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0. Introduction

There are four processes which commonly occur when a nasal consonant and an obstruent form a prenasalized consonant. These processes, shown in (1), are voicing of a stop, despirantization of a fricative, deletion of the nasal, and coalescence of the nasal and consonant.

(1) a. Voice assimilation

$C \rightarrow [+voice] / N\_\_$

ex: Kikuyu: /N+ ker-a/ [^{ŋ}gereete] 'cross'

b. Continuancy assimilation

$C \rightarrow [-cont] / N\_\_$

ex: Kikuyu: /N+ βor-a/ [^{m}bureetɛ] 'lop off'

c. Nasal deletion

$N \rightarrow ø / \_\_C$

ex: Ndali: /iN+ fuwa/ [ifuwa] 'hippo'

d. Coalescence

$$\begin{array}{ccccc} \begin{bmatrix}+cons\\ +nasal\end{bmatrix} & \begin{bmatrix}+cons\\ \alpha place\end{bmatrix} & \rightarrow & ø & \begin{bmatrix}+cons\\ +nasal\\ \alpha place\end{bmatrix} \\ 1 & 2 & & 1 & 2 \end{array}$$

ex: UMbundu: /N+ popya/ [mopya] 'I speak'

Superficially, these processes have nothing in common; however, all four processes conspire to create only prenasalized voiced stops from a nasal and any type of obstruent. For example, the effects of Nasal Deletion and Coalescence are to eliminate prenasalized consonants other than prenasalized voiced stops by creating a single segment and the effects of the assimilation rules are to create a voiced stop with which the nasal consonant can form a prenasalized consonant. The rules in (1), however, do not reflect the conspiratory nature of the processes. These processes are shown here to follow from the representation of prenasalized consonants which serves as the environment for all the rules in (1). Deletion and coalescence occur when the unification of the nasal and the consonant into a prenasalized consonant yields an illicit representation. It is argued here that the assimilation rules, (1a&b), are not rules that spread [voice] or [cont], but rather these rules follow from a constraint on the representation of prenasalized consonants that forces the nasal and the obstruent to share features. The constraint has effects similar to Steriade's (1982) Shared Feature Convention.

The proposed constraint on the representation of prenasalized consonants is actually a constraint on the branching of autosegmental tiers which limits the number of possible contour segments, i.e., segments that are specified as [αF] and [-αF] on the same tier. Consider the autosegmental representation of a prenasalized stop originally proposed by Goldsmith (1976) and incorporated unchanged into the feature-geometry models proposed by Clements (1985) and Sagey (1986).

(2) ex. [^{m}b]

[-cont
+ant
-cor]

[+nasal] [-nasal]

The autosegmental representation overcomes the problems caused by prenasalized consonants in feature-matrix proposals (Chomsky and Halle 1968, Ladefoged 1971, Anderson 1976) as well as account for some interesting phonological properties of prenasalized stops with respect to harmony processes (Goldsmith 1976). However, the autosegmental representation fails to capture the fact that prenasalized consonants must have one place of articulation and usually must have one laryngeal articulation. This is complicated by the existence of prenasalized voiceless stops, e.g. [^{m}p], which include a [voice] contour. However, there is a dependency between [nasal] contours and [voice] contours because the latter do not exist independently of the former. This dependency is shown to be a consequence of the constraint on the branching of autosegmental tiers.

Another problem concerning prenasalized consonants is the markedness of different types of prenasalized consonants. In particular, any language with prenasalized consonants must have a series of prenasalized voiced stops. This fact, among others, indicates that prenasalized voiced stops are the least marked prenasalized consonants (Herbert 1986). Some languages, such as Luganda, have a series of prenasalized voiceless stops and others, such as Swahili, have prenasalized voiced fricatives. However, it appears no language can have a series prenasalized voiced stops, prenasalized voiceless stops, and prenasalized voiced fricatives without also having a series of prenasalized voiceless fricatives. These markedness implications are also shown to be a consequence of the constriant on contours. A prenasalized voiced stop is the least marked prenasalized consonant because it requires the minimal amount of branching. Other prenasalized consonants require more complex branching hence these segments are more marked.

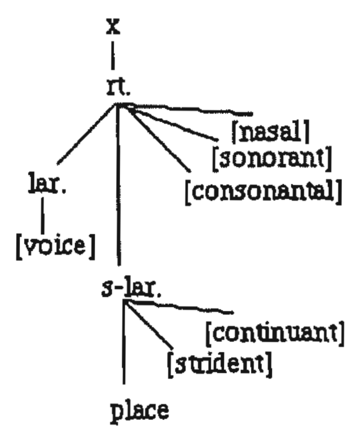
This paper is in four sections. The first section contains an outline of the feature-geometry and the theory of underspecification used throughout the paper. The second section contains the proposed constraint on feature-geometry and some of its consequences. The third section contains the analysis of the four processes shown in (1) and the fourth section contains a discussion of some further consequences of the affects of the proposed constraint on branching in feature-geometry. The discussion throughout this paper concerns only prenasalized consonants which are derived from underlying nasal-consonant sequences. Prenasalized consonants can also be derived by the spreading of [nasal] from vowels to consonants, but these prenasalized consonants have different properties which are not discussed here (see Piggott 1988a, 1990).

1. Theoretical Preliminaries

1.1. Feature-geometry

The feature-geometry assumed here is given below.

(3)



This arrangement of the features above the place node is based on modifications made by Archangeli and Pulleyblank (1986) (henceforth A&P), Piggott (1987) and Schein and Steriade (1986). Clements (1985) and A&P show the supralaryngeal node dominating the features [continuant], [sonorant], [nasal] and [strident]. The status of the supralaryngeal node has been questioned (see McCarthy (1988), Iverson (1990) for arguments against the supralaryngeal node and Davis (1989) for arguments supporting the supralaryngeal node). However, the supralaryngeal node (which is the same as Clements' (1987) Oral Cavity Node) is retained from earlier proposals because there is a need for a class node between the root node and the place node. For example, such a node is necessary to capture intrusive stop formation (Clements 1987). Sagey and Schein and Steriade show the root node dominating [continuant], [strident] and [sonorant] and the supralaryngeal node (which dominates the soft-palate node in Sagey's model) dominates [nasal]. Piggott (1987) argues that [nasal] must link directly to the root node so that nasal stability phenomena can be explained. The feature-geometry proposed here has the root node dominating [nasal] and [sonorant] and the supralaryngeal node dominating [continuant] and [strident]. The arrangement of features below the place node is the same as the arrangement proposed by Sagey.

1.2. Theory of Underspecification

Archangeli (1984) and Archangeli and Pulleyblank (1986) propose a theory of underspecification in which one or both feature values are absent in underlying representation and that only one value of a given feature can be present underlyingly. The insertion of the default feature-values is regulated by the Redundancy Rule Ordering Constraint (A&P 1986) which roughly states that default feature-values, i.e., the absent feature-value, are inserted as late as possible in the phonology or at the first instance the feature value is referred to in the phonology. For example, if the default value [+high] is not referred to by a rule, the default value will be inserted as late as possible. Therefore, it will be absent from the phonology. If a rule makes specific reference to [+high], then the default value is inserted as early as possible with respect to the rule. In other words, the default value is introduced at the same time the rule applies. The insertion of the default feature-value must also be constrained by compatibility with other feature-values. This is particularly relevant in linked structures. For example, [nasal] is not compatible with [+cont]. Now assume a situation where [+nasal] and [-nasal] are linked, as in a prenasalized consonant. The only feature-value of [cont] that is compatible with both [+nasal] and [-nasal] is [-cont]. Therefore, [-cont] is inserted as the default value for nasal segments even though [+cont] might be the default value for nonnasal segments in the language.

