Morphological Consonant Mutation as Gestural Affixation

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1 Introduction

Languages utilize many different methods for expressing morphological information. Particularly interesting are those languages that employ processes of mutation of elements of a root form as morphological markers. Many instances of morphological consonant mutation are analyzed as the product of featural affixation, in which a segmentally unaffiliated or 'floating' feature acts as an affix, docking with a segment in a root (Lieber 1987; Akinlabi 1996; Wolf 2007).

Not addressed in such analyses is the fact that many consonant-affiliated features are not attested as featural affixes. Attested featural affixes describe some vocal tract action that is added to the action(s) already required of the docking segment. This paper proposes that gaps in attested consonant-mutating featural affixes can be explained if the articulatory actions themselves are taken to be the affixed units, and therefore the representational units of a phonological system, as in Articulatory Phonology (Browman & Goldstein 1986, 1992). Adopting gesture-based rather than segment- or feature-based phonological representations provides a better typological fit between attested and predicted mutation phenomena.

Another advantage to the adoption of gestures as representational units stems from the fact that some consonant mutation phenomena, such as prenasalization, involve complex timing relations between root and affixal gestures. This complexity is easily captured in Articulatory Phonology by manipulating the temporal organization, or coupling, between root and affixal gestures. This manipulation of coupling relations is achieved by developing a grammar that operates over gestural representations. This work proposes new constraints within Optimality Theory (Prince & Smolensky 1993/2004, henceforth OT) that determine ideal patterns of gestural coupling.

The paper is organized as follows. Section 2 examines the different typological predictions for possible consonant mutation phenomena made by adopting gestural versus featural representational units. Section 3 presents the basics of the OT grammar necessary for dealing with gestural affixation. Section 4 demonstrates the workings of this grammar with a case study of consonant mutation in Zoque. Section 5 concludes the paper.

2 Consonant mutation: featural vs. gestural affixation

In some languages, morphological information may be signaled not by simple concatenation of an affix with a root but by mutation of some consonant in a root form. For example, in Zoque (Mixe-Zoquean), palatalization of a root-initial consonant signals the third person (Wonderly 1951).

(1)
a. pata 'mat' — p^jata 'his mat'
b. mula 'mule' — m^jula 'his mule'
c. kama 'cornfield' — k^jama 'his cornfield'
d. hajah 'husband' — h^jajah 'her husband'

Zoque also uses nasalization of a root-initial consonant to mark the first person, though note that the result is a prenasalized stop rather than a full nasal.

(2)
a. buru 'donkey' — ^{m}buru 'my donkey'
b. disko 'record' — ^{n}disko 'my record'
c. pama 'clothing' — ^{m}bama 'my clothing'
d. tatah 'father' — ^{n}datah 'my father'

These examples of consonant mutation from Zoque can be analyzed as the affixation and subsequent docking of the features [coronal] (vowel-place) and [nasal], respectively, using the feature inventory of Clements & Hume (1995).

However, when looking at the various types of consonant mutation that are attributed to floating feature affixation, there is an apparent mismatch between the full set of phonological features and those that are attested featural affixes. A feature-based approach predicts that any non-root node feature should be able to float, or be unaffiliated with a segment, and therefore to act as a morpheme. In reality, the features implicated in featural affixation are only a subset of those found in a fully articulated structure of consonant-affiliated features. The following is a consonantal feature geometric tree from Clements & Hume (1995), and the highlighted features are those that are attested as affixes.

