Similarity and contrast in consonant harmony systems

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Recent typological studies (Hansson 2001, Rose & Walker 2004) argue that segments participating in consonant harmony systems must be highly similar to one another. This paper proposes that contrastive features within a language determine similarity. Contrasts are determined by hierarchic ordering of features with some features taking scope over others (Jackobson and Halle 1956, Dresher 2003). This is applied to the analysis of consonant harmony in Anywa, Luo, and Bumo Izon. In these languages, segments which participate in harmony processes are similar to one another in that they form a natural class of segments contrastively specified for the harmonic feature.

1. *Introduction*

Consonant harmony is a well-attested, crosslinguistic phenomenon which raises a number of interesting issues for phonological theory. Recent typological studies of consonant harmony systems (Hansson 2001, Rose & Walker 2004) have highlighted some characteristics of long distance consonant assimilation which distinguish it from local assimilation and vowel harmony. While long-distance consonant assimilation is found in many languages, its distribution is more restricted than both local assimilation and vowel harmony. Features which are active in consonant harmony processes are limited to laryngeal features, nasality, and features such as retroflex, strident, and anterior which specify coronal segments. These are a subset of the active features found in local assimilation processes. In addition, the segments that interact in consonant harmony processes must share a certain degree of similarity. Rose & Walker (2004) and Hansson (2001) show that targets and triggers in harmony processes must 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.

Two theoretical issues raised in the study of consonant harmony are locality and similarity. How are segments at a distance able to interact without affecting intervening segments? What is the relevant definition of similarity as it is manifested in consonant harmony systems? The issue of locality concerns both phonological representations and phonological operations. From a representational perspective we may ask whether there is a tier-based definition of locality so that interacting segments are adjacent with respect to the harmonic feature. A related question is whether harmony results in multiply linked structures

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(see Odden 1994, Gafos 1996 for discussion of locality in harmony processes). Operationally, we can investigate the mechanisms implementing consonant harmony: do they involve autosegmental spreading akin to that of local harmony processes or correspondence relations as posited in recent OT accounts (e.g. Hansson 2001, Rose & Walker 2004)? The issue of similarity, however, is purely representational. What are the representations that allow us to determine which segments are similar? What is the threshold of similarity necessary for consonant harmony? Are the relevant definitions of similarity universal or language-specific?

This paper focuses on the issue of similarity in consonant harmony. I propose that similarity is dependent on featural specifications which are in turn influenced by the system of contrasts in a given language. The level of similarity between two segments can thus differ from language to language depending on the structure of the inventory in which the segments are found. Even languages that appear to have the same surface inventory may have different underlying systems of contrast and thus different similarity relations between segments.

I will begin by reviewing previous theories of phonological similarity with an emphasis on work which has addressed consonant harmony systems. Although the issue of similarity is inherently a representational one, much current work on the role of similarity is undertaken by researchers who have rejected representational theories such as underspecification. As a result, these works are based on either universal similarity hierarchies which use intuitive feature assignments (e.g. Hansson 2001) or use a similarity metric which, while taking into account the contrasts in a system, is incapable of accounting for the patterning of consonant harmony in languages with asymmetric inventories (e.g. Frisch et al. 2004).

The following sections will propose an alternative view of similarity that is linked to the notion of contrast. This proposal will be illustrated in analyses of cooccurrence restrictions and consonant harmony in Luo, Anywa and Bumo Izon.

2. *Similarity and consonant harmony: previous approaches*

A body of work has developed focusing on the issue of determining targets and triggers in consonant harmony processes (e.g. Mester 1986, Hansson 2001, Rose & Walker 2004, Frisch et al. 2004). These works all argue that similarity determines which segments will participate in consonant harmony processes. Work arguing that similarity is crucial in determining participating segments in consonant harmony systems has been carried out in a variety of theoretical and representational frameworks. This section will review recent work arguing for universal similarity hierarchies that are reflected in constraint rankings (Hansson 2001, Rose & Walker 2004) and Frisch et al.'s proposal that similarity of a pair of segments can be given a numerical value based on natural classes.

Recent typological studies (Hansson 2001, Rose & Walker 2004) have argued that consonant harmony is motivated by constraints which require surface segments to be in a correspondence relation with one another. Like correspondence relations between input and output, correspondence relations between output segments entail the existence of faithfulness constraints which demand identity between corresponding segments. In the case of surface correspondence, highly ranked faithfulness constraints will result in consonant harmony.