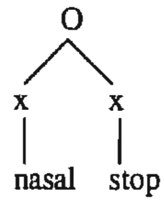
Archangeli and A&P allow for language-specific changes to the set of redundant values. For example, A&P consider [+high] to be the default value for [high]. However, it is possible that a language might have [+high] underlyingly. A Complement Rule is established to change the default value in this case from [+high] to [-high] and [-high], as the default value in this case, cannot appear underlyingly. The selection of default feature values is a function of the phonology of the language.

2. The Representation of Prenasalized Stops

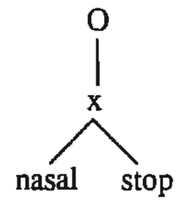
2.1. The Representation of Duration

The first question relevant to the representation of prenasalized stops concerns the representation of the time duration. Feinstein (1979) proposes that prenasalized stops in Sinhalese are simply tautosyllabic nasal-stop sequences. However, Feinstein's syllabification analysis is ambiguous because it only states that the nasal and the stop feature matrices are tautosyllabic without any reference to the duration of the segments. Feinstein's proposal can be represented formally as (4a) or (4b). (4a), however, does not capture the traditional notion of prenasalized stops as a brief nasal onset before the oral segment with a shorter duration than a nasal-stop sequence. (4b), on the other hand, seems to capture the traditional characterization of prenasalized stops.

(4) a.



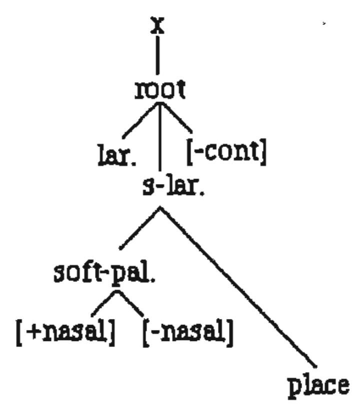
b.



Herbert (1975) and Maddieson (1989) provide acoustic evidence to support the representation in (4b). They show that prenasalized stops may be marginally longer in duration than single segments, but prenasalized stops do not have the duration of nasal-stop sequences. The phonological evidence for (4b) is drawn from syllable structure, compensatory lengthening, and reduplication. For example, the syllable structure of many languages prohibits consonant clusters in the onset, but prenasalized stops occur. If (4b) is the correct representation, the prohibition against consonant clusters can be stated as a restriction on the number of skeletal points dominated by the onset.

Sagey (1986) provides a representation of prenasalized stops that consists of one root node and the features [+nasal] and [-nasal] are dominated by a single soft-palate node.

(5)



Sagey maintains Steriade's (1982) position that contour segments are represented as branching terminal features. According to Sagey, distinctive features are phonologically ordered on any given tier and so [+nasal] is phonetically realized before the [-nasal]. Alternatively, it is possible to suppose that adjacent specifications of the same feature are each associated with its own class node. Sagey rules out the latter option by postulating that branching class nodes are prohibited.

(6) Contour segments may branch for terminal features only.
No branching class nodes are allowed. (Sagey 1986;50)

Sagey provides three arguments for (6), two of which are discussed here and the third is discused section 2.3. The first argument is from the behaviour of tones which also form contours. Sagey considers tone to be dominated by the laryngeal node because there are some cases where tone spreading is blocked by other laryngeal features. However, there are many cases where tone is not blocked by other laryngeal features. Piggott (1990) suggests that tone can either be dominated by the laryngeal node or by the skeletal point depending upon the phonetic function of tone. The second argument Sagey uses against branching class nodes is motivated by prenasalization in Guarani where prenasalized stops are derived by interaction with nasal spreading (Goldsmith 1976, van der Hulst and Smith 1982).

(7)

a. [+nas] [-nas] [+nas] [-nas]

ne-tupa --> n e - t u p a [ndetupa] 'thy bed'

b. [+nas] [+nas] [+nas] [+nas]

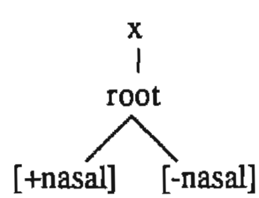
ne-tupa --> n e - t u p a [nẽtũpã] 'thy god'

The representation of prenasalized consonants in (5) accounts for prenasalization in Guarani because [-nasal] attaches to a segment already specified as [+nasal]. However, Guarani can also be used as evidence against Sagey's representation of prenasalized consonants. Piggott (1988) argues that prenasalized stop formation in Guarani is not typical because most cases of nasal spreading do not create a prenasalized stop. Piggott claims that prenasalized stops that are formed as a result of nasal spreading are more adequately explained by abandoning Sagey's prohibition against branching class nodes and Piggott proposes an alternative to Sagey's prohibition against branching class nodes which is discussed in the following section.

2.2. The Representation of Prenasalized Stops on the Root Tier

In the feature-geometry assumed here, Sagey's representation of the nasal contour in a prenasalized stop would be (8).

(8)

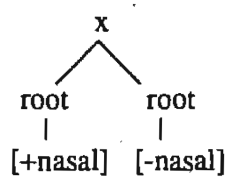


Piggott (1988) proposes an alternative to Sagey's representation of contour segments which is stated in (9).

(9) A node may immediately dominate no more than one value for a given feature.

In the case of the representation of prenasalized stops, this means there are two root nodes linked to one skeletal point as shown in (10).

(10)



Piggott argues that the interaction of prenasalized stops and nasal spreading is evidence for the representation in (10) by showing that nasal spreading in Malay, Warao, Sundanese, and Capanahua does not nasalize the opaque consonant. The absence of derived nasal contours is not surprising if the opaque segment blocks spreading and cannot be a target of spreading. Piggott captures this in a theory of spreading that prohibits the spreading of a feature to a position already specified for that feature.

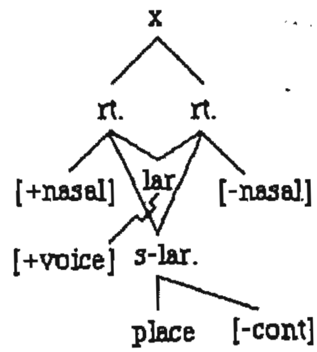
(11) Spreading Theory (in part) (Piggott 1988)
a. a node [or feature] (X) may spread only to a position not specified for X.
b. the spreading of a node [or feature] (X) may be arrested only by a position specified for (X).

Guarani now appears to be a counterexample to Piggott's Spreading Theory because [nasal] spreads to a segment specified for [nasal]. Piggott preserves Spreading Theory by proposing that the /n/ of the morpheme ne in (7) is represented as one skeletal point dominating two root nodes and one (the leftmost) is specified as [+nasal] but the other (the rightmost) is not specified for [nasal]. The leftward spreading of nasality in (7b) spreads to the unspecified root node creating a configuration where one skeletal point dominates two [+nasal] root nodes which is then reduced to one root node. Prenasalization occurs in (7a) as a consequence of the absence of nasal spreading. Piggott rejects the [-nasal] spread rule assumed by van der Hulst and Smith: the [-nasal] specification is inserted as a default value. Therefore, the unspecified root node of /n/ of ne in (7a) is specified as [-nasal] by redundant feature value insertion thus creating the configuration of a prenasalized stop.

