveolar, however, harmony optionally applies, causing the suffix coronal to be realized as alveolar.

(3)   a. Dholuo   (Tucker 1994)   b. Mayak (Hansson 2001 from Andersen 1999)

t̪ed̪o	'to forge'	leɣ-it̪	'tooth'
d̪ɔd̪ɔ	'to suckle'	gim- it̪	'cheek'
tedo	'to cook'	tuɣ-it̪ ~ tuɣ-it	'back of head'
diedo	'to balance'	dɪ:n-ɛt̪ ~ dɪ:n-ɛt	'bird'

The related patterning of dentals and alveolars in Dholuo and Mayak justifies a unified treatment, regardless of the fact that one language limits harmony to the root and another extends it to affixes. (See Hansson 2001 for other formal and empirical arguments for including morpheme structure constraints within the category of consonant harmony systems.)

1.3 Contrast and Phonological Representations

This thesis examines a range of consonant harmony processes and proposes that the notion of similarity relevant for determining interacting segments in these cases is

evaluated over contrastive feature specifications. In determining which phonological features are contrastive, I adopt the theory of the contrastive hierarchy (Dresher 2003, forthcoming). According to the theory of the contrastive hierarchy, contrasts are determined by hierarchic ordering of features with some features taking scope over others. The hierarchy of features can vary from language to language. Contrastive specifications are influenced by the shape of the phonemic inventory but inventory shape does not uniquely determine contrastive specifications. Under this model, different contrastive specifications are possible for similar, or even identical, inventories

In a simple three-vowel system, for example, two contrastive features will be necessary in order for each segment to be uniquely specified. What the contrastive features are can potentially vary. Some candidates are shown below:

(4)   Some potentially contrastive features in three-vowel system
a.   [high]   b.   [round]

The specifications that each segment receives will also be determined by the order of features in a contrastive hierarchy. If we choose the features [high] and [round] there are two possible orderings. If [high] is ordered first, it will be contrastive for the entire inventory with the vowels divided into [+high] and [-high] sets. When the feature [round] is added it will only be contrastive for the [+high] vowels because the vowels in that set are not uniquely specified (5a). If the order is [round] over [high], all segments will be contrastively specified for [round] and the feature [high] will only be relevant for the [-round] set (5b).

(5)   a. [high] > [round]   b. [round] > [high]

```
              /\                                          /\
      [+high]    [-high]                       [-round]      [+round]
        /\          |                            /\              |
       /  \         A                           /  \             U
 [-round]  [+round]                        [+high]  [-high]
     |        |                               |         |
     I        U                               I         A
```
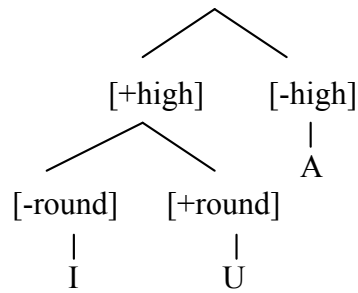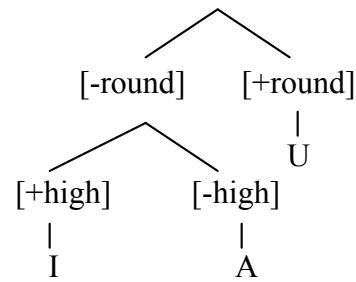
The two vowel systems above, though identical on the surface, are expected to pattern differently in the phonology. System (5a) might show alternations or neutralization between /i/ and /u/ whereas in system (5b) /i/ might be more closely related to /a/.

The theory of the contrastive hierarchy requires all segments in an inventory to be uniquely specified. Which features are contrastive for which segments will depend, not only on the relevant set of features, but also on their order in the language-particular contrastive hierarchy. Arguments for the contrastive hierarchy have been put forward in analyses of vowel harmony (Dresher and Zhang 2004), local assimilation (Hall 2007), loanword adaptation (Herd 2005), language change (Moulton 2003) and language acquisition (Dresher 2004).

The questions addressed in this thesis are necessarily representational ones. What are the representations that allow us to determine which segments are similar? What is the threshold of similarity necessary for segments to interact in a consonant harmony process? What properties of segments enter into the evaluation of similarity? The theory of the contrastive hierarchy as a theory of phonological representations plays a significant role in this thesis and in the answers proposed to these questions.

Nonetheless, some assumptions about phonological operations also play an important role in the analyses put forward in the following chapters. When explicit proposals regarding the operational mechanisms of consonant harmony are given, they are carried out in the framework of Optimality Theory (Prince and Smolensky 2004). Representational theories and assumptions are given relatively little explanatory power in OT. This is largely due to the principle of Richness of the Base. According to Richness of the Base, there are no language-specific restrictions on inputs and all phonological processes and generalizations are accounted for through the interaction of universal constraints on output forms. In this thesis, I assume a version of Stratal Optimality Theory (Kiparsky 2000, 2002, Berumdez-Otero 2003, forthcoming, Rubach 2000, 2003) in which the output of one grammatical evaluation serves as the input to subsequent evaluations. Richness of the Base holds for the earliest level of evaluations but subsequent levels are restricted to outputs selected at earlier levels.

1.4 Structure of the Dissertation

The structure of the dissertation is as follows. Chapter 2 provides an overview of previous literature on phonological similarity and contrastive feature specifications. The theory of the contrastive hierarchy is explored in greater detail and located within the context of other theories of phonological representations. In Chapter 3, analyses of several cases of consonant harmony are proposed. In each case, I demonstrate that participating segments can be determined on the basis of contrastive feature specifications. Given the theory of the contrastive hierarchy, the set of segments that participate in these processes can be described as the natural class of segments contrastively specified for the harmonic feature. Chapter 4 examines cases of consonant

harmony in which the notion of natural class is not adequate to describe the set of participating segments. These cases include consonant harmony processes in which participating segments must share major place specifications. I argue that segments that interact in these cases are similar according to the following definition; they may differ in no more than a single marked and contrastive feature specification. Chapter 5 moves beyond definitions of similarity and provides an account of the mechanisms of some particularly complex laryngeal harmony processes in Peruvian and Bolivian Aymara. The analyses in this chapter are carried out in the framework of Stratal Optimality Theory. In Chapter 6, I review literature arguing for gradient definitions of similarity and show that such definitions are unnecessary in the analysis of consonant harmony processes. Chapter 7 concludes the thesis.

CHAPTER 2
PREVIOUS APPROACHES TO CONTRAST AND SIMILARITY

The significance that similarity plays in phonological patterning can be seen simply in the terminology used to describe common phonological processes. Assimilation and dissimilation comprise the majority of segmental phonological processes and are understood as changes leading to greater or lesser similarity between a segment and its surrounding context. While this thesis focuses on the role of similarity in assimilatory processes and morpheme structure constraints, theories of similarity in phonology have largely developed in the analysis of dissimilatory patterns. The fact that similarity motivates dissimilatory processes and morpheme structure constraints has been recognized in phonological theory at least since Trnka's (1936) work on the role of similarity and distinctness in phonotactic restrictions. Dissimilation processes and restrictions on the well-formedness of morphemes serve to prevent similar segments from cooccurring.

The need for similarity avoidance has been formalized in terms of the OCP (Leben 1973, Goldsmith 1976). Originally formulated with respect to tone patterns, the OCP states that identical adjacent elements are banned from the representation of a morpheme. Work by McCarthy (1979, 1986) extended the use of the OCP to the study of root and pattern morphology in Semitic. McCarthy was able to use the OCP to account for restrictions against homorganic consonants in Semitic roots by arguing that consonants and vowels are represented on different tiers. In this account, sequential

identical consonants are adjacent on the consonantal tier and consequently barred by the OCP.

The role of the OCP in explaining phonological generalizations increased with developments in autosegmental phonology and feature geometry. Models of feature geometry (e.g. Clements 1985, Sagey 1986, Clements and Hume 1995) propose that, rather than consisting of unordered bundles of features, segments have internal, hierarchical structure. Classes of features are grouped together into constituents and these constituents are hierarchically ordered with some features or nodes dominating others. These models account for the tendency of certain groups of features to behave as a unit with respect to phonological processes.

Also integral to models of feature geometry is the notion of tier-based locality. Feature specifications are arrayed on separate tiers and may interact with other features that share the same tier. The notion of separate tiers for separate features allows the OCP to apply not just to identical segments, but also to similar ones. Although labial stops and labial continuants are not identical, their labial specifications are identical. Even if a labial stop and continuant are not strictly adjacent, their [labial] specifications may be adjacent on the labial tier leading to an OCP violation.

The OCP has been an extremely successful and influential principle in phonology and has been invoked in numerous and diverse works (e.g. Goldsmith 1976, McCarthy 1979, 1986, Yip 1988, Odden 1986 among others). Accounts of segmental phenomena that make reference to the OCP rely on abstract representations based on models of feature geometry. In these works, theories of feature specification and particularly

feature organization are foregrounded. Tier-based locality relies on theories of feature organization in order to determine which feature sequences will be barred by the OCP.

In contrast to OCP-based analyses, much recent work on the role of similarity has been undertaken by researchers who reject representational theories such as feature geometry and underspecification. As a result, some of this work adopts universal similarity hierarchies based on phonetic properties (e.g. Hansson 2001). Other work incorporates the notion of natural classes into the calculation of similarity, thus allowing inventory shape to influence similarity while maintaining full specification for all features (Frisch et al. 2004). Features continue to play a role in the determination of similarity in these frameworks but that role is minimized and discussions of feature theory are relegated to the background.

The model of similarity advocated in this thesis is crucially dependent on particular assumptions about features and feature specifications. I argue that similarity is evaluated over contrastive feature specifications with contrast being determined via a hierarchical ordering of features. The following sections provide an overview of previous approaches to the study of similarity, contrast and featural representations with an emphasis on those approaches that have been applied to studies of consonant harmony processes.

2.1 Feature Geometry and the OCP

Geometric organization and the OCP have been central analytic tools in many analyses of consonant harmony and cooccurrence restrictions (e.g. Mester 1986, McCarthy 1989, Yip 1989, Shaw 1991, Lombardi 1990). Mester's (1986) study of consonant and vowel harmony processes is of particular interest here as it proposes an

explicit definition of similarity and criteria for determining which segment pairs have the requisite level of similarity to interact in harmony systems. His proposal begins with the premise that the featural content of a segment is organized with a melodic core and more peripheral elements. Features that are in the core include major class features such as [sonorant] and [consonantal]. Other features are linked to the core and are ordered in a dependency relation. The ordering and resultant dependencies may vary from language to language. OCP effects are influenced by feature ordering and will thus also vary between languages.[1]

Mester applies this theory of feature dependency to consonant cooccurrence restrictions in Ngbaka. In Ngbaka, homorganic voiced and voiceless stops may not occur together in a root. Voiced stops also cannot occur with prenasalized stops which are also barred from occurring with homorganic nasals. Using the labial series, Mester presents the following scale in which adjacent elements are subject to cooccurrence constraints.

(6)   p - b - ᵐb - m

Mester argues that, in Ngbaka, both nasality and major place features are directly linked to the melodic core with voicing dependent on place. He claims that the location of voicing and nasality in the geometry is subject to parametric variation but that it is a linguistic universal that primary articulation features are linked to the melodic core.

---

[1] In this respect, Mester's approach differs from other work in feature geometry which argues for a universal model of segment structure (e.g. Clements and Hume 1995). In allowing variation in feature structure between languages, Mester's work is similar in spirit to the theory of the contrastive hierarchy adopted in this thesis.

(7)   Ngbaka feature ordering.

                    [voice]
                       |
                    [place]   [nasal]
                       |
                       X
                  [melodic core]
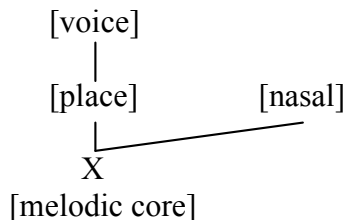
Mester also assumes the following feature specifications for Ngbaka labials.

(8)   Labial feature specifications.

        p   [+labial]
         b   [+labial] [+voice] [-nas]
         ᵐb [+labial] [+nasal] [-nasal]
        m   [+labial] [+nasal]

Within the framework of autosegmental phonology, segments and features need
not have a one-to-one relationship. A single feature specification may be linked to
multiple segments and a single segment may be specified for more than one value of a
given feature. Given these assumptions, Mester's use of feature organization and the
OCP is able to account for the Ngbaka data. /p/ and /b/ cannot cooccur because that
would incur an OCP violation on the labial tier (see (9) below below). This could be
corrected through having a single labial specification linked to two segments but, because
voicing is dependent on place, the two segments would necessarily also share voicing
features (10).

(9)

        *   [+voice]
                                     |
             [+labial]   [+labial]   [-nasal]
                 | |
                 p   b
          [melodic core]   [melodic core]

(10)

$$[+\text{voice}]$$

$$[+\text{labial}] \qquad\qquad\qquad [-\text{nasal}]$$

b   b

[melodic core]   [melodic core]
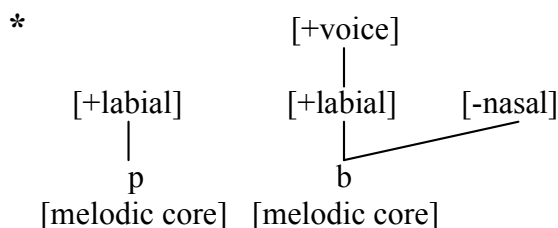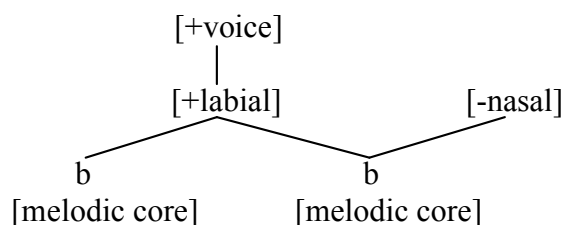
The diagram in (9) illustrates the structure of cooccurring /p/ and /b/. As stated above this sequence is banned due to an OCP violation on the labial tier. (10) shows a possible resolution in which adjacent stops share a labial specification and hence must share the value of [voice]. In this illustration, I show the resolution maintaining the [+voice] specification of the /b/ rather than the lack of voicing specification of underlying /p/. Ngbaka has only static cooccurrence restrictions and does not have any alternations which provide evidence as to how an underlying /p/-/b/ sequence would be repaired.

In Mester's account, /b/ and /^{m}b/ cannot cooccur because they incur an OCP violation on the nasal tier. There are identical specifications adjacent on the nasal tier: the [–nasal] of the /b/ and the [-nasal] of the prenasalized stop. That /^{m}b/ is also specified for [+nasal] does not alleviate the OCP violation. A multiply linked structure with a single nasal specification replaces the adjacent identical specifications leading to two segments with identical nasality.

(11)   OCP violation [-nasal]

*   [+labial]

b ^{m}b

[melodic core]   [melodic core]

[-nasal]   [-nasal]
                      [+nasal]
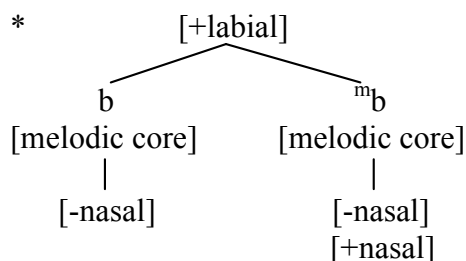
Mester (1986) distinguishes between fusional harmony and spreading harmony. Fusional harmony is that which requires target and trigger to share a specific degree of similarity and therefore is instantiated by an OCP violation which is repaired by deleting one of the specifications and creating a linked structure. In spreading harmony, there are no similarity requirements on target and trigger and harmony is the result of spreading the specification of the trigger with potential delinking of target specifications.

Mester's account makes crucial use of the OCP and proposes a specific definition of similarity. According to Mester, segments must be identical at the core level in order to be similar enough to constitute an OCP violation and thus to participate in harmony. In addition to being identical at the core, some identical specification at a higher featural level must be present in order for the OCP to trigger fusion. If the feature responsible for the OCP violation has dependents, the effects of fusion will be visible as harmony processes or cooccurrence restrictions.

2.2 Natural Classes and Structured Specification

As crosslinguistic studies in autosegmental phonology developed, the OCP as a universal principle drew criticism in light of evidence that it does not apply in all languages and, in those languages which do have evidence of OCP effects, it does not apply uniformly (see e.g. Odden 1986). Other critiques of autosegmental phonology similarly focused on the complexity of proposed representations and the lack of evidence for universality in the form of representations. With the rise of Optimality Theory (Prince and Smolensky 2004), emphasis on interaction of constraints on surface forms replaced emphasis on the structure of underlying representations.

Recent studies of OCP effects have also encompassed a wider range of data, considering not only sequences of similar segments that are ill-formed, but also sequences that are infrequent. For example, Frisch (1996) and Frisch et al. (2004) examine the frequency of cooccurrence of various consonant pairs in Arabic and argue that the autosegmental OCP is inadequate and incapable of accounting for the full range of data. They argue that the frequency of consonant cooccurrence is determined by similarity with highly dissimilar pairs cooccurring most often and highly similar pairs cooccurring least often. Frisch (1996) and Frisch et al. (2004) propose a model of specification and similarity in which similarity between segments can be measured and assigned a numerical value. These works reject underspecification and autosegmental representations yet do not deny the significance of redundancies in the phonological component of the grammar. Rather, redundancies are viewed as relations between segments in an inventory. Segments in an inventory are arranged according to natural classes. Similarity is then measured by dividing the number of natural classes shared between two segments by the number of shared plus unshared natural classes.

$$\text{Similarity} = \frac{\text{Shared natural classes}}{\text{Shared + unshared natural classes}}$$

Frisch et al. adopt the representational theory of structured specification (Broe 1993, 1995). Structured specification directly encodes natural classes in set relations. For example, consider a three vowel inventory with the feature specifications shown below (from Frisch 1996: 23).

(12)

	/a/	/i/	/u/
[high]		+	+
[low]	+		
[front]		+	
[back]	+		+

Using these features, there are six natural classes of segments, (a,i,u), (i,u), (a,u), (i), (a), (u).[2] These sets are ordered in the following set containment relations.

(13)　{a, i, u} ⊇ {a, u}, {i, u};　[vowels]
　　　{a, u}⊇ {a}, {u};　[back]
　　　{i, u} ⊇ {i}, {u};　[high]
　　　{a}, {i}, {u} ⊇ 0

The similarity metric given above determines the relative similarity of segments. The segments /a/ and /u/ have two shared natural classes, (i, a, u) and (a, u), and three non-shared classes, (i,u), (u), and (a). The similarity measurement of shared over shared plus non-shared natural classes is thus 2/5. This can be compared with other possible pairs of vowels. /a/ and /i/, for example share only the class of vowels and have a similarity measure of 1/5.

Frisch et al. argue that their similarity metric allows redundancies to play a role in the grammar directly, without the need for underspecification of non-contrastive features. Previous analyses making reference to similarity have made use of contrastive underspecification in determining which features are crucial in determining the relative similarity of segments (see Pierrehumbert 1993). Frisch et al. argue against underspecification. In their account, redundancy plays a role, not in determining the featural representation of segments, but in determining the similarity values computed over the natural classes. By computing similarity over natural classes, redundancy influences similarity directly, not by influencing feature specifications.

---

[2] Frisch (1996) assumes monovalent features with some consequences of binarity replicated through the use of antagonistic monovalent features such as [front] and [back]. Frisch et al. (2004) use binary values for certain features, including [voice]. They state that this use of binarity is not crucial as the same natural classes would result if monovalent features such as [+voice] and [+unvoiced] were used (2004: 200).

The choice of feature specification still influences similarity values, however. For example, in the case of the three vowel inventory discussed above, if the feature [round] is used instead of [back], the set of natural classes will change and with it the relative similarity of segments. Frisch clearly acknowledges this; 'naturally, given different feature assignments, different natural classes may result' (1996: 20). Despite the obvious influence of feature specification on similarity, Frisch et al. claim that 'the similarity metric is stable under relabeling of features' (2004: 200) and that '… the exact… features used and their labels is not crucial' (2004: 201).

These statements are misleading in their denial of the crucial impact that choice of features and feature specifications have on the outcome of the similarity metric. Frisch et al. seek to minimize the influence of feature specifications, and specifically the possible influence of underspecification, on the evaluation of similarity. The natural classes referred to by the similarity metric, however, are determined on the basis of distinctive features. What the natural classes model of similarity does accomplish (as discussed in Frisch 1996: 20) is a restriction on the number of features that have the potential to influence similarity values. This restriction is related to the size and shape of the inventory. Specification of additional features that are truly redundant, creating no additional natural classes, will not affect the computation of similarity values.

2.3 Contrast and Phonological Representations

The theories outlined above determine similarity by comparing feature specifications of segments. The approaches differ in terms of how these comparisons are to be made. In Mester's analysis, some features are core and some are peripheral. For segments to reach the threshold of similarity needed to trigger a phonological process such as harmony, the core features of interacting segments must be identical. For Frisch

et al., features are used to delineate natural classes in an inventory. Pairs of segments are then assigned a similarity value determined by dividing the set of natural classes shared by the two segments by the set of shared and unshared natural classes.

The theories of similarity differ in terms of how similarity values are computed and how variation between languages is accounted for. Frisch et al's similarity measure is affected by inventory shape because the computation is based on shared and unshared natural classes. Mester allows for different ordering of dependent features in different languages. Both theories, however, must start with feature specifications that can be counted, ordered and computed. And both authors are inconsistent when determining what those specifications are.

In his analysis of Ngbaka consonant harmony, Mester assumes that [voice] is specified for /b/ but not for /p/. This suggests that unmarked feature values may be absent from underlying representations. A general principle of underspecification cannot be assumed in his analysis, however, as he also crucially assumes that /b/ is specified for [-nasal]. The feature specifications used in his analysis are able to derive the desired pattern of consonant harmony but are not discussed or motivated in any way. Similarly, Frisch uses a binary feature, [±nasal], to specify nasals and stops while other segments are left unspecified for nasal. Frisch et al. claim to use only trivial underspecification (in the sense of Steriade 1995) but it is unclear why the feature [nasal] is relevant for voiceless stops but not for liquids, glides or fricatives.

The vagueness of the discussion of feature specification in these works is understandable because of a need for flexibility in analyses of different languages. Neither author is willing to be pinned down to a set of feature specifications that will be

used consistently at all times. However, if similarity is to be computed based on a set of feature specifications, theories of similarity cannot be evaluated in the absence of a theory of features and a theory of feature specification.

In this work, I adopt a theory of feature specifications based on the notion of a contrastive hierarchy of features (Jakobson and Halle 1956, Dresher 2003, forthcoming). This theory allows for variation between languages and makes explicit how contrastive features are determined. The theory of the contrastive hierarchy attempts to account for the observation that features which are not needed to contrast segments in an inventory are often inert with respect to phonological processes. In doing so, the theory of the contrastive hierarchy shares research questions with earlier theories of underspecification.

The theory of Radical Underspecification (Kiparsky 1982, Archangeli 1984, 1988) advanced the position that, in addition to the absence of predictable features from URs, for any binary feature only one value, the marked value, can be specified at the underlying level. While this principle makes strong claims about which features may be present in underlying representations, few cases of phonological analyses relying crucially on radical underspecification were put forward in the literature. Part of the difficulty in assembling clear evidence for Radical Underspecification stemmed from the Redundancy Rule Ordering Constraint (Archangeli 1984). The RROC states that a redundancy rule inserting some feature value will be applied prior to any phonological rule referring to that feature. This eliminates possible arguments against underspecified URs on the basis of feature activity. Such arguments cannot be made, as unspecified features are expected, and in fact required, to be added to the representation as soon as any rule affecting such features is applied. (See Dresher forthcoming for further

discussion of this point.) In addition, assuming the RROC leads to a number of rule ordering problems when crosslinguistic data are considered (see Steriade 1995).

The theory of Contrastive Specification (Steriade 1987) differs from Radical Underspecification in arguing that the difference between contrastive features and redundant features is central in the determination of underlying feature specifications. In addition, the theory of Contrastive Specification does not require, or permit, unmarked feature values to be unspecified in URs. Rather, both plus and minus values of a feature must be present underlyingly if that feature is needed to differentiate segments in an inventory.

The notion that contrast is the crucial factor determining which features may be left unspecified from URs is at the heart of the theory of Contrastive Specification. The importance of contrast in determining specifications is also clearly appealed to in theories like Radical Underspecification that argue for logically minimal underlying specifications. Despite the central role that contrast plays in determining phonological representations in these theories, there has never been a consensus on how to determine which features are contrastive and which are redundant for a given inventory. As a result, a number of arguments have been leveled against underspecification, including claims that underspecification is basically arbitrary and that redundant features are, in fact, active in phonological processes and hence must be present in the representation.

The rise of OT (Prince and Smolensky 2004) has also drawn attention away from issues of representation in general and theories of underspecification in particular. In OT, representational devices such as underspecification have been rejected in favour of constraints on output forms. All aspects of phonological structure and behaviour are

accounted for by the free ranking of universal, violable constraints on outputs. This position extends to the phonemic inventory of particular languages, which in OT are argued to be derived through constraint interaction and to enforce no limitations on inputs to the phonological evaluation.

Despite the arguments raised against underspecification and the rejection of limitations on inputs espoused in OT, the original insight that there is a link between contrast and phonological activity still requires an account. Analyses that assume full specification of URs and analyses that assume that specification in the UR is unimportant and that the burden of explanation is on the interaction of constraints on output forms still continue to make reference to some features as being important and not others. Only a small subset of the features proposed in crosslinguistic analyses is ever appealed to in the analysis of any particular language. A theory is needed to account for which features are important in a particular language and which features will be active in phonological processes.

The theory of the contrastive hierarchy (Dresher 2001, 2003, forthcoming) adopts the position, advocated in earlier theories of underspecification, that contrast determines which features will be active in the phonology of a given language. Unlike previous work on underspecification, the theory of the contrastive hierarchy proposes a principled method for determining the set of contrastive features in an inventory. According to the theory of the contrastive hierarchy, contrastive features must be ordered hierarchically with some features taking scope over others. A feature which is higher in the hierarchy will be contrastive for a larger set of segments than features lower down in the hierarchy. Inventory shape and phonological processes provide evidence of the hierarchical order of

features in a particular language. Although explicit discussion of how contrasts are determined is rare in phonological work, the theory of the contrastive hierarchy has roots in early generative phonology (e.g. Halle 1959, Jakobson and Halle 1956).

According to the theory of the contrastive hierarchy, feature specifications are determined by the Successive Division Algorithm (SDA). The SDA determines the scope of contrastive features in the following way: An initial state is assumed in which all tokens are interpreted as variants of a single phoneme. When evidence forces a learner to divide the set into more than one phoneme, a feature is chosen which divides the set in two. This evidence may come from phonological processes which provide evidence of feature activity or from minimal and near minimal pairs which provide evidence that a particular feature is needed to contrast lexical items. This process is repeated for each set of tokens until every phoneme of the language is uniquely specified. The order in which features are selected is the contrastive hierarchy for a particular language.

The theory of the contrastive hierarchy draws a connection between inventory shape and segmental representations and behaviour. At the same time, the possibility of different ordering of features in the hierarchy allows for variation between languages with similar inventories. In this work, I adopt the theory of the contrastive hierarchy as well as the assumption that only contrastive features, as designated by the SDA, are active in phonological processes. With respect to similarity, this entails that any method of determining relative similarity of segments by comparing feature specifications must be carried out making reference only to contrastive features.

The theory of the contrastive hierarchy shares some properties with the theories of similarity discussed above. Like Mester's theory of feature dependency relations, a contrastive hierarchy analysis involves an ordering of features. The theory of the contrastive hierarchy differs from Mester's approach in that the contrastive hierarchy of features, in conjunction with the shape of the inventory, determines which features must be specified for which segments. For Mester, the patterning of OCP effects will be influenced by the ordering of features but the presence or absence of features from segmental representations is not determined. This leads to inexplicit or arbitrary choices of feature specification and underspecification.

Like Frisch et al. (2004), the theory of the contrastive hierarchy allows inventory shape to influence similarity. Unlike Frisch et al., the contrastive hierarchy predicts variation in relative similarity between languages with similar inventories. In addition, the theory of the contrastive hierarchy again brings feature specifications to the foreground in determining segmental similarity.

Previous work on harmony systems has also recognized the significance of contrast. The relation between contrastiveness in segments and the value of harmonic features has played a crucial role in autosegmental analyses of harmony systems. For example, Shaw (1991) provides a feature geometric analysis of Chumash sibilant harmony. Assuming some version of contrastive specification, Shaw accounts for the fact that only sibilants participate in [anterior] harmony, not because they are more similar to one another than to other coronals, but because the feature [anterior] is only contrastive within the sibilants and can thus be left unspecified from other segments in underlying representations.

Hansson (2001) develops an account of consonant harmony based on similarity and correspondence relations and works in a framework that rejects representational theories such as underspecification. Nonetheless, he often refers to the contrasts in an inventory when giving descriptions of consonant harmony systems. He suggests that it may be 'reasonable to encode contrast-sensitivity directly into the analysis rather than have it mediated by relative similarity in a highly stipulative manner.' (2001: 437) Hansson proposes a possible constraint type which would incorporate contrast and preclude the need for the surface correspondence constraints developed in his analysis. Constraints of the type ANTICIPATE [F] are markedness constraints which penalize a consonant which precedes another consonant which has a distinct specification for a contrastive feature. Hansson, however, does not develop an analysis using the ANTICIPATE constraints, nor does he propose a method for determining what is contrastive.

The analyses presented in the following chapters support earlier work arguing for the importance of contrast in the patterning of consonant harmony processes. This analysis differs from previous accounts (such as Shaw 1991) in its theoretical assumptions concerning how contrasts are determined. By using the theory of the contrastive hierarchy, I am able to provide analyses of consonant harmony systems that cannot be accounted for in theories of radical underspecification or full specification. Cases that have been argued to be a problem for contrast based approaches (see Rose and Walker 2004) can be accounted for using the theory of the contrastive hierarchy.

CHAPTER 3
SIMILARITY AS NATURAL CLASSES

This chapter provides analyses of several consonant harmony systems within the framework of the contrastive hierarchy. These cases are taken largely from the typological studies of Hansson (2001) and Rose and Walker (2004), both of which argue that segments participating in consonant harmony processes must be highly similar to one another. In each case analyzed in this chapter, I demonstrate that, given representations consistent with the contrastive hierarchy, segments that participate in harmony can be described as the natural class of segments specified for the harmonic feature. No other definition of similarity is needed in order to distinguish segments which participate in harmony from segments that do not.

The following sections provide analyses of consonant harmony systems in Bumo Izon, Kalabari Ijo, Dholuo, Anywa, Päri and Chaha using the theory of the contrastive hierarchy to assign feature specifications. Only features deemed contrastive by hierarchical ordering will be taken into account in determining relative similarity of segments and determining active values in harmony processes. The chapter concludes with a comparison of the predictions made by the contrastive hierarchy and those made by other theories of similarity.

3.1 Bumo Izon and Kalabari Ijo

An example of a consonant harmony system in which contrast plays a crucial role is the case of implosive harmony in Bumo Izon and Kalabari Ijo (Niger-Congo: Ijoid). Bumo Izon, Kalabari Ijo and related Ijoid languages have a cooccurrence restriction

barring implosive and plosive stops from occurring in a morpheme (Efere 2001, Hansson 2001, Harry 2004). Some examples of harmonic forms are given below.

(14)　Bumo Izon　　　　　　　　　　　　　　　(from Efere 2001)

　　　búbú　　　　'rub (powder in face)'
　　　bídɛ́　　　　'cloth'
　　　ɓúɓaɪ　　　　'yesterday'
　　　ɗɔ́:ɗɔ́:　　　'cold'
　　　ɗáɓá　　　　'swamp'

(15)　Kalabari Ijo　　　　　　　　　　　　　　(from Harry 2004)

　　　bébé　　　　'whole'
　　　bàdàrà　　　'very large'
　　　ɓíɓí　　　　'mouth'
　　　ɗáɓá　　　　'dream'

Implosive /ɗ/ and /ɓ/ are barred from occurring with plosive /b/ and /d/ in any combination and any order. In both languages, however, the velar and labiovelar stops do not participate in the cooccurrence restriction and may freely occur with members of both the plosive and implosive series.

(16)　Bumo Izon　　　　　　　　　　　　　　　(from Efere 2001)

　　　igódó　　　　'padlock'
　　　ɗúgó　　　　'to pursue'
　　　 ɓúgǐ　　　　'to wring (hand)'
　　　 gbáɓu　　　'crack (of a stick breaking)'
　　　gbódagbóda　'(rain) hard'

(17)　Kalabari Ijo　　　　　　　　　　　　　　(from Harry 2004)

　　　ɗùgò　　　　'tell'
　　　búgúmà　　　'Buguma'
　　　ìmgbú!ɓá　　'seed type'
　　　ígbéɓírí　　'hoop of a cask'

The failure of the velar and labiovelar stops to participate in the cooccurrence restriction can be related to the shape of the inventory in both Bumo Izon and Kalabari Ijo (as previously noted by Hansson (2001) for Bumo Izon). As illustrated in the inventory charts shown below, there is no contrast along the pulmonic/implosive dimension at the velar or labiovelar place of articulation in either language. Within the set of voiced stops in Bumo Izon, there is a single, plain voiced velar and a single, implosive labiovelar. In Kalabari Ijo, there are velar and labiovelar voiced stops but implosives are lacking at both these places of articulation.

(18)   Bumo Izon Oral Stop Inventory   (based on Efere 2001)

	Labial	Alveolar	Velar	Labio-velar
Plosive	p	t	k	kp
	b	d	g	
Implosive	ɓ	ɗ		gɓ

(19)   Kalabari Ijo Oral Stop Inventory   (from Harry 2004: 11)

	Labial	Alveolar	Velar	Labio-velar
Plosive	p	t	k	kp
	b	d	g	gb
Implosive	ɓ	ɗ		

Intuitively, the voiced velar and labiovelar stops do not participate because they lack a partner at the same place of articulation that differs in terms of the pulmonic/implosive distinction.

According to the theory of the contrastive hierarchy, features are ordered, with features higher in the hierarchy being contrastive for a greater portion of the inventory than features ordered lower in the hierarchy. The pattern of cooccurrence constraints in

Bumo Izon and Kalabari Ijo can be accounted for within the theory of the contrastive

hierarchy by ordering place features before laryngeal features.

The following tree diagram illustrates a contrastive hierarchy for the inventory of

Bumo Izon stops. At the top of the tree, all stops are considered together. As each of the

segments shown here constitutes a separate phoneme in the inventory of Bumo Izon, they

must be differentiated by contrastive feature specifications. I propose that the feature

[labial] is ordered first in the hierarchy. This results in contrastive specification in the

feature [labial] for all segments of the inventory.   The feature [dorsal] is ordered next

and both the [+labial] and the [-labial] sets are divided according to the feature [dorsal].

The resulting subsets of the inventory are further divided by the features [voice] and

[constricted glottis] resulting in unique specification for each segment.

(20)　　Hierarchy for Bumo Izon
　　　　[labial] > [dorsal] > [voice] > [constricted glottis]

```
                         p, t, k, kp, b, d, g
                             ɓ, ɗ, ɠɓ
                          ╱           ╲
                    [+lab]              [-lab]
               ɓ, p, b, kp, ɠɓ       t, k, d, g, ɗ
                ╱       ╲              ╱        ╲
         [+dorsal]   [-dorsal]   [+dorsal]   [-dorsal]
          kp, ɠɓ      p, b, ɓ       k, g       t, d, ɗ
          ╱    ╲      ╱    ╲       ╱    ╲       ╱    ╲
      [+vce] [-vce] [+vce] [-vce] [+vce] [-vce] [+vce] [-vce]
       ɠɓ     kp    b, ɓ    p      g      k     d, ɗ    t
                   ╱    ╲                       ╱    ╲
               [+cg]   [-cg]               [+cg]   [-cg]
                ɓ       b                   ɗ       d
```
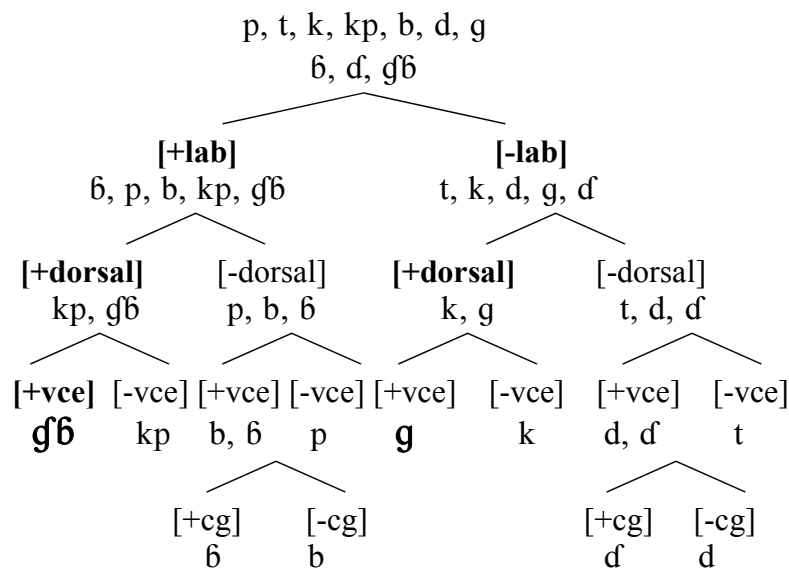
As the above diagram illustrates, with this ordering of features the place features

[labial] and [dorsal] are contrastively specified for the entire set of stops. The groups of

segments distinguished by place features all contain both voiced and voiceless segments.

The feature [voice] is therefore also contrastive for all oral stops. The voiceless stops /p/, /t/, /k/, /kp/ are all uniquely specified at this point and receive no further feature values. The velar stop /g/ and labiovelar implosive /ɠɓ/ are also uniquely specified and require no further feature specifications. The labial and coronal sets, however, both contain two members and require an additional feature in order to be uniquely specified. The feature [constricted glottis] is ordered next and distinguishes between the implosive and pulmonic voiced stops leaving all segments contrastively specified.

The hierarchy and specifications proposed above for Bumo Izon can carry over directly to an analysis of Kalabari Ijo. The only difference in the inventories of the two languages concerns the realization of the labiovelar stop. In Bumo Izon, this segment is realized as an implosive and in Kalabari Ijo it is a pulmonic. According to the theory of specifications assumed here and the hierarchy of features given above, the labiovelar is not contrastively specified for the feature [constricted glottis] in either language. The differences between the two languages show that, in the absence of a phonological contrast, the phonetic implementation of a particular set of feature specifications can vary from language to language. In Bumo Izon, the segment specified simply as [+labial, +dorsal, +voice] is realized as an implosive. In Kalabari Ijo, the segment with the same specifications is realized as a pulmonic.

With the ordering of features given above, the feature [constricted glottis] is only contrastive for the set of voiced alveolar and labial stops. All voiceless segments are distinguished without reference to [constricted glottis], as are the velar and labiovelar stops. A constraint banning segments with distinct specifications for the feature

[constricted glottis], formulated as (21) below, will correctly select the labials and alveolars as the only segments participating in the cooccurrence restriction.

(21)   *[αcg] [-αcg]$_{Root}$: distinct specifications of [constricted glottis] are banned within a root

The constraint given above is similar to the family of AGREE[F] constraints used in a number of OT analyses of local and non-local assimilation (e.g. Lombardi 1996, 1999, Bakovic 2000). The constraint proposed here differs from AGREE constraints only in making explicit reference to binary features. Together with the theory of features and specification assumed here, constraints of the form *[αF]…[-αF] clearly indicate which segment combinations will lead to a constraint violation. In addition, I assume that markedness constraints *[αF]…[-αF] may apply to specified domains such as the root or the word and that segments with distinct specifications need not be adjacent in order to incur a violation.

The importance of contrast in determining the patterning of consonant harmony systems is particularly clear in Bumo Izon and Kalabari Ijo due to the asymmetric shape of their consonant inventories. Those segments which do participate, /b/, /d/, /ɓ/, and /ɗ/, are similar in that they are all voiced stops. However, the segments /g/ and /ɠɓ/ in Bumo Izon and /g/ and /gb/ in Kalabari Ijo also share the properties of voiced stops and do not participate in the harmony process. The velar and labiovelar stops differ from the participating segments in that they are not contrastively specified for the feature [constricted glottis].