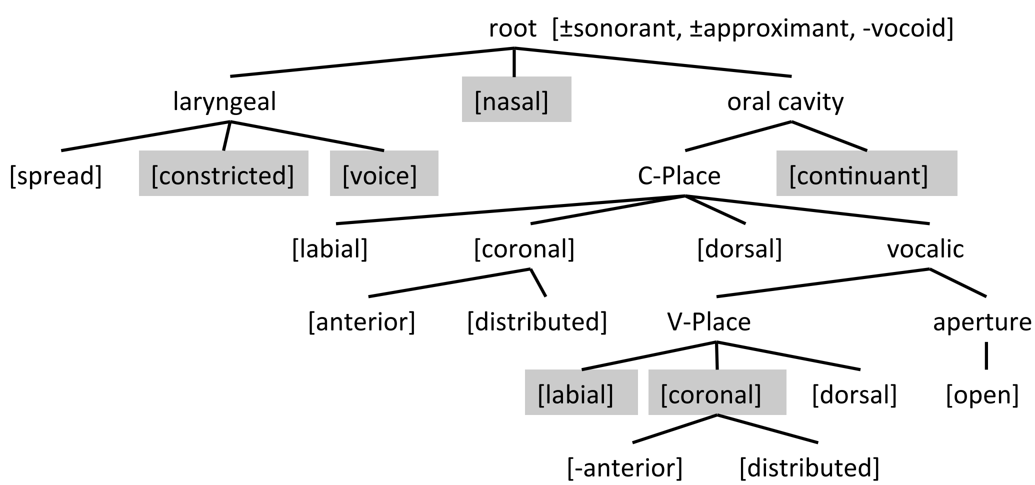


Figure 1: Consonantal feature geometric tree from Clements & Hume (1995), with attested featural affixes highlighted

Looking at this feature geometric structure, it is clear that very few features may float and thus act as morphemes. Furthermore, those that do are not grouped together geometrically. However, these features are set apart by the fact that they describe some action of the vocal tract (lip protrusion, velum opening, glottis spreading, etc.), with the exception of [continuant]. Lieber (1987) observed this fact, stating that those features that correspond to articulatory actions or configurations may be given their own autosegmental tiers. In her analysis, this gives a feature the ability to act as a morpheme. Why this distinction between two types of features and their abilities to act as morphemes should exist, whether by occupying their own tiers or by floating, is not obvious. In addition, it is a division between feature types based on vocal tract actions, which do not have any formal status within segment- or feature-based phonological frameworks.

Instead, the gaps in attested featural affixes can be explained if the articulatory actions themselves are taken to be the units that are added as affixes, and therefore that these actions are the units of representation of a phonological system. This is the basis of Articulatory Phonology (Browman & Goldstein 1986, 1992), in which forms are represented as combinations of gestures rather than features or segments. Gestures are representational units that specify goal actions of the vocal tract. The set of gestures is not in one-to-one correspondence with the set of segments or features; thus, these two sets of representational units make different predictions regarding what units are available to serve as morphemes. Most features do not have gestural analogs, and these are the features that are not attested as affixes (with the exception of [continuant]). By adopting gestures as representational units, those features that do not have gestural analogs are eliminated as possible morphemes, resulting in a more constrained typology of possible consonant-mutating affixes.

The following table states the gestures that have featural rather than segmental analogs, as well as the consonant mutation phenomena for which they are responsible and some of the languages in which these phenomena are attested.

Gesture	**Mutation Phenomenon**	**Language**
palatal narrow constriction	Palatalization	Zoque, Chaha
lip protrusion	Labialization	Chaha
velum opening	Nasalization	Zoque, Terena
glottal opening	Voicing	Breton, Aka
glottal closure	Glottalization	Yowlumne

Table 1: Gestures implicated in consonant mutation

As can be seen, all of the gestures that have featural rather than segmental analogs are attested as sources of consonant mutation.

There are many more gestures than those listed in table (1), however, and these gestures should be able to act as morphemes as well if gestures are a better typological fit to the set of units that may act as morphemes. This is indeed the case, though the affixation of many gestures results in what would be analyzed in a traditional framework as typical segmental affixation rather than featural affixation or consonant mutation. Most gestures represent phones that would be captured within a traditional phonological framework by full segments.

The following table provides a list of the consonant-affiliated gestures of English, along with an example of a segmental or featural analog. Those gestures that are (or can be) represented by features are highlighted. The set of English gestures was chosen to exemplify a set of consonant-affiliated gestures because it is the most elaborated set of gestures developed so far within Articulatory Phonology, and because the set includes all of the gestures of interest here, namely those that are attested as affixes responsible for consonant mutation. The inclusion of gestural inventories from additional languages would expand this table somewhat, but would only add gestures that correspond to full segments.

Labial closure /b/	Tongue Tip-alveolar closure /d/	Tongue Body-velar closure /g/	Glottis open [-voice]
Labial critical /v/	Tongue Tip-dental critical /ð/	Tongue Body-palatal narrow /j/, /ʲ/	Glottis closure /ʔ/, [constricted glottis]
Lip Protrusion [round]	Tongue Tip-alveolar critical /z/		Velum open [nasal]
	Tongue Tip-alveopalatal critical /ʒ/		
	Tongue Tip-alveopalatal closure /dʒ/		
	Tongue Tip-palatal narrow /ɹ/		
	Tongue Tip-alveolar narrow /l/		