2.3. The Representation of Prenasalized Stops Below the Root Node

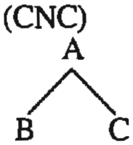
Having established that prenasalized stops must be represented as one skeletal point dominating two root nodes and using the feature-geometry proposed in (3), prenasalized voiced stops have the following representation.

(12)



Now it is appropriate to return to Sagey's objections to branching class nodes. Her third argument in favour of (5) emanates from the apparently unconstrianed nature of branching in feature-geometry. For example, if the root node can form a contour, then any two segments can be dominated by one skeletal point. It is possible however to propose a restriction concerning possible contour segments using feature-geometry proposed in (3). Furthermore, note that (12) reflects the fact that the nasal and oral components of a prenasalized voiced stop (the least marked prenasalized consonant) have a unique specification for place of articulation, voice, and continuancy. The following condition on representation captures these phonetic agreements and also restricts the set of possible contour segments.

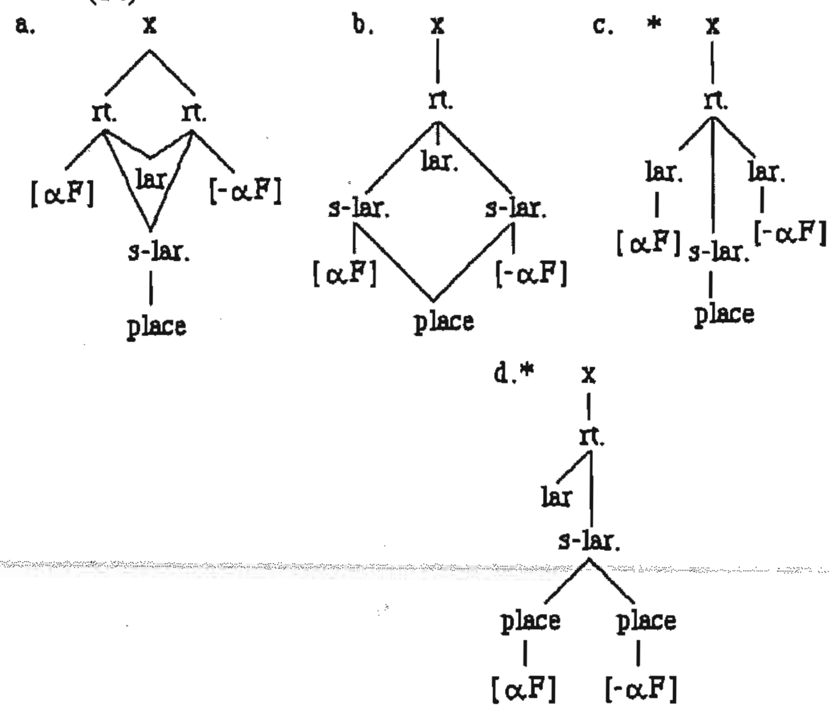
(13) Contour Node Condition (CNC)
Given the configuration:



B,C on tier T must dominate the same nonempty set of subordinate class nodes.

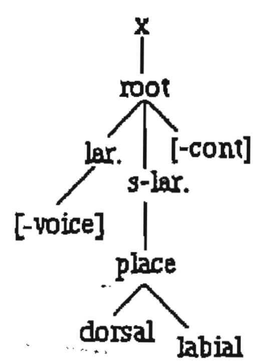
The statement of the CNC stipulates that the set of class nodes must be nonempty. This means that class nodes B and C must dominate at least one class node. The CNC ensures prenasalized (voiced) stops agree for voicing, continuancy, and place of articulation and that affricates have a single place of articulation. The CNC also correctly predicts (14a,b) are possible contours, but (14c,d) are not possible contours. (14a) is the representation of prenasalized stops as previously mentioned and (14b) is the representation of affricates. (14c and d) are ill-formed contours because the laryngeal node and the place node are terminal class nodes and they do not dominate any other class nodes.

(14)



The CNC affects only the class nodes that are organizational nodes, that is, the root, laryngeal, supralaryngeal, and place nodes. The articulator nodes, which are also class nodes, are excluded from forming contours because all articulator nodes have phonetic value. Hence the articulator nodes are naturally separable from the organizational class nodes and can be removed from the domain of the CNC. Restricitng the CNC to organizational class nodes is necessary otherwise complex segments, which have multiple articulator nodes (Sagey 1986), would be ill-formed.

(15) [kp]



The CNC as stated in (13) is too strong because it excludes prenasalized voiceless stops and prenasalized fricatives from the set of contour segments.

However, the strong version CNC, as stated in (13), is assumed for the present discussion and these exceptions to the CNC are discussed in detail in section 5.

It is now possible to delimit the set of possible contour segments. As a consequence of the CNC, contours can only be formed at the root and supralaryngeal nodes. Therefore, any feature dominated by the other class nodes cannot form contours. However, since the root node dominates [consonantal] and [sonorant] and the supralaryngeal node dominates [strident], the set of possible contour segments is not exclusively limited to [nasal] and [continuant] contours. In order to properly limit the set of contour segments, it must be stipulated that contour segments are restricted to [-sonorant] root nodes and contours formed by [strident] must be accompanied by a contour for [continuant]. The CNC also correctly predicts that complex segments, such as [kp], must have a unique specification for voice because branching laryngeal nodes violate the CNC.

Thus far, the CNC is able to capture the shared phonetic properties of contour segments and complex segments as well as delimit the set of possible contour segments. The CNC is also crucial in the account of the four phonological processes which during prenasalized stop formation.

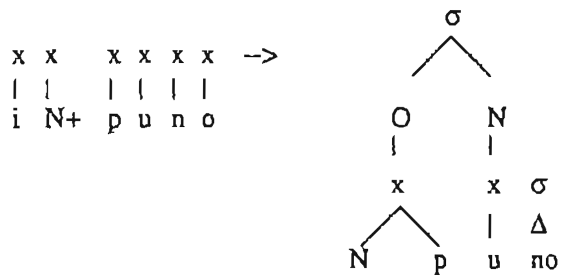
3. Unification (Prenasalized Stop Formation)

Unification, i.e., Herbert's (1986) process that merges a nasal-obstruent sequence into a prenasalized consonant, is explained by the principles of syllabification. Clements (1985a) proposes that prenasalization in Luganda is the result of a nasal and an obstruent being forced under the same the same C-slot on the CV tier thus producing compensatory lengthening of the preceding vowel. Other instances of prenasalized stop formation, e.g., as a result of morpheme concatenation, can also be derived from syllabification. Consider the following example from Ndali.

(16) Ndali (Vail 1972)
a. /iN+ puno/ [i^{m}buno] 'nose'

Since Ndali has a strict CV syllable structure, the syllabification rules force the skeletal point of the nasal and the skeletal point of the word-initial obstruent under the same onset. However, Ndali does not allow onsets to branch. Therefore, one of the skeletal points deletes and the nasal and the word-initial obstruent are attached to the same skeletal point thus merging the nasal and the obstruent into one segment. Voice and place assimilation then follow.

(17) [i^{m}buno]



Cross-linguistically, it is common for the nasal segment of the prefix to delete when the root is nasal-initial.