The role similarity plays in consonant harmony processes is captured in these analyses by proposing that these constraints are universally ranked with constraints requiring the establishment of a correspondence relation between more similar segments ranked above

constraints requiring establishment of a correspondence relation between less similar segments.
The constraint type that establishes correspondence relations between output segments is formulated in Rose & Walker (2004) as shown below.

(1) 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. An example hierarchy from Rose & Walker is shown in (2).

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

The highest ranked constraint in (2) 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 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.

The constraints proposed by Rose & Walker (2004) and Hansson (2001) predict that crosslinguistic variation in harmony systems will result from different rankings of input-output faithfulness constraints with respect to the family of CC-correspondence constraints. In order for a language to have consonant harmony at all, it must have both highly ranked surface correspondence constraints and highly ranked IDENT-CC constraints requiring surface segments in correspondence with one another to share identical specifications for some feature. If input-output faithfulness constraints referring to the harmonic feature are ranked above the corresponding IDENT-CC constraints, harmony will not take place as faithfulness to input values of the harmonic feature take priority in the grammar. If the IDENT-IO constraint is below the constraint requiring segments that differ only in voicing to be in correspondence with one another, but above the constraint requiring correspondence between segments that differ in both place and voicing, then homorganic segments will participate in the harmony and heterorganic segments will not.

Both Rose & Walker (2004) and Hansson (2001) show the similarity hierarchies in terms of segments without any detailed discussion about the feature system they are assuming. Rather, the hierarchies suggest an intuitive assessment of features and their importance relative to one another.

Frisch et al. (2004) provide a more explicit method for evaluating relative similarity while attempting to account for the role that redundancy relations play in that evaluation. Assuming full specification for all features, they determine the set of natural classes of which each segment is a member. Natural classes are defined as segments that share some feature or set of feature specifications. The similarity of any pair of segments is then measured and assigned a numerical value by dividing the number of natural classes the segments share by the shared and unshared natural classes.

Contrast and redundancy are able to play a role in determining the similarity measure of segment pairs, because a noncontrastive feature will not lead to the creation of an additional natural class in the similarity equation. In this way, Frisch et al. (2004) are able to reject underspecification and other representational theories while simultaneously attributing importance to redundancy.

3. *Contrast and similarity: an approach to consonant harmony*

This paper proposes that it is the underlying contrasts in a system which determine the similarity of segments and that determine which segments will participate in harmony systems. Segments which are contrastively specified for the feature active in the harmony process may participate, redundantly specified segments will not. Segments which are similar to one another in their contrastive specifications will interact, not necessarily segments which are most similar phonetically, although phonetic properties constrain possible contrastive specifications. The model of contrast employed here is that of the contrastive hierarchy (Jakobson & Halle 1956, Dresher 2003). The contrastive hierarchy provides a method for determining contrasts in an inventory by ranking features so that some features take scope over others.

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 underspecification, 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's (2001) account of consonant harmony is 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 acknowledges the limitation of fixed similarity hierarchies and suggests that it may be "more 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 role of contrast in determining the structure of phonological representations has been stated most obviously in the framework of contrastive underspecification (Steriade 1987) which claims that only noncontrastive features may be absent from underlying representations. Despite the wide range of work making reference to contrast and the explicit use of contrast as a criterion in work in contrastive underspecification, there has never been a consensus on how to determine which features in an inventory are contrastive.

The search for such a method is the subject of recent work by Dresher (2003), who revives a claim of Jackobson & Halle (1956) that contrastive features must be hierarchically ordered with some features taking scope over others. Dresher claims that the language learner first posits all sounds to be allophones of a single, undifferentiated phoneme. When evidence requires more than one sound to be present in the inventory the learner splits the sounds into two phonemes on the basis of a feature. That feature is contrastive for the entire inventory and all sounds will be specified for it. We then have two subsets of sounds. When they are required to be split into more phonemes the process is repeated with features being chosen until every phoneme in the inventory is uniquely specified. Features lower down in the hierarchy will be contrastive in smaller sets of segments, only those segments that still require the feature in question in order to be contrastively specified.

The contrastive hierarchy for an inventory is determined by examining evidence from phonological processes. If a feature is active in a harmony process, that feature must be specified and thus must be contrastive for at least the segments which spread the feature in the harmony process. Evidence from minimal pairs and inventory shape is also taken into account, but is secondary to evidence from phonological processes.