The constraint responsible for the ban on implosive and pulmonic stops cooccurring need not be formulated with direct reference to similarity. Rather, a constraint stating that differing specifications of the feature [constricted glottis] are

disallowed root-internally will be sufficient to account for the data. The segments which interact clearly share many properties. Instead of making direct reference to similarity, however, the fact that similar segments will interact is a result of the fact that only segments which are not distinguished by some other feature need be distinguished from one another with a lowly ordered feature like [constricted glottis]. /g/ also shares many properties with /b/ and /ɓ/ but it does not participate in the cooccurrence restrictions because it is not contrastively specified for the active feature in these restrictions.

Assuming the theory of the contrastive hierarchy along with the specific hierarchy of features proposed for Bumo Izon, the constraint motivating implosive harmony can be formulated simply as a ban on segments with distinct specifications in the feature [constricted glottis]. No definition of similarity is needed to ensure that labials and alveolars participate whereas velars and labiovelars are neutral. The segments that participate share a natural class. They constitute the complete set of segments that are contrastively specified in the harmonic feature.

A natural class is some complete set of segments that share some feature specification or some set of feature specifications. The natural class is one of the most basic concepts in phonological theory. The fact that certain sets of segments behave as a group with respect to phonological processes provides evidence that segments are not the smallest units of grammatical organization, but can themselves be analysed as compositions of phonological features. Statements about phonological patterning can thus be stated over features themselves, leading to generalizations that are missed if segments are considered indivisible primitives. Sets of segments that act together need

not be viewed as an arbitrary grouping, but constitute a natural class specified with the same phonological features.

According to the theory of the contrastive hierarchy, feature specifications are influenced by two language particular factors; the structure of the phonemic inventory and the hierarchy of contrastive features. With this approach, not all segments that share some phonetic property are necessarily phonologically specified for that property. They therefore do not necessarily share a natural class. In the case of Bumo Izon, not all segments that lack glottal constriction are contrastively specified as [-constricted glottis]. The velar and labiovelar stops are uniquely specified by features ordered higher in the hierarchy and are therefore not contrastively specified for [constricted glottis]. These segments do not belong to the natural class of segments contrastively specified in the harmonic feature and are not subject to the cooccurrence constraint.

Asymmetrical inventories like that of Bumo Izon and Kalabari Ijo highlight the importance of determining which features are contrastive. In this case, the lack of a partner for the pulmonic velar and the implosive labiovelar results in a lack of specification in these segments for the feature active in the cooccurrence restrictions. Other orderings of contrastive features could result in different specifications and different patterns in harmony and cooccurrence constraints.

Harmony patterns in asymmetric inventories pose a problem for analyses relying on intuitive notions of feature specification and feature counting in order to determine relative similarity of segments (as noted in Hansson 2001: 434 with respect to his framework). In such an approach, an explicit justification is needed to show how /b/ and /ɗ/ are more similar to one another than are /g/ and /ɗ/.

In the contrastive hierarchy analysis proposed here, the participating segments share a natural class, namely the class of segments contrasting in the harmonic feature. Due to its low position in the feature hierarchy, [constricted glottis] is only contrastive for segments that have identical specifications for voicing and place features. The segments specified for [constricted glottis] are thus highly similar in feature specifications. There is no need to refer to similarity, however, in order to delimit the set of segments that participate in the cooccurrence restriction. Within the theory of feature specifications assumed here, the notion of the natural class specified for the harmonic feature is able to describe the set of interacting segments.

3.2 Dental Harmony in Nilotic

Anywa and Dholuo (Nilo-Saharan: Nilotic) are Western Nilotic languages. Both languages have contrasting dental and alveolar stops and both have cooccurrence constraints barring dentals and alveolars from occurring in the same form. The dental/alveolar contrast is not present in the nasal series where both languages have only a single, coronal nasal.

The coronal inventories of Dholuo and Anywa are presented below.

(22)   Dholuo coronal inventory: (based on Tucker 1994:30)

	Voiceless Stops	Voiced Stops	Prenasal Stops	Nasals
Alveolar	t	d	^{n}d	n
Dental	t̪	d̪	^{n}d̪	

(23)   Anywa coronal inventory: (based on Reh 1996: 23)

	Voiceless Stops	Voiced Stops	Nasals
Alveolar	t	d	n
Dental	t̪	d̪	

The /n/ behaves differently with respect to the cooccurrence restrictions in the two languages. In Anywa, [n], like the other alveolars, may not occur with a dental stop. A dental [n̪] appears allophonically in roots containing dental stops.

(24)   Anywa   (Reh 1996)

n̪ùd̪ò 'to lick' *nùd̪ò   núudó 'to press something down'
ōd̪óòn̪ 'mud'   *ōd̪óòn   d̪ín   'to thrash something'
t̪ùd̪   'ropes'   tūud 'pus'

Dholuo patterns differently from Anywa in that the /n/ does not participate in the cooccurrence constraint and occurs freely with dental stops.

(25)   Dholuo   (Tucker 1994)

t̪uno 'breast'   dino 'deaf, to be stopped up'
t̪ʊɔn 'brave man'   tîn   'small'
t̪ed̪o 'to forge'   tedo 'to cook'
d̪ɔd̪ɔ 'to suckle'   diedo 'to balance'

3.2.1 A Correspondence Account (Rose and Walker 2004)

Rose & Walker (2004) use the patterning of dental harmony in Anywa as an argument against the claim that contrast is the crucial factor determining interacting segments in harmony systems. /n/ participates in the cooccurrence constraints in Anywa even though there is no dental/alveolar contrast among nasals. From this, Rose & Walker (2004) conclude that contrast cannot be the determining factor in selecting participating segments. Rather, they point to the fact that all the segments that participate in the harmony in Anywa are highly similar as the crucial explanatory factor in accounting for their participation.

In Rose & Walker's approach to consonant harmony processes, harmony is the result of surface correspondence constraints which require output segments to be in

correspondence with one another. These constraints are ranked in a universal hierarchy with constraints requiring correspondence between more similar segments ranked above constraints requiring correspondence between less similar segments. Faithfulness constraints referring to surface correspondents then demand that output segments agree in some feature. Rose and Walker adopt the similarity metric of Frisch et al. (2004) when giving their similarity rankings.

The constraint type that establishes correspondence relations between output segments is formulated in Rose & Walker (2004) as shown below.

(26)   CORR-C↔C
Let S be an output string of segments. If consonants C_i, $C_j \in S$, then C_i is in relation with C_j, that is, C_i and C_j are correspondents of one another.

Surface correspondence constraints are organized into constraint families with a fixed ranking based on similarity.[3] An example hierarchy from Rose & Walker is shown in (27).

(27)   CORR-T↔T >> CORR-T↔D >> CORR-K↔T >> CORR-K↔D

The highest ranked constraint in (27) requires a correspondence relation to be present between surface segments that are identical. The next constraint in the hierarchy establishes correspondence between segments that have the same manner and place but differ in voicing and the following constraint establishes a correspondence relation

---

[3] To be accurate, the ranking of constraints requiring surface correspondence relations between various segments is not necessarily fixed across languages, according to Rose and Walker (2004). The constraints are in a fixed ranking according to similarity but similarity is evaluated according to Frisch et al.'s (2004) similarity metric (discussed in the preceding chapter). This metric allows the inventory to play some role in determining relative similarity of segment pairs. In the case of Anywa and Dholuo, however, the inventory of the two languages is the same and the framework adopted by Rose and Walker (2004) requires similarity values to be identical between languages with identical inventories.

between surface segments that differ in place but agree in voicing and manner. The lowest ranked constraint in this particular constraint family is the constraint CORR-K↔D that requires a correspondence relation to exist between oral stops that differ in both place and voicing.

Although Rose & Walker do not provide a formal account of dental harmony in Anywa, their approach to consonant harmony would require constraints establishing correspondence relations between similar oral stops to be ranked above the constraint establishing correspondence relations between less similar oral and nasal stops. I will use the feature [distributed] to distinguish dental from alveolar place of articulation. In Anywa, the input-output faithfulness constraint referring to [distributed] must be ranked below the constraint establishing a correspondence relation between oral and nasal coronal stops. In Dholuo, the ranking would be the reverse and the higher ranking IO-FAITH constraint prevents dental nasals from appearing in the output.

The following tableaux are intended to illustrate what a correspondence account of dental harmony in Dholuo and Anywa would look like. Subscript indices represent the presence of a correspondence relation between the relevant surface segments.

(28)   Anywa

nud̪o	ID-CC[dis]	CORR d̪/t̪ - n	ID -IO [+dis]	ID -IO[-dis]
a. nud̪o		*!		
b. n$_x$ud$_x$o			*!	
☞c. n̪$_x$ud̪$_x$o				*

(29)   Dholuo

ţuno	ID-CC[dis]	**ID-IO [+dis]**	**ID -IO[-dis]**	CORR d̪/ţ - n
☞a. ţuno				*
b. t_xun_xo		*!		
c. ţ_xun̪_xo			*!	

Both tableaux show evaluations of disharmonic inputs, and both have an undominated ID-CC constraint requiring surface segments that are in correspondence with one another to agree in specification for the feature [distributed]. In (28), the faithful candidate is eliminated because it fails to satisfy the highly ranked constraint requiring correspondence relations between oral and nasal coronal stops. Candidate (c) is the winner because it satisfies this constraint as well as the constraint ID-IO [+dist] which demands that dental segments in the input are realized as dental segments in the output. This tableau shows how a disharmonic input in Anywa can result in a harmonic output containing dental nasals.

The tableau in (29) shows the evaluation of a disharmonic input in Dholuo. The ranking in (29) differs from (28) in that the input-output faithfulness constraints referring to [distributed] are ranked above the constraint establishing correspondence relations between oral and nasal stops. In this case, a disharmonic input will be realized as the faithful candidate, candidate (a) in this example, because faithfulness to input feature values of [distributed] take precedence over the establishment of surface correspondence relations between nasal and oral stops.

Rose & Walker (2004) argue that contrast is not the relevant factor determining which segments will participate in the cooccurrence constraints. In an account using a fixed hierarchy of constraints referring to similarity, both languages are assumed to have

the same system of contrasts and similarity will likewise be uniform in both languages. The constraint family establishing correspondence relations between surface segments is universally ranked according to relative similarity. The only difference between Dholuo and Anywa is the ranking of IDENT-IO [distributed] with respect to the similarity hierarchy. In Dholuo it is ranked above the constraint establishing correspondence relations between nasal and oral stops and in Anywa it is ranked below this constraint.

The case of dental harmony in Anywa is presented in Rose & Walker (2004) as a counterexample to any claims that contrast is crucial in determining consonant harmony patterns. In Anywa, [distributed] is not contrastive among the nasals yet the nasal participates in the cooccurrence constraints.

3.2.2 A Contrastive Hierarchy Account

Within the framework of the contrastive hierarchy, it does not follow that identical surface inventories result from an identical system of contrasts at the level of feature specification. The lack of a nasal phoneme at the dental place of articulation in the two languages corresponds to two possible orderings of contrastive features. One possibility is that the feature distinguishing dental and alveolar segments is ordered first. All segments are split according to [distributed], which is thus contrastive for the entire inventory, including the coronal nasal. The other possibility is that [distributed] is ordered below the feature distinguishing sonorants and obstruents, or nasals and non-nasals. If [distributed] is ordered below [sonorant], the nasal will be isolated from the other coronal stops before the feature [distributed] is specified. [distributed] will not be contrastive for the nasal.

These two possible orderings of contrastive features are able to account for the different behaviour of the nasal stop in Dholuo and Anywa. In Anywa, the ordering of features corresponds to the first possibility described above. The feature [distributed] is ordered above the feature [sonorant]. /n/ will be specified [-distributed] and [+sonorant]. After these features are added, /n/ is uniquely specified and requires no other features. A feature distinguishing voiced and voiceless obstruents will be required to uniquely specify the voiced and voiceless coronal stops, both dental and alveolar. The contrastive hierarchy for Anywa is illustrated in the tree diagram of figure (30).

(30)   Anywa contrastive hierarchy
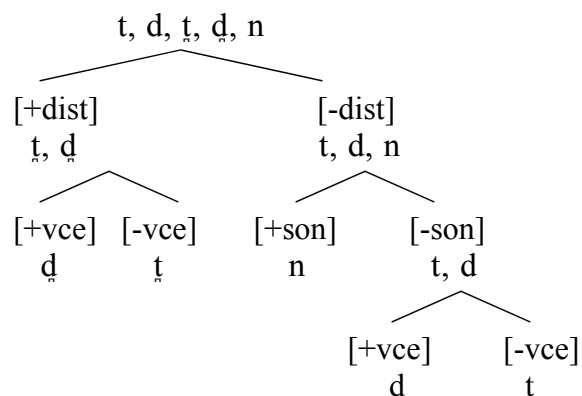
The hierarchy of contrastive features in Dholuo differs from that of Anywa and corresponds to the second possibility described at the beginning of this section. The inventory of coronal stops in Dholuo is greater than that of Anywa due to the presence of prenasalized stops. I assume that prenasalized stops are sonorants in Dholuo and as such are specified [+sonorant] and are not phonologically specified for nasality.[4] Nothing

---

[4] There is some question as to the motivation for treating prenasalized stops as sonorants. In Dholuo, prenasalized stops pattern with sonorants in failing to undergo final devoicing. They do, however, pattern with obstruents with respect to other processes such as the formation of the imperative. In imperative

crucial hinges on this assumption. The feature [nasal] distinguishes the nasal stops from prenasalized stops. The feature [sonorant] is ordered first, dividing the coronals into sonorants and obstruents. The feature [nasal] is ordered next and distinguishes the nasal from the prenasalized stops. At this point, the /n/ is uniquely specified and requires no other features. The feature [distributed] is ordered next and is contrastively specified on both the obstruents and the prenasalized stops. A feature distinguishing between voiced and voiceless segments is again required to specify the obstruents.

A tree diagram illustrating the order [sonorant] > [nasal] > [distributed] > [voice] is shown in figure (31) below.

(31)   Dholuo contrastive hierarchy
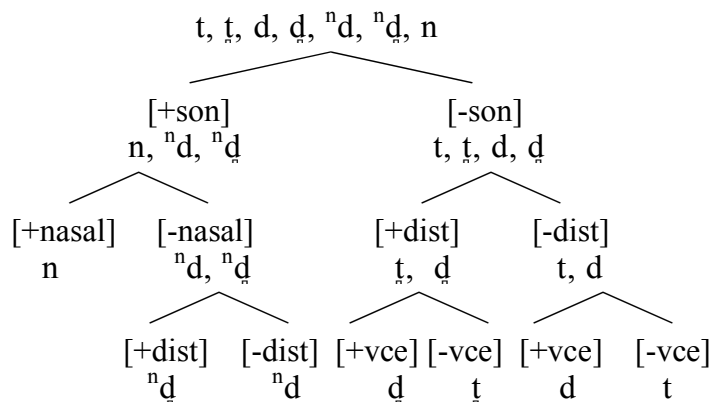
The contrastive hierarchies given above and the resulting feature specifications are capable of accounting for the different patterning of the two languages. In Anywa, the nasal is subject to the cooccurrence restriction barring alveolar and dental stops, and a

---

forms, a stem of the form CVC takes a suffix /-i/ if it ends in an obstruent or prenasalized stop (Tucker 1994: 332). Stems ending in sonorants do not take a suffix. The following examples are from Tucker (1994: 332); tedí 'cook!', luoŋgí 'call!' vs. kĕl 'bring!', lwŏr 'surround!'.

An alternative analysis with the prenasalized stops being specified as [-sonorant] is possible. The crucial point for the analysis at hand is that the nasal is not contrastively specified for [distributed] in either case and hence is not expected to participate in dental harmony.

dental nasal surfaces allophonically in harmonic forms. In this language, the nasal is contrastively [-distributed]. The feature responsible for the contrast between dentals and alveolars is thus contrastive for the set of nasals. If the cooccurrence restriction is formulated as a ban on coronal segments with different values for the feature [distributed], the nasal will violate this restriction when it occurs with a dental stop. This violation can be remedied by spreading the feature [+distributed] from the dental to the alveolar nasal resulting in a harmonic form and a dental nasal on the surface.

In Dholuo, the nasal does not participate in the cooccurrence restrictions and there are no surface dental nasals. The feature [distributed] is ordered after [sonorant] and [nasal]. The coronal nasal is thus already uniquely specified when the feature [distributed] is added leaving [distributed] noncontrastive and unspecified for the nasal stop. If the cooccurrence constraint for both languages is formulated as a ban on segments with distinct specifications for the feature [distributed] (as in (32) below), the contrastive specifications proposed here will require the /n/ to participate in the harmony in Anywa and not in Dholuo.

(32)   *[αdist] [-αdist]$_{Root}$: distinct specifications of [distributed] are banned
        within a root

In this account, determining which segments will interact is not achieved by arriving at a similarity measure by counting shared features. Rather, segments which interact form a natural class. In both languages this class can be defined as the set of coronal stops contrastively specified for the feature [distributed]. Distinct segments within this class may not cooccur.

The contrastive hierarchy account draws a connection between the inventory shape and the patterning of the cooccurrence constraint while still allowing variation

between languages with similar inventories. The lack of a contrast in the dental series

leads to the dental not participating in Dholuo. The lack of a dental nasal does not require

the neutrality of /n/, as shown in the patterning of Anywa, where [distributed] is

contrastive for the nasal.

An account relying only on the relative similarity of oral and nasal stops, such as

that suggested in Rose & Walker (2004), does not draw a connection between the failure

of the nasal to participate in Dholuo and the fact that there is no dental nasal in the

inventory. Such an account would be unaffected if nasal stops were phonemic at both

dental and alveolar places of articulation. In Nilotic languages like Shilluk (Gilley 1992)

and Päri (Andersen 1988) that do have a contrast between dental and alveolar segments in

the nasal series, the nasal participates in the cooccurrence restrictions.

(33)   Päri coronal stops: (based on Andersen 1988:66)

	Voiceless Stops	Voiced Stops	Nasals
Alveolar	t	d	n
Dental	t̪	d̪	n̪

(34)   (data from Andersen 1988)

kɔ̀t̪	'rain'	bàt	'arm'
d̪ɔ́k	'mouth'	dè:l	'skin'
ɲa:n̪-	'to move'	yín	'trees'

(35)   àtwá:t 'adult male elephant'
         t̪ut̪   'pierce'
         n̪ɔ̀t̪   'sucking'   * nɔ̀t̪
         d̪á:n̪-ɛ 'person (ergative)'   * d̪á:n

The data in (34) illustrate the general contrast between dental and alveolar

coronals in the voiced, voiceless and nasal series. (35) provides examples of harmonic

forms. The fact that the nasal participates in Päri is predicted by the contrastive hierarchy

analysis. Because the dental/alveolar contrast extends to the nasal series in this language,

no possible ordering of features will result in the nasals lacking contrastive specification for the feature [distributed]. If the cooccurrence restriction in Päri is identical to that proposed above for Anywa and Dholuo, any contrastive hierarchy will require the nasals to participate in the coccurrence constraint.

The contrastive hierarchy account is able to make explicit what feature specifications will be ruled out by structure preservation. The occurrence of dental *n*'s in surface forms in Anywa appears to violate the principle of structure preservation as developed in the theory of lexical phonology (e.g. Kiparsky 1982, 1985). Kiparsky's (1985) definition of structure preservation states that no value of a noncontrastive feature may be specified in the lexical phonology. In the analysis given above, the alveolar nasal in Anywa is contrastively [-distributed]. Because distributed is contrastive for the nasal, structure preservation does not rule out the possibility that the nasal may become specified [+distributed] through phonological processes.

Evidence for this view is found in other phonological processes. Dental nasals also surface outside of harmonic contexts in Anywa. In some morphological processes, a final dental stop becomes nasalized and a dental nasal surfaces. This can even result in surface minimal pairs in the language as seen in the data in (36).

(36)   Anywa   (from Reh 1996)

a) pòonn̪ò   'to become smooth'   < pɔ́ɔd̪ 'be smooth' + no
b) pónnɔ́   'to beat for sb.'

Dental nasals do not appear allophonically in Dholuo on the other hand, even in morphologically complex forms where an alveolar nasal appears adjacent to a dental stop.

(37) Dholuo   (from Tucker 1994)

      a) lot̪ni   'to be loose'   <   lot̪ + ni   lot̪ + o 'to tie loosely'

      b) lʊd̪nɪ   'to be in want' <   lʊd̪ + nɪ   lʊd +ɔ 'to maltreat'

The lack of an underlying dental nasal in Anywa is thus an accidental gap, not required by the system of contrasts in the language. In Dholuo, on the other hand, the lack of a dental nasal is a systematic gap and structure preservation will rule out the creation of a [+distributed] dental nasal, as well as the specification of [-distributed] for this segment. A theory of contrast and reference to the contrastive hierarchy is able to make explicit what feature specifications will be ruled out by structure preservation.

3.4 Chaha[5]

The patterning of dental harmony in Anywa and Dholuo was used by Rose and Walker as an argument against the significance of contrast in determining harmony patterns. The harmony process in Anywa was taken as a case where a segment that does not contrast in the harmonic feature, the coronal nasal, nonetheless participates in the harmony process. The theory of contrast advocated here, however, allows for different contrastive specifications in languages with similar inventories. A contrastive hierarchy in which the harmonic feature is ordered high will result in contrastive specification for the nasal for the harmonic feature.

Another type of case that could be used as an argument against contrast is a case in which segments which are contrastively specified for the harmonic feature fail to

---

[5] Many thanks to Sharon Rose for discussion of the Chaha data as well as for sharing her database of Chaha verb roots.

participate in the harmony process. Rose and Walker (2004) argue that laryngeal

harmony in Chaha (Afro-Asiatic: Semitic) is just such a case.

Chaha is an Ethiopian Semitic language with restrictions on distinct laryngeal

specifications occurring within a root. In Chaha, oral stops within a root must agree for

laryngeal specifications. Stops may be voiced, voiceless or ejective but stops that differ

with respect to laryngeal features may not cooccur.

The data in (38) show forms where all stops are [+cg] and the data in (39) show

forms in which all stops are [-cg] and have the same specification for the feature [voice].

(data from Rose and Walker 2004)

(38)	jɨ-t'ək'ir	t'ɨk'ir	'hide'
	jɨ-rət'ɨk'	nɨt'ɨk'	'snatch'
	jɨ-k'mət'ɨr	k'əmt'ɨr	'amputate'
(39)	jɨ-dəg(ɨ)s	dɨg(ɨ)s	'give a feast'
	j-ad(ɨ)g	əd(ɨ)g	'make fall'
	jɨ-dərg	dɨrg	'hit, fight'
	jɨ-kətf	kɨtf	'hash (meat)'
	jɨ-kəft	kɨft	'open'

Fricatives occur freely with stops of any laryngeal specification.

(40)   sɨgd   'worship'   sɨdɨβ 'curse'   kɨzəβ 'become inferior'

The consonant inventory of Chaha is presented below.

(41)   Chaha phonemic inventory: (based on Banksira 2000)

	bilabial	labio-dental	alveolar	palatal	velar	labio-dorsal	guttural
Stops							
ejective			t'		k'		
voiceless			t		(k)		
voiced			d		g		
Fricatives							
voiceless		f	s				A
voiced			z				
Spirants					x		
Sonorants		m	N				
Nasal							
Approximant	β		r	I		U	

Rose and Walker use the data above as an argument against the importance of contrast in determining interacting segments in consonant harmony processes. [+cg] fricatives are not present in the inventory. A contrast-driven analysis therefore may expect the fricatives to be neutral with respect to [cg] harmony. However, the fact that fricatives contrast for the feature [voice] yet do not participate in voicing harmony is not predicted by contrast-driven approaches.

Rose and Walker argue that the segments which participate are highly similar stops with less similar fricatives remaining neutral in the harmony process. Rose and Walker clearly state 'Contrast plays no role in favoring stops for agreement over the coronal fricatives' (498).

Rose and Walker's analysis of Chaha uses the surface correspondence constraints familiar from previous sections. Constraints requiring correspondence relations between surface segments are universally ranked according to segmental similarity. This entails that constraints requiring correspondence between homorganic stops are ranked above constraints requiring correspondence between heterorganic stops and constraints

requiring correspondence between segments that have the same laryngeal specifications
are ranked above those requiring correspondence between segments that differ in
laryngeal specifications.

In the case of Chaha, agreement takes place between all oral stops, including
heterorganic segments that disagree in laryngeal specifications. All surface
correspondence constraints referring to oral stops must therefore be ranked above
faithfulness constraints demanding identity in laryngeal specifications between input and
output. The fact that fricatives fail to participate in voicing harmony requires surface
correspondence constraints requiring correspondence relations between stops and
fricatives to be ranked below IO faithfulness constraints requiring input and output values
of [voice] to be identical.

The following tableaux illustrate the analyses presented in Rose and Walker
(2004).

(42)   (based on Rose and Walker 2004: 499)

wɨdək'	ID-CC [cg]	ID-CC [voi]	CORR T↔T	CORR T↔D	CORR K↔T	CORR K↔D	ID − IO/OI [voi]	ID-IO/OI [cg]	CORR T↔Z	CORR K↔Z
a.☞wɨt'ₓək'ₓ							*	*		
b. wɨt'ₓək'_y					*!	*	*	*		
c. wɨdₓək'_y						*!				
d. wɨtₓək'ₓ	*!									
e. wɨdₓək'ₓ	*!	*								

In tableau (42), the optimal candidate contains two stops which are in a surface
correspondence relation and which have identical specifications in both the feature
[voice] and the feature [constricted glottis]. In candidates (b) and (c), the output stops are
not in a correspondence relation. These candidates are eliminated due to violations of

CORRESPOND K ↔ T and CORRESPOND K↔ D, respectively. These constraints require

both homorganic and heterorganic stops in the output to be in correspondence with one

another. In candidates (d) and (e), the output stops are in correspondence with one

another but differ in their specifications for one or more laryngeal features. In the case of

candidate (d), the stops differ in [constricted glottis] and the form incurs a fatal violation

of highly ranked IDENT-CC[cg], which requires surface segments in correspondence with

one another to have the same specification for the feature [constricted glottis]. The stops

in candidate (e) differ in their specifications for both [constricted glottis] and [voice].

This candidate therefore violates both IDENT-CC[cg] and IDENT-CC[voice].

(43)

kɨzəβ	ID-CC [cg]	ID-CC [voi]	CORR T↔T	CORR T↔D	CORR K↔T	CORR K↔D	ID – IO/OI [voi]	ID- IO/OI [cg]	CORR T↔Z	CORR K↔Z
a.☞k_xɨz_yəβ										*
b. k_xɨz_xəβ		*!								
c. k_xɨs_xəβ							*!			

Tableau (43) demonstrates that the failure of fricatives to participate in voicing

harmony can be accounted for with the proposed constraint ranking. The optimal

candidate in this case is the faithful candidate which contains a stop and fricative that are

not in a correspondence relation with one another and that do not agree in voicing. This

candidate violates the constraint CORRESPOND K↔ Z which requires correspondence

relations to be established between stops and fricatives in output forms. Unlike

constraints requiring output stops to be in a correspondence relation with one another, the

constraint CORRESPOND K↔ Z is lowly ranked. This ranking is fixed, in Rose and

Walker's (2004) analysis, due to the fact that stops and fricatives are less similar than

stops are to one another. Candidates (b) and (c) have a correspondence relation between the stop and fricative in the output. These candidates are eliminated due to violation of the constraint requiring output correspondents to agree in voicing, in the case of candidate (b), and violation of the constraint requiring input-output faithfulness in voicing, in the case of candidate (c). Crucially, the constraint IDENTIO-[voice] outranks the constraint requiring correspondence relations between output stops and fricatives but does not outrank the constraint requiring multiple output stops to be in a correspondence relation with one another.

3.4.1 More on Chaha

The case against a contrast-driven analysis of Chaha laryngeal constraints rests on the behaviour of the fricatives and the presence of harmony for the feature [voice]. If harmony is restricted to the feature [cg] and not all laryngeal features, a contrast-driven analysis will be able to account for the neutrality of fricatives, as the fricatives do not contrast for the feature [cg].

In this section, I argue that the Chaha data are consistent with an analysis in which the harmony process applies only to the feature [constricted glottis] and not to laryngeal features generally. Under this analysis, the failure of fricatives to participate in harmony does not contradict the position that contrastive features are crucial in determining targets and triggers of harmony processes. The fricatives, while contrastively specified for [voice], are not contrastively specified for [constricted glottis].

[cg] harmony alone will account for a substantial portion of the data, ruling out the following consonant pairs; /t, k'/, /g, t'/, /g, k'/, /d, t'/, /d, k'/. In addition, Chaha is a

Semitic language, and is subject to an OCP-place constraint that rules out the following consonant pairs; /g, k'/, /d, t'/, /d, t/, /g, k/.

A number of potential consonant pairs that would be ruled out by voicing harmony are thus independently ruled out by [cg] harmony and the OCP. The evidence for [voice] harmony therefore depends only on the absence of the pairs /t, g/ and /k, d/. Drawing conclusions from the frequency of these pairs is further complicated by the fact that the phonemic status of /k/ is controversial. Banksira (2000) and Banksira and Kenstowicz (1999) argue that [k] is an allophone of /x/ that occurs in forms with continuant obstruents.

The laryngeal constraint has exceptions. According to Rose and Walker (2004), the analysis of laryngeal harmony in Chaha is based on a database of 855 verb roots of which 117 contain relevant stop combinations. Agreement is found for 83% of these forms. Given the other restrictions on consonant cooccurrence and the exceptions to laryngeal harmony in general, empirical evidence for [voice] harmony requires that occurrences of /t, g/ and /k, g/ be significantly less than expected by a random distribution of segments and that these pairs occur no more frequently than exceptions to laryngeal harmony that involve disagreement for [cg].

Rose and King (2007) calculate Observed/Expected ratios for consonant pairs in Chaha. The calculations take into account the general frequency of each consonant in the database and from this determine the number of forms that would be expected to contain a given pair of consonants if there was no laryngeal constraint. An O/E ratio approaching 1 shows that the combination of consonants is unrestricted. An O/E ratio approaching 0 indicates the presence of a constraint against the combination of consonants. The chart

below shows the results reported by Rose and King. Shaded cells were reported as

statistically significant.

(44)   Observed/Expected Ratios for Laryngeal constraint in Chaha

(from Rose and King 2007: 461)

	C1C2	C2C3	C1C3	Total
different [cg] [voice] k' d t' g	0.00	0.27	0.70	0.32
different [voice] k d t g	0.96	0.00	2.27	1.08
different [cg] k t' t k'	0.00	0.00	0.00	0.00
Total	0.32	0.09	0.99	0.47

The table shows that consonant pairs that differ in [cg] occur less frequently than

expected. This provides additional evidence for harmony for the feature [cg]. /k, d/ and

/t, g/, the crucial consonant pairs for establishing evidence of [voice] harmony, are

generally not underrepresented. The O/E ratios fail to provide evidence for a

cooccurrence restriction referring to the feature [voice].

3.4.2 Contrastive Hierarchy Analysis

The Chaha data presented above support an analysis in which there is harmony

for the feature [cg] but not for the feature [voice]. The laryngeal cooccurrence restriction

of Chaha can be accounted for with the following constraint:

(45)   *[αcg] [-αcg]$_{Root}$: distinct specifications of [constricted glottis] are banned
         within a root

A contrastive hierarchy analysis predicts the fricatives to be neutral with respect

to [cg] harmony, if the feature [cg] is ordered after features dividing stops from

continuants. The contrastive hierarchy proposed for Chaha is shown below.

(46)   Hierarchy for Chaha
        [continuant] > [cg] > [voice]
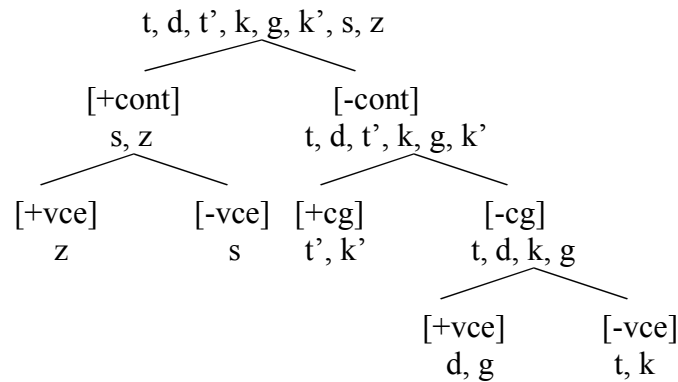
With this ordering of features, the fricatives are not contrastively specified for

[cg] and are not expected to be affected by the constraint barring segments with distinct

specifications for [cg].

Additional evidence for the role of contrast in the patterning of cooccurrence

restrictions in Chaha can be found in the behaviour of labial segments. There is no labial

ejective present in the Chaha inventory. In addition, while surface [p] and [b] are found,

they are not phonemic and are analyzed as allophones of /β/ found in contexts where

gemination or strengthening occur. Surface [p] and [b] occur freely with ejectives.

(data from Banksira 2000: 79)

(47)   Jussive   Perfective
        yə-t'ɨβs   t'əbəs   'roast'
        y-a-k'βaβz   a-k'βabəz   'deny the truth'
        yə-t-zraβət'   tə-zrabət'   'crave'
        yə-zɨβk'   zəbək'   'daub'

In the output correspondence analysis, the constraints requiring correspondence

relations between similar segments refer specifically to output segments. A [p] or [b] in

the output should then be subject to laryngeal harmony as they will be as similar to [k']

as other participating stops such as [t] or [d]. The contrastive hierarchy analysis, on the other hand, predicts that labial stops should occur freely with ejectives as they are not contrastively specified for the feature [cg].

3.5 Voicing Harmony and Potential Counterexamples

The preceding section has shown that, counter to claims in Rose and Walker (2004), Chaha does not have harmony in the feature [voice], but only harmony in the feature [consticted glottis]. Fricatives do not contrast minimally in [constricted glottis], thereby allowing a contrastive hierarchy analysis in which fricatives are unspecified in the harmonic feature. The neutrality of fricatives in Chaha is thus unsurprising given the framework of the contrastive hierarchy. There are languages with laryngeal harmony, however, in which [voice] patterns as a harmonic feature and fricatives, though contrasting in [voice], fail to participate. These patterns are found in Zulu and Ndebele and are analyzed in Hansson's (2004) analysis of voicing harmony systems in the framework of evolutionary phonology.

Zulu and Ndebele are related languages belonging to the Nguni group of the Bantu language family. Both languages have a three-way laryngeal contrast between voiceless, voiced and aspirated stops and both languages have laryngeal harmony as a cooccurrence restriction requiring stops within morphemes to agree in laryngeal features.

(48) Harmonic roots in Zulu (Khumalo 1997 cited in Hansson 2004)

-k^{h}et^{h}a 'to choose'   -peta 'to dig up'   -guba 'to dig'
-p^{h}at^{h}a 'to hold'   -tapa 'to collect'

In both Zulu and Ndebele, a ban on non-initial aspirated /k^h/ overrides harmony leading to disharmonic surface forms in morphemes containing a medial /k/ (49a). Forms

containing multiple velars pattern exceptionally with harmony overriding the ban on non-initial /kʰ/ in these cases (49b).

(49)   Aspiration harmony and velar patterning in Ndebele   (CBOLD)

    a.   -pʰeka   'cook, brew'   *-pʰekʰa
          -tʰikaza   'be disturbed'   *-tʰikʰaza

    b.   -kʰokʰa   'pull, draw out'
          -kʰukʰula   'sweep away'

Hansson (2004) shows that voicing harmony interacts with place of articulation in exactly the same way as aspiration harmony. Forms with non-initial velars may be disharmonic except in cases where the intial stop is also velar. This despite the fact that there is no ban on non-initial /g/ in Zulu or Ndebele.

(50)   Voicing harmony and velar patterning in Ndebele   (CBOLD)

    a.   -dakwa   'be drunk'   *-dagwa
          -dikisa   'palpitate, twitch'   *-digisa

    b.   -guga   'wear out'

Hansson argues that, while the patterning of velars in aspiration harmony results from independent phonotactic constraints, the absence of such an explanation in the case of voicing harmony suggests that voicing harmony is modeled after aspiration harmony. From this, he suggests that voicing harmony arose through analogic generalization of aspiration harmony making voicing harmony secondary to aspiration harmony.

If this perspective is correct, the failure of fricatives to participate in voicing harmony in these cases may be derived from the fact that fricatives do not contrast in aspiration and do not participate in aspiration harmony. The failure of medial /k/ to undergo voicing harmony does not result from any aspects of the phonological patterning of /k/ with respect to voicing but rather from aspects of the phonological patterning of /k/

with respect to aspiration. The failure of fricatives to participate in voicing harmony may also result from the lack of an aspiration contrast between fricatives and the failure of fricatives to undergo aspiration harmony.

The mechanisms for how such a harmony process could arise through analogy remain unclear, as acknowledged in Hansson (2004). Nonetheless, the patterning of velars in laryngeal harmony provides evidence that voicing harmony is derivative of aspiration harmony. It is also worth noting that, although the failure of fricatives to participate in voicing harmony in Zulu and Ndebele is not predicted by the contrastive hierarchy, it also fails to support an account of consonant harmony based on general similarity. While fricatives are clearly less similar to stops than stops are to each other, voiced and voiceless fricatives are as similar to one another as voiced and voiceless stops. Thus, an account of participating segments in voicing harmony based on relative similarity predicts that, even if fricatives fail to harmonize with stops, fricatives will harmonize with each other. This is not the case. Pairs of voiced and voiceless fricatives occur freely within morphemes in Zulu and Ndebele as illustrated below.

(51)   Ndebele fricatives   (CBOLD)

-sizi   'black powder'   -sizila   'to iron out, press'
-suza   'to break wind'   -zwisa   'cause to feel'

The failure of fricatives to particpate in voicing harmony in Zulu and Ndebele is not predicted by the definition of similarity proposed in previous sections. Fricatives minimally contrast in [voice] and thus must belong to the natural class of segments contrastively specified in the harmonic feature. However, other aspects of voicing harmony in Zulu and Ndebele, such as the failure of medial /k/ to undergo voicing harmony, are not predicted in any framework. As argued in Hansson (2004), this

patterning can be accounted for if voicing harmony is modeled on and secondary to aspiration harmony. A contrastive hierarchy analysis can straightforwardly account for the failure of fricatives to participate in aspiration harmony. The evolutionary account in Hansson (2004) is therefore consistent with a contrastive hierarchy account of the failure of fricatives to participate in aspiration harmony. Furthermore, the fact that fricatives fail to harmonize with one another undermines any claims that differing behaviour of stops and fricatives results from general similarity.

3.6 Predictions and Comparison with Other Approaches

The analyses of consonant harmony patterns presented above argue that the sets of segments participating in harmony can be defined without reference to a notion of similarity that is distinct from the independently needed notion of natural class. In Bumo Izon, Kalabari Ijo, Anywa, Dholuo and Chaha the set of participating segments is defined as those segments that are contrastively specified for the harmonic feature. This claim depends upon a theory of contrast and specification that allows for crosslinguistic variation in contrastive specifications, even between languages with similar inventories. The theory of contrast advocated here is that of the contrastive hierarchy (Jackobson and Halle 1956, Dresher 2001, 2003, forthcoming).

Other approaches to consonant harmony have argued that similarity determines which segments will participate. In some work, similarity is defined as shared feature specifications with featural representations of segments assumed to be universal across languages (e.g. Hansson 2001). In Frisch et al. (2004), similarity is defined by determining the shared natural classes of a pair of segments and dividing this by the set

of shared and unshared natural classes. (This similarity metric is also adopted by Rose and Walker 2004).

Despite the differences between previous approaches and that argued for here, there is a significant amount of overlap in the predictions of similarity-based analyses and the contrastive hierarchy analyses. Under the theoretical assumptions of the contrastive hierarchy, a feature will be contrastively specified for some set of segments only if it serves to distinguish segments that are otherwise identical according to any specifications for more highly ordered features. In practice, this means that if the harmonic feature is relatively low in the hierarchy, the natural class of segments that are contrastively specified for the harmonic feature will also be similar in the sense of sharing a large number of feature specifications. The contrastively specified segments will thus be similar according to the notion of similarity employed in Hansson (2001). The contrastively specified segments will also share a number of other natural classes in addition to the class of segments specified for the harmonic feature. They are thus likely to be deemed similar according to the similarity metric proposed in Frisch et al.