(18)

	Swahili (Welmers 1973)		
a.	/N+ mende/	[mende]	'cockroach'
	UMbundu (Schadeberg 1982)		
b.	/N+ mola/	[mola]	'I see'
	Shona (Fivaz 1970)		
c.	/N+ nomwe/	[nomwe]	'seven'
	Ndali (Vail 1972)		
d.	/iN+ ŋoshi/	[iŋoshi]	'sheep'
	Kikuyu (Armstrong 1967)		
e.	/meñ-a/	[meñeete]	'know'

Nasal deletion before nasal-initial roots is easily explained. The two [+nasal] root nodes that are dominated by the same skeletal point after unification simplify leaving only one [+nasal] root node.

The syllabification account of unification maintains Herbert's (1986) claim that prenasalized stops may be derived from nasal-stop clusters. The deletion of the prefix before a nasal-initial root follows from the autosegmental representation of syllables and segments. The above discussion, however, does not attempt to explain the assimilation phenomena that occur during unification. These assimilation processes are examined in the following section.

4. The Phonological Processes of Prenasalized Stop Formation

Although langauges can have a variety of prenasalized consonants, the most common inventory of prenasalized consonants for a language is prenasalized voiced stops. Languages with only prenasalized voiced stops often have a number of phonological processes to ensure only prenasalized voiced stops surface. For example, some languages have no phonemic voiced stops but have prenasalized stops. This is often considered to be the result of a voice and continuant assimilation rules. Furthermore, the nasal might delete during unification to avoid the creation of a prenasalized fricative or the nasal and the consonant might coalesce to avoid the creation of a prenasalized voiceless stop. However, the rules required to describe these processes, shown in (1), have nothing in common. There are shown to follow from the CNC and the theory of underspecification. Each phonological process is discussed separately. All cases of prenasalized stop formation discussed in the remainder of this paper involve prenasalized stops that are formed by syllabification. Instances of these rules occurring as a result of other processes are not discussed here.

4.1. Post-nasal Voicing

Many languages have a process called 'post-nasal voicing' which voices an obstruent when the obstruent is preceded by a nasal. Consider the following data from Kikuyu.

(19) Kikuyu (Armstrong 1967)

a. /N+ tɛm-a/ [^{n}dɛmɛɛtɛ] 'cut 1p. perf. ind.'

b. /N+ tom-a/ [^{n}domeete] 'send'

c. /N+ kom-a/ [^{ŋ}gɔmɛɛtɛ] 'sleep'

d. /N+ ker-a/ [^{ŋ}gereete] 'cross'

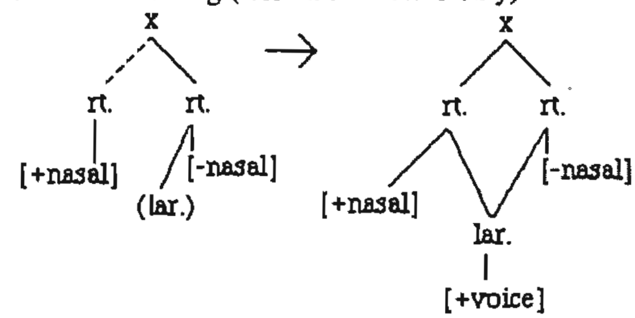
Following Clements (1985), the Kikuyu stops need not be specified for [voice] because stops are voiced only when preceded by a nasal and voiceless elsewhere. Therefore the value for [voice] is predictable. Using A&P's (1986) theory of underspecification, the phonemic inventory of obstruents in Kikuyu (Armstrong 1967) has the following underlying specification for [voice] and [nasal].

(20) Kikuyu

	p	t	c	k	β	ð	γ	N(= m,n,ɲ,ŋ)
[voice]					+	+	+	
[nasal]								+

Post-nasal voicing is based on the premise that the stops which are not specified for [voice] receive their specification for [voice] from the nasal, but the voicing of the stop is not the result of spreading. The root node of the nasal and the root node of the obstruent are dominated by the same skeletal point as a consequence of syllabification. However, the CNC dictates that the two root nodes must share the same laryngeal node. Therefore, the laryngeal nodes are forced to merge hence the nasal and the obstruent must have the same specifications of the laryngeal node. Only [+voice] can be inserted by the default rules even though [-voice] is the default-value for Kikuyu because the nasal cannot be specified as [-voice].

(21) Post-nasal Voicing (relevant structure only)[1]



4.2. Post-nasal Hardening

Many languages also have a process called 'post-nasal hardening' (Herbert 1986) that apparently despirantizes fricatives during unification. Consider the data from Kikuyu in (22).

(22) Kikuyu (Armstrong 1967)

a. /N+ βor-a/ [^{m}bureetɛ] 'lop off 1p. perf. ind.'

b. /N+ ɣor-a/ [$^{\text{ŋ}}$goreetɛ] 'buy'

The labial and velar fricative must surface as a fricative in all environments except post-nasally. This can be related to the fact that the fricatives are unspecified for [continuant]. The proposed specification for Kikuyu obstruents is given in (23).

(23) Kikuyu

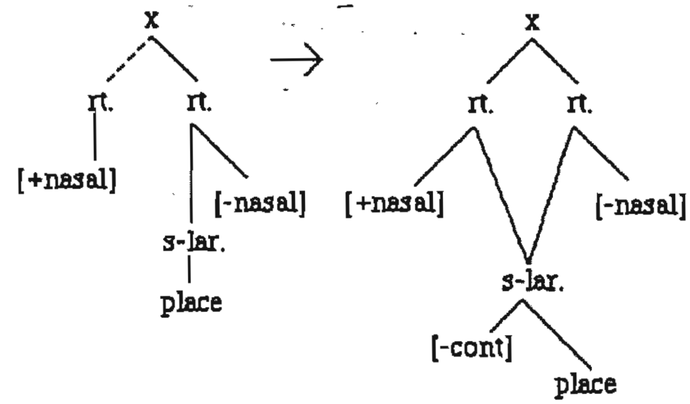
	p	t	c	k	β	ð	γ	N(= m,n,ɲ,ŋ)
[voice]					+	+	+	
[cont]	-	-	-	-				
[nasal]								+

Complement Rule: [ ] --> [-voice]
Default Rules: [ ] --> [-nasal]
[ ] --> [+cont]

Further support for the feature specification in (23) is drawn from the universal properties of phonemic inventories. Kikuyu has a series of voiced fricatives, but no voiced stops which is unusual, but the voiced segments, as proposed in (23), are not underlyingly fricatives because they are not specified for [continuant]. Therefore, Kikuyu has only stops at the phonemic level.

Post-nasal hardening, like post-nasal voicing, is a consequence of the CNC. Since the obstruent and the nasal are dominated by the same skeletal point, both must share the same supralaryngeal node. As in the case of post-nasal voicing, the shared node can only receive one feature-value which is compatible with both the nasal and the obstruent. In post-nasal hardening only [-cont] can be shared by both, hence the obstruent surfaces as a stop.

(24) Post-nasal Hardening (relevant structure only)



Post-nasal hardening and post-nasal voicing are not the result of spreading features, but rather the CNC forces the nasal and the obstruent to share the same set of class nodes. As a result, only certain feature-values can be inserted.