With respect to consonant harmony, the theory of the contrastive hierarchy predicts that, when the set of participating segments is determined by similarity, the relevant features in determining similarity will be contrastive for the segments in question. In addition, the active feature in the harmony process will be contrastive for that set of segments. The contrastive hierarchy can vary from language to language. This approach thus predicts that the set of segments subject to a harmony process or cooccurrence restriction may differ from language to language and will not be directly dependent on surface phonetic properties.

The following sections provide analyses of consonant harmony systems in Luo, Anywa, and Bumo Izon 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.

4. Bumo Izon

An example of a consonant harmony system in which contrast plays a crucial role is the case of implosive harmony in Bumo Izon. Bumo Izon and related Ijoid languages have a cooccurrence restriction barring implosive and plosive stops from occurring in a morpheme. Some examples of harmonic forms are given below. Data are from Efere (2001).

(3)	búbú	‘rub (powder in face)
	bɪdɛ́	‘cloth’
	ɓʊ́ɓaɪ	‘yesterday’
	ɗɔ̃́:ɗɔ̃́:	‘cold’
	ɗáɓá	‘swamp’

Implosive /ɗ/ and /ɓ/ are barred from occurring with plosive /b/ and /d/ in any combination and any order. The velar plosive /g/ and the labiovelar implosive /ɠɓ/, however, may freely occur with members of both the plosive and implosive series.

(4)	igódó	‘padlock’
	ɗugó	‘to pursue’
	ɓugí	‘to wring (hand)’
	ɠɓaɓú	‘crack (of a stick breaking)’
	ɠɓódaɠɓóda	‘(rain) hard’

The failure of the plosive /g/ and labiovelar /ɠɓ/ to participate in the cooccurrence restriction can be related to the shape of the Bumo Izon inventory. As illustrated in the inventory chart shown below, there is no implosive at the velar place of articulation and no plosive labiovelar

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

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

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. Using the contrastive hierarchy, the pattern of cooccurrence constraints can be accounted for by ordering place features before laryngeal features.

Specifications of the stop series are shown below with the ordering [labial] > [dorsal] > [voice] > [glottalic].

(6) Hierarchy for Bumo Izon
[labial] > [dorsal] > [voice] > [glottalic]

p, t, k, kp, b, d, g
ɓ, ɗ, ɠɓ

- **[+lab]** ɓ, p, b, kp, ɠɓ
  - **[+dorsal]** kp, ɠɓ
    - **[+vce]** **ɠɓ**
    - [-vce] kp
  - [-dorsal] p, b, ɓ
    - [+vce] b, ɓ
      - [+glot] ɓ
      - [-glot] b
    - [-vce] p
- **[-lab]** t, k, d, g, ɗ
  - **[+dorsal]** k, g
    - [+vce] **g**
    - [-vce] k
  - [-dorsal] t, d, ɗ
    - [+vce] d, ɗ
      - [+glot] ɗ
      - [-glot] d
    - [-vce] t

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. The feature [glottalic] is ordered next and distinguishes between the implosive and pulmonic voiced stops leaving all segments contrastively specified.

With this ordering, the feature [glottalic] is only contrastive for the set of voiced alveolar and labial stops. All voiceless segments are distinguished without reference to glottalic, as are the voiced velar and implosive labiovelar stops. The set of segments that are banned from occurring together are those segments which bear distinct contrastive specifications for the feature [glottalic].

The importance of contrast in determining the patterning of consonant harmony systems is particularly clear in Bumo Izon due to the asymmetric shape of the inventory. 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/ also share the properties of voiced stops and do not participate in the harmony process. /g/ and /ɠɓ/ differ from the participating segments in that they are not contrastively specified for the feature [glottalic].

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 [glottalic] are disallowed morpheme-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 [glottalic]. /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.

Asymmetrical inventories like that of Bumo Izon 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 result 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 (e.g. Hansson 2001). 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/.

Hansson (2001) discusses the case of Bumo Izon and acknowledges that it poses a problem for his account. He also points out that the similarity metric advocated by Frisch et al. (2004), while giving a more explicit method of determining similarity, is unable to account for the Bumo Izon data. Hansson (2001) shows that the 'natural classes' method of determining similarity advocated by Frisch et al. falsely predicts that /g/ is more similar to the implosive stops /ɓ/ and /ɗ/ than are the voiced stops /b/ and /d/.