In many cases, the predictions of various similarity-based approaches to consonant harmony will coincide with the predictions made by the contrastive hierarchy approach. For this reason, this section will examine the predictions made by various approaches in more detail and compare them to the predictions of the contrastive hierarchy approach. I will argue that there are significant differences between the various approaches and that the predictions of the contrastive hierarchy approach are supported.

3.6.1 The role of the inventory

A central claim of the theory of the contrastive hierarchy is that, for a given language, the shape of the inventory influences contrastive specifications. While differences in the order of features may lead to different specifications in languages with similar inventories, the influence of feature ordering is limited by inventory shape.

This point has been made repeatedly in the above analyses. In the case of Anywa and Dholuo, both languages have only a single coronal nasal whereas other coronal stops have both a dental and alveolar. The inventory is asymmetric in the sense that a contrast that is present throughout the coronal series in general is absent in the set of nasals. This gap in the inventory allows different orderings of features in the feature hierarchy to make a difference in the feature specifications of the nasal segments. If the feature [nasal] is ordered above [distributed], then the nasal will be distinguished from the other coronals before [distributed] is assigned and it will not be contrastively specified for the harmonic feature. This is the case in Dholuo. If the feature [distributed] is ordered above [nasal], the nasal will be contrastively specified for [distributed]. This is the case in Anywa. However, if a language with a harmony pattern like that of Dholuo and Anywa does have a dental/alveolar contrast in the nasal series, every possible ordering of contrastive features will result in contrastive specification of [distributed] in the nasal set.

The claim that participating segments in consonant harmony systems can be defined as natural classes specified for the contrastive feature, taken together with the theory of contrastive specifications argued for here, predicts that if two segments are minimally distinguished by the harmonic feature, they must participate in the harmony process. In the case of dental harmony, if two coronal nasals differ only in the feature

[distributed] they are predicted to participate in harmony. This prediction is not made by similarity-based approaches that account for the lack of participation of nasals in Dholuo on the basis of similarity between interacting segments. According to the approach in Rose and Walker (2004) and Hansson (2001), the nasals do not participate and oral stops do participate because nasals are less similar to oral stops than oral stops are to each other. The gap in the inventory is irrelevant. As demonstrated in section 3.2 above, the prediction of the contrastive hierarchy is supported by data from Nilotic languages that do have a distinction between dental and alveolar nasals. In such languages, the nasals participate in harmony.

The prediction that segments minimally differing in the harmonic feature must participate in consonant harmony is falsifiable. The Chaha case, as presented by Rose and Walker (2004), constitutes an apparent counterexample. In this case, a closer examination of the data shows that there is no evidence for voicing harmony and the failure of fricatives that contrast in [voice] to participate is therefore consistent with the claims made here.

The notion of similarity as based on the evaluation of shared feature specifications, with feature assignment being universal across languages, does not allow inventory shape to influence similarity values and in turn does not allow inventory shape to influence the patterning of consonant harmony processes. The approach to similarity proposed in Frisch et al. (2004) and adopted by Rose and Walker (2004), however, does allow for inventory shape to influence the relative similarity of segments. As outlined in Chapter 2, Frisch et al. assume full specification. They nonetheless allow the inventory to play a role in determining similarity by evaluating similarity on the basis of natural

classes and not on features directly. The similarity for a given pair of segments is calculated by dividing the number of natural classes the two segments share by the number of shared and unshared natural classes.

Frisch et al. apply their similarity metric to an analysis of OCP effects in Arabic verbal roots and are able to account for the effect of the inventory on OCP restrictions. In Arabic, segments that share major place of articulation are generally banned from cooccurring within a root. The coronal class is an exception. Coronal obstruents and sonorants may cooccur freely but segments that are both coronal and share the same value for the feature [sonorant] may not cooccur. According to Frisch et al., the patterning of coronals can be accounted for in the following way.   There are many more phonemic distinctions within the class of coronals than within any other major place category. There are thus more distinct natural classes that share the major place specification [coronal]. Coronals that differ in the sonorant/obstruent distinction will thus have a greater number of unshared natural classes than will labials or gutturals that differ in sonorancy. This will lead to a lower similarity value, one permitted by the Arabic OCP constraint.

In the case of languages with asymmetric inventories, however, the similarity metric of Frisch et al. makes the wrong predictions. In the Bumo Izon example in section 3.1, the velar and labiovelar stops do not participate in implosive harmony while the alveolar and labial stops do. This is accounted for in the contrastive hierarchy analysis by ordering major place features above the feature [constricted glottis]. There is only a single, pulmonic voiced velar and a single, implosive labiovelar. These segments lack partners with the same place of articulation that differ along the pulmonic/implosive

dimension. When the feature [constricted glottis] is assigned, the velar and labiovelar are already uniquely specified. [constricted glottis] is not contrastive for these segments.

The Bumo Izon case is discussed by Hansson (2001) who shows that the similarity metric of Frisch et al. makes the wrong predictions for this case. When shared natural classes are divided by shared and unshared natural classes, 'partnerless' segments will appear more similar to other segments in the series. This is because laryngeal specifications for the partnerless segments, /g/ and /ɠɓ/ in this case. do not lead to an additional unshared natural class in the denominator of the similarity calculation.[6]

If similarity determines the patterning of consonant harmony processes, Frisch et al.'s natural classes model wrongly predicts that segments that lack partners in an asymmetric inventory should participate, even if other segments do not. In the contrastive hierarchy analysis, the partnerless segments may fail to participate if the feature hierarchy results in unique specification for these segments before the harmonic feature is assigned. If the harmonic feature is ordered high, the segments will be specified and may participate in harmony.

3.6.2 Which features determine similarity?

One prediction of the contrastive hierarchy approach to harmony (outlined in the above section) is that is if there is a minimal contrast between two segments in the harmonic feature, those segments must participate in harmony. This prediction has consequences for which features are expected to influence the set of participating

---

[6] See also Hansson (2004) for difficulties encountered by the similarity metric of Frisch et al. in accounting of the patterning of implosives in voicing harmony systems.

segments in different types of harmony processes. For example, in sibilant harmony

systems, sibilants in a form undergo harmony in the feature [anterior]. Given the

predictions of the contrastive hierarchy, if there is a general voicing contrast among

sibilants, that is, if there is a voiced and a voiceless pair for every sibilant in the

inventory, then no order of contrastive features will result in the contrastiveness of the

feature [anterior] being dependent on voicing. Thus, voicing should not play a role in

determining which segments participate. All sibilants should participate and the voicing

value of interacting segments should not matter. On the other hand, if similarity is

dependent on general counting of shared features or a more involved metric like Frisch's

then we expect voicing to interact with the similarity evaluation as a whole. In this case,

whether interacting segments agree in voicing or not is expected to be crucial in some

cases. That is, in some languages, the constraints driving harmony should require

harmony between segments that differ only in [anterior] but not between segments that

differ in both [anterior] and [voice].

The evidence that bears on this issue is relatively substantial as sibilant harmony

is the most common of all consonant harmony types. 40 cases of sibilant harmony are

included in Hansson's exhaustive typological study of consonant harmony processes. In

39 out of 40 cases, voicing plays no role in determining which segments participate. In

these cases, sibilants that differ in both [voice] and [anterior], such as /s/ and /ʒ/, interact

in exactly the same manner as sibilants that differ only in [anterior], such as /s/ and /ʃ/.

The one case in which voicing is argued to play a role is quite complex. In Nkore Kiga

(Bantu), the rightmost sibilant determines the [anterior] value of preceding sibilants in a

word. When this sibilant is [-anterior], voicing plays no role in the patterning and

segments that disagree in voicing interact exactly as do segments that agree in voicing. When the sibilant in a position to trigger harmony is [+anterior], however, only segments that have the same voicing value as the trigger undergo harmony. While this case is problematic for the approach proposed here, the data are complex and inconclusive.[7] In the majority of cases, voicing has no influence on sibilant harmony as predicted by the contrastive hierarchy analysis of consonant harmony processes.

Proponents of a similarity-based analysis of consonant harmony may argue that the lack of a voicing influence in sibilant harmony patterning is simply because segments that differ only in the features [voice] and [anterior] are very similar and differences in voice do not affect similarity enough to influence harmony processes. There are a number of problems with this argument. Most obviously, none of the authors arguing for a similarity-based analysis of interacting segments propose a particular level of similarity that is necessary for interaction to occur (or, conversely, a level of difference sufficient to prevent interaction). Any claim that [voice] does not affect similarity values significantly enough to influence harmony patterns is therefore lacking in any theoretical motivation. In addition, differences in the feature [voice] do determine interacting segments in other types of consonant harmony. In nasal consonant harmony processes, segments that interact are commonly the set of nasals and the set of voiced oral consonants. The majority of nasal harmony systems described by Hansson require interacting segments to have the same value for the feature [voice].

---

[7] Other factors that may complicate the analysis of sibilant harmony in Nkore Kiga include the largely contextually determined distribution of /s/ and /ʃ/, the fact that the distance between target and trigger influences the spreading of [-anterior] and the fact that stems with a voiced sibilant as C1 and a voiceless sibilant as C2 simply do not occur.

The significant role played by the feature [voice] in nasal harmony systems can be accounted for within the contrastive hierarchy account of consonant harmony. If the feature [voice] is ordered above the feature [nasal], then [nasal] will not be contrastive for the voiceless segments. There are no voiceless nasals and the feature [nasal] will not further split the set of [-voice] segments. The voiced segments, on the other hand, may be contrastively specified for [nasal]. The set of segments participating in nasal harmony in languages where all voiced consonants participate can thus be defined as the set of segments contrastively specified for the harmonic feature. This is the method of defining participating segments that is argued for throughout this chapter.

3.7 Conclusion

This chapter has examined consonant harmony as a phenomenon which has been argued to be motivated by similarity (see Hansson 2001, Rose and Walker 2004, Frisch et al. 2004 etc). Looking at data from Bumo Izon, Kalabari Ijo, Dholuo, Anywa and Chaha, I have argued that those segments that participate in consonant harmony processes can be defined as the set of segments contrastively specified for the harmonic feature. I adopt the theory of the contrastive hierarchy, according to which contrastive specifications are determined by an ordering of features, with features ordered high in the hierarchy being contrastive for a larger set of segments than features that are ordered lower. With this method of determining contrastive specifications, consonant harmony patterns can be described without reference to a notion of similarity that is distinct from the notion of natural class.

In the cases examined here, the set of segments that interact in consonant harmony processes is that set of segments which are contrastively specified in the

harmonic feature. Participating segments can thus be described as members of a natural class with no need to refer to a distinct notion of similarity. I argue that natural classes are determined on the basis of contrastive feature specifications. Given the theory of the contrastive hierarchy, feature specifications are not determined solely on the basis of phonetic properties. Rather, crosslinguistic differences in phonemic inventories and feature hierarchies can lead to differences in contrastive specifications between languages. Natural classes are therefore also not determined solely on the basis of phonetic properties. Segments share a natural class if they share contrastive specifications in a given feature.

This chapter argues that segments participating in consonant harmony processes constitute the natural class of segments contrastively specified in the harmonic feature. This claim makes predictions about the patterning of consonant harmony processes that differ from those of previous analyses. Specifically, this approach predicts that the inventory influences consonant harmony patterns. If two segments differ only in their specifications for the contrastive feature, they are predicted to participate in harmony. If two segments differ in the harmonic feature and some other feature or set of features, the participation of the segments will depend on the contrastive hierarchy of the language. Crosslinguistic variation in harmony patterning is expected in these cases and is illustrated in the dental harmony processes found in Anywa and Dholuo. The relationship drawn between the inventory, contrastive specifications and consonant harmony patterns in this approach also predicts that different features are likely to be significant in determining participating segments depending on the harmonic feature.

CHAPTER 4
GLOBAL SIMILARITY EFFECTS

The preceding chapter has argued that targets and triggers of consonant harmony must belong to the natural class of segments that are contrastively specified for the harmonic feature. No theory of similarity distinct from a theory of feature specification and natural classes is required for the cases discussed thus far. Some processes discussed in the consonant harmony literature, however, do require reference to a notion of similarity distinct from the notion of natural classes. These include cases in which segments sharing major place specifications must either be identical or differ in multiple properties.

This chapter reviews representative cases from the consonant harmony literature for which the definition of similarity as natural classes is inadequate. For these processes, I propose that interacting segments are similar according to a global measure based on counting of shared marked and contrastive features. I adopt the proposal of Calabrese (1995, 2005) that phonological generalizations may make reference to contrastive features or the more limited set of features that are both marked and contrastive. While this requires a somewhat weaker notion of interacting segments than that argued for in the preceding chapter, the notion of similarity that is relevant in determining interacting segments is nonetheless severely restricted. Features that are relevant in determining similarity are contrastive phonological features. In addition, a global notion of similarity is necessary only in cases where interacting segments share major place specifications.

The following sections provide analyses of cases in the consonant harmony literature that require reference to a global definition of similarity. The cooccurrence constraints on homorganic segments in Ngbaka constitute perhaps the most famous case of consonant harmony. The need to refer to global similarity is clear in this case as the restrictions involve not a single, harmonic feature but rather make reference to similarity along multiple dimensions. Ngbaka cooccurrence constraints have garnered much attention, including analyses in Mester (1986), Broe (1993), van de Weijer (1994) and Rose and Walker (2004).

Other cases analyzed in this chapter are drawn from MacEachern's (1999) typological study of laryngeal cooccurrence constraints. Her study includes a variety of languages in which the distribution and cooccurrence of aspirated and glottalized segments is restricted. In a subset of these cases, homorganic segments with different specifications in laryngeal features are disallowed while identical segments are permitted. This pattern is analyzed here as harmony in the relevant laryngeal feature that is active only between homorganic segments.[8] In each case, I demonstrate that similarity can be evaluated on the basis of marked and contrastive feature specifications and that interacting segments differ in only a single marked feature.

Analyses of these cases are followed by an evaluation of the analysis of MacEachern (1999) and a discussion of some of the implications that follow from a definition of similarity as differing in only a single feature specification.

---

[8] MacEachern (1999) does not link these cases to other cases of consonant harmony or vowel harmony. They have, however, been analyzed as consonant harmony processes in previous literature (Rose and Walker 2004, Hansson 2001).

4.1 Ngbaka

In Ngbaka (Niger-Congo: Adamawa-Ubangi), homorganic voiced and voiceless

stops may not cooccur within a morpheme. Homorganic voiced and prenasalized stops

may not cooccur and homorganic prenasalized and nasal stops may not cooccur.

The following data illustrate the pattern of cooccurrence constraints.

(52)	nanɛ̀	'today'	*na^{n}dɛ̀
	^{m}bɛɛ̀^{m}bɛ	'snail'	*^{m}bɛɛ̀mɛ
	boma	'how'	
	maò^{ŋ}gaò	'net'	
	mini	'tongue'	
	^{ŋ}gaè^{m}ba	'navvy'	

Previous analyses of Ngbaka consonant cooccurrence constraints have been

carried out in the framework of structured specification (Broe 1993), autosegmental

phonology (Mester 1986) and agreement-as-correspondence in OT (Rose and Walker

2004). Here, as in the preceding chapters, I focus on the issue of determining which

segments will interact and propose that segments that participate in the cooccurrence

constraint differ in only a single marked and contrastive feature.

The phonemic inventory of Ngbaka as presented in Thomas (1963) is shown in

(53) below.[9]

---

[9] The segments /b'/, /f/, and /v/ are marginal in the language occurring in very few forms. Thomas (1963) does not discuss the patterning of these segments with respect to cooccurrence restrictions and I will not include them in my analysis here.

(53)   Ngbaka consonant inventory   (from Thomas 1963:55)

	Bilabial	Labio-dental	Apical	Sibilant	Palatal	Dorsal	Labio-velar	Glottal
voiceless	p	f	t	s		k	kp	
voiced	b	v	d	z		g	gb	
glottal	b'							
prenasal	^{m}b		^{n}d	^{n}z		^{n}g	^{n}gb	
nasal	m		n		ɲ			
glide					y		w	
liquid			l					
occlusive								ʔ
continuant								h

Ngbaka has a vowel inventory of seven oral and three nasal vowels. In addition
to the consonantal cooccurrence restrictions addressed here, Ngbaka has a complex
pattern of vowel cooccurrence constraints. Vowels of the same height but differing values
for backness or ATR are disallowed morpheme internally (see Chomsky and Halle 1968,
Mester 1986).

The consonantal cooccurrence restrictions are summarized in the tables below.
Cells filled with an X indicate banned combinations. In each case the barred segments
may not occur together in either order.

(54)   Cooccurrence constraints

Labials				
	p	b	^{m}b	m
p		x		
b	x		x	
^{m}b		x		x
m			x	

Coronals				
	t	d	^{n}d	n
t		x		
d	x		x	
^{n}d		x		x
n			x	

Dorsals				
	k	g	^{n}g	ɲ
k		x		
g	x		x	
^{n}g		x		x
ɲ			x	

Sibilants				
	s	z	^{n}z	n
s		x		
z	x		x	
^{n}z		x		x
n			x	

The general pattern illustrated in the above tables is as follows. Homorganic voiced and voiceless stops may not cooccur within a morpheme. Homorganic voiced and prenasalized stops may not cooccur and homorganic prenasalized and nasal stops may not cooccur. Segments which have different places of articulation may occur together regardless of laryngeal and nasal specifications.

Previous work on Ngbaka has acknowledged the difficulties in analyzing these constraints as a harmony process. The pattern above shares some features of nasal harmony systems (and is analyzed as such by Rose and Walker 2004) and some features of laryngeal harmony systems and cannot be analyzed as spreading of a single harmonic feature.

As in previous analyses by Broe (1993) and van de Weijer (1994), I analyze the Ngbaka facts as resulting from a constraint banning segments with a specific degree of similarity.[10] The present task is thus to motivate a system of feature specifications for Ngbaka which shows the segments banned from occurring together as more similar than

---

[10] As in the analysis developed here, van de Weijer (1994) proposes that segments barred from cooccurring differ by only a single feature. His account uses a different model of representations and makes different predictions from the present analysis. Contrary to the assumptions used here and claims in previous literature, van de Weijer claims that homorganic voiceless and nasal stops may not occur together and that voiced and prenasalized stops may occur together. His interpretation of the data is based only on an examination of the labial series. I am following the description of the cooccurrence restrictions in Thomas (1963) and previous literature.

those which may occur freely. I will begin with the labial series and assume that contrastive specification will be able to separate the segments into the relevant place classes. This assumption will need to be revisited and justified when the coronal and sibilant series are taken into account.

In order to determine the specifications of the consonants participating in the cooccurrence restrictions, it is necessary to determine what the relevant features in the system are and their order in the contrastive hierarchy. Leaving aside the nasal, I look to work on laryngeal systems by Avery (1996) in determining the features distinguishing /p/, /b/ and /^{m}b/. Avery documents crosslinguistic differences in the patterning of voiceless and voiced stops showing that the segments behave differently in different languages. In some languages, the voiced stop appears to be marked and voicing may spread in consonant clusters. Avery refers to these languages as laryngeal voicing systems and claims that the voiced stops in these languages have the feature [voice] which is absent in the voiceless segments. In other languages, the voiced stops appear to pattern with sonorant segments. They only participate in voicing assimilation processes if other sonorants do and are subject to processes such as nasal harmony which otherwise target sonorant segments. These are sonorant voicing languages and the voiced stops of these languages have a feature [sonorant voice]. In the third type of language, voiced stops sometimes pattern with sonorants and sometimes with obstruents. They do not trigger voicing assimilation but are targets, often taking on the voicing characteristics of surrounding sounds. These are contextual voicing languages. In these languages, voiced segments are unmarked and it is the voiceless segments which have a marked feature specification distinguishing them from the voiced segments.

In Avery's representations, the voiceless segments in a contextual voicing language have an organizing node labeled Laryngeal. If the Laryngeal node does not dominate any features, the feature [spread glottis] is added through a rule of phonetic enhancement. Although I am following the typology and feature specifications of Avery (1996), I differ from Avery in not assuming any model of geometric organization. I will use the feature [laryngeal] to specify voiceless segments in contextual voicing languages. Avery (1996) discusses work by Kingston (1985) and Keating (1990) which demonstrates that the abduction of the vocal folds which is generally understood as the phonetic implementation of the feature [spread glottis] may or may not result in aspiration depending on the timing of glottal abduction relative to stop closure and release. I use [laryngeal] instead of [spread glottis] to indicate that segments specified as [laryngeal] need not be realized as aspirated.

With respect to prenasalized stops, I follow Piggott (1992), Rice (1993) and Avery (1996) in assuming that prenasalized stops are not necessarily phonologically specified for the feature [nasal]. Rather, a prenasalized stop is one possible phonetic implementation of the feature [sonorant voice].

In Ngbaka, the voiced stop /b/ patterns as similar to both the voiceless stop /p/ and the prenasalized stop /^{m}b/. This is suggestive of a contextual voicing language in which voiced stops pattern both with the voiceless stops and with sonorants. The following order of contrastive features is able to achieve specifications consistent with a contextual voicing language.

(55)   [laryngeal] > [sonorant voice] > [nasal]

The contrastive specifications of the labial series are illustrated in the tree diagram below.

(56)

```
                         p, b, ᵐb, m
                        ╱          ╲
                  [+lar]          [-lar]
                     p             b, ᵐb, m
                                  ╱        ╲
                            [+sv]          [-sv]
                             ᵐb, m           b
                            ╱      ╲
                      [+nasal]    [-nasal]
                         m           ᵐb
```
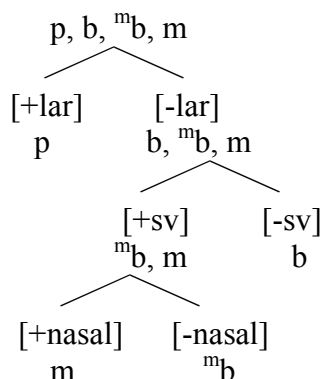
This hierarchy results in the following specifications in the labial series.

(57)   p   b   ᵐb   m
       [+laryngeal]   [-laryngeal]   [-laryngeal]   [-laryngeal]
                          [-sv]   [+sv]   [+sv]
                                         [-nasal]   [+nasal]

The above representations can be examined to determine what differentiates the consonant pairs that occur freely together from consonant pairs that are barred from cooccurring. The nasal and prenasalized stop may not cooccur. These segments differ from one another in only a single feature specification. The prenasalized stop is [-nasal] and the nasal is [+nasal]. These segments are identical with respect to all other specifications. The nasal can occur freely with all other segments in the series and it differs from all other segments by more than one feature specification. The nasal differs from the voiced stop in that the nasal is [+sv] and the voiced stop is [-sv] and the nasal has a [+nasal] specification which the voiced stop lacks. The nasal differs from the voiceless stop in that the nasal is [-laryngeal] and the voiceless stop is [+laryngeal]. In addition, the nasal is specified as [+sv] and [+nasal], features which are not designated as contrastive for the voiceless stop. If only the behaviour of the nasal is examined,

consonant pairs barred from cooccurring can be defined as those pairs that differ in only a single feature specification.

Such a definition does not hold up, however, when we consider cooccurrence constraints that do not involve the nasal segment. The prenasalized stop is also barred from coocurring with the voiced stop. These segments have distinct specifications for the feature [sv] with the prenasalized stop being [+sv] and the voiced oral stop being [-sv]. They differ in another respect, though. The prenasalized stop has a [-nasal] specification which the voiced stop lacks. A parallel situation is found when we examine the voiced stop and the voiceless stop. These segments may not cooccur. They have distinct specifications for the feature [laryngeal] and also differ in that the voiced stop is [-sv] and the voiceless stop is not contrastively specified for that feature. While the nasal and prenasalized stops differ in only a single feature specification, the other barred consonant pairs, /b…^{m}b/ and /p…b/ have distinct specifications in one feature but also differ in that one member of the pair is specified for a feature which is unspecified in the other member.

Note that in each case where a member of an ill-formed consonant pair is specified for some feature that the other member of the pair lacks, the specification is for the negative value of the feature. A segment specified for a positive value of a feature may occur freely with segments for which that feature is simply unspecified.   /b/ occurs freely with /m/, for example, although these segments have distinct specifications only in the feature [sv]. They also differ due to the specification of the feature [nasal] in the /m/. In this case, the [nasal] specification is a positive one. /m/ and /b/ thus differ in two positive feature values. The /m/ is [+sv] and [+nasal] whereas the /b/ is [-sv] and lacks

contrastive specification for [nasal] altogether. Forms containing both /m/ and /b/ are well-formed.

To this point in the thesis, I have made use of a three-way distinction between segments that are positively specified in a given feature, segments that are negatively specified in a given feature and segments for which that feature is not contrastive. In order to draw this three-way distinction, I have made crucial use of binary features. The distinction between segments which are contrastively specified for the negative value of a feature and segments for which the feature in question is noncontrastive and hence simply absent must be referred to by the grammar. This distinction is crucial in defining segments that participate in harmony in Bumo Izon, Kalabari Ijo, Dholuo, Anywa, Päri and Chaha.

In the case of Bumo Izon, for example, the voiced alveolar stop is contrastively [-constricted glottis]. The cooccurrence constraint enforcing harmony bars [-constricted glottis] segments from occurring with [+constricted glottis] segments. Voiced alveolar /d/ is therefore barred from occurring in forms with the implosives /ɓ/ and /ɗ/. The voiced velar stop, on the other hand, although phonetically similar to /d/ in terms of laryngeal properties, is not contrastively specified for any value of [constricted glottis] and occurs freely with both the [+constricted glottis] implosives and the [-constricted glottis] alveolar /d/.

Use of a binary feature system does not, however, entail that positive and negative feature values have an identical status within the grammar. The examination of the representations of Ngbaka labials above, in light of their patterning with respect to the cooccurrence constraints, suggests otherwise. I follow the proposal of Calabrese (1995,

2005) that phonological generalizations may make reference to contrastive features or the more limited set of features that are both marked and contrastive. Positive feature values are marked and negative feature values are unmarked.[11] The position advocated here is nonetheless more restrictive than that of Calabrese as he also allows for phonological rules to make reference to all features, including non-contrastive features.

If a distinction between marked and unmarked feature values is adopted, the segment pairs that are barred from cooccurring in Ngbaka differ in only a single marked and contrastive feature. This is illustrated in (58). These representations are the same as those shown in (57) except that here negative, or unmarked, feature values have been omitted.

(58)　　　　p　　　　　　　b　　　　　ᵐb　　　　　　m
　　　　　[+laryngeal]　　　　　　　　[+sv]　　　　[+sv]
　　　　　　　　　　　　　　　　　　　　　　　　　[+nasal]

When we consider only marked feature values, each segment pair banned from cooccurring differs in terms of only a single feature. The voiced segment is unmarked. It is specified only for negative feature values and hence has no relevant specifications when only marked features are considered. It differs from both the voiceless and prenasalized segments by a single marked feature, [+laryngeal] and [+sonorant voice] respectively. The nasal differs from the prenasalized stop on account of the feature [+nasal].

---

[11]This is a great oversimplification of the relationship between markedness and feature values. See Rice (2007) for discussion of how markedness diagnostics vary between languages and may be influenced by inventory shape. For the features and cases I consider here, it is sufficient to assume that positive values are marked.

The labial series provides evidence that differing in no more than a single marked and contrastive feature is the definition of similarity relevant for determining participating segments in Ngbaka cooccurrence restrictions. The ordering and specifications of the labial series can be straightforwardly extended to the other places of articulation. If place features are ordered above laryngeal features, all segments will be specified for major place of articulation. The presence of the glottal stop and fricative in the inventory ensures that place features will be contrastively specified for all other segments, including coronals.

A hierarchy of features capable of grouping all segments into the relevant place classes is shown below. The tree shows contrastive specifications for all segments that participate in cooccurrence restrictions as well as the glottal stop and fricative.

The feature hierarchy illustrated below is [labial] > [dorsal] > [sibilant] > [coronal].

(59) p, b, ^{m}b, m, t, d, ^{n}d, n, s, z, ^{n}z, k, g, ^{n}g, ɲ, kp, gb, ^{n}gb, ʔ, h

[+labial]
p, b, ^{m}b, m, kp, gb, ^{n}gb

[-labial]
t, d, ^{n}d, n, s, z, ^{n}z, k, g, ^{n}g, ɲ,ʔ, h

[+dorsal]
kp, gb, ^{n}gb

[-dorsal]
p, b, ^{m}b, m

[+dorsal]
k, g, ^{n}g, ɲ

[-dorsal]
t, d, ^{n}d, n, s, z, ^{n}z, ʔ, h

[+sibilant]
s, z, ^{n}z

[-sibilant]
t, d, ^{n}d, n, ʔ, h

[+cor]
t, d, ^{n}d, n

[-cor]
ʔ, h
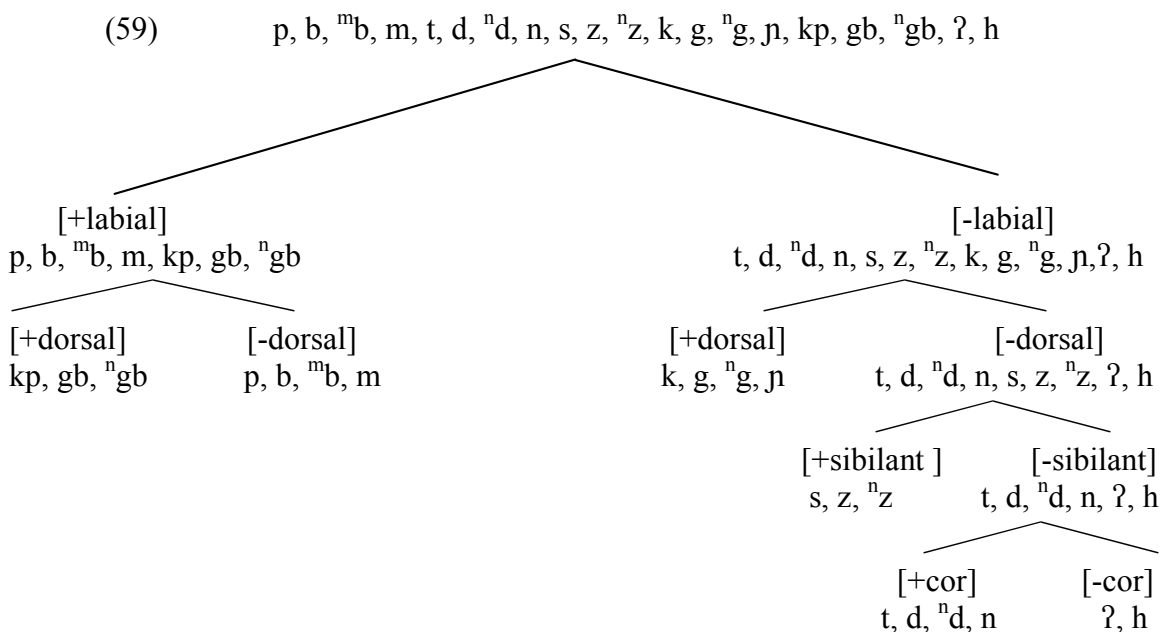
The groups of segments shown at the terminal nodes in figure (58) will be further differentiated using the order of features proposed above, namely [laryngeal] > [sonorant voice] > [nasal]. None of these features will distinguish the two glottal segments from one another. Thus an additional feature such as [continuant] or [spread glottis] will be needed to distinguish the glottal segments.

To this point I have argued that the order [laryngeal] > [sonorant voice] > [nasal] is able to distinguish the segments within place classes and is able to show segments barred from cooccurring as differing in only a single marked feature. In addition, the ordering of place features illustrated in figure (58) is able to divide segments into the relevant place classes. With respect to the coronal segments, the feature [sibilant] is ordered above the feature [coronal]. Once the sibilant series is distinguished from the other segments the feature [coronal] will not serve to further distinguish segments specified for the feature [sibilant] and will thus not be contrastive for these segments. With this ordering, the specification of the sibilants is parallel to that of other place classes. As opposed to being a subset of coronals, sibilants constitute a distinct set of segments, members of which are barred from cooccurring if they differ in only a single marked and contrastive feature.

Marked and contrastive specifications for the sibilants and coronals are illustrated below.

(60)   Marked feature values in the coronal and sibilant series

t	d	^{n}d	n
[+coronal]	[+coronal]	[+coronal]	[+coronal]
[+laryngeal]		[+sv]	[+sv]
			[+nasal]

s	z	^{n}z	
[+sibilant]	[+sibilant]	[+sibilant]	
[+laryngeal]		[+sv]	

The specifications above show /t/ and /d/ differing in terms of a single, marked feature [+laryngeal], /d/ and /^{n}d/ differing in the feature [+sonorant voice] and /^{n}d/ and /n/ differing only by the marked feature specification [+nasal]. A cooccurrence restriction banning segments differing in a single marked feature would thus correctly account for the data given the representations of the coronal stops shown above. In the sibilant series, the differences in laryngeal specifications are identical to those of the other series discussed and the formulation of the constraint as banning segments which differ by only a single marked feature can be upheld.

There is an additional complication in the data that presents a problem for the analysis presented here as well as for previous analyses. The coronal nasal /n/ is banned from occurring with both /^{n}d/ and /^{n}z/. The representations above, however, show /n/ as differing from /^{n}d/ by only the feature [nasal] and differing from /^{n}z/ by both [nasal] and [sibilant]. A representation allowing /n/ to participate in both the stop and sibilant series is not achieved in the account provided here.

A solution to the problem of the dual behaviour of /n/ remains to be found. Previous work by Broe (1993) undertaken in the structured specification framework claims that the feature [sibilant] refers to a place of articulation and that there are two underlying /n/'s, a coronal one and a sibilant one. While a similar solution is available in the model developed here, lack of independent motivation limits the appeal of such an account. Other attempts to account for Ngbaka cooccurrence restrictions have dealt only with the pattern in the labial series (e.g. Mester, 1986, van de Weijer 1994) and have not attempted to account for the coronal and sibilant series.

The cooccurrence constraints of Ngbaka do not give rise to active alternations. This, however, does not differentiate the Ngbaka case from many of the cases discussed in the consonant harmony literature or indeed in this thesis. Many cooccurrence restrictions make reference to the same features and the same sets of segments that participate in active harmony processes and what is a static constraint on morpheme structure in one language may be realized as active alternations in related languages. For these reasons, cooccurrence constraints are given the same status and type of analysis as other harmony processes.

In the case of Ngbaka, the set of segments that are barred from occurring together may differ in any of a number of features. That is, while segments barred from cooccurring differ in only a single marked and contrastive feature, what that feature is differs in different cases. /p/ and /b/ may not cooccur and these differ only in the feature [laryngeal]. /b/ and /^{m}b/ may not coocur and these differ only in [sonorant voice]. /^{m}b/ and /m/ may not coocur and these differ only in [nasal]. If we consider how a hypothetical form that violated this constraint might be repaired, we must assume that Ngbaka has a number of harmonic features. A form that contains a pair of segments that differ in only one marked and contrastive feature may be repaired through agreement in any of the features [laryngeal], [sonorant voice] or [nasal].

The order of contrastive features proposed for Ngbaka is [labial] > [dorsal] > [sibilant] > [coronal] > [laryngeal] > [sonorant voice] > [nasal]. This order of features achieves specifications in which all segments are uniquely specified and segments barred from cooccurring differ in only a single marked feature value.

Within the theory of the contrastive hierarchy, when an initial feature is specified that feature is contrastive for the entire inventory. The positive value of the feature, however, is only specified for a subset of the inventory. Other segments are specified for the negative or unmarked value of the feature. I propose that consonant harmony processes that refer to a global definition of similarity must refer only to positive feature values, that is to features that are both marked and contrastive.

4.2 Hausa

Hausa (Afro-Asiatic: Chadic) has a complex system of cooccurrence restrictions affecting glottalized consonants. Multiple non-identical glottalized segments, either ejective or implosive, are prohibited from occurring together within a morpheme (61). In addition, there is a constraint against the cooccurrence of glottalized segments and their homorganic, non-glottalized counterparts (62).

(61)   (data from Newman 2000, tones omitted)
    *ɓak'a   ɓaɓe   'quarrel'
    *s'aɓa   s'as'a   'rust'
    *k'aɗa   k'uk'uta 'try hard'

(62) *ɓaba   *s'asa
      *ɗadi   *k'aka

The cooccurrence restrictions of Hausa have been described in the consonant harmony literature (Hansson 2001, MacEachern 1997). The general constraint against multiple glottalized segments is not an example of consonant harmony and could, in fact, be thought of as a kind of dissimilation in which hypothetical inputs containing multiple ejectives are repaired through the loss of glottalization in one consonant. The constraint against homorganic glottalized/non-glottalized pairs, however, is amenable to a consonant harmony analysis. This constraint, together with the fact that identical

segments are exempt from the ban on multiple, glottalized segments, can be analyzed as harmony in the feature [constricted glottis] that is parasitic on place. As such, it has properties that we have seen in previous examples of consonant harmony. Bumo Izon and Kalabari Ijo have consonant harmony in the feature [constricted glottis]. The nasal and voicing harmony found in Ngbaka and discussed in the previous section occurs only between segments that share major place of articulation.

Like the Ngbaka case, [constricted glottis] harmony in Hausa cannot be analyzed as simply agreement between any segments contrastively specified for the harmonic feature. Some global similarity measure is necessary in order to account for the requirement that participating segments share major place of articulation. In fact, the Hausa pattern requires that participating segments share not only major place of articulation, but also all feature specifications. The result of [constricted glottis] harmony is total, segmental identity.

The Hausa consonant inventory is presented in (63) below. Note that the glottalized series is shown as implosive at the labial and coronal places of articulation and ejective at the velar place of articulation. Newman (2000) describes the labial and coronal as 'laryngealized, sometimes implosive' (2000:393) whereas the velars are true ejectives.

(63)   Hausa consonant inventory   (from Newman 2000)[12]

labial	coronal	palatal	velar	labialized velar	palatalized velars	laryngeals
(f, fʲ)	t	tʃ	k	kʷ	kʲ	
b	d	dʒ	g	gʷ	gʲ	
ɓ	ɗ	(j')	k'	kʷ'	kʲ'	ʔ
f, fʲ	s	ʃ				h
	z					
	s'					
m	n					
	l					
	r					
	ɽ					
		j		w		

4.2.1 Contrastive hierarchy analysis

The restriction against homorganic glottalic and non-glottalic segments is given in

(64) below (from Newman 2000).

(64)   Glottalized consonants may not occur with their homorganic, non-
        glottalized counterparts (e.g. *ɓ…b, *ɗ…d, *k'…k, *s'…s).

Note that this description clearly shows that restrictions on glottalized and non-

glottalized segments are parasitic not only on place, but also on voicing. Implosive /ɓ/ is

barred from occurring with /b/ and implosive /ɗ/ is barred from occurring with /d/

whereas ejective /k'/ is barred from occurring with plain /k/ and so on. There is one

---

[12] In Hausa, there is no phonemic contrast between /f/ and /p/. I am treating /f/ phonologically as the voiceless counterpart of /b/ and include it in the chart along with the voiceless stops (following Newman 2000). Phonetically, /f/ is alternately realized as [f], [p] or [h] depending on dialect and phonological context. /j'/ represents a glottalized palatal glide. According to Newman (2000), this phoneme is a recent innovation that occurs in very few lexical items. The following discussion of restrictions on glottalized segments does not consider the behaviour of /j'/.

systematic exception to this pattern. In the alveolar series, a directional effect is found such that /ɗ/ followed by /d/ is unattested whereas the reverse is found in some forms (e.g., daaɗıı 'pleasantness', daɗè 'last long'). The following analysis therefore accounts for a restriction against glottalized segments and their non-glottalized counterparts that agree in both place and voicing. I do not provide an account of the directionality effects in the alveolar series.

The fact that ejectives cannot occur with homorganic voiceless stops and that implosives may not occur with homorganic voiced stops suggests that the voicing difference among the glottalized segments is present in the phonological representations and is not simply a matter of phonetic implementation. This can be achieved if we order the feature [voice] over the feature [cg] in a contrastive hierarchy.

The following diagram shows feature specifications for Hausa obstruents given the feature order [labial] > [dorsal] > [coronal] > [voice] > [continuant] > [constricted glottis].