4.3. Nasal Deletion

Nasal segments often delete during unification when followed by a nasal (as shown in section 3) or by certain obstruents. Consider the following data.

(25) Ndali (Vail 1972)

a.	/iN+ puno/	[i^{m}buno]	'nose 9/10 class'
b.	/iN+ tunye/	[i^{n}dunye]	'banana'
c.	/iN+ kunda/	[i^{ŋ}gunda]	'dove'
d.	/iN+ βale/	[i^{m}bale]	'plate'
e.	/iN+ fuwa/	[ifuwa]	'hippo'
f.	/iN+ satu/	[isatu]	'python'
	Swahili (Welmers 1973)		
g.	/N+ boga/	[^{m}boga]	'vegetable'
h.	/N+ devu/	[^{n}devu]	'beard'
i.	/N+ fimbo/	[fimbo]	'stick'
j.	/N+ simba/	[simba]	'lion'

Although deletion triggered by fricatives seems natural, there is no explanation for the fricatives /f,s,š/ to trigger deletion and the fricatives /β, γ/ to trigger hardening.

Post-nasal voicing and hardening (25a-d) in Ndali, like in Kikuyu, are accounted for by proposing the stops are not specified for [voice] and the fricatives are not specified for [cont]. However, the proposed underspecification of Ndali obstruents (given in below) is complicated by the larger number of consonants.

(26) Ndali (obstruents only)

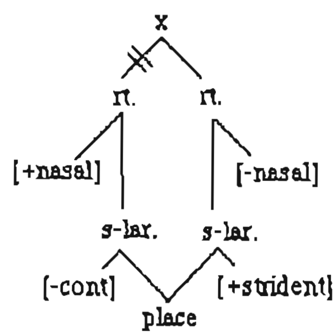
	p	t	c	k	f	s	š	β	γ	N(=m,n,ɲ,ŋ)
[voice]								+	+	
[cont]	-	-	-	-						
[strident]					+	+	+			
[nasal]										+

Complement Rule: [ ] --> [-voice]
Default Rules: [ ] --> [+cont]
[ ] --> [-strident]
[ ] --> [-nasal]

The only difference between the phonemic inventories of Ndali and Kikuyu is that the latter includes voiceless fricatives. These voiceless fricatives are also the only strident phonemes hence they are specified as [+strident].

Nasal deletion is actually the delinking of the nasal segment from the skeletal point, but this delinking in Ndali must be related specifically to /f, s, š/. Since these fricatives are [+strident], they have a supralaryngeal node specified as [+strident] which is not compatible with [+nasal]. Therefore, the supralaryngeal nodes of the nasal and the obstruent cannot merge. As a result, the nasal and the obstruent do not dominate the same supralaryngeal node and there is a violation of the CNC. As a result, the nasal delinks to avoid violating the CNC.

(27)



The use of [strident] as the trigger for nasal deletion is not arbitrary because it appears that strident fricatives never undergo post-nasal hardening in languages where there are both strident and nonstrident fricatives.

Nasal deletion can also be triggered by voiceless stops.[2]

(28) Venda (Ziervogel et al. 1972)

a.	/N+ pala/	[phalo]	'scratching'
b.	/N+ tsumbula/	[tsumbulo]	'roll in dust'
c.	/N+ khakha/	[khakho]	'err'
	Swahili (Welmers 1973)		
d.	/N+ pembe/	[pembe]	'horn'
e.	/N+ tembo/	[tembo]	'elephant'
f.	/N+ kuku/	[kuku]	'chicken'

The deletion phenomena in Venda and Swahili follow from the CNC provided that stops are specified as [-voice] and that [+voice] is the default value, unlike Kikuyu and Ndali. Since Venda and Swahili stops are specified as [-voice], the [+voice] laryngeal node of the nasal cannot merge with the [-voice] laryngeal node of the stop. The two root nodes in this case do not dominate the same laryngeal node. As a consequence, the nasal delinks to avoid a violation of the CNC.

This change in feature specification seems arbitrary, but there is an important difference between Ndali and Kikuyu and Swahili and Venda. The voiced stops in the latter two languages contrast with voiceless stops. It seems that languages with contrasting voiced and voiceless stops do not neutralize following a nasal. The only way to block neutralization is to specifiy the voiceless stops as [-voice] hence merger is blocked.

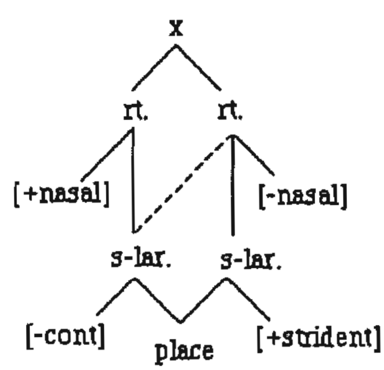
In some languages, the merger of a nasal and a strident does not trigger the deletion of the nasal, but rather a prenasalized affricate is created. This is actually a strategy to avoid CNC violations.

(29) Venda (Ziervogel et al 1972)

a. /N+ vuledza/ [^{m}bvuledzo] 'finishing'
b. /N+ zwima/ [^{n}dzwimo] 'hunting'
Kihungan (Clements 1987)
c. /luN+ vaatis/ [lu^{m}bvaatis] 'dress'

The prenasalized affricate is formed by spreading the supralaryngeal node of the nasal to the root node of the fricative. The configuration of a prenasalized affricate does not satisfy the CNC because the [+strident] supralaryngeal node is not dominated by the [+nasal] root node; however, the CNC is modified in section 5 to accommodate prenasalized affricates. Prenasalized affricate formation in (30) is similar to the representation of intrusive stop formation proposed by Clements (1987).

(30)

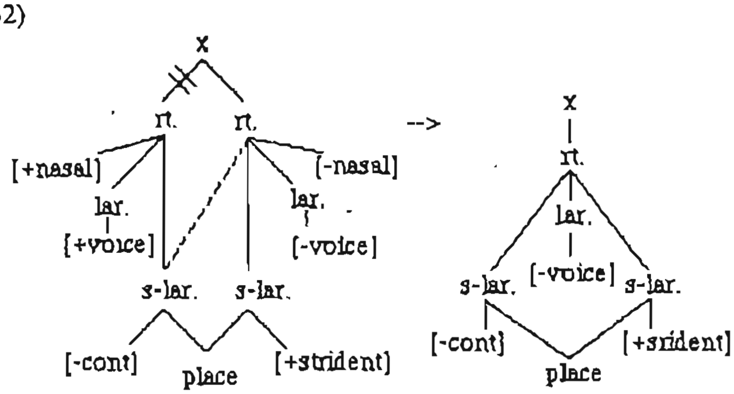


Languages with intrusive stops also have voiceless fricatives becoming affricates as a result of prefixation.

(31) Venda
a. /N+ fula/ [pfulo] 'pasture'
b. /N+ senga/ [tsengo] 'court-hearing'
Kihungan
c. /liN+ sey/ [lutsey] 'mock'
d. /luN+ fut/ [lupfut] 'pay'

Clements (1987) proposes that the node dominating [continuant] (called the oral cavity node) spreads to the stop as in intrusive stop formation. A rule then causes the nasal segment to delete, but the obstruent surfaces as an affricate because it has the nasal's specification for [cont]. The affrication of voiceless stops is also accounted for by the CNC. Although intrusive stops prevent CNC violations at the supralaryngeal tier, a voiceless segment specified as [-voice] will create a CNC violation at the laryngeal tier. As in Clements' analysis, the nasal root node delinks and the nasal's supralaryngeal node remains attached to the obstruent creating a voiceless affricate.