Recall that Frisch et al. (2004) reject underspecification of noncontrastive features and claim that redundancy relations can accurately be reflected in natural classes without the omission of redundant information. When shared natural classes are divided by shared and unshared natural classes in order to achieve a measure of similarity, 'partnerless' segments will appear more similar to other segments in the series. If a segment lacks a partner with which it minimally contrasts in some feature, that segment will be a member of fewer natural classes than segments that have such a partner. This will lead to a higher similarity value between this segment and a corresponding segment in the series because there will be fewer unshared natural classes that shared natural classes must be divided by. In the case of Bumo

Izon, laryngeal specifications for /g/ do not lead to an additional unshared natural class in the denominator of the similarity calculation

The ‘natural classes’ model thus wrongly predicts that segments without ‘partners’ in asymmetric inventories will behave as if they are more similar than other segments in a series. The contrastive analysis, on the other hand, shows that the partnerless segment is less similar to the other segments in the series in that it lacks a specification for the harmonic feature.

4. Dental harmony in Nilotic

A contrast between dental and alveolar places of articulation is common in Western Nilotic languages, many of which also have morpheme structure constraints banning the occurrence of dentals and alveolars in the same form. This section provides a contrastive hierarchy analysis of the patterning of dental harmony in two Nilotic languages, Anywa and Luo.

Both languages have a dental/alveolar contrast among the coronal stops and in both languages this contrast is not present within the nasals series which contains only a single coronal /n/. Both languages have coocurrence restrictions on dentals and alveolars. The /n/ behaves differently with respect to the cooccurrence restrictions of the two languages, however.

In Anywa, /n/, like the other alveolars, may not occur with a dental stop. A dental [n̪] appears allophonically in roots containing dental stops.

(7) Anywa (Reh 1996)

n̪ùd̪ò	‘to lick’	núudó	‘to press something down’
ōd̪óòn̪	‘mud’	dɪ̄n	‘to thrash something’
t̪ùd̪	‘ropes’	tūud	‘pus’

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

(8) Luo (Tucker 1994)

t̪uno	‘breast’	dino	‘deaf, to be stopped up’
t̪ʊɔn	‘brave man’	tɪn	‘small’
t̪ed̪o	‘to forge’	tedo	‘to cook’
d̪ɔd̪ɔ	‘to suckle’	diedo	‘to’

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.

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 Luo, 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 Luo and Anywa would look like. Subscript indices represent the presence of a correspondence relation between the relevant surface segments.

(9) Anywa

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

(10) Luo

t̪uno	ID-CC[dis]	**I D-IO [+dis]**	**ID -IO[-dis]**	CORR d̪/n̪ - n	*n̪
☞a. t̪uno				*	
b. t$_x$un$_x$o		*!			
c. t̪$_x$un$_x$o			*!		*

Both tableaux show evaluations of disharmonic inputs, and both have an undominated ID-CC constraint requiring surface segments that are correspondence with one another to agree in specification for the feature [distributed]. In (9), 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 (10) shows the evaluation of a disharmonic input in Luo. The ranking in (10) differs from (9) 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 Luo and Anywa is the ranking of IDENT-IO [distributed] with respect to the similarity hierarchy. In Luo 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.

Within the framework of the contrastive hierarchy, however, it does not follow that identical surface inventories result from an identical system of contrasts at the level of feature specification. The consonant inventories of Luo and Anywa are presented below, followed by a contrastive hierarchy account of the different patterning of cooccurrence restrictions in the two languages.

(11) Luo consonant inventory (from Tucker 1994:30)

	Labial	Dental	Alveolar	Palatal	Dorsal	Glottal
voiceless stops	p	t̪	t	c	k	ʔ
voiced stops	b	d̪	d	ɟ	g	
prenasal stops	ᵐb	ⁿd̪	ⁿd	ᶮɟ	ᵑg	
nasals	m		n	ɲ	ŋ	
fricatives	f		s			h
liquids			r,l			
glides	w			y		

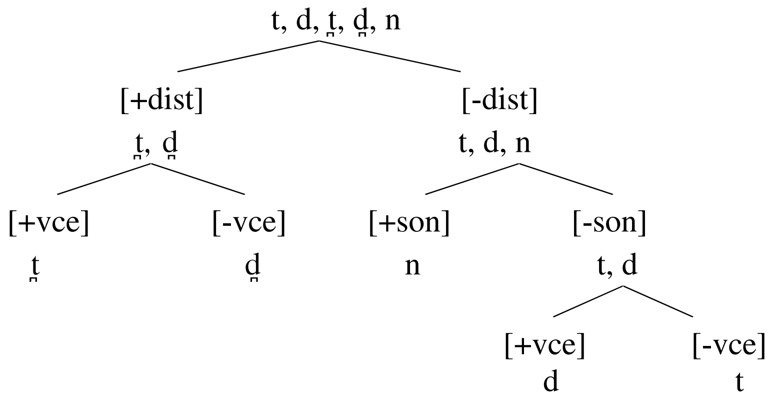
(12) Anywa consonant inventory (from Reh 1996:23)