(65)   Hausa obstruents

f, b, ɓ, t, d, ɗ, k, g, k', s, z, s', h, ʔ

[+lab]   [-lab]
f, b, ɓ   t, d, ɗ, k, g, k', s, z, s', h, ʔ

[+vce] [-vce]   [+dorsal]   [-dorsal]
b, ɓ   f   k, g, k'   t, d, ɗ, s, z, s', h, ʔ

[+cg] [-cg]   [+vce] [-vce]   [+cor]   [-cor]
 ɓ   b   g   k, k'   t, d, ɗ, s, z, s'   h, ʔ

                                  [+cg] [-cg] [+vce]   [-vce]   [+cg] [-cg]
                                   k'   k   d, ɗ, z   t, s, s'   ʔ   h

                                              [+cont] [-cont]   [+cont] [-cont]
                                                 z   d, ɗ   s, s'   t
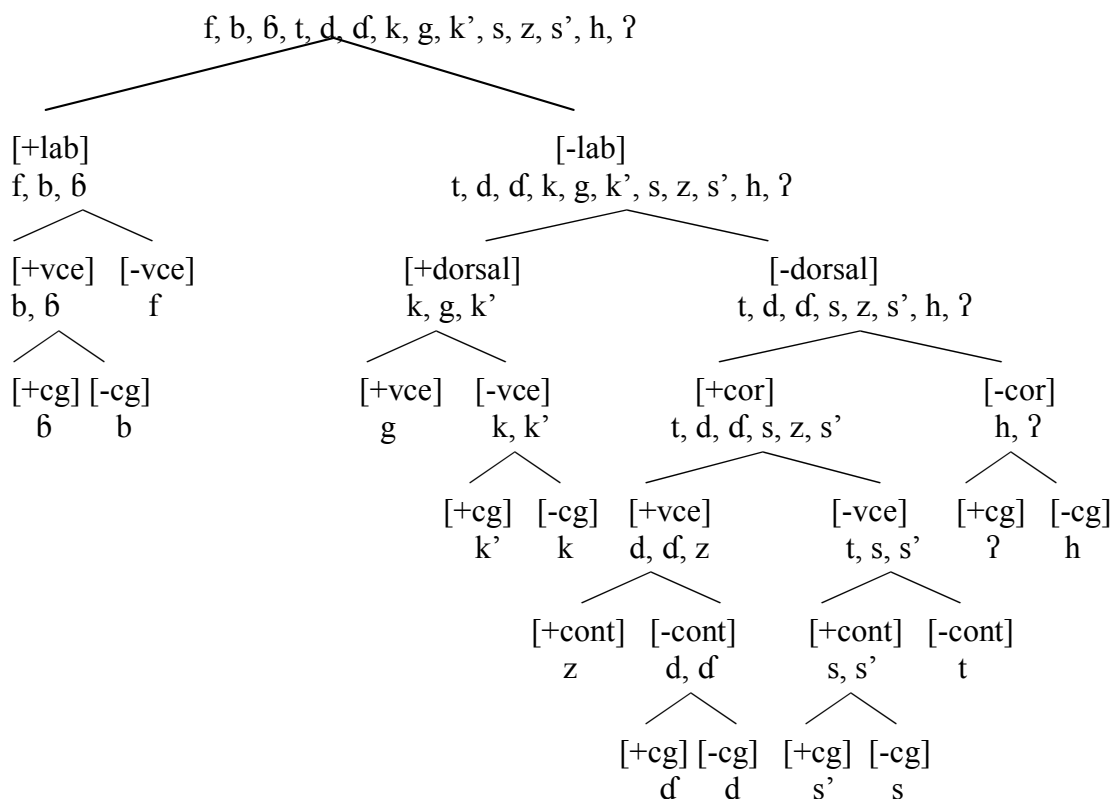
                                                     [+cg] [-cg] [+cg] [-cg]
                                                       ɗ   d   s'   s

The feature ordering illustrated above gives the following marked and contrastive specifications for the Hausa coronal series.

(66)   Marked specifications of Hausa coronals

t	d	ɗ	s	s'
[+cor]	[+cor]	[+cor]	[+cor]	[+cor]
	[+voice]	[+voice]	[+cont]	[+cont]
		[+cg]		[+cg]

Cooccurring segments may not differ only in [constricted glottis]. This generalization will correctly rule out the cooccurrence of glottalized and non-glottalized counterparts.

The Hausa cooccurrence constraint examined here, like the Ngbaka case discussed above, requires reference to a global notion of similarity. Segments that have

distinct contrastive values for the harmonic feature *can* cooccur if they differ in other features. For example, /s'/ can occur with /d/ even though /d/ is contrastively [-cg]. These segments may occur together in Hausa because they differ in other feature values, namely [voice] and [continuant]. Unlike Ngbaka, which appears to have many features that can act as harmonic features in order to prevent an unwanted level of similarity, Hausa has a single harmonic feature, [constricted glottis]. Segments that are distinct in a single feature specification may occur together if they agree in the harmonic feature. Hence, /t/ and /d/ may cooccur, although they are highly similar and have distinct specifications only in the feature [voice]. They may occur together because they do not have distinct specifications for the feature [constricted glottis] and thus already satisfy a requirement that such similar segments agree in the harmonic feature (or at least, not have distinct specifications in the harmonic feature).

With respect to the sibilant series, /s'/ is the glottalized counterpart of /s/ from which it differs only in its specification for [constricted glottis]. /s'/ and /s/ are thus predicted not to cooccur. This prediction is correct, without exception in the case of /s'/ followed by /s/. There are a few cases of /s/ followed by /s'/ (e.g., sans'ɪ 'slipperiness'). In this respect, the sibilants pattern with the other members of the coronal series in that there is a directionality effect in the cooccurrence restriction.

There is one additional complication in the data that is not easily accounted for in any analysis. /s'/ enters into restrictions with other segments which are not predicted by the preceding analysis. /s'/ may not be followed by /t/, although the reverse order is permitted (Newman 2007, p.c.). Again, the directionality is consistent with other restrictions in the coronal series. An account of this restriction is possible in the present

framework if /s'/ is assumed to be simply a [+constricted glottis], [-voice] segment and, as such, the glottalized counterpart of /t/. A representation that accounts for both restrictions without modifying the formulation of the constraint is unavailable given my assumptions about feature specifications. In addition, /s'/ is also prohibited from being followed by /z/, a further complication not accounted for here.

In his discussion of the Hausa phonemic inventory, Newman (2000: 394) gives the following description of /s'/:

> Synchronically, the ejective /s'/ can be viewed as the glottalized member of the /s, z, s'/ triad in the same way that /k'/ is the glottalized member of the /k, g, k'/ triad. Although we lack solid information about the history of this phoneme, my hunch is that it will not turn out to be a glottalized /s/, but rather will be found to be derived from an ejective /t/ or /c/ or from a possibly non-glottalized alveolar affricate /ts/.

The final possibility given in Newman's description allows for an analysis in which /s'/ differs from both /t/ and /s/ in only a single feature specification. If /s'/ is phonologically not an ejective fricative, but rather a non-glottalized alveolar affricate, it may be represented as a strident stop. The following representations are consistent with a contrastive hierarchy analysis.

(67)   Alternative marked coronal specifications
           t   s'   s
                      [+strident]   [+strident]
                                          [+continuant]

The representations given above show /s'/ as being distinct from both /t/ and /s/ in only a single marked feature value. The /s'/ is not contrastively specified for the feature [constricted glottis], however. As a result, any constraint prohibiting the cooccurrence of /s'/ and /t/ and /s'/ and /s/ would necessarily make reference to other harmonic features, namely [strident] and [continuant]. Such a constraint would also predict restrictions on

the cooccurrence of /ʃ/ and /tʃ/. I offer this as a speculative possibility and leave a comprehensive account of the patterning of /s'/ to future research.

The analysis given here proposes that the constraint on the distribution of glottalized segments in Hausa can be formalized as a requirement that homorganic segments that differ in only a single marked and contrastive feature must agree in the feature [constricted glottis]. A contrastive hierarchy in which place features and [voice] are ordered above [constricted glottis] results in specifications that can account for the restriction on the cooccurrence of voiced segments and implosives and voiceless segments and ejectives.

4.2.2 Coronal Sonorants

The previous section has provided an analysis of the restriction barring homorganic glottalic/non-glottalic pairs within Hausa forms. As noted earlier, other cooccurrence restrictions are active in Hausa. This section addresses the cooccurrence constraint affecting coronal sonorants. The restriction given below is from Newman (2000: 410).

> In normal CVCV sequences, /l/ and /n/, and /l/ and /ɽ/ cannot co-occur…
> The l/ɽ restriction applies only to the flap /ɽ/. It does not affect the rolled
> /r/, i.e., words with the sequence /r/-/l/ and /l/-/r/ occur, e.g., lùùra 'look
> after', ruulà 'ruler (for measuring length)'. In the case of flap /ɽ/ and /n/,
> there is a unidirectional restriction: /ɽ/ - /n/ occurs readily, e.g., ɽinàà
> 'dye', ɽaanì 'dry season', but /n/ - /ɽ/ does not, the word naɽkèè being an
> exception.

In this section, I propose that the restriction against cooccurring coronal sonorants in Hausa is similar to other cooccurrence constraints seen in this chapter in that it can be formulated as a ban on homorganic segments that differ in only a single marked and

contrastive feature. I further show that the representations argued for here are supported by data from local assimilation processes.

The following hierarchy of distinctive features is proposed for the coronal sonorants of Hausa.

(68)   [approximant] > [rhotic]

```
                          n, l, r, ɽ
                  ╱                       ╲
            [+approx]                  [-approx]
              l, ɽ                       n, r
          ╱        ╲                 ╱          ╲
    [+rhotic]   [-rhotic]       [+rhotic]    [-rhotic]
        ɽ           l               r            n
```
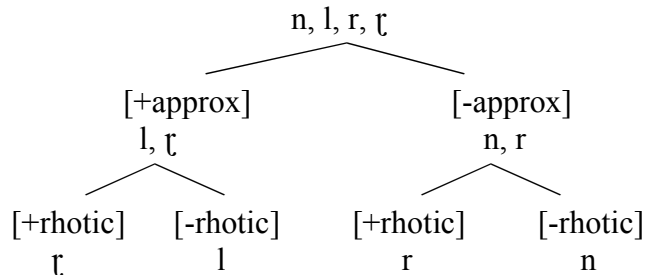
This ordering results in the following set of marked and contrastive feature specifications for the Hausa sonorants.

(69)   Marked specification of Hausa sonorants

n	l	r	ɽ
	[+approx]	[+rhotic]	[+approx]
			[+rhotic]

If the cooccurrence constraint affecting coronal sonorants in Hausa is formulated as a ban on homorganic segments that differ in only a single marked and contrastive feature, the above specifications correctly predict that /n/ is unable to occur with /l/ and that /l/ is not permitted to occur with the retroflex /ɽ/. /l/ and alveolar trilled /r/ are correctly predicted to cooccur as they differ in two marked and contrastive features, with /l/ being [+approximant] and /r/ being [+rhotic].

The above representations also predict that the two /r/'s are unable to occur together, as they differ only in one marked feature specification, [+approximant], and that the trilled alveolar /r/ is unable to occur with /n/ from which it differs only in its [+rhotic]

specification. While neither of these constraints is discussed in the grammar of Hausa, Newman (2007, p.c.) states that /r/ and /ɽ/ do not occur together within morphemes, although they are found together when /r/ functions as a definite article or genitive linker. Similarly, /r/ does not occur with /n/ in monomophemic forms but they may occur together when one is a linker or article. As the cooccurrence restrictions within Hausa generally hold over the domain of the morpheme, I take the specifications above to correctly predict the absence of /r/ and /ɽ/ and /r/ and /n/ within morphemes.

The only restriction not accounted for with the proposed representations is the restriction between /n/ and /ɽ/. While all of the other restrictions on coronal sonorants involve segments that differ in only a single marked and contrastive feature, /ɽ/ has two marked features that /n/ lacks, [+approximant] and [+rhotic]. Note that the patterning of the restriction on the cooccurrence of /n/ and /ɽ/ differs from the other restrictions among coronal sonorants in that it holds in one direction only. /ɽ/ followed by /n/ is permitted but the reverse is not possible. All other restrictions among coronal sonorants are bidirectional. I propose that, in addition to the constraint barring cooccurrence of coronal sonorants that differ in only a single marked and contrastive feature, there is a directional constraint affecting the coronal nasal. /n/, as the least marked sonorant, may not be followed by any other coronal sonorant in a morpheme.

In addition to accounting for the cooccurrence restrictions, the features proposed above find support in local assimilation processes. Note that the feature [nasal] is not specified for the /n/. In this I follow work by Rice and Avery (1991) and Avery (1996), who argue that nasals often function as the unmarked sonorant and that a segment

specified simply as sonorant but lacking any additional feature specifications may be realized as nasal through a default or enhancement rule. Rice and Avery (1991) and Avery (1996) support this position with data from a number of languages in which nasals pattern as unmarked in that they participate in asymmetric assimilation processes. Languages discussed by Rice and Avery (1991) and Avery (1996) include Ponopean, Toba Batak and Klamath. In all these examples, /n/ assimilates to a following /l/ or /r/ but does not trigger assimilation of a preceding sonorant.

Just such an assimilation process is found in Hausa. /n/ assimilates completely to a following /l/, /r/ or /ɽ/. /n/ does not trigger assimilation of preceding sonorants, a pattern that is consistent with positive, or marked, feature values, being active in phonological processes in cases where corresponding negative values are not.

(70)   /n/ assimilation (examples from Newman 2000: 413)

ɗan lādì ⇒ [ɗallādì] proper name
watàn ràmàlân ⇒ [watàrràmàlâŋ] 'month of Ramadan'
sôn ɽâi ⇒ [sôɽɽâi] 'selfishness (lit. loving of life)'

The local /n/ assimilation process illustrated above may also provide insight into the directional restriction barring /n…ɽ/. As previously noted, this restriction differs from the other restrictions on coronal sonorants in its limited directionality and in the number of marked features distinguishing the interacting segments. The unmarked status of /n/ with respect to the feature specifications proposed here is supported by the data from local assimilation. The restriction on /n…ɽ/ sequences may be accounted for if, at some point, Hausa had a non-local assimilation process, parallel to the local assimilation process, in which /n/ assimilates to marked features of a following sonorant.

Other feature specifications that may require some discussion are the specifications of trilled /r/ as [-approximant] as opposed to the [+approximant] specification of the lateral and the retroflex /ɽ/. This aspect of the proposed specifications suggests that the trilled /r/ is less sonorous than the other liquids. Some phonetic justification for this choice can be given considering that the /r/ in question is a tap or trill which involves periods of complete constriction in the vocal tract. Further, the trilled /r/ in Hausa is an allophone of coronal obstruents in certain positions. In word-internal codas, coronal obstruents are realized as /r/. This is seen as a historical change and as an active, synchronic process.

(71)   Rhotacism of coronal obstruents (examples from Newman 2000: 413)

kaɗà	'beat'	karkàɗā	'beat repeatedly'
mas'ā̀	'pester'	marmàs'ā	'pester repeatedly'
maza	'quickly'	marmaza	'very quickly'
ɓātā̀	'to damage'	ɓàrnā	'damage, destruction'

Although the two /r/'s are contrastive, the contrast is neutralized in certain positions. Only trilled /r/ is found in word-final position. In onset position, the retroflex flap is found in most native vocabulary items. In coda position preceding coronal obstruents, only trilled /r/ occurs. According to Newman (2000), the retroflex flap is the native Hausa rhotic and the trilled /r/ has come into the language through loan words, as an allophone of alveolar obstruents in coda position and through phonemicization of sounds found in the ideophonic vocabulary (Newman 2000: 395). I propose that the [-approximant] specification of trilled /r/ accounts for its closer relationship to obstruents than the liquids /l/ and /ɽ/.

4.3 Tzutujil

In Hausa, the glottalized series is not uniform. The labial and coronal stops are voiced and implosive while the coronal fricative and velar stops are voiceless and ejective. This pattern can be explained with an appeal to functional considerations, as there are articulatory difficulties in maintaining the high supraglottal air pressure needed for ejectives when the constriction is forward in the vocal tract. (Similarly, segment inventories with a voiced/voiceless contrast may have a gap in the voiceless labial position.) In Hausa, the differences in voicing of glottalized segments are phonologically specified. This can be seen by the patterning of the cooccurrence constraint against glottalized segments and their non-glottalized counterparts. Implosives may not cooccur with homorganic voiced stops and ejectives may not cooccur with homorganic voiceless stops.

Tzutujil is a member of the Quichean branch of Mayan. The dialect considered here is that of San Juan La Laguna (Dayley 1985, MacEachern 1999). Tzutujil has an inventory shape similar to that of Hausa in having a glottalized stop series which is implosive at the labial and alveolar places and ejective elsewhere. There are also similar cooccurrence constraints on glottalized segments in the two languages.

(72)   Tzutujil consonant inventory   (based on Dayley 1985:13)

p	t	ts	tʃ	k	q	
ɓ	ɗ	ts'	tʃ'	k'	q'	ʔ
	s		ʃ		χ	h
m	n					
	l					
	r					
w			j			

Cooccurrence restrictions affecting glottalized segments in Tzutujil are described in MacEachern (1999/1997) as follows.

i) There is only one ejective per syllable, unless the ejectives are identical: tʃ'ihtʃ' 'metal', q'iiq' 'north wind', *tʃ'iiq', *k'its'

ii) Syllables with homorganic ejective and plain stops do not occur: *kiik'

According to MacEachern, implosives do not participate in the restrictions and occur freely with ejectives and with homorganic, plain stops.[13]

These restrictions are similar to those of Hausa. The fact that only ejectives participate in the constraints to the exclusion of implosives suggests that, as in Hausa, voicing is phonologically specified in the implosives and plays a role in determining the patterning of cooccurrence restrictions. The structure of the phonemic inventory, however, is significantly different in the two languages.

Hausa has a three-way contrast between stops at all places of articulation. The analysis presented above argued that Hausa contrasts plain voiceless stops, voiced stops and glottalized stops with implosives being specified as both voiced and glottalized. Tzutujil, on the other hand, has only a two-way contrast between stops at any given place of articulation. If cooccurrence restrictions between glottalized/plain pairs are parasitic on voicing such that ejectives may not occur with homorganic voiceless stops but implosives can, then voicing must be specified in the implosives. Importantly, if place features are ordered above laryngeal distinctions, the structure of the inventory precludes

---

[13] The fact that ejectives participate in the restriction against multiple, glottalized segments and that implosives fail to participate in this restriction is robustly supported by the data. The data on the restriction against homorganic plain/glottalized pairs is less clear as the number of relevant forms in the source material (Dayley 1985) is limited. I assume the constraints are as described in MacEachern (1999) but acknowledge that more data is needed. MacEachern (1999) also acknowledges the ambiguity of the data and the possibility that implosives may participate in the restrictions on homorganic segments.

the possibility of the implosives being contrastively specified for both [voice] and

[constricted glottis]. This is shown in the following contrastive hierarchy of Tzutujil

stops.

(73)   Contrastive hierarchy for Tzutujil
        [labial] > [dorsal] > [coronal] > [voice] > [constricted glottis]
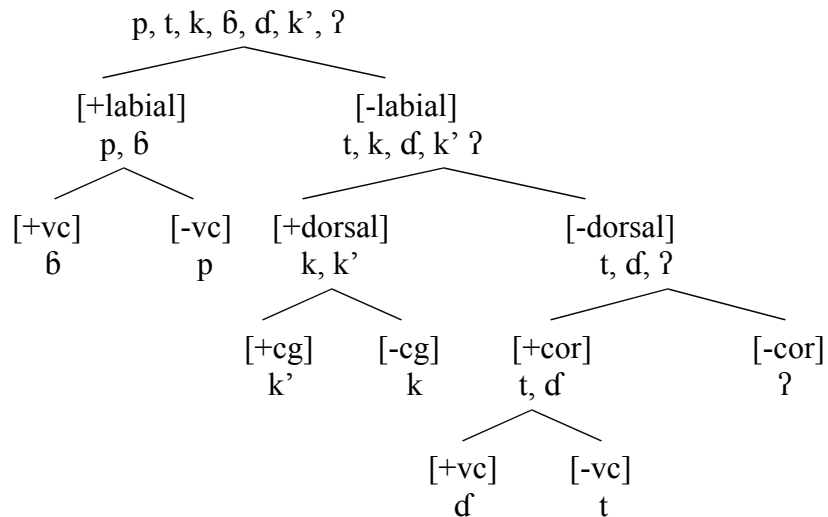
The hierarchy above does not include all stops in the Tzutujil inventory. I have

omitted the uvulars and affricates. If the additional segments are considered, additional

features are required in order to distinguish uvulars from velars, alveolars from

postalveolars and stops from affricates. These additional features are not crucial to the

analysis at hand.

Place features are ordered first and, once all place features have been specified,

the stops are separated into their relevant homorganic pairs, /p, ɓ/, /t, ɗ/, /k, k'/ in the

examples illustrated here. At this point the feature [voice] is added. [voice] serves to

differentiate segments in the labial and alveolar sets and members of these sets are

specified plus or minus [voice]. The feature [voice] does not serve to further differentiate

members of the velar set, however, so it is not contrastively specified for any member of

this set. The feature [constricted glottis] is then added in order to uniquely specify the velars. At this point, the labials and coronals are already uniquely specified and do not acquire any additional specifications. If the feature [voice] is ordered above [constricted glottis], is not possible for the labials and coronals to be contrastively specified for both [voice] and [constricted glottis].

The marked and contrastive feature specifications for labial and velar stops are shown in (74).

(74)   p   ɓ   k   k'
       [+labial]   [+labial]   [+dorsal]   [+dorsal]
                   [+voice]   [+cg]

These specifications illustrate that the velar voiceless stop and the velar ejective differ only in the [+constricted glottis] specification of the ejective. This segment pair will be subject to [constricted glottis] harmony as they differ only in one marked feature, the harmonic feature. The labials have no specifications for the feature [constricted glottis] and cannot participate in [constricted glottis] harmony.

The fact that implosives behave differently from ejectives with respect to [constricted glottis] harmony demonstrates that the feature [voice] is specified on implosives. Again, if segments are separated into place classes before laryngeal features are added, implosives cannot be specified for both [voice] and [constricted glottis]. If these segments are not specified for [constricted glottis], they may be expected to behave differently from ejectives with respect to phonological processes other than laryngeal harmony.

This is the case if we consider the markedness constraint banning multiple non-identical ejectives to be distinct from laryngeal harmony. In Tzutujil, multiple non-

identical ejectives may not cooccur but implosives can occur freely with ejectives and with each other. This is to be expected if the ban on multiple ejectives is a ban on multiple [+constricted glottis] features. The implosives are not specified for the feature [constricted glottis] and are predicted not to be subject to the markedness constraint. This contrasts with the situation in Hausa. In Hausa, voicing is also phonologically specified for the implosives, and implosives can occur with voiceless, homorganic stops but not with voiced homorganic stops. However, Hausa has a three-way contrast between stops at all places of articulation. Even though the Hausa labials and alveolars are specified as [+voice], they still can acquire specification in the feature [constricted glottis] and, in fact, must acquire such a specification in order to be differentiated from their plain voiced counterparts. Hausa also has a general ban on multiple glottalized segments. The implosives participate in this restriction exactly as the ejectives do. Implosives in Hausa may not occur with ejectives or with each other. This is expected if the ban on multiple, glottalized segments in Hausa is a ban on multiple [+cg] feature specifications in a form. Data illustrating the different patterning of the restrictions on glottalized segments in Hausa and Tzutujil is shown below.

(75)   Constraint on glottalized segments

Tzutujil		Hausa
* tʃ'iiq'		*s'ak'a
* k'its'		*k'as'a
ɓats'	'thread'	*ɓak'a
huɓiɗ	'a tear'	*ɗaɓa

In Tzutujil, the fact that [voice] is contrastive in the implosives and [constricted glottis] is not is somewhat surprising. After all, [constricted glottis] appears to be a more important feature in the system. It differentiates a greater number of phonemes and it is

referred to in significant phonological generalizations like laryngeal harmony and the markedness constraint on multiple ejectives. However, if place features are ordered above laryngeal distinctions, the contrastive hierarchy predicts that different place classes may have different systems of contrasts. The labial and coronal places appear to be special in other ways. For example, these are the only places that support a contrast between oral and nasal stops.

Further evidence for the significance of place features in the structure of laryngeal distinctions is found if we look at related languages. Proto-Mayan, like Tzutujil, has a contrast between plain and glottalized stops. In Proto-Mayan, the labial is implosive and all other glottalized stops are ejective (Campbell 1997). Many descendent languages, related to Tzutujil, have a richer set of contrast among stops *only in the labial series.* Modern Yucatec (Straight 1976), Classical Yucatec (McQuown 1967), Chol (Coon and Gallagher 2007), Tsotsil (Weathers 1947) and Izaj Maya all have a voiceless /p/, an ejective /p'/ and a voiced /b/. In some of the sources, the voiced segment is described as implosive, in others it is described simply as voiced or as pre-voiced. In all of these languages, a voicing contrast is not found at other places of articulation in the native vocabulary.[14]

If Proto-Mayan has a system of contrasts parallel to that proposed here for Tzutujil, the expansion of the inventory at the labial place of articulation in descendant languages can be thought of as filling in a gap in the inventory. It is further evidence that

---

[14] Tzutujil has an implosive at the coronal as well as the labial place of articulation. This is not the case, however, in Proto-Mayan or in many other Mayan languages. This discussion therefore focuses on contrasts in the labial series.

the contrast between labial implosives and labial voiceless segments is not exactly

analogous to the contrast between ejectives and voiceless segments at other places of

articulation. In the proto language, the feature [constricted glottis] was not contrastive in

the labial series but was contrastive at other places. If contrastive specification for

[constricted glottis] is extended into the labial series, it creates an additional, three-way

contrast, as the feature [voice] is already contrastive among labials. This leads to the

contrast between ejective, voiced and voiceless labials seen in many Mayan languages.

4.4 A Note on Voicing and Implosives

The claim that implosives are phonologically voiced in Hausa and Tzutujil may

be a controversial one. Work on a variety of languages and a variety of phonological

processes has shown that implosives fail to pattern as a natural class with voiced

segments. For example, in his study of consonant harmony patterns involving the feature

[voice], Hansson (2004) demonstrates that implosives fail to trigger or undergo voicing

harmony in Kera and Ngizim. In addition, in languages with consonant/tone interaction,

voiced obstruents are associated with low tone and voiceless obstruents are associated

with high tone. Implosives tend to pattern with voiceless obstruents or pattern as neutral

(see for example Ohala 1973, Demolin 1995, Wright and Shyrock 1993).

The failure of implosives to pattern with voiced obstruents in consonant/tone

interactions can be accounted for with appeals to phonetic naturalness. Phonetic

motivations for the differing behaviour of voiced and voiceless obstruents in tone

languages include differences in transglottal airflow and larynx height. Both these

factors are correlated with F_0. The release of voiceless obstruents has a higher rate of

transglottal airflow than the release of voiced obstruents leading voiceless obstruents to

trigger tone raising and voiced consonants to trigger tone lowering. In addition, voiceless obstruents have a higher larynx position than voiced obstruents. While phonetic research on the interaction of tone and implosives is sparse, it suggests that transglottal airflow is great due to the rapidly descending larynx (Odden 2005). Phonetically, we therefore expect implosives to pattern with voiceless segments in languages with consonant/tone interaction.

A central claim of the theory of the contrastive hierarchy is that phonological specifications may vary between languages, regardless of phonetic and crosslinguistic tendencies. If the features [voice] and [constricted glottis] are phonological features that may be ordered differently in the contrastive hierarchies of different languages, the theory of the contrastive hierarchy predicts that implosives may pattern as voiced in some languages. Odden (2005) provides evidence for such a case from the domain of consonant/tone interaction. In Zina Kotoko, implosives pattern with voiced consonants in triggering a process lowering a mid tone to a low tone.

The fact that implosives pattern as phonologically voiced in Tzutujil and Hausa is accounted for in the theory of the contrastive hierarchy by ordering the feature [voice] over [constricted glottis] in the feature hierarchy. The reverse order is clearly possible and appears to be more common. When [constricted glottis] is ordered above [voice], implosives fail to pattern with voiced consonants. This is the pattern found in voicing harmony in Kera and Ngizim as well as in the majority of documented consonant/tone interactions.

While the constrastive hierarchy allows for variation between languages, it is restrictive in the sense that contrastive feature specifications must be consistent across

phonological processes within a language. Ngizim is a language with both voicing harmony and consonant/tone interactions. In both types of processes, the implosives fail to pattern as a natural class with other voiced obstruents. This is expected if the contrastive hierarchy [constricted glottis] > [voice] results in representations in which implosives are not contrastively specified for the feature [voice].

4.5 Previous Accounts: MacEachern (1999)

This section provides a review of MacEachern's analysis of laryngeal harmony in Hausa and Tzutujil. Previous work on Ngbaka was discussed earlier in the chapter and I know of no other formal accounts of the harmony patterns affecting coronal sonorants in Hausa.

The cooccurrence restrictions affecting glottalized segments in Hausa and Tzutujil are discussed in MacEachern's (1999) crosslinguistic study of laryngeal cooccurrence constraints. MacEachern's study does not address the issue of consonant harmony directly but rather focuses on restrictions against multiple laryngeally marked segments such as ejectives, implosives, aspirates and the glottals /h/ and /ʔ/. Nonetheless, a number of the languages in MacEachern's survey pattern like Hausa and Tzutujil in exempting identical segments from general restrictions on the cooccurrence of segments with marked laryngeal features. Like Hausa and Tzutujil, these cases also ban homorganic segments that differ in laryngeal features. This leads to a distribution of laryngeal features consistent with an analysis as laryngeal harmony between homorganic segments. Again, while MacEachern's work is not a study in consonant harmony per se, the presence of cases like Hausa and Tzutujil make MacEachern's work a rich source of

data on laryngeal harmony systems that are restricted to homorganic segments, hence requiring reference to a definition of global similarity.

The questions addressed in this chapter necessarily differ from those addressed by MacEachern. Here, laryngeal harmony in Hausa and Tzutujil have been considered within a larger context of consonant harmony processes and theoretical work arguing for the significance of similarity in determining the patterning of consonant harmony. Throughout this thesis, I have been seeking a restrictive definition of similarity and arguing that, when similarity is crucial in determining phonological patterning, similarity is evaluated over contrastive phonological specifications. In the preceding chapter, I made a stronger claim; that, given the proper theory of featural representations, similarity can be dispensed with in favour of the basic notion of natural class. This chapter has considered cases in which the notion of natural class is insufficient in determining participating segments and I have argued that in these cases, interacting segments may differ in only a single marked feature specification.

The emphasis in MacEachern's work is different. She is seeking an explanation for typological patterning in cooccurrence restrictions affecting laryngeal segments and she argues that similarity plays a crucial role in those patterns. The similarity scale below is from MacEachern (1999).

(76)   The following chart is presented in MacEachern (1999: 16)

1	$t^h \leftrightarrow ʔ$	least similar
2	$t' \leftrightarrow h$	
3	$t^h \leftrightarrow ɓ$	
4	$ɗ \leftrightarrow h$	
5	$h \leftrightarrow ʔ$	
6	$t^h \leftrightarrow h$	somewhat similar
7	$d^ɦ \leftrightarrow h$	
8	$t^h \leftrightarrow k'$	moderately similar
9	$t^h \leftrightarrow g^ɦ$	
10	$d^ɦ \leftrightarrow g^ɦ$	
11	$t^h \leftrightarrow k^h$	
12	$t^h \leftrightarrow d^ɦ$	
13	$ʔ \leftrightarrow ɗ$	very similar
14	$ʔ \leftrightarrow t'$	
15	$t' \leftrightarrow ɓ$	
16	$ɓ \leftrightarrow ɗ$	
17	$t' \leftrightarrow k'$	
18	$t' \leftrightarrow t^h$	

This scale is motivated by typological observations to the effect that languages which allow segment pairs lower in this scale, or very similar segment pairs, to cooccur also allow segment pairs higher in the scale, or less similar segment pairs, to cooccur. MacEachern speculates that this similarity scale, and the typological facts behind it, is determined by auditory similarity. She proposes the following similarity continuum.

(77)   h - - - - - C^h - - - - - C' - - - - - ʔ   (from MacEachern 1999: 10)

According to MacEachern, elements adjacent on the continuum are similar in the following respects; /h/ and aspirates share aspiration, aspirates and ejectives share a delay in VOT relative to other stops, ejectives and glottal stop share glottalization.

MacEachern's proposal that auditory similarity accounts for typological patterns of constraints on the cooccurrence of ejectives, implosives and other laryngeally marked segments is unmotivated. There is no evidence that these patterns are determined by

similarity. Rather, they result from constraints on the distribution and cooccurrence of marked feature specifications.[15] The similarity scale in (76) is also dubious. Ejectives are deemed to be highly similar, regardless of differences in place and manner (line 17). Homorganic aspirates and ejectives are also deemed highly similar but there is no level of similarity attributed to homorganic pairs in which one member is a plain voiced or voiceless stop. Restrictions on the cooccurrence of plain voiced and voiceless segments and laryngeally marked segments are seen in MacEachern's study, however. In Hausa, homorganic voiced stops and implosives may not cooccur. Furthermore, MacEachern is able to frame the cooccurrence restrictions on Hausa ejectives and voiceless segments as a restriction on laryngeally marked segments only through a controversial assumption that voiceless stops are phonologically aspirated. These facts leave even the typological evidence for the similarity scale in doubt.

While MacEachern's work contains extensive discussion of the similarity scale in (76), the similarity continuum in (77) and the significance of similarity in general, her formal analysis of laryngeal harmony and cooccurrence constraints makes no direct reference to similarity. Her analysis is undertaken in the framework of OT and relies on two conflicting constraint types. The first is BEIDENTICAL. This constraint is violated by any pair of segments that are not identical in every respect. The suggested functional motivation behind this constraint is the fact that it requires more effort in articulation and planning to execute distinct segments than to execute identical segments.

---

[15] This is more or less the position formalized in MacEachern's OT account as shown in her use of OCP constraints referring to larygneal features.

The force that conflicts with BeIdentical is a family of Generalized Obligatory Contour Principle constraints. These constraints include OCP Root Node which is also referred to as *Identity. This constraint naturally has a violation profile exactly opposite to that of the constraint BeIdentical. MacEachern also uses OCP constraints that refer to laryngeal features; OCP[constricted glottis], OCP[spread glottis].

Although MacEachern argues that auditory similarity is the motivating force behind laryngeal cooccurrence constraints, her formal analysis of cooccurrence patterns does not make direct reference to similarity. In order to derive similarity effects using constraints that refer only to featural identity and total identity, MacEachern introduces a number of complex, conjoined constraints. The following is an example from MacEachern (1999: 18).

(78)   OCP RootNode & OCP[constricted glottis] – This constraint is violated just in case one or both of the component constraints is violated.

This conjoined constraint will be violated by any segment pair that is identical *or* any segment pair that contains identical [constricted glottis] specifications. (Note that this use of constraint conjunction differs from common usage in other works in which conjoined constraints are violated only when both individual constraints in the conjunction are violated.) By collapsing the OCP constraint on the feature [constricted glottis] with the constraint against completely identical segments, MacEachern is able to penalize segments that have met a threshold of similarity, that of sharing a laryngeal

feature specification, along with segments that exceed that threshold, up to complete, segmental identity.[16]

MacEachern uses these constraints along with standard faithfulness constraints MAX, DEP and IDENT in order to account for the variation she finds across languages with cooccurrence restrictions referring to laryngeal features.

Tableaux illustrating MacEachern's analysis of Hausa are shown below.

(79)   (modified from MacEachern 1999: 100)[17]

ɓak'a	BEIDENTICAL	*ID&OCP[cg]	MAX [cg]$_{IO}$
a) ɓak'a	*	*!	
b) ☞ bak'a	*		*

A form with two non-identical glottalized segments is evaluated in the tableau in (79). Both the faithful candidate and the candidate with only a single glottalized segment violate BEIDENTICAL. High ranking constraints requiring input/output identity in place features (not shown) will eliminate any potential candidates capable of satisfying BEIDENTICAL. The conjoined markedness constraint *IDENTITY&OCP[constricted glottis] is violated by any form containing identical segments *or* multiple segments with

---

[16] The analysis in MacEachern (1999) differs from the analysis in the unpublished version of her thesis (MacEachern 1997). Most dramatically, the original version of the thesis does not use constraint conjunction but rather uses a family of *SIMILARITY constraints that penalize similarity directly. In most cases, the conjoined constraints used in MacEachern (1999) have the same violation profile as the *SIMILARITY constraints of MacEachern (1997)

[17] MacEachern (1999) assumes that voiceless stops in Hausa are aspirated. This is consistent with her general statements that restrictions on cooccurring segments affect laryngeally marked segments such as aspirates and ejectives. Her typological observations do not include discussion of restrictions on glottalized segments and plain voiceless or voiced segments. Despite MacEachern's arguments that Hausa voiceless stops are aspirated, they are not described as such in previous literature. The position that voiceless segments are aspirated also has little impact on her formal analysis of Hausa. For this reason, I show Hausa voiceless stops as unaspirated and have omitted constraints referring to aspiration, such as DEP[spread glottis], from her tableaux.

[constricted glottis] specifications. The faithful candidate violates this constraint and is

eliminated. Candidate (b), in which the implosive /ɓ/ in the input is mapped to a plain /b/

in the output, satisfies *IDENTITY&OCP[cg] and is selected as optimal. It violates only

the relatively lowly ranked faithfulness constraint MAX[cg]. This ranking is able to

account for the ban on multiple, glottalized segments in Hausa.

(80)   (modified from MacEachern 1999: 101)

	ɓaba	BEIDENTICAL	*ID&OCP[cg]	MAX [cg]IO
a)	ɓaba	*!		
b) ☞	baba		*	*

Tableau (80) is more directly relevant to consonant harmony. The input contains

homorganic segments that differ only in [constricted glottis]. In this case, the relevant

segments are implosive /ɓ/ and plain voiced /b/. The faithful candidate is eliminated due

to a violation of BEIDENTICAL. In candidate (b), the [constricted glottis] feature of input

/ɓ/ is not realized in the output. The candidate is therefore able to satisfy BEIDENTICAL

and is selected as optimal.

MacEachern does not demonstrate the evaluation of an input candidate with

identical glottalized segments. Tableau (81) shows how such a candidate would be

evaluated given her constraint ranking.

(81)   (modified from MacEachern 1999: 101)

	ɓaɓa	BEIDENTICAL	*ID&OCP[cg]	MAX [cg]IO
a) ☞	ɓaɓa		*	
b)	baba		*	*!*
c)	ɓaba	*!		*

Candidate (c) shows a mapping in which one of the implosives in the input is mapped to a plain stop in the output. While this allows the candidate to satisfy *IDENTITY&OCP[cg], it leads to a fatal violation of high-ranking BEIDENTICAL. The competition is therefore between faithful candidate (a) and the candidate without any glottalized segments, candidate (b). Both candidates violate *IDENTITY&OCP[cg]. The faithful candidate is selected as optimal due to violations of MAX[cg] incurred by candidate (b).

The constraints and constraint rankings put forward in MacEachern (1999) are capable of accounting for the patterning of consonant harmony in Hausa. This solution, however, makes crucial use of constraint conjunction, an extremely powerful mechanism. Moreover, the interpretation of conjoined constraints such as *IDENTITY&OCP[cg] deviates from standard interpretations of constraint conjunction. As noted above, MacEachern requires this constraint to be violated by any candidate that violates either of the simplex constraints forming the conjunction.

The conjoined constraint *IDENTITY&OCP[cg] is crucial in MacEachern's analysis. As shown in tableau (81), this constraint must be violated equally by candidates with identical non-glottalized segments and by candidates with identical glottalized segments. If not, the faithful candidate which contains multiple implosives would never be selected over the candidate with identical plain stops. Both candidates satisfy BEIDENTICAL and both must fare equally well on the markedness constraint penalizing multiple glottalized segments in order for the attested output form to be selected. This solution is counterintuitive. There is no evidence that identical segments are disfavoured in Hausa. Hausa has no OCP-type restrictions on identical segments or segments of the

same place of articulation cooccurring within morphemes. The constraint *IDENTITY

plays a role in MacEachern's analysis of Hausa only as a member of the conjoined

constraint *IDENTITY&OCP[cg] and here it serves to make forms with multiple plain

consonants, such as /baba/, which are well-formed and subject to no restrictions, violate

the same markedness constraint as completely ill-formed sequences such as /ɓak'a/.

The complexity of the machinery used in MacEachern's account is even more

evident in her analysis of Tzutujil. The basic mechanisms are the same as those used in

the analysis of Hausa. BEIDENTICAL outranks some markedness constraint penalizing

multiple glottalized segments which in turn outranks the faithfulness constraint MAX[cg].