(32)



Languages with intrusive stops differ from languages with deletion insofar as the former have a language-specific process which is to spread the supralaryngeal node from the nasal to avoid CNC violations. CNC violations at the laryngeal node, however, cannot be avoided. Therefore, the nasal must delink after supralaryngeal node has spread thus creating a voiceless affricate.

4.4. Coalescence

Schadeberg (1982) notes that voiced stops in UMbundu only occur when a continuant is preceded by a nasal, i.e., the voiced stop of a prenasalized stop is the result of post-nasal hardening as in (33a).

(33) UMbundu (Schadeberg 1982)

a.	/N+ vanja/	[ᵐbanja]	'I look'
b.	/N+ fela/	[fela]	'I dig'
c.	/N+ seva/	[seva]	'I cook'
d.	/N+ popya/	[mopya]	'I speak'
e.	/N+ tuma/	[numa]	'I send'
f.	/N+ kwata/	[ŋwata]	'I take'

(33b&c), on the other hand, are cases of nasal deletion which have been observed in other languages but (33d,e,&f) are interesting. Voiceless stops should either undergo post-nasal voicing when not specified for [voice], as seen in Kikuyu and Ndali, or trigger nasal deletion when specified for [voice], as seen in Venda and Swahili. Instead, voiceless stops in UMbundu trigger coalescence. This phenomenon occurs in other langauegs as well, for example, voiceless stops in Kihehe and Si-Luyana also trigger coalescence.

(34) Si-Luyana (Givon 1970)

a.	/N+ poko/	[moko]	'arm, knife'
b.	/N+ tabi/	[nabi]	'prince'
c.	/N+ kuku/	[ŋuku]	'chicken'
d.	/N+ supa/	[supa]	'soup'
	Kihehe (Odden and Odden 1985)		
e.	/N+ teefu/	[neefu]	'reed mats'
f.	/N+ kaanzi/ .	[ŋaanzi]	'walls'
	"the nasal deletes before voiceless fricatives" (p. 498n.)		

(35) shows the specification of features in UMbundu from which hardening, deletion, and coalescence can be derived.

(35) UMbundu

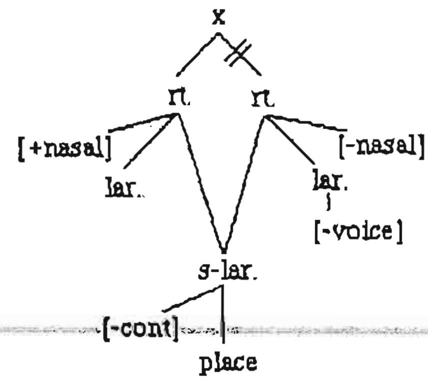
	p	t	c	k	ν	f	s	N(= m,n,ɲ,ŋ)
[voice]	-	-	-	-		-	-	
[cont]						+	+	
[nasal]								+

Default Rules: [ ] --> [+voice]
[ ] --> [+cont]
[ ] --> [-nasal]

The approximant /ν / is not specified for [cont] hence it can undergo post-nasal hardening, but the fricatives /f/ and /s/ are specified as [+cont] (because both are strident) therefore a CNC violation occurs during unification and the nasal delinks, as in Ndali. Using [-voice] as the underlying value for [voice] in UMbundu is justified for the following reason. Since voiced stops in UMbundu occur only after nasals, the stops should be unspecified for [voice]. However, UMbundu has underlying prenasalized stops which would be unspecified for [voice] thus allowing the voiceless stops to be specified as [-voice].

Coalescence, like nasal deletion, is the result of delinking a root node from the skeleton. The [-voice] specification of the UMbundu stops creates a CNC violation because the [-nasal] and [+nasal] root nodes do not dominate the same laryngeal node. Since prenasalized stops consist of two root nodes linked to one skeletal point, there are two association lines that may delink to avoid a CNC violation. Coalescence is the result of two processes: 1. nasal-stop assimilation, i.e. place node merger and 2. delinking the [-nasal] root node. As a result, the [+nasal] root node remains with the place features of the obstruent.

(36) Coalescence (relevant structure only)



Interestingly, coalescence can apply to both voiced and voiceless stops as in Uma Juman (a Borean language).

(37) Uma Juman (Blust 1977)

a.	/ŋ+ pugut/ [mugut]	'to rub'
b.	/ŋ+ bagiʔ/ [magiʔ]	'to share'
c.	/ŋ+ tadav/ [nadav]	'to dive'

The CNC cannot predict the coalescence of the nasal and the voiced stop because the CNC is satisfied. However, Uma Juman does not have prenasalized stops which means that coalescence in Uma Juman is a simplification process which delinks the obstruent to avoid a configuration in which there is a branching skeletal point.

The different causes of delinking which create coalescence in Uma Juman and nasal deletion in Ndali raise the question of the relationship between the CNC and structure-preservation (Kiparsky 1982, 1985). In Uma Juman, coalescence is the result of structure-preservation because prenasalized stops are not licit anywhere in the phonology. Coalescence in UMbundu might also be explained by structure-preservation. Since there is a series of underlying prenasalized voiced stops, stucture-preservation can block any ill-formed structure. However, the delinking processes associated with nasal deletion and coalescence cannot always be the result of structure-preservation. For example, Ndali has both the creation of prenasalized stops and nasal deletion. It seems impossible to relate either processes to structure-preservation because Ndali does not have does not have a series of underlying prenasalized stops.

To summarize, the two assimilation processes (post-nasal voicing, post-nasal hardening) and the two deletion processes (nasal deletion and coalescence) follow from the CNC and underspecification. Post-nasal voicing and hardening occur when the obstruent is unspecified for [voice] and [strident], respectively. As a result, the nasal can merge with the obstruent. Deletion and coalescence occur when the obstruent is specified for [-voice] or [+strident] hence merger is prohibited and a CNC violation occurs. These four processes conspire to create only prenasalized voiced stops by maintaining the correct representation of a prenasalized voiced stop, which is dictated by the CNC.

4.5. Other Phonological Processes

Thus far, only the behaviour of obstruents during unification has been examined, but other consonants behave in interesting ways during unification. For instance, glides and liquids become their corresponding obstruent stops, e.g. w ~ b, y ~ j, r ~ d. The hardening of these sonorants is interesting because there is a change in sonorancy as well as a change in continuancy.

4.5.1. The Hardening of Sonorants

Consider the following alternation between glides and prenasalized stops.

(38) Swahili
a. /N+ wati/ [^{m}bati] 'hut poles'
Ndali
b. /N+ yuki/ [^{ɲ}juki] 'bee'

The fact that the labial and the palatal glides alternate with the labial and palatal stops is not too surprising because the glides and the stops have the same place of articulation. The hardening of glides to stops can be accounted for in the same way as the hardening of obstruents. Glides are not specified for [cont] because all vocoids are redundantly [+cont]. Therefore, the nasal and the glide can share the same supralaryngeal node after merging. As in the case of obstruent hardening, only [-cont] can be inserted because the nasal must be [-cont].