Table 2: Set of consonant-affiliated gestures of English

The adoption of Articulatory Phonology's gestures as representational units allows for a more restricted typology of consonant mutation phenomena without stipulating that some gestures can act as morphemes and some cannot. All gestures in the table above can stand on their own as morphemes. There is no need to distinguish between featural affixation and typical segmental affixation, and there is no need to distinguish between different types of features that may or may not act as morphemes. The only thing that distinguishes the gestures that are implicated in consonant mutation is the fact that these gestures are the ones that would be analyzed as the addition of features in a traditional framework. The affixation of any other gesture would be analyzed as the addition of a full segment, and thus would not be analyzed as featural affixation. For instance, the Tongue Tip – alveolar closure gesture above, represented in traditional analyses as the segment /d/, is attested as an affix: the English past tense marker. Goldstein

(2011) presents such an analysis. On the other hand, the Velum – open gesture, represented in traditional analyses as the feature [nasal], is also attested as an affix, the Zoque first person. While in a segment- or feature-based phonological system these would be seen as different types of affixation, in a gesture-based framework these are both simply instances of gestural affixation.

Another advantage of adopting the representations of Articulatory Phonology is the ability to represent more complex timing relations between gestures. Gestures can be coupled together in either in-phase (synchronous) or anti-phase (sequential) relations, which allow for the modeling of various types of gestural overlap (Browman & Goldstein 2000). This is particularly useful for capturing consonant mutation phenomena that show complex timing between affixal and root gestures, such as Zoque nasalization. Prenasalization rather than full nasalization of root-initial consonants cannot be captured by simple docking of a [nasal] feature to a segment's root node, as discussed in Section 4.2.3.

3 A grammar of gestural affix landing sites: constraints over gestural organization

Adopting the gestures of Articulatory Phonology leads to better representation of consonant mutation phenomena both in terms of the inventory of possible gestural affixes and the temporal coupling relations that can exist between gestures. What is lacking is a mechanism for determining what those coupling relations are, as well as the optimal landing sites for gestural affixes. A closer inspection of consonant mutation phenomena shows that it is not as simple as coupling a gestural affix to an edgemost root gesture, as will be shown in Section 4. This section elaborates a mechanism for determining coupling relations between gestures, both within and across morpheme boundaries, within the framework of OT, which operates here over gestures.

3.1 Inputs and outputs

Because gestures enter into coupling relations with one another in principled ways, the OT grammar developed here should operate to establish coupling relations between gestures. Therefore, the input to EVAL can be thought of as a set of gestures that are linearly ordered, but otherwise not specified for more specific temporal organization. In the following figure, consonantal and vocalic gestures form a sequence that can be transcribed as /badag/, with subscript numbers indicating the gestures' linear ordering indices.

Labial closure$_1$	Tongue Body pharyngeal wide$_2$	Tongue Tip alveolar closure$_3$	Tongue Body pharyngeal wide$_4$	Tongue Body velar closure$_5$	/b_1 a_2 d_3 a_4 g_5/

Figure 2: Linearly ordered gestures for sequence /badag/

Some consonants, such as nasals, liquids, voiceless consonants, and consonants with secondary articulations, are made up of multiple gestures. The composite gestures of a multigestural consonant are represented as sharing an underlying linear ordering indexation. The following figure illustrates the gestural input form for /matag/, which includes two multigestural consonants, a nasal stop at index one and a voiceless stop at index three.

Labial closure$_1$	Tongue Body pharyngeal wide$_2$	Tongue Tip alveolar closure$_3$	Tongue Body pharyngeal wide$_4$	Tongue Body velar closure$_5$	/m_1 a_2 t_3 a_4 g_5/
Velum open$_1$		Glottis open$_3$			

Figure 3: Linearly ordered gestures for sequence /matag/

Once the optimal coupling relations between these gestures have been determined by EVAL, the outputs take on the form of a coupling graph, as shown below. Lines between gestures indicate that they are coupled in some way. Solid lines represent in-phase coupling (gestures occur synchronously), while dashed arrows represent anti-phase coupling (gestures occur in sequence, with the arrow pointing toward the later gesture).