Formulating exactly what that markedness constraint is, however, is challenging given

that Tzutujil bans multiple ejectives but allows multiple implosives. MacEachern

proposes the following constraint.

(82)   (MacEachern 1999:105)

GOCP: [constricted glottis] ∨ [-sonorant] ∨ [-voice] (=*2(CG ∨[-son] ∨ [-voice]).
The cooccurrence of two ejectives is prohibited.

Here MacEachern uses a different, and more standard, version of constraint

conjunction which she terms constraint disjunction. This constraint is violated just in

case all the constraints OCP[constricted glottis], OCP[-sonorant] and OCP[-voice] are

violated. Use of this constraint will allow forms containing multiple ejectives to be

penalized without penalizing multiple implosives or combinations of implosives and

ejectives. Note that MacEachern is treating [constricted glottis] as a privative feature but

treating [sonorant] and [voice] as binary features. She acknowledges that she treats

[voice] as a privative feature elsewhere in her study but she requires reference to [-voice]

in order to distinguish ejectives from implosives. The [-sonorant] feature is necessary in order to exclude glottal stop from the cooccurrence constraint.

There are more serious problems with this constraint. While the constraint as defined is violated by any form violating OCP[cg], OCP[-sonorant] and OCP[-voice], the intended application of the constraint is to penalize only forms in which all three simple constraints are violated by the same segment pair. A hypothetical form such as /ɓut'ik/ would violate OCP[cg] because it contains an implosive and an ejective. It would also violate OCP[-sonorant] and OCP[-voice] because it contains two voiceless obstruents, /t'/ and /k/. Yet this form is not ill-formed according to the morpheme structure restrictions of Tzutujil, as it does not contain two ejectives.[18]

In order for MacEachern's analysis of Tzutujil to work, the above conjoined constraint must itself be conjoined with *IDENTITY. This complex conjoined constraint is interpreted as violated when either of its conjuncts is violated, with one of the conjuncts being the complex conjoined/disjunctive constraint discussed above.

(83)   (MacEachern 1999:106)

Conjunctive Constraint: *IDENTITY & *2(CG ∨ [-son] ∨ [-voice]).
This constraint is violated by the cooccurrence of two identical segments and/or two ejectives.

The following tableaux illustrate MacEachern's analysis of restrictions on multiple ejectives and laryngeal harmony between homorganic segments in Tzutujil.

---

[18] This is an example of a more general problem with constraint conjunction. See McCarthy (2007) for discussion of how constraint conjunction erroneously leads to penalizing marked structures in proximity to one another as opposed to marked structures that interact.

(84)   (modified from MacEachern 1999: 106)

q'ak'	BEIDENTICAL	*ID & *2(CG V[-son] V [-voice])	MAX [cg]
a) q'ak'	*	*!	
b) ☞ q'ak	*		*

Here an input with multiple non-identical ejectives is evaluated. Both candidates

violate BEIDENTICAL The faithful candidate is eliminated due to a violation of *IDENTITY

& *2(CG V[-son] V [-voice]) caused by the presence of two ejectives in the form.

Candidate (b) is optimal. It is able to satisfy the conjoined markedness constraint and

incurs only a violation of lowly ranked MAX[constricted glottis].

(85)   (modified from MacEachern 1999: 107)

k'ok	BEIDENTICAL	*ID & *2(CG V[-son] V [-voice])	MAX [cg]
a) k'ok	*!		
b) ☞ k'ok'		*	

Tableau (85) considers the fate of a disharmonic input with homorganic ejective

and plain stops. The faithful candidate is eliminated due to violation of BEIDENTICAL.

The harmonic candidate is selected as optimal.

While MacEachern's analyses of Hausa and Tzutujil are observationally adequate,

they entail the use of multiple constraint conjunction. In fact, two different types of

conjoined constraints, disjunctively interpreted and conjunctively interpreted, are needed

and, in the analysis of Tzutujil, a complex, disjunctively interpreted conjoined constraint

is further conjoined with a simple markedness constraint with the entire constraint being

conjunctively interpreted (in MacEachern's terms). Furthermore, MacEachern's analysis

crucially hinges on conjoined constraints of the form *IDENTITY&OCP[F] which serve to

conflate markedness constraints against multiple, marked laryngeal features with a penalization of identity in a highly counterintuitive fashion.

The contrastive hierarchy analyses of consonant harmony cases presented in preceding sections have focused on representational issues. What is the degree of similarity needed for segments to participate in harmony and what are the representations over which similarity is evaluated? I have not directly addressed issues concerning the mechanisms of consonant harmony in a fashion analogous to that of MacEachern. Nonetheless, it is worth noting here that some of the complications in MacEachern's analysis stem from representational issues. The conjoined constraint *2(CG V[-son] V [-voice]) must be formulated as such in order to prevent implosives from participating in constraints against multiple glottalized segments. In the contrastive hierarchy analysis advocated above, implosives are argued to behave differently from ejectives precisely because they are not contrastively specified for the feature [constricted glottis]. The contrastive hierarchy analysis does not require that all phonetic aspects of a given segment be represented by phonological feature specifications. The implosives are contrastively [+voice] and once this feature is added they do not acquire further contrastive specifications. They are therefore not specified for the feature [constricted glottis] and are not expected to participate in rules or constraints referring to this feature. Given these proposals, a constraint banning multiple [+constricted glottis] segments could be formulated simply, with no need for constraint conjunction or reference to additional features. Implosives would not be subject to such a constraint as they are not specified for the relevant feature. In the case of harmony, a constraint requiring laryngeal harmony between segments that differ in only a single marked feature specification

would not affect implosive/plain pairs as these do not have distinct specifications in [constricted glottis] and would thus be unable to undergo harmony.

While MacEachern argues that a gradient, auditory notion of similarity is crucial in shaping crosslinguistic patterning of laryngeal cooccurrence constraints, her formal analysis does not make direct reference to such a notion. Indeed, she acknowledges that her proposed constraints, if freely ranked, would wildly overgenerate and produce many unattested restrictions on the distribution of laryngeally marked segments. She argues instead that auditory similarity plays a role in shaping cooccurrence patterns without being represented within the formal system of the grammar itself. Although the constraints used in her analysis have the potential to generate unattested patterns, MacEachern suggests that her proposed similarity continuum would prevent such systems from being learned or maintained. Exactly why and how this happens is not clear. Furthermore, no basis for the similarity continuum is provided outside of the cooccurrence patterns themselves.

This thesis has taken a different position and argued that, when similarity is referred to in phonological processes such as consonant harmony, it is computed over phonological features present in the grammar.[19] How such features can be referred to is extremely constrained.

---

[19] This position does not preclude the possibility that some aspects of sound patterning are determined by extragrammatical factors originating in aspects of perception, language learning and language change. See chapter 6 for further discussion.

4.6 Implications

In chapter three, I argued that a number of cases in the consonant harmony literature that have been argued to be determined by similarity can, in fact, be described using the notion of natural class. While the notion of natural class is certainly a type of similarity, it is an extremely easy one to formalize and it is a notion which is unavoidable in the analysis of any range of phonological generalizations.

The cases in this chapter have required reference to a different notion of similarity. All cases have involved interacting segments that share major place specifications. I have argued that segments that interact in these cases differ in a single marked feature specification. The definition of similarity used here, identical in all but a single feature, is more difficult to refer to formally in rules or constraints than the notion of natural class. This definition does lead us to certain conclusions, however. Segments that interact in harmony must, by definition, differ in the harmonic feature prior to the application of harmony. If interacting segments can differ in only a single marked feature specification, then that feature must be the harmonic one. And, if segments subject to harmony may differ in only a single feature, the outcome of harmony must be complete segmental identity between participating segments, which is the case in all cases considered in this chapter.

The preceding section argued that MacEachern's similarity scale is poorly motivated and that her analysis of laryngeal cooccurrence constraints and harmony between homorganic segments relies on a highly complex and counterintuitive use of constraint conjunction. With respect to the mechanisms of laryngeal harmony, however, MacEachern's account provides important insights. In her analysis, it is the constraint

BEIDENTICAL and its ranking relative to featural faithfulness constraints, rather than any restrictions on similarity, that leads to laryngeal harmony in output forms. This mechanism, taken together with the proposal argued for here that interacting segments differ in only a single marked feature specification, allows for the possibility that only identity, and not similarity at all, need be referred to in cases of consonant harmony in which interacting segments cannot be described simply as a natural class. This possibility will be explored further in the following chapter, where the representations argued for in these chapters are integrated with a system of phonological operations.

The definition of similarity proposed here is also able to account for the special role of major place features in determining similar segments. The beginning of this chapter observed that all consonant harmony processes that appear to require reference to a global definition of similarity involve interacting segments that agree in major place specifications. As discussed above, if segments that interact differ in only a single feature specification, that feature must be the harmonic one. It is widely observed in typological studies of consonant harmony that cases of consonant harmony involving major place features are unattested (Hansson 2001, Rose and Walker 2004). If place features are never harmonic, then segments that interact may never differ in place features as they can differ only in specification for the harmonic feature. The absence of consonant harmony in major place features remains to be explained but the need for interacting segments to share major place specifications can be reduced to the fact that major place features are not harmonic.

CHAPTER 5
HARMONY AND ORDERING RESTRICTIONS IN AYMARA

The preceding chapters have argued that the definition of similarity relevant to determining the patterning of consonant harmony processes is highly constrained. In Chapter 3, I argued that, for a large number of cases, the set of participating segments can be determined using the notion of natural class without any reference to an independent notion of similarity. The success of this proposal crucially depends on the contrastive hierarchy as a theory of feature specifications. Given this theoretical background, participating segments can be classified as the set of segments contrastively specified for the harmonic feature. In chapter 4, I examined a number of cases in which the notion of natural class is not able to describe the set of segments that participate in harmony. In these cases, participating segments must share a number of properties including major place of articulation. Here I showed that segments that interact are distinctly specified only in the harmonic feature. The result of harmony in these cases is total segmental identity. Again, evaluation of identity and near-identity is based on contrastive specifications.

The preceding chapters have thus made strong claims about what definition of similarity, if any, is needed to determine which segments will interact in consonant harmony systems. In addition, data from consonant harmony processes provided support for broader claims about phonological representations. I have argued that only contrastive features are active in phonological processes and that only contrastive features enter into the evaluation of similarity. I have further argued that contrastive

features are determined by hierarchical ordering with some features taking scope over others.

The issues focused on in this thesis and summarized above are purely representational ones. What is the relevant threshold of similarity necessary for consonants to participate in harmony? What features enter into the evaluation of similarity? How are features specified? How are contrasts determined? To this point, this work has been completely neutral about the mechanisms responsible for consonant harmony and more general issues of phonological operations. In this chapter, I will present a proposal for how contrastive specifications can be achieved through constraint interaction and how the resulting representations enter into phonological operations.

To illustrate these proposals, I provide an analysis of laryngeal harmony and cooccurrence restrictions in Bolivian and Peruvian Aymara. This case is similar to the patterning of laryngeally marked segments in Hausa and Tzutujil, discussed in chapter 4. In Aymara, however, harmony, cooccurrence constraints, ordering restrictions and segmental markedness constraints interact in a particularly complex way.

5.1. Contrastive specifications, constraint interaction and Richness of the Base[20]

According to the theory of the contrastive hierarchy, contrastive features are ordered and the relative order of features may vary from language to language. Features are ordered in accordance with the Successive Division Algorithm (discussed in chapter 2). The SDA assumes the perspective of a language learner who has yet to acquire featural representations and phonemic contrasts. For the learner, all tokens are

---

[20] This section is based, in part, on Mackenzie (2002) and Mackenzie and Dresher (2004).

interpreted as allophones of a single phoneme. When the learner has evidence that distinctions between tokens are linguistically significant, that is, that tokens must be members of more than one phoneme, a feature is selected that splits the set of sounds into two groups. Evidence leading to the selection of a feature may come from phonological processes or contrasts among lexical items (minimal pairs and near minimal pairs). This process is repeated until every phoneme of the language is uniquely specified.

The analyses presented in this thesis have assumed that only features designated as contrastive by the Successive Division Algorithm are active in phonological processes and that only these contrastive features enter into the evaluation of similarity, natural classes and identity. These assumptions are consistent with work in underspecification theory which argues that some features may be absent in underlying representations and, indeed, throughout the phonological computation. (Details of which features may be underspecified and how and when such features may be supplied vary between works and are discussed in chapter 2.) The position held here, however, does not require that non-contrastive features be absent from underlying representations, merely that features are designated as contrastive through the Successive Division Algorithm and that contrastive features may be referred to by the grammar, to the exclusion of non-contrastive features.

Regardless of whether or not contrastive features are the only features present in phonological representations or simply have a special status relative to other specifications, the theory of the contrastive hierarchy allows phonological representations to vary between languages and requires language-specific representations to play an explanatory role in accounting for phonological processes. The explanatory role accorded to representations in the contrastive hierarchy framework, underspecification theory and

feature geometry has been largely rejected within Optimality Theory. According to the principle of Richness of the Base, there are no language-specific restrictions on the input. All linguistically significant generalizations, including apparently language-specific phonemic inventories, result from the interaction of universal constraints on output forms.

In this section, I demonstrate that contrastive specifications, as defined by the theory of the contrastive hierarchy, can be achieved within the framework of OT through a ranking of basic markedness and faithfulness constraints. The principle of Richness of the Base can be upheld, as constraint ranking is capable of deriving contrastive specifications, regardless of the type of specifications present in input forms.

The most essential principles of the contrastive hierarchy require that the number of features that enter into phonological processes is limited and is tied to the structure of the inventory. Phonemes must be sufficiently specified to be uniquely distinguished and contrastive features are hierarchically ordered. The notion of a hierarchy of features is naturally compatible with the notion of constraint ranking in Optimality Theory. A contrastive hierarchy of features can result from a hierarchy of classic OT faithfulness constraints referring to particular phonological features. The limitation of feature specifications to segments which require such specifications to be uniquely determined can be achieved through contextual markedness constraints that limit the domain of a feature.

The types of constraints used to achieve contrastive specifications are defined below.

IO-IDENT F	Correspondent segments must have the same value of the feature F (either + or −).
*[αF, Φ]$_{Segment}$	Exclude αF in the context Φ, where α ranges over + and −, and Φ is the set of feature values (with wider scope than F) forming the context of F. The exclusion holds within the domain of the segment.
*[F]	No features may be specified.

Any contrastive hierarchy can be converted into a ranking of constraints according to the following algorithm.

(86) Converting a contrastive hierarchy into a constraint hierarchy (adapted from Mackenzie 2002 and Mackenzie and Dresher 2004).

   a. Select a faithfulness constraint IDENT F$_i$, where F$_i$ is a contrastive feature. If there are no more contrastive features, go to (d).
   b. Above this faithfulness constraint, rank any co-occurrence constraints of the form *[αF$_i$, Φ]$_{Segment}$, where Φ consists of features ordered higher than F$_i$.
   c. Go to (a).
   d. Rank the constraint *[F] and end.

Below I illustrate the operation of this algorithm with the contrastive hierarchy for Hausa, discussed in Chapter 4. A sub-hierarchy of Hausa is shown as (87) below. Recall that place specifications were ranked above laryngeal features in the analysis previously presented. Here, only the labial series is shown, illustrating the feature ordering [voice] > [constricted glottis].

(87) Contrastive hierarchy of Hausa labials
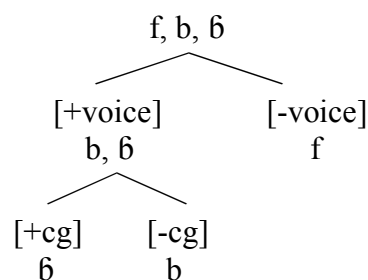
Within the sub-inventory of Hausa labials, the highest ordered feature is [voice]. All labials are contrastively specified for this feature. The feature [constricted glottis] is ordered next and is contrastive only within the [+voice] set. The ordering of [voice] > [constricted glottis] was motivated by differences in the patterning of ejectives and implosives with respect to [constricted glottis] harmony. Implosives are barred from occurring with homorganic, plain, voiced stops, indicating that harmony in [constricted glottis] takes place between these segments. Ejectives, on the other hand, occur freely with their homorganic, voiced counterparts but may not cooccur with homorganic voiceless stops. This pattern provides evidence that the feature [voice] is contrastive for the [+constricted glottis] segments and supports the ordering of [voice] over [constricted glottis]. Note that this order also results in contrastive specification for the /f/ as soon as the feature [voice] is added. /f/ is unspecified for [constricted glottis] or for other features such as [continuant]. While this aspect of the hierarchy was not discussed in the previous chapter it is supported from the patterning of /f/ in Hausa. /f/ does not participate in [constricted glottis] harmony. The continuancy of this phoneme also varies, with [p] being an allophone of /f/ in a variety of phonological contexts.

In order to convert this hierarchy into a constraint ranking, I follow the algorithm in (86). First, I follow step (a) and select the faithfulness constraint IDENT[voice]. [voice] is the highest ordered feature for this sub-inventory and the constraint demanding the preservation of input values of [voice] will be the highest ranking constraint. Step (b) requires a contextual markedness constraint referring to features higher in the hierarchy to be ranked above the featureal faithfulness constraint. As [voice] is the highest ordered feature, there are no features ordered above [voice] in the hierarchy and this step does not

apply. Next, I rank IDENT[constricted glottis] below IDENT[voice]. Step (b) again

requires a contextual markedness constraint to be ranked above this faithfulness

constraint. In this case, the feature [constricted glottis] is excluded within the [-voice] set

as it does not serve to further differentiate members of this set. This is achieved by

ranking the markedness constraint *[α cg, -voice] above IDENT[voice], as required by

step (b). At this point, there are no more contrastive features and we proceed to step (d)

and rank the constraint *[F] below IDENT[cg].

The constraint ranking discussed above is summarized below.

(88)   IDENT[voice] > *[α cg, -voice]_{Segment} > IDENT[cg] > *[F]

The following tableaux illustrate how inputs containing redundant feature

specifications will map to contrastively specified outputs, given the ranking in (88). I am

not assuming that the output of this evaluation is isomorphic with surface forms. Rather,

this output may be subject to further levels of evaluation. See below for further

discussion.

(89)

f [-voice, -cg, +cont]	IDENT[voice]	*[α cg, -voice]_S	IDENT[cg]	*[F]
a) f [-voice, -cg, +cont]		*!		***
b) ☞ f [-voice]			*	*
c) f [-cg]	*!			*
d) f [-voice, +cont]			*	**!

Tableau (89) illustrates the evaluation of an input with the segment /f/ specified for [voice], [constricted glottis] and [continuant]. The faithful candidate, which maintains specification in all features, is eliminated due to violation of the contextual markedness constraint *[α cg, -voice]$_{Segment}$. This constraint is violated by a segment specified for any value of [cg] if that segment is also specified as [-voice]. Candidate (b), the contrastively specified candidate, is selected as optimal. This candidate maintains input specifications in the feature [voice] but lacks specification in the feature [constricted glottis], allowing it to satisfy the contextual markedness constraint. Candidate (c) is specified only for [constricted glottis]. While eliminating the input specification in the feature [voice] allows the candidate to satisfy the contextual markedness constraint *[α cg] [-voice], it incurs a violation of high-ranking IDENT[voice] leading to this candidate's elimination. The final candidate illustrates an output specified for the feature [voice] and the feature [continuant]. This candidate fares well on IDENT[voice] and *[α cg, -voice]$_{Segment}$, as the optimal candidate does. Also like the optimal candidate, this candidate violates IDENT[cg]. It therefore falls to the relatively lowly ranked *[F] to decide between candidate (d) and the contrastively specified candidate. Here, the contrastively specified candidate fares better as it incurs only a single violation compared to the two violations incurred by candidate (d). *[F] penalizes any feature specification, and while specification in the feature [voice] is needed to satisfy a highly ranked faithfulness constraint, there is no high-ranking constraint that compels specification in the feature [continuant]. Candidate (d) is therefore eliminated due to gratuitous violation of *[F].

This constraint ranking will result in output specification in both [voice] and [constricted glottis] within the [+voice] set of labials, as illustrated below.

(90)

b [+voice, -cg]	IDENT[voice]	*[α cg, -voice]	IDENT[cg]	*[F]
a) ☞ b [+voice, -cg]				**
b) b [+voice]			*!	*

In this case, faithful candidate (a) is selected over candidate (b) which is unspecified for [constricted glottis]. The contextual markedness constraint penalizes [constricted glottis] specifications only in segments that are [-voice] and so will have no impact in this case. Candidate (a) wins because it satisfies the faithfulness constraint IDENT[cg].

The same constraints that result in contrastive specifications in output forms will necessarily prevent input-output mappings that result in non-phonemic segments in the output. This is illustrated below where /v/, a segment that is absent from the phonemic inventory of Hausa, is evaluated.

(91)

v [+voice, -cg, +cont]	IDENT [voice]	*[α cg, -voice]	IDENT[cg]	*[F]	IDENT [cont]
a) v [+voice, -cg, +cont]				***!	
b) v [+voice, +cont]			*!	**	
c) ☞ b [+voice, -cg]				**	*

In this tableau, a segment specified for [voice], [constricted glottis] and [continuant] is evaluated. Candidate (b) lacks the [constricted glottis] feature present in the input and is eliminated due to a violation of IDENT[cg]. The faithful candidate is specified for three features, thereby incurring three violations of *[F]. Candidate (c) is optimal. It satisfies highly ranked faithfulness constraints IDENT[voice] and IDENT[constricted glottis] and has two violations of *[F], satisfying this constraint better than the faithful candidate.

The faithfulness constraint IDENT[continuant] has been added to this tableau. The feature [continuant] is phonologically active in many languages and, as constraints are universal, a faithfulness constraint requiring input/output identity in [continuant] must be part of the constraint set. However, the contrastive hierarchy and the algorithm for converting a contrastive hierarchy to a constraint ranking require that all faithfulness constraints referring to non-contrastive features be ranked below *[F]. As a result, the constraint IDENT[continuant] will have no impact on the selection of the optimal output.

Optimal candidate (c) is specified as [+voice, -constricted glottis] and is transcribed as /b/ in the tableau. The feature specifications of this candidate are consistent with a number of possible segments. The voiced stop /b/ however, is a member of the phonemic inventory and is argued to be contrastively specified for exactly these feature values. I therefore assume that the mechanisms of phonetic implementation of Hausa lead to a [+voice, -constricted glottis] segment being realized as /b/ as opposed to some other voiced, pulmonic segment such as /v/. Given these assumptions, the ranking of markedness and faithfulness constraints argued for here will prevent

specification of non-contrastive features for members of the phonemic inventory and will also prevent segments that are not members of the phonemic inventory from surfacing.[21]

The preceding discussion has demonstrated that contrastively specified representations may be achieved within a constraint-based framework. The principle of Richness of the Base may be upheld and ranking of basic markedness and faithfulness constraints can result in output forms specified in accordance with the contrastive hierarchy. The constraints responsible for contrastive representations have been shown here in isolation, without any indication of how such constraints might interact with other constraints and rankings in the grammar.

The analyses presented in earlier chapters have focused on representations and definitions of similarity. Nonetheless, implicit assumptions about phonological operations have been evident. Most clearly, when constraints on the well-formedness of words or morphemes have been discussed these constraints have been assumed to operate over contrastively specified representations. If this assumption is taken together with the principle of Richness of the Base, it is unclear how the constraints and constraint rankings introduced here to achieve contrastive representations will interact with the rest of the constraint hierarchy in order to ensure that only contrastive features play a role in morpheme structure constraints and phonological processes.

---

[21] The constraints and rankings presented here are capable of preventing redundant specifications and segments not present in a given inventory from surfacing in the output. Assuming Richness of the Base, however, a constraint ranking should also be able to map inputs that lack adequate contrastive specification to contrastively specified outputs. The constraints introduced here are unable to do that. That is, there are no constraints that compel specification in a given feature. While such constraints could be added, it is not clear that the learning situation requires them. A full consideration of this issue is beyond the scope of this discussion. See Dresher (forthcoming) for a discussion of how underspecified inputs may be mapped to contrastively specified outputs. See also Hall (2007) for general discussion of underspecification in OT.

Hall (2007) provides detailed argumentation that a single-level, purely parallel OT evaluation is not capable of limiting the role of non-contrastive features in phonological processes. Because of these issues and other issues, such as opacity, that offer challenges to classic Optimality Theory, I assume a serial or multi-stratal version of Optimality Theory (Kiparsky 2000, 2002, Bermúdez-Otero 2003, forthcoming, Rubach 2000, 2003). Within the framework of Stratal OT the output of one OT evaluation serves as the input to following evaluations. Constraint rankings may differ between levels of evaluation. Support for a stratal version of OT follows, in part, from the results of Lexical Phonology. Efforts to determine principled limitations on rerankings between evaluations and to link distinct strata to independently motivated domains such as the lexical and postlexical levels are ongoing. With respect to the issues addressed in this thesis, I assume that the output of the algorithm for achieving contrastive specifications serves as the input to later levels of evaluation. Evaluations that lead to phonological processes are therefore carried out over representations containing only features deemed contrastive by the contrastive hierarchy. Most importantly, this section has demonstrated that the notion of contrastive specifications assigned through hierarchical ordering of features is not incompatible with a constraint-based theory of phonological operations and can, in fact, be achieved through ranking of basic markedness and faithfulness constraints.

The following section provides an OT analysis of a case in which consonant harmony interacts with ordering restrictions and segmental markedness effects resulting in a complex pattern governing the distribution of laryngeally marked segments.

5.1 Aymara

Aymara (Aymaran) is an indigenous language spoken in Bolivia, Peru and Chile. Aymara has a three-way contrast between plain, aspirated and ejective stops. Constraints limiting the possible cooccurrence of ejective and aspirated stops are present in all varieties of Aymara and are similar to the constraints on glottalized segments found in Hausa and Tzutujil. In addition to restrictions on the cooccurrence of multiple laryngeally marked segments, Aymara also has a set of complex restrictions on the location and ordering of such segments. The patterning and stringency of the cooccurrence constraints and ordering restrictions varies between dialects. Following MacEachern (1997/1999), I will discuss two dialects, Peruvian Aymara and Bolivian Aymara.

The cooccurrence restrictions of Aymara have been analyzed within the consonant harmony literature (MacEachern 1997, 1999, Hansson 2001, Rose and Walker 2004). In her typological study of laryngeal cooccurrence constraints, MacEachern proposes that the differences between different dialects of Aymara result from different ranking of faithfulness constraints requiring the preservation of input feature specifications relative to conjoined markedness constraints penalizing the cooccurrence of similar segments. Rose and Walker (2004) also use the case of Aymara laryngeal restrictions to illustrate the typological implications of their analysis. They argue that distinct ranking of input/output faithfulness constraints relative to the hierarchy of constraints requiring correspondence relations between similar output segments can account for the different patterning of cooccurrence restrictions in Aymara relative to

similar patterns in other languages. Both accounts make reference to a notion of global similarity.

In the following sections, I provide an account of the restrictions on laryngeally marked segments in Bolivian and Peruvian Aymara. This account draws a formal and conceptual connection between cooccurrence constraints and ordering restrictions and does not require any reference to similarity apart from the independently needed notion of identity. The patterning of constraints on laryngeally marked segments in Bolivian and Peruvian Aymara are analyzed separately below, followed by a comparison of the account offered here with those provided in MacEachern (1997) and Rose and Walker (2004).

5.2 Peruvian Aymara

The consonant inventory of Peruvian Aymara is shown in (92).

(92)   Aymara consonant inventory (from Deza Galindo 1989, cited in
        MacEachern 1997)

p	t	tʃ	k	q	
p'	t'	tʃ'	k'	q'	
pʰ	tʰ	tʃʰ	kʰ	qʰ	
	s				h
m	n	ɲ			
	l	ʎ			
w		j			

The constraints on the cooccurrence and location of ejective and aspirated stops are summarized in (93) below. Although the following account argues for a formally unified analysis of cooccurrence constraints and ordering restrictions, I list them separately below for clarity.

(93)   Peruvian Aymara cooccurrence restrictions:

    i)   There is only one ejective per morpheme, unless the ejectives are identical.

    ii)   There is only one aspirated stop per morpheme, unless the aspirated stops are identical.

    iii)   Ejectives and aspirates may not cooccur.

    iv)   Vowel initial forms do not include ejectives.[22]

    v)   Morphemes with homorganic aspirated and plain stops and morphemes with homorganic ejective and plain stops are not allowed (or are extremely rare).[23]

(94)   Peruvian Aymara ordering restrictions:

    i)   If a morpheme has an ejective, it will be the leftmost stop or affricate in the form.

    ii)   If a morpheme has an aspirate, it will be the leftmost stop or affricate in the form.

The restrictions in (93) are similar to cases discussed in the previous chapter. In Peruvian Aymara, as in Hausa and Tzutujil, multiple, non-identical ejectives may not cooccur. All three languages also forbid the cooccurrence of ejective segments and their homorganic, plain counterparts. Peruvian Aymara differs from Hausa and Tzutujil in having aspirates in addition to ejective and plain stops. The patterning of aspirates in Peruvian Aymara is completely parallel to the patterning of ejectives. Non-identical aspirates may not cooccur and aspirates may not occur with their homorganic plain counterparts. Ejectives and aspirates are also barred from cooccurring. In addition,

---

[22] MacEachern (1999/1997) argues that vowel-initial forms always surface with an initial glottal stop and provides an analysis of this restriction based on restrictions on [constricted glottis]. I assume the basis of this analysis is correct but do not provide a formal analysis of restrictions on vowel initial forms and make no further reference to this restriction.

[23] MacEachern (1999/1997) provides an exhaustive list of exceptions to this restriction. I do not discuss the status of exceptions here and my analysis assumes this constraint is categorical.

Peruvian Aymara is subject to ordering restrictions. If there is an ejective or aspirate in a form, it must be the leftmost stop. Illustrative data are provided in (95) below.

(95)   Non-identical aspirates and ejectives may not cooccur

k'anta	'spinning wheel'	*k'ant'a
qʰatu	'market'	*qʰatʰa
sirk'u	'nerve'	*k'antʰa
hajpʰu	'in the dark'	*qʰat'a

Aspirates and ejectives must be the leftmost stops in a form

*kant'a   *qatʰu

Homorganic ejectives/aspirates and plain stops may not cooccur

k'ink'u	'clay'	*k'inku
t'ult'u	'field of barley'	*t'utu
pʰuspʰu	'boiled beans'	*pʰupu

5.2.1 The Contrastive Hierarchy of Peruvian Aymara

The preceding analyses of Tzutujil and Hausa have focused on the restriction between homorganic plain and glottalized segments. I have proposed that in these cases, harmony in the feature [constricted glottis] is active between segments that are highly similar with similarity defined as differing in only a single marked and contrastive feature. This definition carries over straightforwardly to the cooccurrence restrictions in Peruvian Aymara with the slight complication that Aymara has two harmonic features, [spread glottis] and [constricted glottis]. A contrastive hierarchy of laryngeal features in Peruvian Aymara is illustrated below. This tree shows only the labial stops. As shown in the inventory in (92), the laryngeal contrasts among non-continuant obstruents are completely symmetrical at all places of articulation. Thus, the ordering of place features relative to laryngeal features is not relevant in determining laryngeal specifications and an illustration of specifications for one place of articulation will be completely analogous

to specifications for all other places of articulation. In addition, I assume that the features

[sonorant] and [continuant] are ordered above laryngeal features, making the laryngeal

features non-contrastive in fricatives and sonorants.

(96)　　　　p, p^h, p'
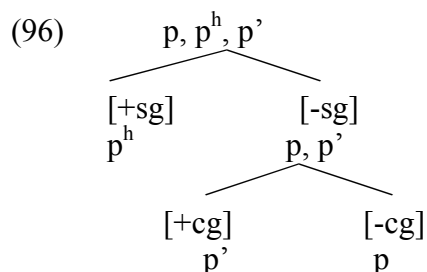
　　　　[+sg]　　　　　[-sg]
　　　　p^h　　　　　p, p'

　　　　　　[+cg]　　　　[-cg]
　　　　　　p'　　　　　　p

(97)　　Specifications in the labial series

　　　p　　　　　　　p^h　　　　　　p'
　　　[-sg]　　　　[+sg]　　　　[-sg]
　　　[-cg]　　　　　　　　　　[+cg]

The contrastive specifications shown above can be achieved through the

following constraint ranking.

(98)　　IDENT[sg] > *[α cg, +sg]$_{Segment}$ > IDENT[cg] > *[F]

Tableaux illustrating the evaluation of fully specified aspirated and plain input

segments are given below.

(99)

p [-sg, -cg, -voice]	IDENT [sg]	*[α cg, +sg]	IDENT[cg]	*[F]	IDENT [voice]
a)　p [-sg, -cg, -voice]				***!	
b) ☞ p [-sg, -cg]				**	*
c)　p [-cg]	*!			*	*

In the above tableau, the fully specified candidate is eliminated due to three

violations of *[F]. Candidate (b) is optimal. It is the contrastively specified candidate

according to the previously proposed hierarchy of features. This candidate incurs only

two violations of *[F]. It violates a faithfulness constraint, IDENT[voice], but this

constraint is ranked below *[F] as are all other faithfulness constraints referring to

features that are not deemed contrastive by the contrastive hierarchy. Candidate (c) is

specified only for the feature [constricted glottis]. It is eliminated due to violation of

high-ranking IDENT[spread glottis].

The following tableau shows the evaluation of a fully specified aspirated segment.

(100)

pʰ [+sg, -cg, -voice]	IDENT [sg]	*[α cg, +sg]	IDENT[cg]	*[F]	IDENT [voice]
a) pʰ [+sg, -cg, -voice]		*!		***	
b) pʰ [+sg, -cg]		*!		**	*
c) ☞ pʰ [+sg]			*	*	*
d) p [-cg]	*!			*	*

In this tableau, the faithful candidate is eliminated due to a violation of the

contextual markedness constraint *[α cg, +sg]. This violation is incurred because the

candidate contains a value for [constricted glottis] in a segment that is specified as

[+spread glottis]. Candidate (b) is like candidate (a) except that its [-voice] specification

has been omitted. This candidate also violates the contextual markedness constraint and

is eliminated. The optimal candidate is candidate (c) which is specified for only the

feature [+spread glottis]. This candidate violates IDENT[cg] but satisfies the higher ranked markedness constraint prohibiting [constricted glottis] specifications in segments that are [+spread glottis]. The final candidate considered in this tableau is specified only as [-constricted glottis]. Such a segment incurs a violation of the highly ranked faithfulness constraint IDENT[spread glottis] and is eliminated.

This section has proposed a contrastive hierarchy of laryngeal features for Peruvian Aymara and shown how contrastive specifications consistent with this hierarchy can result from a constraint ranking. The following sections provide an OT analysis for ordering restrictions and laryngeal harmony in Peruvian Aymara. I assume the input to the tableaux shown below are consistent with the output of the constraint ranking argued for here. That is, I assume that the evaluations given in the following section are carried out over contrastively specified representations.

5.2.2 Laryngeal harmony and ordering restrictions

In Peruvian Aymara, plain voiceless /p/ may not cooccur with aspirated /p^h/ or ejective /p'/. (Again, what holds of the labials holds of homorganic stops at all places of articulation.) Plain /p/ and aspirated / p^h/ differ in only a single, marked and contrastive feature, namely the [+spread glottis] specification of the aspirate. Similarly, plain /p/ and ejective /p'/ differ in only the [+constricted glottis] specification of the ejective. Since identical ejectives and aspirates are permitted, a hypothetical input containing homorganic stops that differ in marked laryngeal specifications may be repaired through harmony in the feature [constricted glottis] or [spread glottis]. To this point, the analysis offered here is parallel to that proposed for Hausa and Tzutujil and accounts for the restrictions between aspirates and ejectives and their homorganic plain counterparts.

As in Tzutujil and Hausa, Peruvian Aymara also bans non-identical ejectives. The patterning of ejectives is mirrored in the patterning of aspirates with non-identical aspirates also being ill-formed. In my discussion of Hausa and Tzutujil, I proposed representations and a definition of similarity capable of determining interacting segments in laryngeal harmony. I did not, however, provide a formal analysis of the mechanisms of harmony or of other restrictions on glottalic segments. Here, such a formal analysis will be provided for all restrictions on laryngeally marked segments in Peruvian Aymara. The need for such an analysis is particularly clear in Aymara due to the presence of additional restrictions on ordering of aspirates and ejectives (not yet addressed).

The following proposal begins as an account of the ordering restrictions of Peruvian Aymara. Recall that, in Peruvian Aymara, ejectives and aspirates are always the leftmost stop in a form. After demonstrating that the ordering restrictions result from the proposed rankings and constraints, I show that restrictions on multiple ejectives and aspirates follow, thereby providing a unified account of ordering restrictions and limits on multiple laryngeally marked segments. Laryngeal harmony is also accounted for with the introduction of an additional constraint.

The location of aspiration and glottalization is completely predictable in Peruvian Aymara as a result of the ordering restrictions. While a morpheme may be specified or unspecified for the features [constricted glottis] or [spread glottis], if the presence of a laryngeal feature is known, its location relative to the segmental string is completely predictable. In other words, differences in the location of aspiration in the input or underlying representation of a morpheme will have no effect on the location of these features in the surface form. For these reasons, the following account will use the

faithfulness constraints MAX[+cg] and MAX[+sg] in order to maintain input

specifications of laryngeal features in output forms.[24]

> (101) MAX[+cg] - For any [+cg] feature in the input, there is a corresponding [+cg] feature in the output.

> (102) MAX[+sg] – For any [+sg] feature in the input, there is a corresponding [+sg] feature in the output.

Unlike IDENT constraints, MAX constraints do not require that input and output

segments share identical specifications, merely that features present in the input have

correspondents in the output. Differences between which segment bears a feature in the

input and the output clearly violate some constraints, either IDENT constraints or

LINEARITY constraints requiring identical sequencing of features in the input and output.

Any such constraints referring to laryngeal features must be lowly ranked in Aymara as

input structure has no bearing on the location of laryngeal features in output forms. The

rest of this analysis will therefore rely on MAX constraints to determine faithfulness in

laryngeal features.

I propose the following constraints to account for the leftwards orientation of

laryngeal features.

> (103) *[-cg] [+cg] – A segment specified as [+constricted glottis] may not follow a segment specified as [-constricted glottis].

---

[24] Arguments that features enter into correspondence relations, through MAX and DEP constraints, independently of constraints requiring segmental identity can be found in Rice and Lamontagne 1995, Lombardi 1995 and Causley 1997, among others. Analyses differ as to whether MAX and DEP constraints replace IDENT constraints or coexist with them (see Strujke 2002 for discussion) and as to whether these constraints refer to privative or binary features. While I use binary features throughout this thesis, I nonetheless attribute a different status to marked and unmarked feature values. I assume that constraints MAX[F] refer only to positive or marked feature values.

(104)   *[-sg] [+sg] – A segment specified as [+spread glottis] may not follow a segment specified as [-spread glottis].

These constraints, like constraints used previously in this thesis, refer only to contrastive feature specifications as determined by a hierarchy of features. In Peruvian Aymara, the features [continuant] and [sonorant] are ordered above laryngeal features, resulting in contrastive specifications for [spread glottis] and [constricted glottis] only within the set of stops. As a result, the constraints in (103) and (104) will be violated by forms containing [+constricted glottis] or [+spread glottis] segments that are preceded by stops with the opposite specification but not by forms in which laryngeally marked segments are preceded by fricatives or sonorants which are altogether lacking contrastive specifications for [cg] and [sg]. If these constraints are ranked above faithfulness constraints requiring input specifications to be maintained in output forms, glottalized and aspirated segments will only surface on the leftmost stop in a form. The tableaux below illustrate how these constraints are able to determine the location of glottalization. Identical facts for aspiration are not illustrated.

(105)   Peruvian Aymara

qat'a	*[-cg] [+cg]	MAX[cg]$_{IO}$	IDENT[cg]$_{IO}$
a) qat'a	*!		
b) ☞ q'ata			**
c) qata		*!	*

(106)

q'ata	*[-cg] [+cg]	MAX[cg]$_{IO}$	IDENT[cg]$_{IO}$
a) ☞ q'ata			
b) qata		*!	*
c) qat'a	*!		**

In tableau (105), the faithful candidate contains an ejective segment preceded by a plain stop and, as a result, fatally violates *[-cg] [+cg]. In candidate (b), the [+constricted glottis] feature is realized on the initial stop. This candidate is optimal, as it satisfies both *[-cg] [+cg] and MAX[cg].   The optimal candidate does incur a violation of IDENT[cg] because the [constricted glottis] feature is realized on a different segment in the output than in the input. This constraint is lowly ranked, however, and does not affect the outcome of the evaluation. Candidate (c) has no glottalized segments and is eliminated due to a violation of Max[cg]. In tableau (106), glottalization is present on the initial segment of the input. The faithful candidate satisfies the constraint *[-cg] [+cg] and is thus optimal. These tableaux demonstrate that in forms with multiple stops the location of glottalization in the input has no bearing on the location of glottalization in surface forms. Glottalization will be realized on the initial stop, regardless of its location in the input.