A more interesting phenomenon that occurs during unification with glides is desonorantization. The trigger for the change in sonorancy must lay outside the domain of the CNC because the two segments do not share [sonorant]. It seems that the change in sonorancy follows from an independent restriction that limits the right branch of the contour to [-sonorant] segments. This is discussed again in section 5.

Liquids also harden during unification, as shown in (39).

(39) UMbundu
a. /N+ lamda/ [^{n}danda] 'I buy'
Kihehe
b. /N+ limi/ [^{n}dimi] 'tongues'
Kikuyu

c. /N+ reek-ia/ [ⁿdeeketie] 'finish 1p. perf. ind.'
Shona
d. /N+ refu/ [ⁿdefu] 'tall'

The hardening of /r/ to [d] in (39c,d) is explained the same way as the hardening of glides. That is, [-cont] is inserted after merger and [-sonorant] becomes the major class feature in the contour.

Laterals, like other sonorants, never seem to block prenasalized stop formation. In the case laterals, this fact seems to be a consequence of the position of [lateral] in the feature-geometry. Levin (1987) proposes that [lateral] is dominated by the coronal node and as a result post-nasal hardening is not impeded because the nasal and the lateral can merge supralaryngeal nodes. However, the [+nasal] root node dominates a [+lateral] coronal node. Since [+nasal] and [+lateral] are incompatible, the [+lateral] feature is deleted. It must be assumed that preserving contours by deleting features is only possible below the place node, otherwise the analysis of unification phenomena is undermined. Delateralization, therefore, is phonetic adjustment process which occurs below the place node. This approach to delateralization seems plausible since phonetic adjustment of place-dominated features occurs anyway during unification. For example, the place of articulation of glides can change as a consequence of hardening. After [lateral] has been deleted, [-sonorant] must be assigned to the right root node.

4.5.2. De-implosion

The following data from Shona show that implosive stops become plosives during unification.[3]

(40) Shona (Doke 1967, Fivaz 1970)

a.	/N+ ɓata/	[ᵐbata]	'pincers'
b.	/N+ ɓereka/	[ᵐbereka]	'carrying-skin'
c.	/N+ ɗove/	[ⁿdove]	'wet place'
e.	/N+ pasa/	[mhasa]	'mats'
f.	/N+ tete/	[nhete]	'thin (adj.)'

According to Doke (1967), the implosive stops must be 'significantly distinct' from voiced stops because there are minimal pairs, e.g. [bara] 'write'/[ɓara] 'give birth' in Northeast Shona. Furthermore, voiceless stops contrast with voiced stops and so the former are specified as [-voice]. This accounts for vioceless stops triggering coalesence. Interestingly, prenasalized stop formation is a neutralizing environment for implosive stops but not for voiceless stops.

(41) Specification of Shona stops

	[voice]	[constr. gl.]	[nasal]
p,t,k	-		
b,d,g			
ɓ,ɗ		+	
m,n,ŋ			+

Default Rules:
[ ] --> [+voice]
[ ] --> [-nasal]
[ ] --> [-constr. gl.]

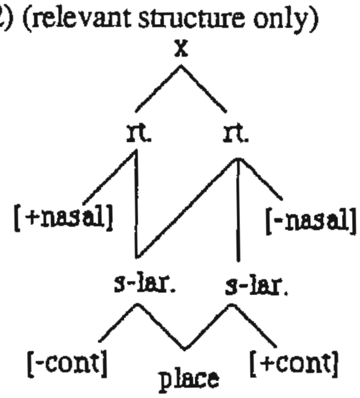
Now what must be explained is the mechanism of neutralization for implosive stops. Neutralization occurs because [+constr. gl.] is compatible with voicing. Therefore, the nasal and the implosive stop can merge because there is no incompatibility between voicing and nasality. Only after merger occurs is [+constr. gl.] deleted.

The CNC, along with the theory of underspecification, provides an analysis that unifies the assimilation processes and the deletion processes that occur during prenasalized stop formation. The version of the CNC used thus far is admittedly problematic because it excludes prenasalized consonants other than prenasalized voiced stops. A revised CNC that accounts for the full range of prenasalized consonants is proposed in the following section.

5. Other Prenasalized Consonants

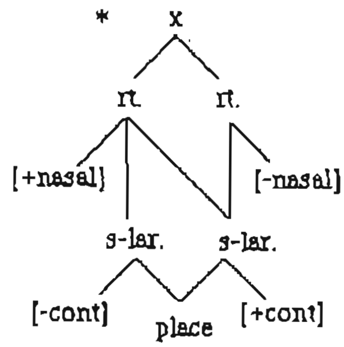
Although the CNC as stated in 2.3 is sufficient for the discussion of the phonological processes, it is too strong because it fails to include a number of prenasalized consonants. For example, prenasalized affricates, which occur in Venda and Kihungan (shown in (29)), are counterexamples to the CNC.

(42) (relevant structure only)



Although the [-nasal] root node dominates the same supralaryngeal node as the [+nasal] root node, the latter root node does not dominate the [+continuant] supralaryngeal node. The CNC, on the other hand, correctly predicts the following is not a possible contour segment.

(43) (relevant structure only)



The [-nasal] root node in (43) does not dominate the [-cont] supralaryngeal node, creating an ill-formed contour that is excluded by the CNC. However, since (42) must be permitted, there is an asymmetry for which the CNC cannot account. This asymmetry is easily explained by the incompatibility of [+nasal] linked to [+cont] in (43) which makes (43) ill-formed.

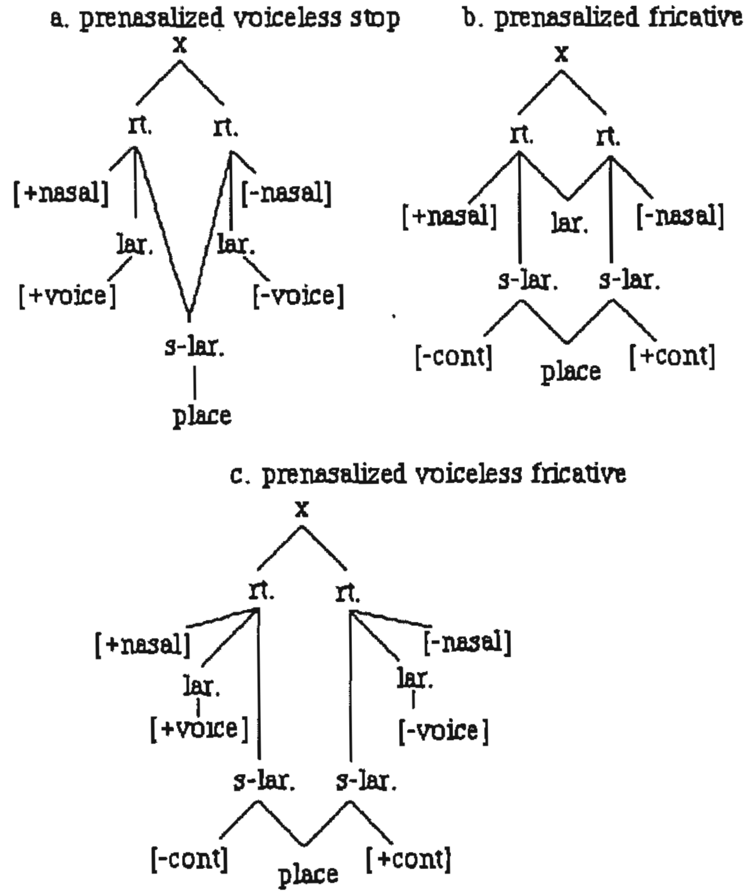
Although the asymmetry between (42) and (43) can be accounted for by the incompatibility of features, there are other interesting properties of contour segments which appear to be aysmmetrical. Shaw (1987) recognizes that contour structures should exhibit some properties derivable from branching and claims that these properties can be related to headedness which defines one branch as more salient than the other. The saliency asymmetry can be defined in terms of the relation between the head and the non-head. Shaw proposes the right branch of a contour segment functions as the head, thus accounting for the lack of structure preservation in reduplication in Nisgha. Shaw accounts for the fact that only the fricative component of an affricate reduplicates by proposing only the head (the right branch of the contour) reduplicates. Right headedness can be used to account for another property associated with the right branch of contour segments. For instance, the obstruent (the right branch) of a prenasalized stop always determines the place of articulation of the prenasalized stop. Hualde (1987) supplies similar evidence for the right headedness of affricates by showing that the place of articulation of the three affricates in Basque is determined by the articulation of the fricative component. Therefore, the notion of right-headedness can be used to determine the articulation of contour segments.