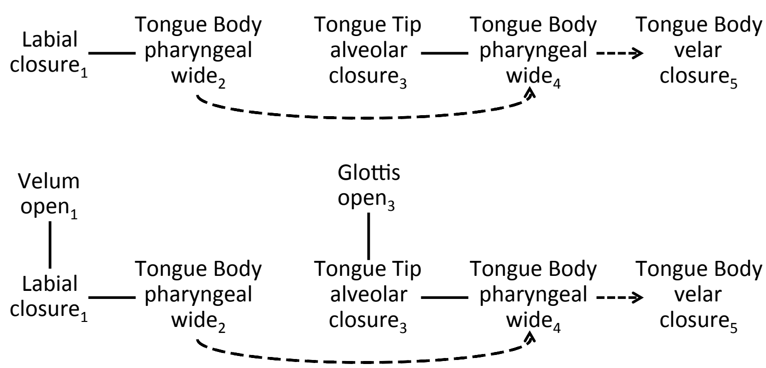


Figure 4: Coupling graphs for [badag] (above) and [matag] (below)

3.2 COUPLE constraints

Establishing coupling graphs based on linearly ordered gestures is achieved by a set of COUPLE constraints, similar to the ASSOC(IATE) constraints of Davidson (2003). These COUPLE constraints determine which gestures are coupled to one another in the output based on their linear ordering in the input, as well as whether they are considered consonantal or vocalic gestures. In addition to representing timing relations between gestures, coupling relations represent gestures' syllabification. Because syllabification is predictable and easily generated from constraint interaction, basic gestural coupling can also be captured by a small set of constraints. There are three basic COUPLE constraints for determining the coupling relations between gestures:

> COUPLE(C,V): Assign a violation mark for any consonantal gesture that is not coupled in-phase to the following nuclear vocalic gesture.

> COUPLE(C,C): Assign a violation mark for any consonantal gesture that is not coupled anti-phase to the following adjacent consonantal gesture.

> COUPLE(V,V): Assign a violation mark for any nuclear vocalic gesture that is not coupled anti-phase to the following nuclear vocalic gesture.

The first of these constraints, COUPLE(C,V) ensures that a consonantal gesture couples to the following vocalic gesture, essentially syllabifying as its onset. The second, COUPLE(C,C), calls for adjacent consonantal gestures to couple sequentially to one another in order to avoid total overlap. Finally, COUPLE(V,V) is responsible for the sequentiality of the vocalic gestures that act as syllable nuclei. In the analysis of Zoque consonant mutation that follows, these constraints are considered high-ranking and are not included in the discussion of the analysis, as only those candidates that satisfy them are considered.

3.3 Gestural co-occurrence constraints

When the coupling of gestures results in a marked structure, the coupling relation between them is penalized by a gestural co-occurrence constraint. There are two basic forms a gestural co-occurrence constraint can take:

> Gest_1—Gest_2: Assign a violation mark for a pair of gestures of type Gest_1 and Gest_2 that are in coupling relation X with one another.

> Gest_1—Gest_2—Gest_3: Assign a violation mark for a gesture of type Gest_2 that is in coupling relation X with a gesture of type Gest_1 and in coupling relation Y with a gesture of type Gest_3.

The first schema outlined above refers to a pair of incompatible gestures, while the second refers to a set of three incompatible gestures. The type of coupling relation that holds between the gestures, denoted as X and Y, need not be specified in an actual constraint. A restriction between the coupling of two incompatible gestures may hold over in-phase relations, anti-phase relations, or both.

When the affixation of a gesture and its subsequent coupling with an edgemost root gesture would result in the violation of a gestural co-occurrence constraint, there are several strategies of markedness avoidance that may come into play. The strategies of markedness avoidance employed by Zoque when gestural affixes are incompatible with root gestures at the relevant edge are the subject of the next section.

4 Marked Structure Avoidance in Zoque Consonant Mutation

4.1 Zoque Palatalization: failure to realize affix

A simple case of markedness avoidance is exemplified by Zoque palatalization, in which an affix simply will not surface when its coupling to a root consonant would result in a marked structure. Recall that in Zoque the third person is indicated by palatalization of a root-initial consonant, which can be represented by a palatal narrowing gesture.

(3)	a. pata ‘mat’	p^jata ‘his mat’
	b. mula ‘mule’	m^jula ‘his mule’
	c. kama ‘cornfield’	k^jama ‘his cornfield’
	d. hajah ‘husband’	h^jajah ‘her husband’

However, this palatal narrowing gestural affix does not couple to the root if that root begins with a consonant cluster.

(4)	a. plato ‘plate’	plato ‘his plate’	*pl^jato, *p^jlato, *p^jato
	b. fruta ‘fruit’	fruta ‘his fruit’	*fr^juta, *f^jruta, *f^juta
	c. mwestra ‘sample’	mwestra ‘his sample’	*mw^jestra, *m^jwestra, *m^jestra

There is apparently a restriction on the coupling of a palatal narrowing gesture to a consonantal gesture when it is part of a cluster, i.e., when it is coupled anti-phase (sequentially) to another consonantal gesture. This restriction can be captured with the following gestural co-occurrence constraint.