	Labial	Dental	Alveolar	Palatal	Dorsal	Mute
voiceless stops	p	t̪	t	c	k	
voiced stops	b	d̪	d	ɟ	g	
nasals	m		n	ɲ	ŋ	
liquids			r,l			
glides	w			y		
mute						‘

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 Luo 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 (13).

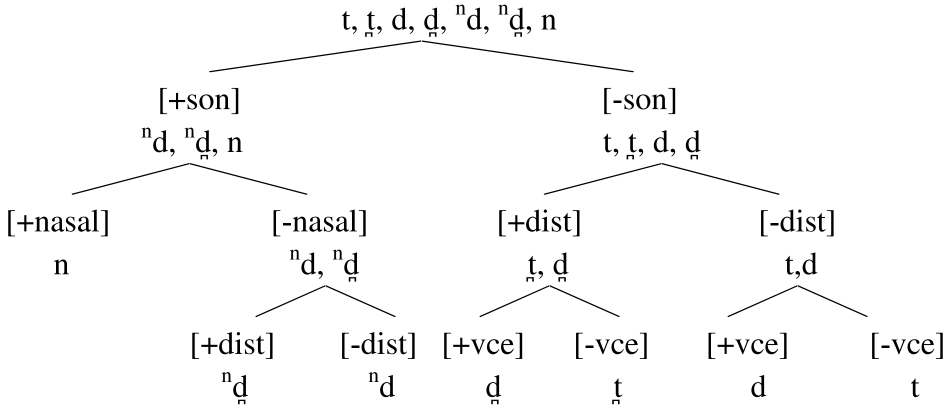
(13) Anywa contrastive hierarchy



The hierarchy of contrastive features in Luo differs from that of Anywa and corresponds to the second possibility described at the beginning of this section. The inventory of coronal stops in Luo is greater than that of Anywa due to the presence of prenasalized stops. I assume that prenasalized stops are sonorants in Luo and as such are specified [+sonorant] and are not phonologically specified for nasality. Nothing 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 (14) below.

(14) Luo 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 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 Luo, 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 restriction for Luo is formulated as a ban on coronals that are specified for different values of [distributed] then the nasal will not participate, as it has no specification for the relevant feature. The nasal may freely cooccur with both dental and alveolar stops without incurring any violation of the cooccurrence restriction.

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. Banned structures are eliminated by spreading the value of the [+distributed] coronal to the [-distributed] coronal.

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 Luo. 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 Luo 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

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 (15).

(15) Anywa (from Reh 1996)

a)	pòon̪n̪ò	'to become smooth'	<	pɔɔd̪ 'be smooth' + no
b)	póonnó	'to beat for sb.'		

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

(16) Luo (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 a dental nasal in Anywa is thus an accidental gap, not required by the system of contrasts in the language. In Luo, 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.

5. Conclusion

The case studies reviewed show the role of contrastive specifications in determining relative similarity and interacting segments in harmony processes. In Anywa, Luo, and Bumo Izon segments which participate form a natural class in that they are all and only the segments specified for the harmonic feature.

The contrastive hierarchy analysis is able to draw connections between inventory shape and patterning of cooccurrence constraints while still allowing variation between languages with similar inventories. This approach can successfully model crosslinguistic differences in harmony patterns and need not be tied to direct phonetic properties.

Questions still arise, however, with respect to the limitations of contrastive ordering. Some contrastive hierarchies seem more plausible than others and the question of what is a possible contrastive hierarchy remains to be answered. Data from consonant harmony systems may shed light on this issue. While this paper has examined crosslinguistic differences in the patterning of coronal harmony systems, Hansson's (2001) typology of harmony systems also suggests some consistencies. For example, none of the laryngeal harmony systems show sonorants participating although they are phonetically voiced. This suggests that no languages with consonant harmony have the feature [voice] ordered above [sonorant]. The data from consonant harmony systems may thus aid in the task of constraining possible orderings within the framework of the contrastive hierarchy.

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