Tableau (107) shows an input containing a glottalized stop that is preceded by the consonants /s/ and /r/. In Peruvian Aymara, glottalization is always realized on the leftmost stop but this need not be the leftmost consonant. Sonorants and fricatives may precede a glottalized stop in a form.

(107)

sirk'u	*[-cg] [+cg]	MAX[cg]$_{IO}$	IDENT[cg]$_{IO}$
a) ☞sirk'u			
b) sirku		*!	*
c) s'irku			*!*

Recall that in the contrastive hierarchy proposed above, the features [continuant] and [sonorant] are ordered above laryngeal features leaving the features [spread glottis]

and [constricted glottis] non-contrastive, and unspecified, in sonorants and fricatives. The input to tableau (107) is the output of a preceding level of evaluation, a level that results in contrastive specifications. As a result, an input to the constraint ranking shown here will never have glottalization on /s'/ as the feature [constricted glottis] is not contrastive in fricatives and any specification of [constricted glottis] for this segment will be ruled out by the previous evaluation. In tableau (107), the faithful candidate does not violate *[-cg] [+cg] precisely because the consonants preceding the ejective, /s/ and/r/, are not contrastively specified for any value of [constricted glottis]. This allows the candidate with a glottalized /s'/ to be ruled out without the need to introduce any additional constraints. A glottalized /s'/ would presumably violate some markedness constraint, but there is no need to refer to a particular markedness constraint in this case. The low ranking faithfulness constraint IDENT[constricted glottis] will eliminate the candidate with glottalization on the /s'/. Because the faithful form satisfies the markedness constraint *[-cg] [+cg], nothing compels the location of glottalization in the output to differ from that of the input.

The constraints *[-cg] [+cg] and *[-sg] [+sg] are similar in structure to the constraints seen throughout chapter 3. Constraints that motivate consonant harmony in which all contrastively specified segments participate, or natural classes harmony, are of the form *[αF] … [-αF]. These constraints bar the cooccurrence of segments with distinct, contrastive specifications for the harmonic feature. In the ordering restrictions of Aymara, the constraints proposed here have a directionality effect. Distinct contrastive specifications of [constricted glottis] and [spread glottis] are not banned per se. Instead, distinct specifications are only penalized when a negative value precedes a positive value.

As they stand at this point, the constraints on distinct specifications of laryngeal features are able to account for the leftward orientation of marked feature specifications. However, they are unable to account for the fact that multiple non-identical ejectives and aspirates may not cooccur. In order to account for this pattern, a revision in the definition of the constraints is given below.

(108)   (revised from (103))
*[αcg] [+cg] – A segment specified as [+constricted glottis] may not follow a segment specified for any value of [constricted glottis].

(109)   (revised from (104))
*[αsg] [+sg] – A segment specified as [+spread glottis] may not follow a segment specified for any value of [spread glottis].

As in all constraints proposed in this thesis, these constraints make reference only to contrastive feature specifications. These constraints specifically restrict the distribution of the positive or marked value of the relevant feature. A positive specification for a laryngeal feature must always be the initial specification for that feature. It may not follow a negative, contrastive specification for the relevant feature or another positive specification.

These constraints are able to rule out forms with multiple ejectives or multiple aspirates as well as forms with aspiration or glottalization that is not on the leftmost stop.

(110)   Peruvian Aymara

qat'a	*[αcg] [+cg]	MAX[cg]$_{IO}$	IDENT[cg]$_{IO}$
a) qat'a	*!		
b) ☞ q'ata			**
c) qata		*!	*

(111)

q'ata	*[αcg] [+cg]	MAX[cg]$_{IO}$	IDENT[cg]$_{IO}$
a) ☞ q'ata			
b)　qat'a	*!		**
c)　qata		*!	*

(112)

q'at'a	*[αcg] [+cg]	MAX[cg]$_{IO}$	IDENT[cg]$_{IO}$
a)　q'at'a	*!		
b) ☞ q'ata		*	*
c)　qat'a	*!		*
d)　qata		**!	**

Tableaux (110) and (111) above are identical to the previously discussed tableaux (105) and (106) with the reformulation of the markedness constraint. They simply demonstrate that the constraint penalizing a positive laryngeal feature specification preceded by any specification of that feature will be violated by sequences of plain stops followed by glottalized stops and can account for the leftward orientation of glottalization and aspiration exactly as the earlier version of the constraint did.

Tableau (112) shows the evaluation of an input that contains multiple ejectives. The faithful candidate violates *[αcg] [+cg] because it contains a [+cg] specification preceded by a [+cg] specification. Candidate (c) maintains glottalization on the second stop in the form and by doing so also incurs a fatal violation of *[αcg] [+cg] due to the presence of a [+cg] specification preceded by a [-cg] specification. Candidate (b) is optimal. In this candidate, glottalization is maintained only on the initial stop in the form. The candidate violates MAX[cg] but satisfies the higher ranked constraint *[αcg] [+cg]. In candidate (d), all stops of the output are plain. This candidate is eliminated due to a gratuitous violation of MAX[cg]. The faithfulness constraint is relatively low ranked and

may be violated. Nonetheless, the second violation in this candidate does nothing to improve the markedness of the candidate. It may satisfy *[αcg] [+cg] with only a single violation of MAX[cg] as in candidate (b). The additional violation of MAX here is therefore fatal.

The revised constraints on the distribution of laryngeal features are able to account for the need for laryngeal features to be realized on the leftmost stop in a form and for the ban on multiple ejectives and multiple aspirates. The ban on multiple laryngeally marked segments has a systematic exception, however, in that identical ejectives and aspirates are able to cooccur. As discussed in MacEachern (1999/1997), the fact that identical segments are able to evade a ban on multiple ejectives is linked to the fact that cooccurrence of homorganic plain and ejective stops is ill-formed.

In the preceding section, I argued that the ban on homorganic plain and glottalized segments and the ban on homorganic plain and aspirated segments is a reflex of consonant harmony in the features [constricted glottis] and [spread glottis]. Segments that interact in harmony are restricted to those segments that differ in only a single marked and contrastive feature. The definition of similarity proposed here is able to accurately restrict the set of segments that interact in [constricted glottis] and [spread glottis] harmony. This definition in itself, however, does not provide any explanation of the mechanisms of harmony or the constraints driving harmony.

Additional constraints are needed to account for harmony in laryngeal features. The following constraint from MacEachern (1997/1999) has been introduced in Chapter 4.

(113)   BEIDENTICAL – (MacEachern 1999: 53) Segments should be identical.
        One violation is assessed for every pair of non-identical segments.

The constraint BEIDENTICAL captures the intuition that identity has a role within the grammar. Functional requirements that sufficient contrast be present between segments and morphemes will make grammars where this constraint is very highly ranked undesirable (and perhaps unlearnable). In Peruvian Aymara, BEIDENTICAL is ranked below faithfulness constraints requiring input specifications of place and manner features to be faithfully realized in the output. It ranks above faithfulness constraints requiring identity between input and output specifications in the harmonic features [constricted glottis] and [spread glottis]. The following tableaux illustrate [constricted glottis] harmony driven by the constraint BEIDENTICAL. While BEIDENTICAL is violated by any pair of non-identical segments, only violations incurred by non-identical consonants will be shown in the following tableaux.

(114)

p'apa	FAITHPLACE/ MANNER$_{IO}$	BEIDENTICAL	*[αcg] [+cg]	MAX [cg]$_{IO}$
a) p'apa		*!		
b) ☞ p'ap'a			*	

The tableau above shows that an input with homorganic plain and ejective stops will map to a harmonic candidate where both stops are ejective. This candidate is preferred to the faithful candidate which incurs a violation of BEIDENTICAL. BEIDENTICAL correctly motivates harmony only between segments that are homorganic and share manner features. The tableau below shows that agreement in the feature [constricted glottis] is not motivated between non-homorganic segments as it will not permit them to satisfy BEIDENTICAL.

(115)

p'aka	FAITHPLACE/ MANNER_{IO}	BEIDENTICAL	*[αcg] [+cg]	MAX[cg]_{IO}
a) ☞ p'aka		*		*
b) p'ak'a		*	*!	
c) p'ap'a	*!		*	

In this tableau, the faithful candidate is optimal. It violates BEIDENTICAL but

satisfies *[αcg] [+cg] as well as the higher ranking constraint requiring faithfulness in

place and manner features. The harmonic candidate in (b) is eliminated by a fatal

violation of *[αcg] [+cg]. As the consonants in this candidate are non-homorganic,

violation of *[αcg] [+cg] does not permit the candidate to satisfy high-ranking

BEIDENTICAL. Candidate (c) shows that with this input, any candidate satisfying

BEIDENTICAL will be eliminated due to a violation of high ranking faithfulness

constraints referring to place and manner features.

The constraints introduced thus far are able to enforce leftward orientation of

laryngeal features, rule out multiple, non-identical aspirates and ejectives and enforce

laryngeal harmony between homorganic plain, laryngealized pairs. There is, however, a

crucial flaw in the analysis. This is shown in tableau (116) below, a repetition of (114)

with an additional candidate considered.

(116)

p'apa	FAITHPLACE/ MANNER_{IO}	BEIDENTICAL	*[αcg] [+cg]	MAX [cg]_{IO}
a) p'apa		*!		
b) p'ap'a			*!	
c) ☹ papa				*

Candidate (c) is a harmonic candidate in which both stops are plain. Given the constraints and assumptions introduced thus far, this candidate will always win over the actual output (candidate (a)) because it is able to satisfy both BEIDENTICAL and *[αcg] [+cg]. This requires a violation of MAX [cg], but this constraint must be lowly ranked in any case.

This problem can be overcome if we allow output candidates with linked feature specifications to be considered. Multiple linking in output forms is used in OT analyses of many phenomena including vowel harmony (Walker 2004), underspecification (Ito, Mester and Padgett 1995) and coalescence (Causley 1999), among many others. Linked structures are generally considered to violate markedness constraints against complex representations. The following constraint is used here.

(117) *LINK – A feature specification may not be associated to more than one segment.

The following tableau shows that a harmonic form with multiple linking will be selected as optimal over alternative candidates.

(118)

p'apa	BEIDENTICAL	*[αcg] [+cg]	MAX[cg]$_{IO}$	*LINK
a) p'apa	*!			
b) p'ap'a | | [+cg] [+cg]		*!		
c) papa			*!	

d) ☞ p'ap'a
     ∨
   [+cg]
				*

Candidate (d) is optimal. It violates only the constraint penalizing features linked to multiple segments, *LINK, but is able to satisfy all higher ranked constraints.

Tableau (119) shows that the use of multiply linked features will not allow forms with multiple, non-identical ejectives to surface in the language.

(119)

p'ak'a | | [+cg] [+cg]	BEIDENTICAL	*[αcg] [+cg]	MAX[cg]IO	*LINK

a)   p'ak'a
     | |
  [+cg] [+cg]
	*	*!		

b) ☞ p'aka	*		*	

c)   p'ak'a
      ∨
    [+cg]
	*		*	*!

Candidate (b) is correctly selected as optimal here. Although the candidate with a multiply-linked [cg] feature is able to avoid a violation of *[αcg] [+cg], it violates MAX[cg] because there are two [cg] features in the input and only one in the output. The violation of lowly ranked *LINK is thus able to eliminate candidate (c). The candidate containing a single ejective will be selected as optimal even if we assume multiple linking in the input, as illustrated in (120).

(120)

p'ak'a
   ∨
  [+cg]
	BEIDENTICAL	*[αcg] [+cg]	MAX[cg]IO	*LINK

a)   p'ak'a
     | |
  [+cg] [+cg]
	*	*!		

b) ☞ p'aka	*			

c)   p'ak'a
      ∨
    [+cg]
	*			*!

As in the previously discussed tableau, violation of *LINK prevents the harmonic candidate from surfacing. Note that with this ranking *LINK will only be violated in an optimal candidate if it allows that candidate to satisfy high ranking BEIDENTICAL. Participating segments in laryngeal harmony are thus correctly restricted to segments that are homorganic.

The only pattern of Peruvian Aymara that has not been accounted for in the analysis thus far is the cooccurrence constraint against ejectives and aspirates. Hypothetical inputs of the form C'…C^h will be ruled out with the constraints already introduced and no additions to the analysis are required. This is shown in the tableau below.

(121)

q'at^{h}a	*[αsg] [+sg]	MAX[cg]$_{IO}$	MAX[sg]$_{IO}$
a) q'at^{h}a	*!		
b) ☞ q'ata			*
c) qat^{h}a	*!	*	

Recall that the contrastive hierarchy of laryngeal features proposed for Peruvian Aymara is [spread glottis] > [constricted glottis]. With this ordering, the feature [spread glottis] is contrastive for all stops and, crucially, ejectives are specified as [-spread glottis]. The faithful candidate in (121) thus violates the markedness constraint *[αsg] [+sg] and is eliminated in favour of a candidate with a single laryngeally marked segment on the left edge.

In the case of hypothetical inputs of the form C^h…C', however, the analysis is not so straightforward. According to the theory of the contrastive hierarchy, features must be hierarchically ordered and this order results in differences of scope among features. In

the case of Peruvian Aymara, the order [spread glottis] > [constricted glottis] results in unique specification of aspirated segments before the feature [constricted glottis] is added. Again, I assume that specifications consistent with this hierarchy of features are achieved through the constraint ranking introduced in section 5.2.1 and that the input to the evaluations shown here are contrastively specified representations. As a result, aspirates lack contrastive specification in the feature [constricted glottis]. The markedness constraint *[αcg] [+cg] is thus unable to prevent an input of the form $C^h...C'$ from surfacing.

(122)

$q^hat'a$	*[αcg] [+cg]	MAX[cg]$_{IO}$	MAX[sg]$_{IO}$
a) ☹$q^hat'a$			
b) q^hata		*!	
c) qat'a	*!		*

The faithful candidate is selected in the tableau above, as it does not violate any of the relevant constraints. In order to prevent this result, I propose an additional constraint on the distribution of [+constricted glottis] specifications.

(123) *[αsg] [+cg] – A segment specified as [+constricted glottis] may not follow a segment specified for any value of [spread glottis].

This constraint will be able to rule out forms in which an aspirate is followed by an ejective.

(124)

$q^hat'a$	*[αcg] [+cg]	*[αsg] [+cg]	MAX[cg]$_{IO}$	MAX[sg]$_{IO}$
a) $q^hat'a$		*!		
b) ☞ q^hata			*	
c) qat'a	*!	*		*

Admittedly, the introduction of an additional markedness constraint needed only to account for the absence of forms with aspirates followed by ejectives seems like an undesirable complication resulting directly from the assumption of contrastive specifications. However, the following sections will provide an analysis of the distribution of ejectives and aspirates in a related dialect, Bolivian Aymara. In this case, differences in the mechanisms accounting for the absence of $C^h...C'$ forms and $C'...C^h$ forms will be crucial in giving a successful account of some very complex data.

5.2.3 Summary of the analysis of Peruvian Aymara

The following summary recaps the basic facts on the distribution of aspirates and ejectives in Peruvian Aymara and the constraint rankings that account for them.

(125)   Peruvian Aymara cooccurrence restrictions:

i)   There is only one ejective per morpheme, unless the ejectives are identical.

This restriction rules out forms such as *q'at'a. These forms are eliminated by the ranking:

$*[\alpha cg] [+cg] > \text{MAX}[cg]_{IO}$

ii)   There is only one aspirated stop per morpheme, unless the aspirated stops are identical.

This restriction rules out forms such as *q^{h}at^{h}a. These forms are eliminated by the ranking:

$*[\alpha sg] [+sg] > \text{MAX}[sg]_{IO}$

iii)   Ejectives and aspirates may not cooccur.

This restriction rules out forms such as *q'at^{h}a. These forms are eliminated by the independently motivated (see ii above) ranking:

$$*[\alpha sg]\ [+sg] > \text{MAX}[sg]_{IO}$$

This restriction also rules out forms such as *qʰat'a. These forms are eliminated

by the ranking:

$$*[\alpha sg]\ [+cg] > \text{MAX}[cg]_{IO}$$

> iv) Morphemes with homorganic aspirated and plain stops and
> morphemes with homorganic ejective and plain stops are not
> allowed (or are extremely rare).

This restriction rules out forms such as *p'apa and *pʰapa. These forms are

eliminated by the ranking:

$$\text{BeIDENTICAL} >\ *\text{LINK}$$

(126)   Peruvian Aymara ordering restrictions:

> v) If a morpheme has an ejective, it will be the leftmost stop or
> affricate in the form.

This restriction rules out forms such as qat'a. It is ruled out by the independently

motivated (see i above) ranking:

$$*[\alpha cg]\ [+cg] > \text{MAX}[cg]_{IO}$$

> iv) If a morpheme has an aspirate, it will be the leftmost stop or
> affricate in the form.

This restriction rules out forms such as *qatʰa. These forms are eliminated by the

independently motivated (see ii above) ranking:

$$*[\alpha sg]\ [+sg] > \text{MAX}[cg]_{IO}$$

This concludes the analysis of Peruvian Aymara. The constraints and rankings

used to eliminate multiple ejectives and multiple aspirates are identical to the constraints

and rankings used to eliminate forms with aspirates and ejectives that do not fall on the

leftmost stop in a form. Additional constraints BeIDENTICAL and *LINK are needed to

account for the patterning of laryngeal harmony and the constraint *[αsg] [+cg] is needed to eliminate forms containing aspirates followed by ejectives.

5.3 Bolivian Aymara

The consonant inventory of Bolivian Aymara is identical to that of Peruvian Aymara in all relevant respects. I also assume that the contrastive hierarchy and feature specifications are the same in both varieties of Aymara. The constraints on the cooccurrence and location of ejective and aspirated stops are also similar between the two dialects although with significant differences. Most dramatically, while the restrictions on ejectives in Bolivian Aymara are identical to those found in Peruvian Aymara, the distribution of aspirates is less restricted in the Bolivian variety. The cooccurrence constraints and ordering restrictions are summarized below.

(127)   Bolivian Aymara cooccurrence restrictions:

    i)   There is only one ejective per morpheme, unless the ejectives are identical.
    ii)   Homorganic ejectives and aspirates do not cooccur.
    iii)   Morphemes with homorganic aspirated and plain stops and morphemes with homorganic ejective and plain stops are not allowed (or are extremely rare).

(128)   Bolivian Aymara ordering restrictions:

    i)   If a morpheme has an ejective, it will be the leftmost stop or affricate in the form.
    ii)   If a morpheme has a single aspirate, it will be the leftmost stop or affricate in the form.

The crucial difference between Peruvian Aymara and Bolivian Aymara is that Bolivian Aymara allows multiple non-identical aspirates and the cooccurrence of aspirates and ejectives. This can be accounted for with a simple reranking of the

constraints *[αsg] [+sg] and MAX[sg]$_{IO}$ relative to the ranking found in Peruvian Aymara.
With the ranking MAX[sg]$_{IO}$ > *[αsg] [+sg] multiple aspirates will be able to surface.

(129)   Bolivian Aymara

qʰatʰa	MAX[sg]$_{IO}$	*[αsg] [+sg]
a) ☞ qʰatʰa		*
b) qʰata	*!	

This ranking will also allow aspirates to surface following ejectives.

(130)

k'atʰa	MAX[sg]$_{IO}$	*[αsg] [+sg]
a) ☞ k'atʰa		*
b) k'ata	*!	

The distribution of aspirates in Bolivian Aymara is much less restricted than the
distribution of aspirates in Peruvian Aymara. As shown above, this results from the
difference in the relative ranking of *[αsg] [+sg] and MAX[sg] between the two dialects.
Nonetheless, the distribution of aspirates in Bolivian Aymara is not entirely free. If there
is only a single aspirate within a form it must be the leftmost stop. This is achieved by
the constraint *[αsg] [+sg]. Although this constraint is ranked below MAX[sg] in
Bolivian Aymara, it plays a crucial role in determining the location of aspiration when
there is only a single aspirate in a form.

(131)

katʰa	MAX[sg]$_{IO}$	*[αsg] [+sg]	IDENT[sg]
a) katʰa		*!	
b) ☞ kʰata			*
c) kata	*!		

In tableau (131), an input with aspiration on a non-initial stop is evaluated. Previous tableaux have shown that, unlike in Peruvian Aymara, in Bolivian Aymara the constraint *[αsg] [+sg] is not ranked highly enough to rule out forms with multiple aspirates or combinations of aspirates and ejectives. Such forms will surface faithfully due to high-ranking MAX[sg]. In the case of an input with a single aspirate, however, there is a possible candidate that satisfies both *[αsg] [+sg] and MAX[sg]. In tableau (131), this is candidate (b), which has aspiration only on the initial stop. This candidate violates only lowly ranked IDENT[sg], a constraint that has little impact in the distribution of aspirates and ejectives in Aymara.

The relative ranking of markedness and faithfulness constraints referring to the feature [constricted glottis] is the same as that of Peruvian Aymara and forms with multiple ejectives will continue to be ruled out.

(132)

k'at'a	*[αcg][+cg]	MAX[cg]$_{IO}$	MAX[sg]$_{IO}$	*[αsg] [+sg]
a) k'at'a	*!	*		
b) ☞ k'ata				

BEIDENTICAL will enforce laryngeal harmony between plain stops and their ejective and aspirate counterparts in Bolivian Aymara as in Peruvian Aymara. BEIDENTICAL will also be able to rule out the cooccurrence of homorganic ejective and aspirated segments. In Peruvian Aymara, cooccurrence of ejectives and aspirates is ruled out in all cases and nothing special need be said about homorganic segments. In Bolivian Aymara, however, aspirates may follow ejectives in the general case and it is necessary to demonstrate that the analysis is able to rule out forms containing homorganic ejectives and aspirates.

(133)

t'atʰa	BEIDENT	*[αcg] [+cg]	MAX[cg]	MAX[sg]	*[αsg] [+sg]	*LINK
a) t'atʰa	*!				*	
b) t'ata	*!			*		
c) t'at'a | | [+cg] [+cg]		*!	*		*	
d) tata			*!	*		

e) ☞ t'at'a
       ⌄
    [+cg]
				*		*

In tableau (133), the faithful candidate is eliminated due to violation of

BEIDENTICAL. As in the examples of laryngeal harmony in Peruvian Aymara, the

winning candidate contains a [cg] feature that is linked to multiple, identical segments.

To this point, the patterning of cooccurrence restrictions in Bolivian Aymara can

be accounted for using the same constraints proposed in the analysis of Peruvian Aymara

and a simple reranking of the constraints *[αsg] [+sg] and MAX[sg]$_{IO}$ is able to account

for the differences between the two dialects.

There is, however, a significant complication in the patterning of aspirates and

ejectives in Bolivian Aymara. In forms that contain both an ejective and an aspirate, the

place of articulation of stops affects the order of laryngeal features. If the initial stop is

dental, postalveolar or velar, it will be ejective (134). If the initial stop is labial or uvular,

it will be aspirated (135).

(134)   (data from De Lucca 1987, cited in MacEachern 1999)
t'alpʰa   'wide'
tʃ'ipʰa   'leather net'
k'ipʰa   'said of late potatoes'
t'inkʰa   'tip'
t'aqʰe   'affliction'

(135) pʰant'a   'black coat'
       pʰitʃ'i   'coat pin'
       qʰot'a   'resin of some small plants'
       qʰatʃ'u   'fodder'

I have already shown that the forms in (134) can be derived given the constraint

rankings used thus far. I consider these forms to be the default case and follow

MacEachern (1999/1997) in considering the forms in (135) to be the result of segmental

markedness constraints penalizing ejectives at the labial and uvular places of articulation.

The following markedness constraints are from MacEachern (1999/1997).

(136) *p' – No bilabial ejectives. One violation is assessed for every bilabial
       ejective present in the output.

(137)   *q' – No uvular ejectives. One violation is assessed for every uvular
       ejective present in the output.

The markedness constraints *q' and *p' are supported by crosslinguistic data.

MacEachern (1999) reviews segment inventories and finds support for earlier claims by

Greenberg (1970) and Fordyce (1980) that the presence of a labial ejective in a segment

inventory implies the presence of ejectives with articulations farther back in the oral

cavity. In addition, she shows that /q'/ is also dispreferred by demonstrating that

languages with an ejective/plain contrast among stops will often lack an ejective only at

the uvular (or labial) place of articulation.

Functional explanations for the relative markedness of labial and uvular ejectives

can be found in the areas of acoustic and articulatory phonetics. Ejectives involve the

creation of a high pressure area in the supraglottal chamber by closing the vocal folds and

raising the larynx while a closure is maintained farther forward in the vocal tract. The

creation and maintenance of high air pressure in the supraglottal chamber will be most

difficult with labial stops. The supraglottal chamber of labials is larger than that of other stops leading to a weaker compressive effect when the larynx is raised. In addition, the supraglottal chamber of labials involves a large area of elastic cheek wall (Kingston 1985) making compression difficult.

The considerations that make /p'/ marked should favour the production of ejective uvulars. Uvulars have a very small supraglottal chamber and do not involve any cheek surface. Uvular ejectives do pattern as marked, however, both in Aymara and crosslinguistically. MacEachern (1999) speculates that this may result from the difficulty in maintaining a uvular seal during the production of ejectives due to the softness of the articulators involved (the tongue dorsum, uvula and lower velum).

The ordering of laryngeal features in forms that contain both an aspirate and an ejective provides a classic case of the emergence of the unmarked (McCarthy and Prince 1994). While the marked segments /p'/ and /q'/ are found in Bolivian Aymara in general, they are avoided just in those cases in which the features [constricted glottis] and [spread glottis] cooccur in a form. The following analysis accounts for the patterning of /p'/. The patterning of /q'/ is entirely parallel to that of /p'/. I do not provide tableaux of forms with /q'/ as these would add nothing further to the analysis.[25]

In order to motivate a ranking of *p' relative to the constraints introduced thus far I will focus on a crucial contrast between forms with an ejective and a plain stop and

[25] A question that naturally arises is what happens when aspirates and ejectives cooccur in a form with both a labial and a uvular. Such forms are extremely rare. MacEachern lists four forms from De Lucca (1987) containing aspirates and ejectives in which a uvular is followed by a labial. In two of these forms, the initial uvular is ejective (q'ap^hi 'fragrance', q'ap^ha 'active, diligent'). In the other two forms, the initial uvular is aspirated and the following labial is ejective (q^hop'aki 'meal with meat or fat', q^hop'i 'potter'). The forms with initial aspirated uvulars are noted as dialectal variants. Similar forms with a labial followed by a uvular are unattested. I consider such forms to be beyond the scope of this analysis.

forms containing an ejective and an aspirated stop. If a labial is initial in the form, it will surface as ejective in the first case (a) but as aspirated in the second (b). Also, the generalization that ejectives precede aspirates in forms without labials or uvulars must be maintained (c).

(138)   a.   p'aka
                *pak'a
        b.   pʰant'a   'black coat'
                *p'antʰa
        c.   t'inkʰa   'tip'
                *tʰink'a

In order to account for the data in (138), *p' must be ranked low enough in order to allow ejective labials to be realized when there are no other laryngeally marked segments in a form but high enough to get a reversal of the relative order of ejectives and aspirates in forms that contain both. The following tableaux integrate *p' into the ranking established to this point.

(139)

p'aka	*[αcg][+cg]	MAX[cg]	*p'	MAX[sg]	*[αsg] [+sg]
a) ☞ p'aka			*		
b) pak'a	*!				
c) paka		*!			

Tableau (139) shows that a [+constricted glottis] feature will be realized on the leftmost stop in a form with only one laryngeally marked segment, even if that leads to a violation of *p'. A candidate with [+cg] on the second stop violates the highly ranked constraint prohibiting [+cg] segments from following any segment with a contrastive specification for [constricted glottis]. A candidate in which all output stops are realized without glottalization violates the constraint requiring that [constricted glottis] features in the input be present in the output.

The following tableau shows that an ejective labial will be avoided if an aspirate is present in the form.

(140)

p'akʰa	*[αcg][+cg]	MAX[cg]	*p'	MAX[sg]	*[αsg] [+sg]
a) p'akʰa			*!		*
b) ☞ pʰak'a					
c) p'aka				*!	
d) pʰaka		*!			
e) pak'a	*!				*
f) pʰakʰa		*!			*

In this case, the violation of *p' incurred by the faithful candidate is fatal. Candidate (b), in which the features of the two stops are reversed, is able to satisfy all of the constraints shown here and is selected as optimal. Crucially, this candidate does not violate the constraint *[αcg][+cg] because the initial, aspirated segment is not contrastively specified for the feature [constricted glottis]. The contrastive hierarchy introduced earlier has the order [spread glottis] > [constricted glottis]. The scope of the two features necessarily differs with [spread glottis] being contrastive for all stops but [constricted glottis] being contrastive only in the set of stops that are [-spread glottis]. The [+spread glottis] aspirates are not contrastively specified for the feature [constricted glottis].

Contrastive specifications will necessarily be asymmetrical when used to establish a contrast between a set of three. In this case, the three-way distinction is between plain stops, aspirates and ejectives. The fact that one feature must take scope over another seemed like a liability in the analysis of Peruvian Aymara. Because aspirates are not contrastively specified for the feature [constricted glottis] an additional constraint needed to be introduced to rule out forms with the shape Cʰ…C'. However, the asymmetry in

feature specifications is crucial in the analysis of ordering restrictions in Bolivian Aymara

and avoids an ordering paradox. If aspirates were specified for the feature [constricted

glottis], the constraint *p' would need to be ranked above the constraint *[αcg][+cg] in

order for glottalization to be realized on the second stop in forms with an aspirate and an

initial labial. But the constraint *p' must be ranked below *[αcg][+cg] in order for

glottalization to be realized on the initial labial in forms without any aspirates.

Of course, forms in which ejectives follow aspirates must violate some

markedness constraint in order to ensure the order ejective-aspirate in forms without

labials or uvulars. The relevant constraint is *[αsg] [+cg], introduced to rule out forms

such as C^h…C' in the analysis of Peruvian Aymara. This independently needed

constraint is able to get the correct default ordering between aspirates and ejectives.

(141)

	k^{h}at'a	*[αcg][+cg]	MAX[cg]	*p'	*[αsg] [+cg]	MAX[sg]	*[αsg] [+sg]
a)	k^{h}at'a				*!		
b) ☞	k'at^{h}a						*
c)	k'ata					*!	
d)	k^{h}ata		*!				
e)	kata		*!			*	

The constraint ranking shown above is able to capture the ordering of aspirates

and ejectives in all forms. In the example shown here, an input in which an aspirate

precedes an ejective is evaluated. The form does not contain labials or uvulars so the

constraints *p' and *q' will have no impact in the selection of the optimal form. The

faithful candidate is eliminated due to a violation of *[αsg] [+cg]. The inclusion of this

constraint, in addition to *[αcg][+cg] captures the fact that ejectives have the most severe

restrictions on their distribution. Constraints penalize the occurrence of [+constricted

glottis] segments following plain stops, other [+constricted glottis] segments and [+spread glottis] segments. As a result, candidate (b) is optimal. In this candidate, the ejective is first in the form and only a violation of the lowly ranked constraint *[αsg] [+sg] is incurred.

5.3.1 Summary of the analysis of Bolivian Aymara

(142) Bolivian Aymara cooccurrence restrictions:

i) There is only one ejective per morpheme, unless the ejectives are identical.

This restriction rules out forms such as *q'at'a. These forms are eliminated by the ranking:

*[αcg] [+cg] > MAX[cg]$_{IO}$

ii) Morphemes with homorganic aspirated and plain stops, morphemes with homorganic ejective and plain stops and morphemes with homorganic ejective and aspirated stops are not allowed (or are extremely rare).

This restriction rules out forms such as *p'apa and *pʰapa. These forms are eliminated by the ranking:

BEIDENTICAL > *LINK

(143) Bolivian Aymara ordering restrictions:

iii) If a morpheme has an ejective, it will be the leftmost stop or affricate in the form.

This restriction rules out forms such as qat'a. It is ruled out by the independently motivated (see i above) ranking:

*[αcg] [+cg] > MAX[cg]$_{IO}$

iv) If a morpheme has a single aspirate, it will be the leftmost stop or affricate in the form.

This restriction rules out forms such as *qat^{h}a. These forms are eliminated by the ranking:

*[αsg] [+sg] > IDENT[sg]$_{IO}$

v) If a morpheme contains an aspirate and an ejective, neither of which are uvular or labial, the ejective precedes the aspirate.

This restriction rules out forms such as *k^{h}at'a in favour of forms such as k'at^{h}a.

Forms such as *k^{h}at'a are eliminated by the ranking:

*[αsg] [+cg] > *[αsg] [+sg]

vi) If a morpheme contains an aspirate and an ejective, one of which is uvular or labial, aspiration is realized on the uvular or labial stop, regardless of the relative order of the segments.

This restriction rules out forms such as p'ak^{h}a and q'at^{h}a in favour of forms such as p^{h}ak'a and q^{h}at'a. Forms such as p'ak^{h}a and q'at^{h}a are eliminated by the ranking:

*p'/*q' > *[αsg] [+cg]

This concludes the analysis of Bolivian Aymara. The differences between Bolivian Aymara and Peruvian Aymara result from a reranking of the constraints *[αsg] [+sg] and MAX[sg] in the two dialects. In addition, the fact that aspirates and ejectives can cooccur in Bolivian Aymara and that their relative order is influenced by place of articulation gives evidence for the ranking of the markedness constraints *p' and *q'. The account of the influence of place of articulation on the relative order of aspirates and ejectives also relies crucially on the constraint [αsg] [+cg] and differences in the relative scope of features resulting from the contrastive hierarchy. While both of these aspects of the analysis seemed to offer unnecessary complications in the analysis of Peruvian

Aymara, the more complex patterning of aspirates and ejectives in Bolivian Aymara requires a distinct ranking of [αsg] [+cg] and [αsg] [+sg] as well as reference to contrastive feature specifications consistent with the contrastive hierarchy.

5.4 Implications

Constraints of the form *[αF] [+F] are able to motivate both the cooccurrence restrictions on multiple laryngeally marked segments and the need for such segments to be close to the left edge of a form. These markedness constraints specifically restrict the distribution of segments with positive, or marked, values of laryngeal features. While such constraints may seem like an unwarranted combination of featural OCP constraints and alignment constraints, they capture the intuition that both the ordering restrictions and cooccurrence constraints of Aymara are motivated by the need to restrict the distribution of marked elements. Furthermore, these constraints are able to capture the relative nature of the leftward orientation of laryngeal features in a principled way. Alignment constraints referring to morphological or prosodic domains are well-motivated and are ubiquitous in analyses of directional phenomena. The use of markedness constraints referring to contrastive features, however, is able to account for the fact that only segments that are contrastively specified for laryngeal specifications count as intervenors. A constraint such as ALIGNLEFT[constricted glottis], PROSODICWORD, would be able to account for the preference for realization of laryngeal features on an initial segment but not so straightforwardly for the preference for glottalization to be realized on an earlier, rather than a later, medial stop.

The analysis here also has advantages over previous accounts in that it does not make any reference to similarity. Segments whose cooccurrence and ordering are

restricted are similar in the sense that they are specified for the marked values of laryngeal features. Restrictions on the number and location of marked segments are common and need not depend on any notion of similarity per se.

The limitation of laryngeal harmony to homorganic segments is the result of ranking of BEIDENTICAL with respect to input-output faithfulness constraints. In this respect, I follow the analysis of MacEachern (1999). (More details of MacEachern's analysis are provided in section 5.5.) Input-output faithfulness constraints referring to the features [spread glottis] and [constricted glottis] are ranked below the constraint BEIDENTICAL and faithfulness constraints referring to other features, such as place and manner features, are ranked above BEIDENTICAL. Harmonic features, by definition, have a distribution that is not determined solely by the structure of the input (or UR). Hence, a harmonic feature is less bound by faithfulness than other features. If segmental identity is valued in the grammar, then it will be achieved through a violation of faithfulness in a harmonic feature and only a harmonic feature. The restrictions on participating segments in harmony here can therefore be accounted for with reference to the notion of identity without need for an independent definition of similarity.[26]

---

[26] Bakovic (2005) makes a similar argument with respect to identity avoidance and epenthesis. In some languages where epenthesis functions to prevent the occurrence of surface geminates, epenthetic vowels occur not only between identical consonants, but also between consonants that are merely similar. Bakovic argues that in these cases, consonant clusters broken up by epenthesis consist of segments that differ only in features that assimilate in other contexts. If epenthesis failed to apply, assimilation would render the adjacent consonants identical resulting in a geminate. No reference to similarity is needed to account for the context of epenthesis. Instead, constraints motivating assimilation and penalizing adjacent identical segments are sufficient to derive the attested patterns.

5.5 MacEachern's analysis of Peruvian and Bolivian Aymara

The preceding chapter provided a detailed summary of MacEachern's (1999) approach to the analysis of laryngeal harmony and cooccurrence constraints. While this section will unavoidably overlap somewhat with the preceding discussion, I wish to summarize MacEachern's analysis of the ordering restrictions of Peruvian and Bolivian Aymara in order to clarify where the analysis advocated here differs from her approach.

With respect to laryngeal cooccurrence constraints and laryngeal harmony, the constraints and rankings used by MacEachern are familiar from the previous chapter. In her analysis of Peruvian Aymara, MacEachern uses the following conjoined constraint, similar, but not identical to constraints discussed in chapter 4.

(144)   (from MacEachern 1999: 94)
  *IDENTITY & *2(LAR∨ [-son]) & *2CG. This constraint is violated by
  the cooccurrence of one or more of the following: two identical segments,
  two segments bearing a Laryngeal node and a [-sonorant] specification, or
  two segments characterized by [constricted glottis].

This type of complex conjoined constraint, involving both disjunctive and conjunctive interpretation, is familiar from earlier discussion of MacEachern's work. In this case, she assumes that only aspirates, ejectives and voiced obstruents have a laryngeal node and that voiced sonorants and voiceless obstruents are lacking a laryngeal node. This constraint is ranked below *IDENTITY and above MAX[spread glottis] and MAX[constricted glottis] in order to prevent forms with multiple non-identical aspirates and ejectives from surfacing (see tableau (145)). This constraint ranking will also eliminate disharmonic forms with homorganic segments (tableau (146)). (I do not go over these tableaux in detail. See analogous tableaux and discussion in chapter 4).

(145)   (modified from MacEachern 1999: 92)

t'ak'a	BeIdentical	*Id & *2(Lar V[-son]) & *2CG	Max [cg]
a) t'ak'a	*	*!	
b) ☞ t'aka	*		*

(146)   (modified from MacEachern 1999: 94)

t'at'a	BeIdentical	*Id & *2(Lar V[-son]) & *2CG	Max [cg]
a) ☞ t'at'a		*	
b) t'ata	*!		*
c) tata		*	**!

The preceding tableaux illustrate MacEachern's analysis of the restrictions on cooccurrring ejectives and cooccurring ejective and plain homorganic segments in Peruvian Aymara. Evaluation of inputs with multiple aspirates and homorganic aspirates and plain stops is not shown here. Aspirates and ejectives pattern identically in Peruvian Aymara and only the constraint Max[sg] need be added to the above tableau in order to account for data containing aspirates.

In Bolivian Aymara, aspirates are not subject to the same constraints as ejectives. As discussed in the analysis proposed in this chapter, Bolivian Aymara allows non-identical aspirates to cooccur and also allows the cooccurrence of aspirates and ejectives. To account for this difference between the two dialects, MacEachern uses a different conjoined markedness constraint in her analysis of each dialect. The constraint used in the analysis of Bolivian Aymara is given below.

(147)   (from MacEachern 1999: 97)
*IDENTITY & *2CG. This constraint is violated by the cooccurrence of two identical segments and/or two segments characterized by [constricted glottis].