> *Palatal—C—C: Assign a violation mark to a consonantal gesture that is coupled to a palatal gesture and another consonantal gesture.

*Palatal—C—C is never violated and thus must be high-ranked. However, its violation is not prevented by deleting a member of the root-initial consonant cluster, indicating that these consonantal gestures are protected by a MAX constraint for root elements. Instead, avoiding violation of *Palatal—C—C involves deleting the gestural affix, in violation of another constraint calling for morpheme realization (Samek-Lodovici 1992):

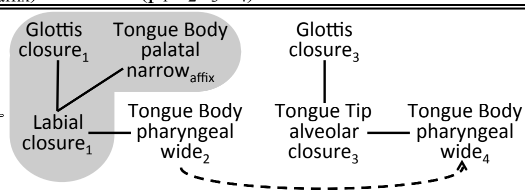
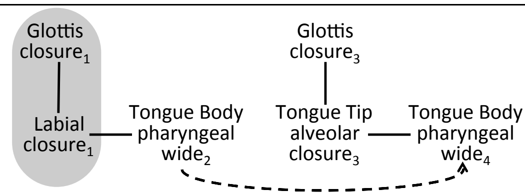
> MORPH(EME)REAL(IZATION): Assign a violation mark if a morpheme does not have some exponent in the output.

This constraint is assumed to be indexed to specific morphemes, following Pater (2000), as different morphemes display differing propensities for surfacing when a marked structure is created.

When realization of the first person morpheme does not require violation of the gestural co-occurrence restraint, as is the case for roots with simple onsets, palatalization surfaces. The following two tableaux demonstrate affixation of a palatal narrowing gesture, surfacing normally on a root-initial consonantal gesture, and failing to surface on a root-initial sequence of two consonantal gestures.

In these tableaux, the input is represented as a linearly ordered set of gestures, with each gesture represented by a box, as in Section 3.1. The linear ordering indexation is included for each gesture, with those gestures sharing an indexation placed one on top of the other. For ease of reading, indexed IPA symbols corresponding to the sets of gestures are included.

(5) Affixation of a palatal narrowing gestural affix

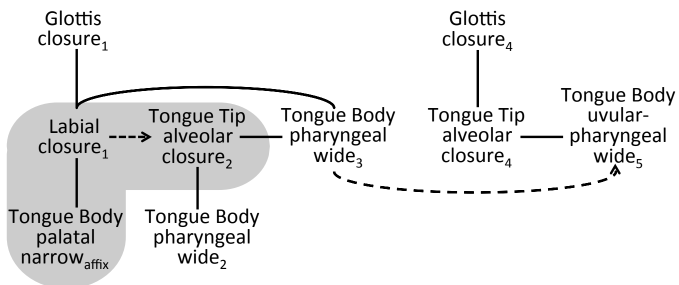
Input: [Tongue Body palatal narrow$_{affix}$] (j_{affix}) [Labial closure$_1$ / Glottis open$_1$] [Tongue Body pharyngeal wide$_2$] [Tongue Tip alveolar closure$_3$ / Glottis open$_3$] [Tongue Body pharyngeal wide$_4$] (p_1 a_2 t_3 a_4)	*Palatal —C—C	MAXGEST (root)-IO	MORPH REAL (j_{affix})
☞ a.  [pʲata]			
b.  [pata]			*!

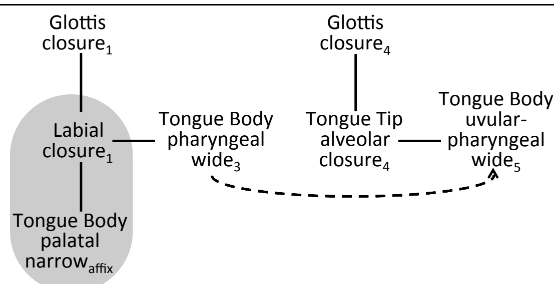
In the tableau in (5) above, Candidate A [pʲata] is the winner by virtue of realizing all underlyingly present gestures in the output without violating the gestural co-occurrence constraint *Palatal—C—C. Candidate B [pata] does not violate *Palatal—C—C either, but violates MORPHREAL unnecessarily.