The head of a contour requires two properties. First the head must be the right branch of the contour and second the right branch must be [-sonorant] for root node contours and [+continuant] for supralaryngeal node contours. The desonorantization of liquids and glides discussed in 5.4.1 would follow from this. Since liquids and glides become heads of contours as a result of unification, [-sonorant] becomes the only possible feature-value.

Postnasalized stops, which are found in a number of languages, imply headedness might be parameterized because postnasalized stops would have [+nasal] on the right branch. There are reasons, however, for excluding postnasalized stops from the set of contour segments. According to Piggott (1988a), postnasalization is never the result of unification, but only appears as a result of interaction with nasal vowels and postnasalized stops do not occur underlyingly. Based on these observations, Piggott (1988a) proposes that postnasalized stops have a representation different from the prenasalized stops that are derived from unification.

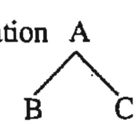
The CNC also excludes the prenasalized consonants shown in (44).

(44)



In each representation in (44), there is a class node that is not dominated by both root nodes. Note that the nodes that are not dominated by both root nodes are the laryngeal node and the supralaryngeal node, but the place node is always dominated by both root nodes. The CNC must be revised so that the laryngeal and supralaryngeal nodes are optional members of the set of class nodes dominated by the two root nodes.

(45) CNC (final form)
given the configuration



B,C on tier T, must dominate the same the nodes in the set S={(lar., s-lar.) place}.

Since the laryngeal and supralaryngeal nodes are optional members of S, there are four possible subsets of S.

(46) S1 {lar., s-lar., place} S2 {s-lar., place}
S3 {lar., place} S4 {place}

These subsets make interesting predictions concerning possible prenasalized consonant inventories. A language which has S1 can only have prenasalized voiced stops because all subordinate class nodes must be dominated by the two root nodes. A language which has S2 can have prenasalized voiceless stops, but must allow prenasalized voiced stops because there is no way to eliminate the possibility that both laryngeal nodes are dominating [+voice].[4] A language which has S3 can have prenasalized voiced fricatives, but must allow for prenasalized voiced stops because there is no way to eliminate the possibility that both supralaryngeal nodes are dominating [-cont]. Furthermore, since the laryngeal node is a member of S3, the prenasalized fricatives and stops must be voiced. A language that has prenasalized voiceless fricatives has S4 and as a result must allow for the full range of prenasalized consonants because there is no way to eliminate the two laryngeal nodes or the two supralaryngeal nodes from being identically specified as [+voice] and [-cont], respectively. Since there are only four subsets of S, there are only four possible prenasalized consonant inventories.

(47)

	prenasalized voiced stops	prenasalized voiceless stops	prenasalized voiced fricatives	prenasalized voiceless fricatives
S1	yes	no	no	no
S2	yes	yes	no	no
S3	yes	no	yes	no
S4	yes	yes	yes	yes

Examples:
S1: Ndali, Kikuyu
S2: Luganda, Kinywaranda
S3: Swahili, Zande
S4: Rundi, Ganda

The subsets of S appear to conform to a markedness convention. S1 is the unmarked subset and S4 is the most highly marked. S2 appears to be less marked than S3 and both are less marked than S4. The markedness hierarchy of the subsets can be related to the propensity for contour segments to maximize the number of similar features. Therefore, S1 is the least marked because all the features dominated by the two root nodes are the same. In other words, S1 is the least marked because there is only one contour. S4 is the most marked because it allows three contours which in turn allow dissimilar features for [voice] and [cont]. The typology of prenasalized consonant systems in (47) leads to predictions concerning the types of processes a language might employ during unification. For example, an S2 language (which allows prenasalized voiceless stops) would not need post-nasal voicing, deletion, or coalescence because there is no CNC violation when a nasal and a voiceless stop are unified. In other words, these processes do not occur because there is no desire to limit the prenasalized consonant series to only voiced stops. However, an S2 language would have deletion to avoid creating prenasalized fricatives.

The CNC maintains that affricates must have one place node because the place node must be a member of S. Hualde (1987) suggests that there are nonhomorganic affricates, thus contradicting the predictions made by the CNC. However, not enough is known about nonhomorganic affricates to consider them here. Furthermore, recent views of the structure of affricates (Hualde 1989, Lombardi 1990) dismiss the notion of the affricate as a contour segment in which the two parts are ordered. Hualde proposes that affricates are unordered complex segments like labialvelar stops and the ordering of the stop and the fricative parts of the affricate occurs as a result of phonetic interpretation. Lombardi proposes that affricates contain the features [stop] and [fricative] which are also unordered in underlying representation. These issues are not addressed here, although it seems plausible to incorporate these views as long as there is a manner node that dominates the place node. The ordering of the parts of the contour (which can be related to headedness) might apply only at the phonetic level.

6. Conclusion

The four phonological processes of prenasalized stop formation all conspire to create prenasalized voiced stops. However, the common goal of these processes is not reflected by the rules required to describe the processes. The representation of prenasalized stops proposed here along with underspecification provides the appropriate environment to trigger these processes. The assimilation rules apply when class nodes are able to merge and the simplification processes, i.e. deletion and coalescence, apply when class nodes cannot merge and the CNC is violated. The four phonological processes, therefore, conspire to preserve the representation of prenasalized consonants.

The CNC also limits possible contour segments to branching at the root node and at the supralaryngeal node. This result is desirable because the only two contour segments (prenasalized stops and affricates) require branching at these nodes. To further limit the number of contour segments, the right branch of a contour node must be [-sonorant].

Footnotes

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1 Hereafter, the right root node is shown specified as [-nasal] for exposition only. The right root node might not be specified for [nasal] during unification. It is assumed that the laryngeal node would not be present when the obstruent has no laryngeal features in underlying representation. In this case, the laryngeal node and its features would be supplied by the default rules.

2 In Venda, Swahili, and other languages the voiceless stops are aspirated as a result of nasal deletion. I do not propose an account of aspiration.

3 The voiceless stops have 'breathy-voice' associated with the nasal (Fivaz 1970). As with aspiration, I offer no analysis of this phenomenon.

4 The identical laryngeal nodes collapse to one node by the Shared Node Convention (Steriade 1982).

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