Unlike the constraint used in the analysis of Peruvian Aymara, this constraint penalizes only the cooccurrence of multiple ejectives and the cooccurrence of identical segments.[27] MacEachern's analysis of Bolivian Aymara also differs from her analysis of Peruvian Aymara in ranking the faithfulness constraint MAX[spread glottis] above MAX[constricted glottis]. The different formulation of the markedness constraint in the two languages, however, makes this reranking non-crucial. The following tableaux illustrate MacEachern's analysis of Bolivian Aymara.

(148)   (from MacEachern 1999: 98)

k'itʰa	BEIDENTICAL	MAX[sg]	*ID & *2CG	MAX [cg]
a) ☞ k'itʰa	*			
b) k'ita	*	*!		
c) kitʰa	*			*!

In tableau (148), none of the candidates violate the conjoined markedness constraint as this constraint is only violated when there are identical segments or multiple segments bearing the feature [constricted glottis]. All candidates violate BEIDENTICAL. The faithful candidate is selected as optimal because it satisfies both faithfulness constraints MAX[cg] and MAX[sg].

Forms containing multiple non-identical ejectives and homorganic ejectives and plain stops will be ruled out in a manner exactly analogous to the analysis of Peruvian Aymara. The ban on homorganic plain/aspirated stops is illustrated in the following tableau.

(149)

---

[27] The constraint also penalizes cooccurrence of ejectives and glottal stop, a pattern not considered here.

tʰata	DEP[sg]	BEIDENTICAL	MAX[sg]	*ID & *2CG	MAX [cg]
a) tʰata		*!			
b) tʰatʰa	*!				
c) ☞ tata			*		

The constraint BEIDENTICAL rules out the faithful candidate in this case. The ranking of DEP[sg], which prevents the insertion of [spread glottis] features in output candidates, over MAX[sg], which prevents the deletion of [spread glottis] features, leads to the selection of the harmonic candidate without aspiration as optimal over the harmonic candidate with aspiration on both stops.

In summary, MacEachern's analysis of laryngeal harmony and cooccurrence constraints in both varieties of Aymara, like her analyses of Hausa and Tzutujil, rely on ranking BEIDENTICAL above some conjoined markedness constraint which in turn outranks faithfulness constraints referring to laryngeal features. The different patterning of aspirates in the two dialects results from different conjoined markedness constraints being active in each dialect. In Peruvian Aymara, the relevant markedness constraint is *IDENTITY & *2(LAR V [-son]) & *2CG and in Bolivian Aymara, the relevant markedness constraint is *IDENTITY & *2CG.

MacEachern's use of different conjoined markedness constraints in the analysis of each variety of Aymara undermines the basic insight of OT that free-ranking of simple constraints can lead to complex differences between languages. By using complex constraints, the types of structures penalized in the two languages are fundamentally different. In the account proposed in this chapter, on the other hand, constraints of the form *[αF] [+F] are the same in both dialects and the relative ranking of these constraints relative to featural faithfulness constraints determines the differences in patterning

between the two dialects. Of course, conjoined constraints themselves must either be universal or be constructed from simple constraints through a universally available operation. It is therefore possible to argue that the differences between Peruvian and Bolivian Aymara result only from constraint ranking even in MacEachern's analysis. Nonetheless, the constraint that is crucial in avoiding multiple ejectives differs in the analyses of the two languages.

Another difference between the analysis argued for here and the analysis in MacEachern (1999) is that this analysis avoids the use of constraint conjunction altogether. Constraint conjunction in general has been criticized for vastly increasing the number of constraints and potential for constraint interaction resulting in problems for learnablility (see Kager 1999 for discussion). The different types of conjunction and interpretation used in MacEachern (1999) greatly increase the power of constraint conjunction thereby strengthening arguments against the use of this analytic tool. More crucially (as discussed in chapter 4), MacEachern's use of constraints that conjoin *IDENTITY with featural OCP constraints lead perfectly well-formed sequences of identical plain segments to be penalized by the same constraint that penalizes ill-formed sequences of non-identical marked segments like ejectives or aspirates. This use of constraint conjunction is highly counterintuitive.

Constraints of the form *IDENTITY & OCP[F] are necessary in MacEachern's analysis in order to allow forms with multiple identical ejectives to surface. If identical segments did not violate some highly ranked markedness constraint, forms with multiple identical ejectives would never be selected as optimal. In harmonic contexts, a candidate that satisfies BEIDENTICAL and markedness constraints against multiple [constricted

glottis] features will always be available, namely a candidate with identical plain stops. MAX[cg] cannot rule out this candidate as it must be ranked below the markedness constraint penalizing multiple [constricted glottis] features in order to prevent forms containing multiple non-identical ejectives from surfacing. By conjoining OCP[constricted glottis] with *IDENTITY MacEachern is able to penalize multiple plain stops that are identical, allowing harmonic candidates with plain stops to be evaluated as equally marked as harmonic candidates with ejectives. Low ranking MAX[cg] can then play a role in selecting the candidate containing multiple identical ejectives as optimal.

The analysis proposed here avoids this difficulty by allowing output representations with multiply linked feature specifications. Forms with multiple identical ejectives do not violate markedness constraints on multiple [constricted glottis] features because they contain only a single [constricted glottis] specification that is linked to multiple segments in the output. This solution necessarily involves a degree of representational complexity lacking in MacEachern's analysis. Analyzing harmony as multiple linking of features is, however, standard within autosegmental analyses of harmony (e.g. Mester 1986, Shaw 1991) and within much work in OT (e.g. Beckman 1998, Walker 1998). Even work that rejects multiple linking as an appropriate analysis for harmony (Hansson 2001, Rose and Walker 2004, McCarthy 2007) allows special relationships to exist between segments in harmonic forms. In the analyses of Hansson (2001) and Rose and Walker (2004), the special relationship between segments in harmonic contexts is one of surface correspondence relations. While a full examination of the empirical and theoretical differences between multiple linking and surface correspondence relations is beyond the scope of this discussion, it is sufficient to note

that use of surface correspondence relations also entails a degree of representational complexity. Output candidates in analyses using surface correspondence relations may differ solely in terms of indices indicating what relationships exist between output segments. Identificational indices are presumably not part of the phonetic signal. Differences in indexical information can therefore be seen as differences in representations between competing output candidates. The crucial point for the present discussion is simply that, while the multiply-linked representations used in the analysis proposed here do entail some representational complexity not necessary in MacEachern's analysis, the use of rich output representations is standard in a wide range of analyses of harmony patterns.[28] This representational complexity allows the use of constraint conjunction to be avoided and is therefore well-justified.

This discussion of the differences between the analysis of laryngeal harmony proposed here and that of MacEachern (1999) is not intended to minimize the significant respects in which these analyses are similar. Most importantly, I follow MacEachern in using the constraint BEIDENTICAL to motivate harmony and the ranking of BEIDENTICAL relative to featural faithfulness constraints to determine when harmony may occur. I consider these aspects of MacEachern's analysis to provide significant insights into the

---

[28] It is worth noting that the multiply-linked representations used here are not needed to account for consonant harmony per se. It is only the interaction of consonant harmony and cooccurrence restrictions on multiple laryngeally marked segments that requires the use of multiply-linked output forms. While the ranking of BEIDENTICAL with respect to input-output faithfulness constraints referring to laryngeal features is able to account for harmony between homorganic segments, multiply-linked representations are needed to account for the fact that the output of harmony is exempt from restrictions on multiple ejectives and aspirates. Rose and Walker (2004) provide an analysis of laryngeal harmony in Aymara using surface correspondence relations. They do not, however, integrate their analysis of harmony with an account of the restrictions against multiple non-identical ejectives. In order to do so, their analysis would also require the use of multiply-linked output representations or some other mechanism in order to account for the fact that harmonic forms are exempt from the cooccurrence restrictions against multiple ejectives and aspirates.

motivation of consonant harmony that appears to make reference to a notion of global

similarity.

To this point, I have summarized only MacEachern's analysis of laryngeal

harmony and restrictions on multiple laryngeally marked segments. When we consider

her analysis of ordering restrictions, differences between her approach and the one

proposed here are even more striking. MacEachern's analysis of ordering restrictions in

Peruvian and Bolivian Aymara requires the following additional constraints.

(150)   (from MacEachern 1999:124)
> LEFTMOST[spread glottis] – [spread glottis] features should occur early in
> the morpheme. One violation is assessed for every available host
> consonant intervening between the beginning of the morpheme and the
> location of aspiration.

(151)

> LEFTMOST[constricted glottis] – [constricted glottis] features should occur
> early in the morpheme. One violation is assessed for every available host
> consonant intervening between the beginning of the morpheme and the
> location of the [constricted glottis] feature.

MacEachern's interpretation of these constraints relies crucially on her notion of

'available host consonant'. These constraints are only violated when a plain stop or

affricate intervenes between the ejective/aspirate and the left edge of the word. Forms

containing multiple ejectives/aspirates or forms containing ejectives/aspirates preceded

by sonorants or fricatives are not considered to violate these constraints.

MacEachern's use of LEFTMOST constraints entails a significant complication in

the analysis of Aymara ordering restrictions when compared to the analysis advocated

here. In the analysis argued for in this chapter, the constraints penalizing multiple

ejectives and aspirates are the same as the constraints requiring ejectives and aspirates to

be realized at the left edge. In the case of ejectives, the constraint *[αcg] [+cg] is violated by forms containing multiple ejectives, which necessarily contain a [+constricted glottis]…[+constricted glottis] sequence, as well as forms in which an ejective is preceded by a plain stop, which contain a [-constricted glottis]…[+constricted glottis] sequence. A single constraint motivates patterns which are motivated by two distinct constraints in MacEachern's analysis.

The advantage of the analysis proposed here is not simply that it requires fewer constraints. MacEachern's analysis also misses a significant insight. If a form contains more than one ejective, both ejectives cannot be at the left edge of the form. There is therefore a conceptual link between the ordering restrictions and the ban on multiple ejectives that is completely overlooked in MacEachern's analysis. The markedness constraint used here, *[αcg] [+cg], captures this link by requiring any [+constricted glottis] feature to be the first [constricted glottis] specification. A [+constricted glottis] specification preceded by another [+constricted glottis] specification will be penalized, ruling out forms of the shape k'at'a, and the same constraint penalizes a [+constricted glottis] specification preceded by a [-constricted glottis] specification, ruling out forms of the shape kat'a.

The use of the contrastive hierarchy and contrastive specifications is also able to capture MacEachern's notion of 'available host consonant' in a principled fashion. In the contrastive hierarchy analysis, an ejective preceded by a sonorant or fricative does not

violate the constraint *[αcg] [+cg] because sonorants and fricatives are not contrastively

specified for any value of [constricted glottis].[29]

---

[29] The ordering restrictions of Bolivian Aymara are more complex than those of Peruvian Aymara and analysis of Bolivian Aymara necessarily requires use of the additional markedness constraints *p and *q. I do not provide a detailed summary of MacEachern's analysis of Bolivian Aymara.

CHAPTER 6
GRADIENT SIMILARITY

Throughout this work I have argued that similarity is evaluated on the basis of abstract phonological features and that these features are determined in accordance with the theory of the contrastive hierarchy. The claims made here are consistent with broader claims in the literature on contrast and the contrastive hierarchy (Dresher 2003, forthcoming, Hall 2007) to the effect that only contrastive feature representations may be active in phonological processes and referred to by phonological operations. In addition to arguing for limits on what features may influence the evaluation of similarity, I have also argued for limits on how these features may be referred to by the grammar. In Chapter 3, I demonstrated that the notion of natural class is able to account for the set of participating segments in a number of consonant harmony systems. This requires only the presence of a shared contrastive feature specification between segments to be referred to by the grammar without any more complex notion of similarity. In Chapter 4, I proposed that interacting segments may differ only in a single marked and contrastive feature in cases which require reference to a global definition of similarity. Chapter 5 provided an OT account of laryngeal harmony, cooccurrence constraints and ordering restrictions in Peruvian and Bolivian Aymara. The account showed that contrastive specifications can be achieved by a ranking of markedness and faithfulness constraints. The constraint BEIDENTICAL motivates harmony in this case, showing that a formal account of harmony that makes reference to identity, and not similarity, is possible in cases where interacting segments differ in a single feature.

There are, however, cases in the literature on consonant harmony and cooccurrence constraints that require reference to similarity measures that cannot be established on the basis of phonological representations. These are cases where the phenomena being considered are truly gradient; not categorical facts about grammaticality but statistical generalizations about frequency in the lexicon. For example, gradient OCP effects have been observed for many languages that are not traditionally analyzed as having OCP constraints (Frisch et al. 2004, Berkley 2000, Coetzee and Pater to appear, Kawahara et al. 2006). In these cases, morphemes with homorganic segments are not ill-formed but are statistically less frequent than expected given a free distribution of segments. A number of definitions of similarity have been proposed to account for data of this type.

The role of gradience in phonology is strongly contested and research in this area is growing. This chapter will be a necessarily incomplete examination of proposals for a gradient definition of similarity. While gradient similarity plays an important role in shaping aspects of sound patterning, I maintain the position held in earlier chapters, that gradient similarity need not be referred to by the computational system of the grammar. Generalizations that make reference to gradient similarity have their origins outside of the grammar proper, in perception, acquisition and language change.

Different works on gradient similarity situate the source of gradience in different parts of the phonological computation. Frisch et al. (2004) calculate similarity between segment pairs on the basis of natural classes. The natural classes themselves are determined on the basis of categorical, phonological feature specifications. Their proposed method of computing similarity over phonological features, however, results in

numerical values of similarity that range between 0 and 1. Similarity itself is therefore gradient, although the phonological representation is categorical. Coon and Gallagher (2007), in their study of consonant harmony and cooccurrence restrictions in Chol, propose that phonological features themselves are weighted. Under their analysis, not all features are equally important in determining the relative similarity of segments. While Coon and Gallagher, like Frisch et al., provide a formula for computing similarity, their definition of similarity differs from Frisch et al.'s in that it is not only the computation that results in gradience, but also the nature of the features themselves. Steriade (2001) argues that similarity plays a significant role in the grammar by constraining well-formed input-output relations. The notion of similarity referred to in Steriade's work is perceptual similarity. She allows for the possibility that similarity is determined without reference to phonological features at all but may be determined on the basis of confusability values.

The following sections will provide a summary of these works and the implications that they hold for phonological theory. In each case, I will show that the proposed definitions of similarity entail a significant complication in the structure of the phonological grammar. The preceding chapters have demonstrated that categorical feature assignments and basic concepts like identity and natural class are able to account for a wide range of cases that have been argued to require reference to similarity. In the case of gradient similarity effects, I hold that the burden of proof is on those proposing significant changes in the theory of grammar to show that the data under consideration cannot be accounted for with categorical representations or extragrammatical factors such as perception and language change.

6.1 Natural Classes and the Computation of Similarity (Frisch et al. 2004)

Frisch et al. (2004) provide an analysis of OCP effects in Arabic and argue that segmental similarity has an inverse correlation with consonant cooccurrence such that more similar segments cooccur less often than less similar segments. They observe that the structure of the inventory affects relative similarity with segments that are part of a large inventory behaving as if they are less similar to one another than segments that are part of a small inventory. In the case of Arabic, cooccurrence restrictions affecting segments with the same place of articulation are most severe for place classes that support relatively few contrasts, such as the labial class, and less severe for place classes that support many contrasts, such as the coronal class.

The observation that inventory shape influences phonological patterning has often been accounted for with theories of underspecification (see Pierrehumbert 1993 for an analysis of Arabic cooccurrence constraints using contrastive specification). Frisch et al. reject contrastive underspecification claiming that it has 'little empirical support' and suffers from 'serious formal shortcomings'(2004: 198 n. 4). Instead, they assume that all segments are fully specified and argue that similarity is computed over natural classes directly, rather than over feature specifications. They adopt the theory of structured specification (Broe 1993) in which natural classes are encoded in set relations. Similarity is then computed by dividing the set of shared natural classes for a given segment pair by the set of shared and unshared natural classes.

Frisch et al.'s definition of similarity was discussed in some detail in Chapter 2 where I show that, despite their rejection of representational theories, the similarity metric proposed in Frisch et al. (2004) is sensitive to feature specifications and slight

differences in the assumed feature system can lead to significant differences in the

similarity evaluation. In Chapter 3, the case of laryngeal harmony in Bumo Izon and

Kalabari Ijo was discussed. An examination of Frisch et al.'s similarity metric shows (as

discussed in Hansson 2001) that it is incapable of accounting for similarity patterning in

systems like Bumo Izon and Kalabari Ijo that have asymmetric inventories. These

discussions have raised serious doubts about the validity of the similarity values that

result from dividing shared natural classes by unshared natural classes. Questions about

the similarity metric will not be revisited in this section, which will instead focus on the

role that Frisch et al. accord similarity values in the grammar and in the structure of

phonological constraints.

Frisch et al. propose that the OCP constraint motivating cooccurrence patterns in

Arabic is a gradient constraint. They provide the following definition of a gradient

constraint.

> A *gradient constraint* is a constraint that is quantitatively sensitive to
> violations of different degrees, such that forms that violate the constraint
> to a lesser degree are more frequent than forms that violate the constraint
> to a greater degree. (2004: 182)

This definition of gradient constraint differs from other approaches to the analysis

of non-categorical data. Probabilistic constraints (Boersma 1998) and unranked

constraints (Anttila 1997, Anttila and Cho 1998) have been proposed to account for

linguistic variation. These proposals, however, are intended to model individual

input/output mappings such that the output that a speaker produces for a given input may

vary from instance to instance depending on the influence of unranked or probabilistic

constraints. In Frisch et al.'s theory, the degree of violation of the OCP constraint does

not govern individual occurrences of a particular output. After all, lexical items

containing rare combinations of highly similar segments are always produced with faithful realization of the similar consonant pair. Rather, the gradient constraint proposed in Frisch et al. governs statistical generalizations over the lexicon as a whole.

Frisch et al's gradient constraint constitutes a significant complication in the model of the grammar as compared to models that use only categorical constraints. They claim that the probability of the gradient constraint being violated is a well-behaved function of similarity. The constraint must therefore refer to numerical similarity values computed over natural classes and evaluate inputs according to these values in order to determine the frequency of various cooccurring consonant pairs in the lexicon.

Functional motivations for gradient OCP effects can be found in the domain of language processing. Frisch et al. cite work by Berg (1998), Boersma (1998) and Frisch 1996) arguing that repetition of similar consonants creates processing difficulties. More specifically, perceptual experiments (Miller and McKay 1994, Boersma 1998) show that repeated identical segments are difficult to perceive as distinct elements. Over time, as the language is acquired by successive generations of speakers, processing constraints will influence the shape of the lexicon. Misperception may lead to changes in the shape of lexical items and functional pressures lead forms with similar segments to be dispreferred as nonce forms and borrowings.

These arguments for functional motivations behind the gradient OCP are compelling, so compelling that they undermine the claim that the gradient OCP must be part of the computational system of the grammar. If the diachronic result of perceptual patterns will lead forms with similar segments to be less frequent than forms with more similar segments, no grammatical constraint need be present to account for statistical

generalizations over the lexicon.[30] Frisch et al. nonetheless claim that '[d]espite the diachronic origin of the dissimilation patterns, … speakers have acquired the OCP-Place constraint and so it must be considered a part of the synchronic linguistic knowledge of the speakers.'

Part of the evidence that Frisch et al. provide in support of a synchronic, gradient OCP constraint comes from experiments carried out by Frisch and Zawaydeh (2001). Native Arabic speakers were presented with nonce words containing consonant pairs of varying degrees of similarity and asked to judge the wordlikeness of the forms. Results were gradient with forms containing highly similar segments judged as less wordlike than forms containing less similar segments. Frisch et al. take these results as evidence that Arabic speakers have a gradient OCP constraint.[31]

While the experimental evidence certainly suggests that Arabic speakers have detailed knowledge of the structure of the lexicon, including knowledge of the frequency of consonant cooccurrence, this does not entail that a gradient constraint is present in the phonological component of the grammar. Grammatical constraints are needed to generate grammatical forms and discriminate between grammatical and ungrammatical utterances. It is not necessary for Arabic speakers to generate statistical regularities in the lexicon as these regularities exist outside of the speaker and, in Frisch et al's words, faithful realization of lexical items 'follows straightforwardly from lexical memory and

---

[30] See also Blevins (2004) for arguments for the explanatory power of perceptual and diachronic factors in accounting for phonological patterning.

[31] See Coetzee and Pater (to appear) for an analysis of these data in the framework of Harmonic Grammar. Coetzee and Pater argue that an analysis using weighted constraints that refer to shared feature values fit the O/E data better than the similarity metric. They also provide data on gradient phonotactics in Muna and show that Frisch et al.'s claims about the role of the inventory in determining OCP effects do not hold crosslinguistically.

morphological competence'(2004: 211).

In summary, Frisch et al. provide evidence that speakers have detailed and gradient knowledge about the shape of the lexicon. This evidence does not, however, require the positing of gradient phonological constraints. In fact, the functional motivations for similarity avoidance discussed in Frisch et al. can account for the statistical regularities in the shape of lexical items through perception and language change, without need to complicate the model of the grammar through the use of gradient constraints that evaluate the lexicon as a whole.

Frisch et al. invoke their similarity metric in order to account for statistical regularities in the frequency of occurrence of various consonant pairs. The role of gradience in phonology is a complex and highly contested issue beyond the scope of this dissertation (see e.g. Coetzee 2004, 2008, Coetzee and Pater to appear, Anttila to appear, among others). It is worth noting, however, that in many proposals for phonological accounts of gradient data, the locus of gradience is neither in gradient constraints nor in gradient representations and similarity values. Rather, gradience results from aspects of phonological operations such as weighted constraint ranking in the framework of Harmonic Grammar (Coetzee and Pater to appear, Pater 2008, Smolensky and Legendre 2006) or implicational relations between various input-output mappings according to Anttila's (to appear) Complexity Hypothesis. These works demonstrate that formal accounts of gradient phonotactic patterning do not necessarily require reference to gradient constraints or gradient similarity values. In the case of proposals by Anttila (2008) and Coetzee (2008), there are no additional mechanisms proposed to the structure of the phonological grammar. Instead, gradience is determined on the basis of

information that is unavoidably present in basic OT grammars (implicational relations

between input output mappings, violation profiles of non-optimal candidates).

6.2 Similarity and Weighted Features (Coon and Gallagher 2007)

Coon and Gallagher (2007) provide an account of cooccurrence restrictions on

ejectives and sibilants in Chol (Mayan). They argue that restrictions on similar segments

cannot be accounted for with an evaluation of similarity based on calculations over

simple phonological features. Instead, they propose that the similarity effects of Chol

require features to be weighted, with some features contributing more to the evaluation of

similarity than others.

Chol, like Hausa, Tzutujil and Aymara, has a cooccurrence restriction that bars

multiple non-identical ejectives from occurring within a form (152a). Identical ejectives

are permitted (152b). Chol also has a restriction on the cooccurrence of non-identical

sibilants (153a). Identical pairs of sibilants can cooccur as can combinations of plain and

ejective sibilants which are exceptionally exempt from the restriction against non-

identical sibilants (153b).

(152) Chol restrictions on ejectives

	a.	*k'ip'	b.	k'ok'	'healthy'
		*p'its'		p'ip'	'wild'
		*tʃ'utʲ'		tʃ'otʃ'	'throat'

(153) Chol restrictions on sibilants

	a.	*tsus	b.	ts'uhts'	'kiss'
		*ʃats		ʃeʃ	'shrimp'
		*setʃ		tʃ'oʃ	'worm'
				sits'	'saliva'

Coon and Gallagher (2007) argue that the Chol restrictions are motivated by similarity avoidance, with roots containing highly similar consonant pairs being ill-formed. Their paper aims to develop a similarity metric which evaluates all non-occurring consonant pairs as more similar than all attested consonant pairs. The model of similarity Coon and Gallagher propose follows Tversky (1977) in assuming that certain features count more in the evaluation of similarity than others. According to this model, similarity is calculated by a formula that adds points for shared features and subtracts points for unshared features. Features are weighted such that some features count more than others.

The relative weights that Coon and Gallagher propose for the distinctive features of Chol are given below.

(154)   Chol feature weights (from Coon and Gallagher 2007: 34)

    ejective 16
    strident 8
    labial 6
    lateral 6
    nasal 4
    dorsal 2
    glottal 2
    coronal 2
    continuant 2
    voice 1
    anterior 1
    sonorant 1

According to Coon and Gallagher (2007), these feature weights were arrived a 'by starting all features at a value of 1, and increasing certain features until the desired pattern was achieved' (2007: 34). I will not give the details of Coon and Gallagher's similarity

calculation here.[32] It suffices to say that, because the feature [ejective] is weighted so

highly compared to other features, all ejective pairs are evaluated as highly similar. The

feature [strident] is also highly weighted, leading pairs of sibilants to be evaluated as

highly similar. The fact that [ejective] is weighted at 16, twice as high as the next most

heavily weighted feature, allows Coon and Gallagher to evaluate pairs of sibilants that

differ in the feature [ejective] as dissimilar. This accounts for the fact that, while non-

identical sibilant pairs are generally barred from cooccurring, sibilant pairs that differ in

[ejective] are permitted.

Like Frisch et al., Coon and Gallagher argue that similarity can be assigned a

numerical value from a calculation carried out over feature specifications. They differ

from Frisch et al. in using feature weighting that allows some features to be more

important in the similarity evaluation than others.

In discussing Frisch et al. (2004), I argued that, while the frequency of

consonantal cooccurrence in the Arabic lexicon may well be influenced by a gradient

---

[32] Coon and Gallagher give the following formula to calculate similarity (from Frisch 1996):

$$\text{similarity}(X, Y) = F[\theta f(X \cap Y) - \alpha f(X - Y) - \beta f(Y - X)],$$
where F is an increasing function,
θ, α, β are positive constants,
f is a measure function of the features,
$X \cap Y$ denotes the features shared by X and Y,
$X - Y$ denotes the features in X but not in Y, and
$Y - X$ denotes the features in Y but not in X.

However, a close examination of the similarity values they present shows that they cannot, in fact, be arrived at with this formula and the feature weights they propose. Instead, F and f of the above formula are omitted entirely in their calculations and the unshared features are divided by two. The resulting formula is as follows (where w_i are the feature weights):

$$\text{similarity}(X, Y) = w_s(X \cap Y) - 0.5(w_x(X - Y) + w_y(Y))$$

notion of similarity, these patterns need not be generated by the synchronic, phonological grammar. In the case of Coon and Gallagher's paper, the situation is different. The phenomena they seek to account for are essentially categorical facts about well-formedness. In Chol, forms with multiple ejectives are not merely underrepresented, but are entirely absent from the lexicon. The fact that forms with multiple ejectives are ungrammatical must be accounted for in a model of the grammar of Chol. However, it is unclear that this fact requires reference to a gradient notion of similarity, or in fact, any notion of similarity at all. In previous chapters, cooccurrence constraints on multiple ejectives have been analyzed as restrictions on the distribution of marked features. Multiple [ejective] features are ill-formed in Chol and no other features are relevant in determining the level of similarity that is banned. This categorical fact is derived in Coon and Gallagher's account by assigning a weight to the feature [ejective] in the similarity calculation that is twice as high as any other feature. It is therefore not possible for gradient similarity to play a role, as the assigned feature weighting ensures that differences in other feature specifications will not be important enough to override the overwhelming value of a shared [ejective] specification.

The Chol facts that provide the strongest arguments for feature weighting and numerical similarity values are those that involve the interaction of [ejective] and [strident]. As noted above, Chol has a general ban on multiple non-identical sibilants. According to Coon and Gallagher, non-identical sibilants that differ in [ejective] are exempt from this ban and cooccur freely. In their account, this pattern is a result of feature weighting. The feature [strident] is highly weighted compared to other features, making segment pairs that share the feature [strident] highly similar. The feature

[ejective], however, is weighted twice as highly as [strident] (with a value of 16 for [ejective] and 8 for [strident]). The importance of [ejective] leads sibilant pairs that differ in [ejective] specifications to be evaluated as non-similar, as they have differing values in an extremely highly weighted feature. Feature weights are significant for these facts as a ban on multiple sibilants that otherwise appears to be categorical can be overridden if differences in a highly weighted feature lead sibilants to be sufficiently dissimilar.

In this case, it is unclear that the facts are as straightforward as Coon and Gallagher claim. There is a process of anterior harmony in Chol. Sibilants that differ in [anterior] (i.e. *s…ʃ, *ts…tʃ, etc.) do not cooccur within roots and [anterior] harmony is also seen as active alternations in the shape of affixes. Coon and Gallagher's similarity metric does not account for this [anterior] harmony which they claim is a process of local spreading that is not motivated by similarity avoidance. [anterior] harmony will prevent sibilants differing in [anterior] from cooccurring within a form. Potential combinations of non-identical sibilants that agree in [anterior] include sibilants that differ in [continuant], sibilants that differ in [ejective] and sibilants that differ in both features. According to Coon and Gallagher, sibilants that differ in [ejective] or [ejective] and [continuant] may cooccur but sibilants that differ only in [continuant] may not.

An examination of Coon and Gallagher's database of Chol roots shows two roots containing sibilants that differ only in [continuant].[33] Coon and Gallagher consider these to be exceptions. There is only one root containing sibilants that differ only in [ejective],

---

[33] In the text of their article, Coon and Gallagher state that there is only one exception to generalization that sibilants differing only in [continuant] may not cooccur. Two roots of this type are listed in their database, however.

although Coon and Gallagher consider such combinations to be well-formed. Five roots contain sibilants that differ in both [ejective] and [continuant]. If we consider both the two instances of sibilant pairs differing only in [continuant] and the single instance of a sibilant pair differing only in [ejective] to be exceptions, the generalization governing the distribution of sibilants in Chol can be formulated as a ban on sibilants that differ in only a single marked and contrastive feature. Segments differing in both [continuant] and [ejective] may cooccur but segments that differ in only one of these features are barred from cooccurring.[34] Coon and Gallagher's position that sibilants differing in [ejective] are able to occur freely and hence have a low similarity value is not supported by the data.

Another significant problem with Coon and Gallagher's analysis concerns the distribution of homorganic segments that differ only in [ejective]. Constraints against homorganic plain/ejective pairs have been seen in discussions of Hausa, Aymara and Tzutujil. Coon and Gallagher do not discuss the possibility of any such constraints in Chol. The data show, however, that homorganic pairs differing only in [ejective] are rare. There is a single form containing a / tʃ'…tʃ/ sequence and three forms containing

---

[34]Coon and Gallagher give values for the expected number of occurrence values for each consonant pair and observed/expected values to demonstrate which combinations are overrepresented and which are underrepresented. I took their expected values for individual consonant combinations and combined them according to features resulting in the following values; total expected differing only in [ejective]: 6.48; total expected differing only in [continuant]: 6.73; total expected differing in both [ejective] and [continuant]: 6.69. I then calculated observed/expected values for these classes as follows: O/E differing only in ejective: 0.15; O/E differing only in continuant: 0.29; O/E differing in both ejective and continuant: 0.75. O/E values below 1 show that a given consonant pair is underrepresented and values above 1 show that a given consonant pair occurs more frequently than expected. The values given here suggest that pairs of sibilants differing in only [ejective] or only [continuant] are underrepresented and the number of forms containing sibilants differing in both features approaches that expected by a random distribution of segments. I have not evaluated the statistical significance of these values.

the sequence /k'…k/. Forms containing the sequence /k…k'/ are unattested as are combinations of /p'…p/, /t^j'…t^j/ and /ts'…ts/ in either order.   If Chol has a constraint against homorganic pairs that differ only in [ejective], a similarity-based analysis would require homorganic plain/ejective pairs to be evaluated as highly similar. But Coon and Gallagher's feature weightings, which accord enormous importance to [ejective] in the evaluation of similarity, leave all ejective/plain pairs as highly dissimilar. Their feature weights are unable to account for this aspect of the patterning of ejectives in Chol.

The facts of Chol do not motivate a notion of gradient similarity or weighted feature values. The feature [ejective] plays a more important role than other features in determining consonant cooccurrence patterns, not because [ejective] contributes greatly to a gradient similarity evaluation, but because a constraint in the grammar specifically militates against multiple ejective segments. The patterning of sibilants is somewhat more ambiguous but appears to refer to the notion of global similarity proposed in chapter 4. Sibilants that differ in a single marked and contrastive feature are barred from cooccurring.

6.3 Perceptual Similarity

Coon and Gallagher's use of weighted features is ostensibly grounded in differences in acoustic salience between features. The feature [ejective] is argued to be acoustically salient because it involves a loud release burst and the feature [strident] is argued to be acoustically salient because it involves intense, high-frequency noise (2008: 34). Coon and Gallagher do not provide a method or theory for how acoustic or perceptual saliency maps to differential weighting of distinctive features. Nonetheless, their claim that acoustic saliency affects the relative similarity evaluations of segment

pairs is consistent with proposals that perceptual similarity plays a crucial role in determining input-output mappings (Steriade 2001a, b).

Steriade (2001a) examines typological predictions of OT grammars. In OT, phonological alternations, and indeed, any differences between inputs and outputs, are motivated by markedness constraints. Violations of faithfulness can only be optimal if they result in an improvement in the markedness of the output form (see Moreton 1996[1999]). For any given markedness violation incurred by a faithful candidate, a number of possible repairs will result in an improvement of markedness. But crosslinguistically, only certain repairs are common, with other repairs being rare and still others being completely unattested. Free ranking of OT constraints predicts a wider range of repairs than what is attested in crosslingusitic studies. This is referred to as the Too-Many-Solutions problem. Steriade (2001a) proposes that repairs of marked structures must maintain maximal similarity between input and output forms. That is, a marked structure will be repaired by mapping to the output candidate that satisfies the markedness constraint and is most perceptually similar to the input. The maintenance of similarity between inputs and outputs is ensured by a fixed ranking of faithfulness constraints with constraints demanding faithfulness in perceptually salient aspects of sound structure ranked above constraints demanding faithfulness in those that are less perceptually salient. This position is termed the P-map hypothesis.

While Steriade (2001a) does not propose a theory of similarity or a definition of perceptual similarity, she does allow for the possibility that similarity is evaluated without any reference to phonological features, possibly through confusability measures. She claims that, even if confusability measures do not turn out to be an appropriate

measure of similarity, similarity evaluations must be based on 'a calculus of perceptual correlates to contrasts, rather than on a calculus of distinctive features' (2001b: 236). Steriade's position represents the most radical departure from the notion of similarity argued for in this thesis. Frisch et al. argue for numerical similarity values based on a calculation of shared natural classes that are dependent on feature specifications and Coon and Gallagher argue for weighted features. Steriade, however, proposes that reference to phonological features is unnecessary in determining perceptual similarity.

The notion of perceptual similarity and the P-map hypothesis of Steriade (2001) have been used in analyses of crosslinguistic patterning of contextual neutralization (Steriade 2001a) and place assimilation (Steriade 2001b) as well as studies of loanword phonology (Kawahara 2006) and studies of half-rhymes in verse (Steriade 2004, Kawahara 2007). Kawahara (2006) proposes an analysis of geminate devoicing in the loanword vocabulary of Japanese. He provides experimental evidence that the feature [voice] is less perceptible in geminates than in singletons and argues that the phonological patterning of geminates in borrowed vocabulary items derives from the faithfulness ranking IDENT[voice]$_{singleton}$ over IDENT[voice]$_{geminate}$. This ranking is consistent with the P-map hypothesis as voicing in singletons is more perceptible than voicing in geminates and the faithfulnesss ranking reflects this difference in perceptual salience. As Kawahara notes, however, his study does not provide evidence for the relative perceptibility of different features, only for the relative perceptibility of the single feature [voice] in different contexts. Furthermore, while Kawahara clearly demonstrates differences in the perceptibility of voicing in singletons and geminates, it does not necessarily follow that perceptual factors drive the patterning of loanword adaptation.

Rice (2006) provides a phonological account of devoicing in loanword vocabulary. In the native vocabulary of Japanese, a voicing contrast is present in singletons but not in geminates. Rice argues that the variable devoicing of geminates in loanword vocabulary may result from different repair strategies adopted by speakers when faced with a contrast that is absent in the native phonology.

Kawahara himself points out that differences between the repairs of voiced geminates in loanword vocabulary and native vocabulary undermine Steriade's (2001) claims about the relative perceptibility of [voice] and [nasal]. In native vocabulary items, potential voiced geminates are repaired through nasalization of the initial member of the geminate whereas in loanword items geminates undergo devoicing. If voicing is generally less perceptible than nasality, the P-map hypothesis predicts that voiced geminates will always be repaired through changes in voicing as opposed to changes in nasality.

Such different repair strategies found within and across languages highlight problems in evaluating the validity of the P-map hypothesis. Claims about the relative perceptibility of different features vary between works. For example, Coon and Gallagher give the feature [sonorant] a weighted value of 1, the lowest of any feature they consider. This suggests that [sonorant] is not a highly perceptible feature. However, Frisch et al. suggest that their similarity metric would provide a better fit for the cooccurrence restrictions of Arabic if the feature [sonorant] could be accorded a greater significance relative to other features in the evaluation of similarity (2004: 204). Similarly, Coetzee and Pater (to appear) demonstrate that the feature [voice] plays a more significant role in determining cooccurrence restrictions in Muna than in Arabic.

A lack of consensus on the relative perceptibility of various features is not necessarily a problem for Steriade's conception of perceptual similarity as the role of phonological features in computing similarity is minimized in her approach. Instead, similarity may be measured over some direct perceptual measure such as confusability rates or perceptual cues that vary from context to context and are not consistent for all instances of a phonological feature. However, if phonological features are excluded, it is not clear exactly what an appropriate measure of perceptual similarity should be based on. Evaluation of different methods for determining similarity is carried out in experimental work by Bailey and Hahn (2005). In their experiments, subjects were presented with two pairs of nonce words that differed by only a single phoneme and were then asked to choose one pair as most similar. The results of these experiments were then compared with perceptual similarity metrics based on confusability data published in previous literature.[35] These include similarity measures based on short-term memory confusions, speech errors and confusability under varying signal-to-noise ratios. Each confusability measure was tested for its ability to predict the similarity ratings in Bailey and Hahn's experiments. In addition, two similarity measures based on feature specifications were also tested; a simple feature counting comparison using features for place, manner and voicing and a similarity measure based on Frisch's (1996) natural classes model.

---

[35] The perceptual similarity metrics in Bailey and Hahn (2005) are based on the following sources; Wicklegren's (1966) study of consonant confusabilities in a serial recall task, Shattuck-Hufnagel and Klatt's (1979) study of production errors in spontaneous speech and Luce's (1986) study of consonant identification errors under varying signal-to-noise ratios.

Bailey and Hahn's (2005) results show the simple feature counting metric as most successful in predicting the similarity ratings. Furthermore, each similarity metric based on a particular set of confusability data, for example speech errors, was relatively unsuccessful at predicting results of other types of confusability data, such as confusability under varying signal-to-noise ratios. Both feature-based metrics were significantly more successful in this respect. Bailey and Hahn's results suggest that any empirical measure of perceptual similarity based on confusability may have limited relevance to general evaluations of segment similarity.

Bailey and Hahn's study is based on experimental tasks and does not provide direct evidence on the role of similarity in the patterning of phonological processes. Evidence against the claim that input-output mappings are constrained by perceptual similarity is presented in Kabak and Idsardi (2004). Their study deals with perception of non-native stimuli, specifically Korean listeners' perception of English consonant clusters. Consonant clusters like [l.n] and [k.n] are unattested in native Korean forms and are repaired by phonological processes of lateralization and nasalization. Nonetheless, these clusters were clearly perceptible to Korean listeners who discriminated between [l.n] and [k.n] and [l.l] and [ŋ.n], their likely output forms in Korean. The Korean listeners' ability to discriminate the clusters was comparable to that of English listeners for whom all the presented clusters are well-formed. The data from this task suggests that the input and output of lateralization and nasalization are highly discriminable, and hence not perceptually similar. This is contrary to the predictions of the P-map hypothesis which requires all input-output correspondents to be maximally perceptually similar.

The work summarized here suggests that perceptual similarity is not required between underlying representations and the output of phonological processes. Also, confusability data are not a reliable predictor of similarity judgments and different types of confusability data do not yield consistent similarity results. Furthermore, to the extent that confusability data are able to predict phonological patterning and similarity judgments, they nonetheless lack explanatory power as they do not address the question of why some segments are more confusable than others. As Bailey and Hahn argue 'theoretically derived, featural measures are not just practically useful metrics – they offer an explanation of the similarity relationships obtained' (2005: 356).

6.4 Summary

The literature reviewed in this chapter has argued for fine-grained similarity metrics that are incompatible with the feature-based similarity assessments advocated in this thesis. The similarity metric in Frisch et al. has been influential in analyses of consonant harmony, most importantly being adopted in Rose and Walker's (2004) typological study of consonant harmony systems. I have argued elsewhere in this thesis that the metric of Frisch et al. is not capable of accurately determining segments that participate in consonant harmony processes. In this chapter, I have argued that the gradient OCP constraint proposed in Frisch et al. constitutes a significant complication in the model of the phonological grammar and, further, that the statistical generalizations motivating this constraint can be accounted for through diachronic and perceptual factors.

Coon and Gallagher (2007) also argue for a calculation of numerical values of similarity based on weighted features with feature weights being influenced by acoustic salience. I show here that their similarity metric is unmotivated and unnecessary in

accounting for the cooccurrence restrictions of Chol. Steriade (2001a, b) and subsequent work also argues for the significance of perceptual salience in determining relative similarity of segment pairs. According to the P-map hypothesis, perceptual similarity influences not only statistical generalizations about the lexicon but also possible input/output mappings and the ranking of faithfulness constraints in the grammar. There is no clear proposal, however, for how perceptual similarity is to be evaluated. Claims about the relevant salience of distinctive features vary between works and non-feature-based measures, such as confusability rates, also fail to provide consistent evaluations of relative similarity.

In summary, none of the works reviewed in this chapter have adduced evidence that contradicts the claims made throughout this thesis, that similarity is evaluated over contrastive feature specifications and that no numerical evaluation of similarity is necessary in order to account for participating segments in consonant harmony processes. Given the theory of the contrastive hierarchy, the notion of similarity relevant in determining consonant harmony patterns can be evaluated over contrastive feature specifications. Segments that interact in consonant harmony can be classified as members of a natural class (as in the cases in Chapter 3) or can be defined as differing in only a single marked and contrastive feature (as in the cases in Chapter 4).

CHAPTER 7
CONCLUSION

This thesis has argued that when similarity is relevant for determining interacting segments in consonant harmony processes it is evaluated over contrastive feature specifications. Two definitions of similarity have been proposed to account for two sets of cases. In one set of consonant harmony processes, interacting segments are similar in the sense that they constitute the natural class of segments contrastively specified in the harmonic feature. In another set of cases, participating segments must be similar according to the following definition; they must differ in only a single marked and contrastive feature specification. These definitions of similarity counter previous proposals in the consonant harmony literature to the effect that segmental similarity is encoded in universal constraint rankings (Hansson 2001), that similarity is a fine-grained dimension determined by dividing the shared natural classes of a segment pair by the shared and unshared natural classes (Frisch et al. 2004, Rose and Walker 2004) and that similarity is determined over acoustic and auditory properties (MacEachern 1999).

This chapter will review some of the major claims of the thesis as well as some outstanding issues and avenues for future research.

7.1 Contrast, Inventories and Crosslinguistic Variation

The analyses of consonant harmony processes presented here have shown interacting segments to be similar, with similarity evaluated over contrastive feature specifications. I have argued that contrastive features are determined in accordance with the theory of the contrastive hierarchy (Dresher 2003, forthcoming). Within this

framework, features are hierarchically ordered with some features taking scope over others. Features must be assigned in the order of a language-specific hierarchy until each segment in a given inventory is uniquely specified. This theory of feature specification allows for the inventory to influence featural representations which in turn influence segmental similarity. The fact that the hierarchy of features may vary from language to language allows feature specifications to vary, even between languages with similar inventories. When applied to the study of similarity, these aspects of the contrastive hierarchy stand in direct contradiction to claims that similarity is evaluated over universal, phonetic properties.

The influence of inventory shape on featural specifications and resulting similarity relations is demonstrated in a number of consonant harmony cases analyzed here. In cases with asymmetric inventories, a contrast that is present throughout much of the inventory may be suspended where there is a gap in the inventory. This is the case in Bumo Izon and Kalabari Ijo (presented in Chapter 3) where the velar and labiovelar stops fail to participate in implosive harmony. These are just the places of articulation where there are gaps in the inventory. Other places have pairs of segments that differ only in that one is a voiced pulmonic stop and one is implosive. At the velar and labiovelar places, a single voiced plosive is present. This allows for a hierarchy of features in which the feature distinguishing implosives from pulmonics is not contrastive for the velar and labiovelar series. The velars and labiovelars therefore fail to participate in harmony because they are not contrastively specified in the harmonic feature. This analysis crucially relies on inventory shape and cannot be accounted for through universal similarity measures. There is nothing in the surface phonetics of the velar and labiovelar

that make them less similar to other voiced plosives than other voiced plosives are to one another. It is the shape of the inventory that affects their contrastive specifications. Other cases reviewed here that demonstrate the influence of the inventory on the patterning of consonant harmony include dental harmony in Dholuo and ejective harmony in Chaha.

The hierarchy of features may vary from language to language, allowing different patterning of consonant harmony processes, even in languages with similar inventories. In the case of dental harmony in Anywa and Dholuo, both languages have a dental/alveolar contrast between voiced and voiceless stops but only a single, alveolar nasal. In Dholuo, the nasal fails to participate in dental harmony. In Anywa, on the other hand, the nasal does participate in dental harmony and dental nasals surface allophonically in harmonic contexts. The contrastive hierarchy analysis presented here accounts for this difference in the two languages through a different ordering of contrastive features. In Dholuo, the feature [nasal] is ordered before the feature [distributed]. The alveolar nasal is thus uniquely specified before the feature [distributed] is added and cannot acquire contrastive specification in the harmonic feature. In Anywa, the feature ordering is the reverse. [distributed] is highly ordered and is therefore contrastive for all coronals, even the nasal. The nasal in Anywa is therefore contrastively specified in the harmonic feature and must be subject to constraints on distinct specifications of [distributed] within a morpheme. Other cases that show the significance of different feature orderings between languages include differences in the order of [voice] and [constricted glottis] in Tzutujil and Hausa as compared to Kera and Ngizim.

The patterning of consonant harmony in these cases shows that contrastive specifications influence similarity evaluations. The fact that pairs of segments that share surface phonetic properties vary in their behaviour across languages provides evidence that surface phonetic properties cannot determine which segments will participate in a consonant harmony process. Rather, abstract phonological representations enter into the similarity evaluation. These representations are influenced by inventory shape and may vary from language to language.

7.2 Mechanisms

The contributions this work makes to the study of consonant harmony systems are largely representational. Following claims that similarity is crucial in motivating consonant harmony processes and determining interacting segments (Hansson 2001, Rose and Walker 2004), I have proposed specific definitions of similarity and argued that similarity is evaluated over contrastive feature specifications. This work differs in focus from work by Hansson (2001) and Rose and Walker (2004) which focus largely on the mechanisms of consonant harmony. Specifically, both Hansson (2001) and Rose and Walker (2004) argue that consonant harmony is mediated through correspondence relations between output segments.

Despite the representational focus of this thesis, some specific claims regarding the operational mechanisms of consonant harmony have been made. Most significantly, Chapter 5 demonstrates that contrastive specifications can be achieved within the framework of OT through ranking of markedness and faithfulness constraints. Although representational assumptions are, in principle, orthogonal to operational ones, work in OT has largely rejected representational theories such as contrastive specification,

underspecification and feature geometry. This rejection follows from the principle of Richness of the Base which states that there are no language-particular restrictions on input forms. Analyses following Richness of the Base must account for all phonological generalizations through the interaction of constraints on output forms. The algorithm for converting a contrastive hierarchy to a constraint ranking proposed in Chapter 5 demonstrates that contrastively specified representations can be achieved in OT and the principle of Richness of the Base can be upheld, if a stratal version of Optimality Theory is assumed.

Constraints motivating harmony have also been proposed. In the natural classes harmony cases analyzed in Chapter 3, I argued that harmony is motivated by constraints of the form *$[\alpha F]$ $[-\alpha F]_{\text{Domain}}$. Like all constraints used to motivate phonological processes in this work, this constraint type refers to contrastive feature values. Constraints of this form ban the cooccurrence of distinct, contrastive specifications of the harmonic feature within some domain such as the root or the word. OT analyses of these cases were not provided. Such analyses are quite straightforward, however, with harmony accounted for through a simple ranking of *$[\alpha F]$ $[-\alpha F]_{\text{Domain}}$ over faithfulness constraints requiring input/output identity in the harmonic feature. In order to ensure that only distinct, *contrastive* features are penalized, the ranking motivating harmony must be applied to outputs of an earlier evaluation which results in contrastive specifications (as discussed in Chapter 5).

In the analysis of Bolivian and Peruvian Aymara, harmony was motivated, not by a constraint banning distinct specifications in the harmonic feature, but by the constraint BEIDENTICAL (MacEachern 1999). BEIDENTICAL requires output segments to be

identical to one another in all feature specifications. Ranking of BEIDENTICAL with respect to featural faithfulness constraints results in harmony only between segments that are highly similar. More specifically, BEIDENTICAL is ranked below constraints requiring input/output faithfulness in all features, except for the harmonic feature. This results in harmony only between segments that are already identical in all other feature specifications.

7.3 Identity or Global Similarity?

A certain ambiguity regarding the appropriate definition of global similarity has been introduced in Chapters 4 and 5. In Chapter 4, I demonstrate that, for a range of cases which cannot be analyzed as harmony between all members of a natural class, segments participating in harmony are similar in that they differ in only a single marked and contrastive feature specification. In Chapter 5, I provide an analysis of laryngeal harmony in Bolivian and Peruvian Aymara using the constraint BEIDENTICAL. The fact that the constraint BEIDENTICAL is able to motivate harmony in Aymara allows for the possibility that identity is the relevant notion referred to by the grammar in these cases and not similarity at all.

The laryngeal harmony processes in Tzutujil, Hausa and Aymara can all be analyzed using only ranking of BEIDENTICAL and featural faithfulness constraints. The fact that harmony is limited to highly similar segments falls out from the relative ranking of these constraints and no formal definition of similarity is required in the analysis. There are, however, two cases reviewed in Chapter 4 for which a formal definition of similarity is crucial. These are the restrictions on homorganic segments in Ngbaka and the restrictions on coronal sonorants in Hausa.

Like the laryngeal harmony systems of Tzutujil, Hausa and Aymara, these processes result in total, segmental identity. However, these cases involve multiple harmonic features and segments that differ in more than one of these features do not interact. In the case of Ngbaka, homorganic voiced and voiceless stops may not cooccur, homorganic voiced and prenasalized stops may not cooccur and homorganic prenasalized and nasal stops may not cooccur. In Chapter 4, I proposed the following set of marked and contrastive features for Ngbaka labials and showed that segments barred from cooccurring may not differ in more than a single marked and contrastive feature specification.

(155)   Ngbaka labials   (repeated from Chapter 4)

p	b	ᵐb	m
[+laryngeal]		[+sv]	[+sv]
			[+nasal]

An analysis using only the relative ranking of the constraint BEIDENTICAL and featural faithfulness constraints will not be able to account for the consonant harmony patterns of Ngbaka. If I follow the analysis of Aymara provided in Chapter 5, harmony between /p/ and /b/ will require ranking BEIDENTICAL above IDENT[laryngeal].

(156)   Ngbaka

	pab	BEIDENTICAL	IDENT[lar]
a)	pab	*!	
b) ☞	pap		*

Harmony between /b/ and /ᵐb/ will also require ranking of BEIDENTICAL above IDENT[sonorant voice].

(157)   Ngbaka

baᵐb	BᴇIᴅᴇɴᴛɪᴄᴀʟ	Iᴅᴇɴᴛ[sv]
a) baᵐb	*!	
b) ☞ᵐbaᵐb		*

To this point, we have seen that an analysis along the lines laid out for Aymara would require BᴇIᴅᴇɴᴛɪᴄᴀʟ to be ranked above both Iᴅᴇɴᴛ[laryngeal] and Iᴅᴇɴᴛ[sv] in order to account for the cooccurrence constraints against homorganic voiced and voiceless stops and homorganic voiced and prenasalized stops. However, voiceless segments can occur freely with prenasalized stops. The ranking motivated for the cooccurrence restrictions discussed above incorrectly predicts that voiceless and prenasalized stops should not cooccur. This is demonstrated in the tableau below.

(158)   Ngbaka

paᵐb	BᴇIᴅᴇɴᴛɪᴄᴀʟ	Iᴅᴇɴᴛ[sv]	Iᴅᴇɴᴛ[lar]
a) paᵐb	*!		
b) ☹ ᵐbaᵐb		*	*

In the above tableau, the faithful candidate, and attested form, is ruled out by a violation of BᴇIᴅᴇɴᴛɪᴄᴀʟ. Candidate (b) is selected as optimal. Although it violates both Iᴅᴇɴᴛ[sv] and Iᴅᴇɴᴛ[laryngeal], these constraints must be ranked below BᴇIᴅᴇɴᴛɪᴄᴀʟ in order to account for cases where harmony does apply.

The situation in Ngbaka contrasts with that of Bolivian Aymara. In both Peruvian and Bolivian Aymara, homorganic aspirates and ejectives may not cooccur. In Peruvian Aymara, aspirates and ejectives are generally barred from coccurring, so no special analysis referring to homorganicity, identity or similarity is necessary to account for this fact. In Bolivian Aymara, however, aspirates may occur with ejectives in the general

case. The impossibility of cooccurring homorganic ejectives and aspirates must therefore

be analyzed as laryngeal harmony, parallel to the ban on homorganic plain stops and

ejectives and homorganic plain stops and aspirates. The analysis provided in Chapter 5

accounts for this pattern straightforwardly, through relative ranking of BEIDENTICAL and

faithfulness constraints.[36]

(159)   Aymara

	p'apʰa	BEIDENTICAL	IDENT[cg]	IDENT[sg]
a)	p'apʰa	*!		
b) ☞	p'ap'a		*	*

Candidate (b) is optimal. In this candidate, the aspirated segment in the input

corresponds to an ejective segment in the output. The [+sg] specification of the input

corresponds to a [-sg] specification in the output leading to a violation of IDENT[sg].

Similarly, the [-cg] specification of the input corresponds to a [+cg] specification in the

output leading to a violation of IDENT[cg]. In the case of Bolivian Aymara, however, the

relative ranking of BEIDENTICAL and featural faithfulness constraints motivated to

account for harmony between segments that differ in only a single feature is sufficient to

account for the patterning between segments that differ in more than one feature. The

fact that the harmonic candidate violates two faithfulness constraints is not relevant to the

determination of optimality. The harmonic candidate, and attested form, satisfies highly

ranked BEIDENTICAL and is selected as optimal.

---

[36] This tableau is simplified with respect to the analysis in Chapter 5. In the full analysis, faithfulness
constraints referring to features must be MAX constraints requiring the preservation of positive feature
values rather than IDENT constraints. Harmony also requires multiple linking of features in output forms.
These complications are needed to account for ordering restrictions and the interaction of harmony and
constraints on multiple, laryngeally marked segments in Aymara. They are not directly relevant to the
comparison with Ngbaka and are hence omitted here.

In Ngbaka, segments that differ in a single potentially harmonic feature are barred from cooccurring but segments that differ in more than one such feature cooccur freely. In Bolivian Aymara, segments that differ only in harmonic features, even if they differ in more than one such feature, are barred from cooccurring and subject to harmony. The difficulty in accounting for the Ngbaka pattern with BEIDENTICAL suggests that, in Ngbaka, it is not pressure towards identity that motivates harmony, but rather a ban on similarity. In order to account for the pattern of Ngbaka, a markedness constraint penalizing segment pairs that differ in only a single marked and contrastive feature is necessary. This constraint must be ranked above faithfulness constraints referring to the harmonic features; [laryngeal], [sonorant voice] and [nasal]. I do not propose a formal definition of this constraint here.

Of the cases classed as global similarity cases in Chapters 4 and 5, laryngeal harmony in Hausa and Tzutujil pattern with the Aymara dialects. These cases can all be accounted for through relative ranking of BEIDENTICAL and featural faithfulness constraints. The restrictions on coronal sonorants in Hausa pattern with Ngbaka. These cases require reference to a constraint against segments that differ in only a single marked and contrastive feature. The differences between these types of cases suggest that three types of similarity are necessary to account for the full range of consonant harmony patterns: (1) natural classes, (2) identity, and (3) near identity, with near identity being defined as differing in only a single marked and contrastive feature. The concepts of natural class and identity are basic notions in phonological analysis required for the account of a wide range of phenomena outside the domain of consonant harmony. Only

the concept of near identity as differing in only a single marked and contrastive feature is a true definition of similarity that cannot be reduced to some more basic notion.

7.4 Concluding Remarks

Through analyses of a range of consonant harmony processes, I have argued that not all references to similarity in the consonant harmony literature are making reference to the same thing. This observation, however, has not required the positing of a plethora of distinct definitions of similarity. Rather, I have shown that a number of consonant harmony cases do not require constraints that refer to similarity at all. Instead, the notions of identity and natural class, basic notions that are central to analyses of a wide range of phonological processes, are capable of accounting for a number of consonant harmony systems. In those cases that require reference to a notion of similarity that cannot be reduced to natural class or identity, segment pairs can be defined as similar if they differ in only a single marked and contrastive feature. In all cases, whether the relevant notion in determining interacting segments is the notion of natural class, the notion of identity or the notion of similarity, these categories are determined on the basis of contrastive feature specifications.

The significance of similarity in phonological patterning goes beyond analyses of consonant harmony processes. Similarity has been argued to play a crucial role in cluster simplification, local assimilation and dissimilation. In Steriade's (2001) work on the P-map hypothesis, similarity influences the structure of the grammar itself, leading to fixed rankings of faithfulness constraints and determining the relative well-formednesss of input-output mappings. Given the repeated reference to similarity in wide-ranging works

of phonological theory and analysis, the development of specific proposals for similarity

metrics that can be evaluated is particularly important.

The typology of consonant harmony processes has provided strong evidence for

the significance of similarity in shaping phonological patterning. The success of

similarity measures based on contrastive feature specifications in accounting for the

consonant harmony processes analyzed here suggests that these similarity measures may

prove promising in the study of other phonological processes that have been argued to be

influenced by similarity.

REFERENCES

Andersen, Torben. 1988. Consonant alternation in the verbal morphology of Päri. *Afrika und Übersee* 71: 63-113.

Andersen, Torben. 1999. Consonant alternation in the verbal morphology of Mayak (Northern Burun). *Afrika und Übersee* 82: 65-97.

Andersen, Torben. 2000. Anywa and Päri I: A phonological and morphophonological comparison. *Afrika und Übersee* 82.

Anttila, Arto. 1997. Deriving variation from grammar. In Frans Hinskens, Roeland van Hout and Leo Wetzels, eds., *Variation, Change and Phonological Theory*, 35-68. Amsterdam: John Benjamins.

Anttila, Arto. to appear. Gradient phonotactics and the Complexity Hypothesis. *Natural Language and Linguistic Theory*.

Anttila, Arto and Young-mee Yu Cho. 1998. Variation and change in Optimality Theory. *Lingua* 104: 31-56.

Applegate, Richard B. 1972. Ineseño Chumash Grammar. Doctoral dissertation, University of California, Berkeley.

Archangeli, Diana. 1984. Underspecification in Yawelmani phonology and morphology. Doctoral dissertation, MIT.

Archangeli, Diana. 1988. Aspects of underspecification theory. *Phonology* 5: 183-207.

Avery, Peter. 1996. The representation of voicing contrasts. Doctoral dissertation, University of Toronto.

Bailey, Todd and Ulrike Hahn. 2005. Phoneme similarity and confusability. *Journal of Memory and Language* 52: 339-362.

Bakovic, Eric. 2000. Harmony, dominance and control. Doctoral dissertation, Rutgers University.

Bakovic, Eric. 2005. Antigemination, assimilation and the determination of identity. *Phonology* 22(3): 279-315.

Banksira, Degif Petros. 2000. *Sound mutations: The morphophonology of Chaha*. Philadelphia/Amsterdam: John Benjamins.

Banksira, Degif Petros and Michael Kenstowicz. 1999. Reduplicative identity in Chaha. *Linguistic Inquiry* 30(4): 573-585.

Beckman, Jill. 1998. Positional faithfulness. Doctoral dissertation, University of Massachusetts.

Berg, Thomas. 1998. *Linguistic Structure and Change: An Explanation from Language Processing.* Oxford: Clarendon Press.

Berkley, Deborah. 2000. Gradient OCP Effects. Doctoral dissertation, Northwestern University.

Bermúdez-Otero, Ricardo. 2003. The acquisition of phonological opacity. In Jennifer Spenader, Anders Eriksson, and Östen Dahl, eds., *Variation within Optimality Theory: Proceedings of the Stockholm Conference on Variation within Optimality Theory,* 25-36. Stockholm: Department of Linguistics, Stockholm University.

Bermúdez-Otero, Ricardo. forthcoming. *Stratal Optimality Theory.* Oxford: Oxford University Press.

Blevins, Juliette. 2004. *Evolutionary Phonology: The Emergence of Sound Patterns.* Cambridge: Cambridge University Press.

Boersma, Paul. 1998. *Functional Phonology.* The Hague: Holland Academic Graphics.

Broe, Michael. 1993. Specification theory and Ngbaka cooccurrence constraints. Ms. Northwestern University.

Broe, Michael. 1993. Specification theory: the treatment of redundancy in generative phonology. Doctoral dissertation, Edinburgh.

Calabrese, Andrea. 1995. A constraint-based theory of phonological markedness and simplification procedures. *Linguistic Inquiry* 26: 373-463.

Calabrese, Andrea. 2005. *Markedness and economy in a derivational model of phonology.* Berlin: Mouton de Gruyter.

Campbell, Lyle. 1997. *American Indian Languages: the historical linguistics of Native America.* Oxford: Oxford University Press.

Causley, Tricia. 1999. Complexity and markedness in Optimality Theory. Doctoral dissertation, University of Toronto.

CBOLD = *Comparative Bantu On-Line Dictionary*, lexicographic database accessible at <http://www.ddl.ish-lyon.cnrs.fr/bdd/cbold/>

Chomsky, Noam and Morris Halle. 1968. *The Sound Pattern of English.* New York: Harper and Row.

Clements, G. N. 1985. The geometry of phonological features. *Phonology Yearbook* 2: 225-252.

Clements, G. N. and Elizabeth Hume. 1995. The internal organization of speech sounds. In John Goldsmith, ed., *The Handbook of Phonological Theory,* 245-306. Oxford: Blackwell.

Coetzee, Andries. 2004. What it means to be a loser: non-optimal candidates in Optimality Theory. Doctoral dissertation, University of Massachusetts.

Coetzee, Andries. 2008. Grammaticality and ungrammaticality in phonology. *Language* 84(2): 218-257.

Coetzee, Andries. to appear. Grammar is both categorical and gradient. In Steven Parker, ed., *Phonological Argumentation: Essays on Evidence and Motivation*. London: Equinox Publishers.

Coetzee, Andries and Joe Pater. to appear. Weighted constraints and gradient restrictions on place cooccurrence in Muna and Arabic. *Natural Language and Linguistic Theory.*

Cole, J. and L. Trigo. 1989. Parasitic harmony. In van der Hulst, H. and Smith, N. eds., *Features, Segmental Structure and Harmony Processes*, 19-39. Dordrecht: Foris.

Coon, Jessica and Gillian Gallagher. 2007. Similarity and correspondence in Chol roots. Ms. MIT.

Côté, Marie-Hélène. 2000. Consonant cluster phonotactics: a perception-based approach. Ph. D. dissertation, MIT.

Côté, Marie-Hélène. 2004. Syntagmatic distinctness in consonant deletion. *Phonology* 21: 1-41.

Dayley, J. 1985. *Tzutujil Grammar*. Berkeley: University of California Press.

De Lucca, Manuel. 1987. *Diccionario aymara-castellano castellano-aymara*. La Paz, Cochabamba: Editorial Los Amigos del Libro.

Demolin, D. 1995. The phonetics and phonology of glottalized consonants in Lendu. In Bruce Connel and Amalia Arvaniti eds., *Papers in Laboratory Phonology IV*. Cambridge: Cambridge University Press.

Deza Galindo, Juan Francisco. 1989. *Diccionario Aymara-castellano castellano-aymara*. Lima, Peru: Consejo Nacional de Ciencas y Tecnologica.

Dresher, Elan. 2001. The logic of contrast. Ms. University of Toronto.

Dresher, Elan. 2003. Contrast and asymmetry in inventories. in A.M. di Sciullo, ed. *Asymmetry in Grammar: Morphology, Phonology, Acquisition,* 239-257. Amsterdam: John Benjamins.

Dresher, Elan. 2004. On the acquisition of phonological contrasts. In Jacqueline van Kampen and Sergio Baauw eds., *Proceedings of GALA 2003, Volume 1,* 27-46. Utrecht: LOT.

Dresher, Elan. forthcoming. *The Contrastive Hierarchy in Phonology*. Cambridge: Cambridge University Press.

Dresher, Elan and Xi Zhang. 2004. Contrast in Manchu vowel systems. In C. Naher, ed., *Proceedings of the First International Conference on Manchu-Tungus Studies, Volume 2: Trends in Tungusic and Siberian Linguistics*. Weisbaden: Harrassowitz.

Efere, Emmanuel. 2001. The pitch system of the Bumo dialect of Izon. *Current Research on African Languages and Linguistics.* Suzanne Gessner, Sunyoung Oh, and Kayono Shiobara eds. *UBC Working Papers in Linguistics* 4.

Fleischhacker, H. 2005. Similarity in phonology: Evidence from reduplication and loan adaptation, Ph. D. dissertation, University of California, Los Angeles.

Fordyce, James. 1980. On the nature of glottalic and laryngealized consonant and vowel systems. *UCLA Working Papers in Phonetics* 50: 120-154.

Frisch Stefan, Janet Pierrehumbert and Michael Broe. 2004. Similarity Avoidance and the OCP. *Natural Language and Linguistic Theory* 22: 179-228.

Frisch, Stefan and Bushra Zawaydeh. 2001. The psychological reality of OCP-place in Arabic, *Language* 77: 91–106.

Frisch, Stefan. 1996. Similarity and frequency in phonology. Doctoral dissertation. Northwestern University.

Gafos, Adamantios. 1996. The articulatory basis of locality in phonology. Doctoral dissertation, John Hopkins.

Gilley, Leoma. 1992. *An Autosegmental Approach to Shilluk Phonology.* Dallas, TX: The Summer Institute of Linguistics at the University of Texas at Arlington.

Goldsmith, John. 1976. Autosegmental phonology. Doctoral dissertation, MIT.

Gordon, Matthew. 2007. Functionalism in phonology. In Paul de Lacy ed., *The Cambridge Handbook of Phonology*, 61-77. Cambridge: Cambridge University Press.

Greenberg, Joseph. 1970. Some generalizations concerning glottalic consonants, especially implosives. *International Journal of American Linguistics* 36: 123-145.

Hall, Daniel Currie. 2007. The role and representation of contrast in phonological theory. Doctoral dissertation, University of Toronto.

Halle, Morris. 1959. *The sound pattern of Russian: A linguistic and acoustical investigation*. The Hague: Mouton.

Hansson, Gunnar. 2001. Theoretical and typological Issues in consonant harmony. Doctoral dissertation, University of California, Berkeley.

Hansson, Gunnar. 2004. Long-distance voicing agreement: an evolutionary perspective. *BLS 30: Proceedings of the 30th Annual Meeting of the Berkeley Linguistics Society*, ed. by M. Ettlinger, N. Fleischer and M. Park-Doob, pp. 130-141. Berkeley: Berkeley Linguistics Society.

Hansson, Gunnar. 2007a. Blocking effects in agreement by correspondence. *Linguistic Inquiry* 38(2): 395-409.

Hansson, Gunnar. 2007b. On the evolution of consonant harmony: the case of secondary articulation agreement. *Phonology* 24(1): 77-120.

Harry, Otelemate. 2004. *Aspects of the tonal system of Kalabari-Ijo*. Stanford: CSLI.

Hayes, Bruce, Robert Kirchner and Donca Steriade, eds. 2004. *Phonetically based phonology*. Cambridge: Cambridge University Press.

Herd, Jonathon. 2005. Loanword adaptation and the evaluation of similarity. *Toronto Working Papers in Linguistics* 24: 65-116.

Ito, Junko, Armin Mester and Jaye Padgett. 1995. Licensing and redundancy: Underspecification in Optimality Theory. *Linguistic Inquiry* 26: 571-614.

Jackobson, Roman and Morris Halle. 1956. *Fundamentals of Language*. The Hague: Mouton &;Co.

Jackobson, Roman, Gunnar Fant and Morris Halle. 1952. *Preliminaries to speech analysis*. MIT Acoustics Laboratory, Technical Report, No. 13. Reissued by MIT Press, Cambridge, Mass., Eleventh Printing, 1976.

Jenewari, Charles E. W. 1989. Ijoid. *The Niger-Congo Languages*. John Bendor-Samuel, ed. Lanham: University Press of America.

Kabak, Baris and William Idsardi. 2004. Syllabically conditioned perceptual epenthesis. *Proceedings of the annual meeting of the Berkeley Linguistics Society* 29: 233-245.

Kager, René. 1999. *Optimality Theory*. Cambridge: Cambridge University Press.

Kawahara, Shigeto, Hajime Ono, and Kiyoshi Sudo. 2006. Consonant co-occurrence restrictions in Yamato Japanese. *Japanese/Korean Linguistics* 14: 27-38. Stanford: CSLI Publications.

Kawahara, Shigeto. 2006. A faithfulness ranking projected from a perceptibility scale: The case of [+voice] in Japanese. *Language* 82(3): 536-574.

Kawahara, Shigeto. 2007. Half rhymes in Japanese rap lyrics and knowledge of similarity. *Journal of East Asian Linguistics* 16(2): 113-144.

Keating, Patricia. 1990. Phonetic representations in generative grammar. *Journal of Phonetics* 18: 321-334.

Kenstowicz, Michael. 1989. Comments on 'The structure of (complex) consonants' by H. van der Hulst and N. Smith. Paper presented at the MIT Conference on Feature and Underspecification Theories, MIT.

Khumalo, James Steven Mzilikazi. 1987. *An autosegmental account of Zulu phonology*. Doctoral dissertation, University of Witwatersrand.

Kingston, John. 1985. The phonetics and phonology of the timing of oral and glottal events. Doctoral dissertation, UC Berkeley.

Kiparsky, Paul. 1982. Lexical phonology and morphology. In I.-S. Yang, ed., *Linguistics in the Morning Calm*, 3-91. Seoul, Hanshin.

Kiparsky, Paul. 1985. Some consequences of Lexical Phonology. *Phonology Yearbook* 2: 85-138.

Kiparsky, Paul. 2000. Opacity and cyclicity. *The Linguistic Review* 17: 351-365.

Kiparsky, Paul. 2002. Syllables and moras in Arabic. In Caroline Féry and Ruben van de Vijver, eds., *The Syllable in Optimality Theory*, 147-182. Cambridge: CUP.

Korn, David. 1969. Types of labial vowel harmony in the Turkic languages. *Anthropological Linguistics* 11: 98-106.

Krämer, Martin. 2003. *Vowel Harmony and Correspondence Theory*. Mouton de Gruyter.

Leben, William. 1973. Suprasegmental Phonology. Doctoral dissertation, MIT.

Lombardi, Linda. 1990. The nonlinear organization of the affricate. *Natural Language and Linguistic Theory* 8: 375-425.

Lombardi, Linda. 1996. Restrictions on direction of voicing assimilation: an OT account. *University of Maryland Working Papers in Linguistics* 4: 84-102.

Lombardi, Linda. 1999. Positional faithfulness and voicing assimilation in Optimality Theory. *Natural Language and Linguistic Theory* 17: 267-302.

Lomontagne, Gregory and Keren Rice. 1995. A Correspondence account of coalescence. *UMOP* 18: 249-384.

Luce, Paul. A. 1986. Neighborhoods of words in the mental lexicon. Doctoral dissertation, Indiana University.

MacEachern, Margaret. 1997 [1999]. Laryngeal Cooccurrence Restrictions. Doctoral dissertation, UCLA. [Published by Garland 1999].

Mackenzie, Sara. 2002. Contrast, vowel harmony and OT. Paper presented at the 2002 annual meeting of the Canadian Linguistics Association, Toronto.

Mackenzie, Sara and Elan Dresher. 2004. Contrast and phonological activity in the Nez Perce vowel system. *Proceedings of the annual meeting of the Berkeley Linguistics Society* 29: 283-294.

McCarthy, John. 1979. Formal problems in Semitic phonology and morphology. Doctoral dissertation, MIT.

McCarthy, John. 1986. OCP Effects: Gemination and Antigemination. *Linguistic Inquiry* 17: 207–263.

McCarthy, John. 1989. Linear order and phonological representations. *Linguistic Inquiry* 20: 71-99.

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

McCarthy, John. 2007b. Consonant harmony via correspondence: Evidence from Chumash. In Leah Bateman, Michael O'Keefe, Ehren Reilly and Adam Werle, eds., *Papers in Optimality Theory III*, 224-238. Amherst: GLSA.

McCarthy, John and Alan Prince. 1994. The Emergence of the Unmarked: Optimality in Prosodic Morphology. *NELS* 24: 333-379.

McQuown, Norman A. 1967. Classical Yucatec (Maya). In Norman McQuown, ed., *Handbook of Middle American Indians Volume 5: Linguistics,* 201-247. Austin: University of Texas Press.

Mester, Armin. 1986. Studies in Tier Structure. Doctoral dissertation, University of Massachusetts.

Miller, Michelle and Donald MacKay. 1994. Repetition deafness: Repeated words in computer-compressed speech are difficult to encode and recall. *Psychological Science* 5: 47–51.

Moreton, Elliott. 1996[1999]. Non-computable functions in Optimality Theory. Ms., University of Massachusetts. [Written in 1996, revised and placed on Rutgers Optimality Archive in 1999.]

Moulton, Keir. 2003. Deep allophones in the Old English laryngeal system. *Toronto Working Papers in Linguistics* 20: 157-173.

Newman, Paul. 2000. *The Hausa language: an encyclopedic reference grammar*. New Haven: Yale University Press.

Odden, David. 1986. On the role of the Obligatory Contour Principle in phonological theory. *Language* 62:353-383.

Odden, David. 1994. Adjacency parameters in phonology. *Language* 70: 289-330.

Odden, David. 2007. The unnatural tonology of Zina Kotoko. In Tomas Riad and Carlos Gussenhoven, eds. *Tones and Tunes: Typological Studies in Word and Sentence Prosody*, 63-90. Berlin: Mouton de Gruyter.

Ohala, John. 1973. The physiology of tone. In Larry M. Hyman, ed., *Consonant Types and Tone,* 1-15. SCOPIL.

Pater, Joe. 2008. Gradient phonotactics in Harmonic Grammar and Optimality Theory. Ms., University of Massachusetts.

Pierrehumbert, Janet. 1993. Dissimilarity in the Arabic verbal roots. *Proceedings of NELS 23*: 367-381.

Piggott, Glyne. 1992. Variability in feature dependency: The case of nasality. *Natural Language and Linguistic Theory* 10: 33-77.

Poser, William J. 1982. Phonological representations and action-at-a-distance. In van der Hulst and Smith, eds., *The Structure of Phonological Representations, Vol. 2*, 121-158. Dordrecht: Foris Publications.

Prince, Alan and Paul Smolensky. 2004. *Optimality Theory: Constraint Interaction in Generative Grammar*. Oxford: Basil Blackwell.

Reh, Mechthild. 1996. *Anywa language: Description and internal reconstruction*. Koln: Ruddiger Koppe Verlag.

Rice, Keren. 1993. A reexamination of the feature [sonorant]: The status of 'sonorant obstruents'. *Language* 69: 308-344.

Rice, Keren. 2006. On the patterning of voiced stops in loanwords in Japanese. *Toronto Working Papers in Linguistics* 26: 11-22.

Rice, Keren. 2007. Markedness in phonology. In Paul de Lacy, ed., *The Cambridge Handbook of Phonology*, 79-97. Cambridge: CUP.

Rice, Keren and Peter Avery. 1991. On the relationship between laterality and coronality. In Carole Paradis and Jean-François Prunet, eds., *The Special Status of Coronals: Internal and External Evidence,* 101-124. San Diego: Academic Press.

Rose, Sharon and Lisa King. 2007. Speech error elicitation and co-occurrence restrictions in two Ethiopian Semitic languages. *Language and Speech* 50: 451-504.

Rose, Sharon and Rachel Walker. 2004. A typology of consonant agreement as correspondence. *Language* 80(3): 475-531.

Rubach, Jerzy. 2000. Glide and glottal stop insertion in Slavic languages: a DOT analysis. *Linguistic Inquiry* 31: 271-317.

Rubach, Jerzy. 2003. Polish palatalization in Derivational Optimality Theory. *Lingua* 113: 197-237.

Sagey, Elizabeth. 1986. The representation of features and relations in non-linear phonology. Doctoral dissertation, MIT.

Shattuck-Hufnagel, Stefanie and Dennis Klatt. 1979. The limited use of distinctive features and markedness in speech production: Evidence from speech error data. *Journal of Verbal Learning and Verbal Behavior* 18: 41–55.

Shaw, Patricia. 1991. Consonant harmony systems: The special status of coronal harmony. In Carole Paradis and Jean-François Prunet, eds., *The Special Status of Coronals: Internal and External Evidence*, 125-157. San Diego: Academic Press.

Smolensky, Paul and Géraldine Legendre. 2006. *The Harmonic Mind: From Neural Computation to Optimality-Theoretic Grammar.* Cambridge: MIT Press.

Steriade, Donca. 1987. Redundant values. In A. Bosch, B. Need and E. Schiller, eds., *CLS 23: Parasession on Autosegmental and Metrical Phonology*, 339-362. Chicago: CLS.

Steriade, Donca. 1995. Underspecification and markedness. In John A. Goldsmith, ed., *The Handbook of Phonological Theory,* 114-174. Cambridge, MA: Blackwell.

Steriade, Donca. 2001a. The phonology of perceptibility effects: the P-Map and its consequences for constraint organization. Ms. MIT.

Steriade, Donca. 2001b. Directional asymmetries in place assimilation. In Elizabeth Hume and Keith Johnson, eds., *The Role of Speech Perception in Phonology*, 219-250. San Diego: Academic Press.

Steriade, Donca. 2004. Knowledge of similarity and narrow lexical override. *Proceedings of the annual meeting of the Berkeley Linguistics Society 29*: 583-598.

Straight, H. Stephen. 1976. *The acquisition of Maya phonology: Variation in Yucatec child language.* New York: Garland.

Struijke, Caro. 2002. *Existential Faithfulness: A Study of TETU, Feature Movement and Dissimilation.* New York: Routledge.

Thomas, Jacqueline. M.C. 1963. *Le parler ngbaka de Bokanga: phonologie, morphologie, syntaxe*. Paris: Mouton

Trnka, Bohumil. 1936. General laws of phonemic combinations. *Travaux du Cercle Linguistique de Prague* 6: 57-62, 1968.

Tucker, Archibald. 1994. *A Grammar of Kenya Luo (Dholuo)*. Koln: Ruddiger Koppe Verlag.

Tversky, Amos. 1977. Features of similarity. *Psychological Review* 84: 327–352.

Walker, Rachel. 1998. Nasalization, neutral segments and opacity effects. Doctoral dissertation, University of California, Santa Cruz.

Walker, Rachel. 2004. Vowel feature licensing at a distance: Evidence from Northern Spanish language varieties. In B. Schmeiser, V. Chand, A.Kelleher and A. Rodriguez, eds., *Proceedings of WCCFL 23*: 787-800.

Weathers, Nadine. 1947. Tsotsil phonemes with special reference to allophones of b. *International Journal of American Linguistics* 13: 108-111.

van de Weijer, Jeroen. 1994. Cooccurrence restrictions in Ngbaka. *Linguistics in the Netherlands* 11: 259-266.

Wicklegren, W. A. 1966. Distinctive features and errors in short-term memory for English consonants. *Journal of the Acoustical Society of America* 39: 388–398.

Wright, Richard and Aaron Shyrock. 1993. The effect of implosives on pitch in SiSwati. *Journal of the IPA* 23: 16-23.

Yip, Moira. 1988. The Obligatory Contour Principle and phonological rules: A loss of identity. *Linguistic Inquiry* 19: 65-100.

Yip, Moira. 1989. Feature geometry and cooccurrence restrictions. *Phonology* 6.2: 349-374.