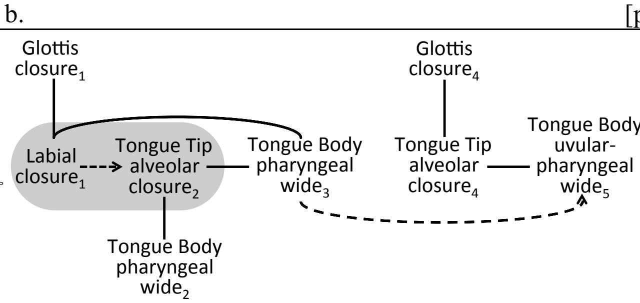
The tableau in (6) demonstrates the failure of the palatal narrowing gestural affix to couple to a root beginning with a consonant cluster. Candidate A [pʲlato] violates *Palatal—C—C by affixing the palatal narrowing gestural affix to one of the members of the root-initial cluster (similar form [plʲato] would also violate this). Candidate B [pʲato] avoids this markedness violation by deleting one of the gestures of the root, eliminating the consonant cluster and thereby allowing affixation of the palatal narrowing gesture. This, however, results in a violation of MAXGEST(root)-IO. Finally, winning Candidate C [plato] preserves the consonant cluster but deletes the gestural affix, violating MORPHREAL.

(6) Failure of the palatal narrowing gestural affix to couple to the root

<table>
<tr>
<td>Input:

<table>
<tr><td>Tongue Body palatal narrow$_{affix}$</td><td></td><td>Labial closure$_1$</td><td>Tongue Tip alveolar closure$_2$</td><td>Tongue Body pharyngeal wide$_3$</td><td>Tongue Tip alveolar closure$_4$</td><td>Tongue Body uvular-pharyngeal wide$_5$</td></tr>
<tr><td></td><td></td><td>Glottis open$_1$</td><td>Tongue Body pharyngeal wide$_2$</td><td></td><td>Glottis open$_4$</td><td></td></tr>
</table>
(j_{affix}) (p_1 l_2 a_3 t_4 o_5)</td>
<td>*Palatal
—C—
C</td>
<td>MaxGest
(root)-IO</td>
<td>Morph
Real
(j_{affix})</td>
</tr>
<tr>
<td>a.


[pʲlato]</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.


[pʲato]</td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>☞ c.


[plato]</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</table>

Zoque palatalization is a fairly straightforward example of markedness avoidance when affixation of a consonant-mutating gesture will result in the violation of a gestural co-occurrence constraint. However, deletion of a gestural affix is only one way to avoid such violation. Other consonant mutation phenomena rely on more complex coupling relations between gestures in order to avoid the creation of marked structures, as demonstrated in the following subsection.

4.2 Zoque nasalization

4.2.1 Alternative coupling

Zoque nasalization demonstrates two strategies for avoidance of marked structures due to gestural affixation. First, a gestural co-occurrence restriction may result in complex temporal organization of gestures in order to avoid marked coupling relations between gestures. Recall that Zoque signals the first person by nasalization of the first consonant of a root (Wonderly 1951).

(7)	a. buru ‘donkey’	^{m}buru ‘my donkey’	*muru
	b. disko ‘record’	^{n}disko ‘my record’	*nisko
	c. pama ‘clothing’	^{m}bama ‘my clothing’	*^{m}pama, *mama
	d. tatah ‘father’	^{n}datah ‘my father’	*^{n}tatah, *natah

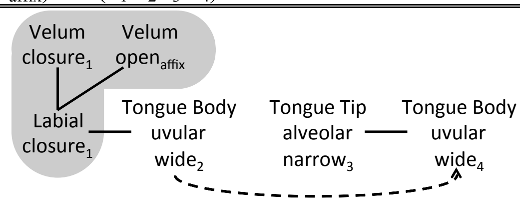
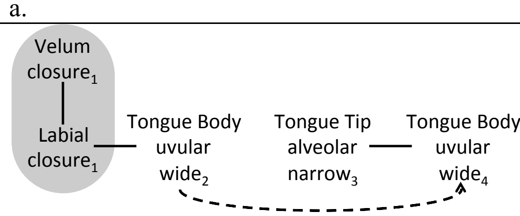
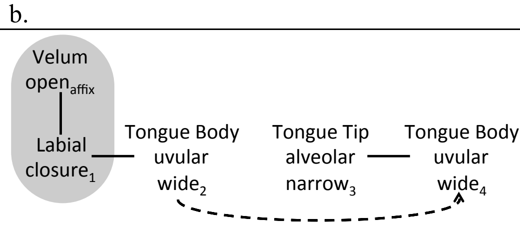
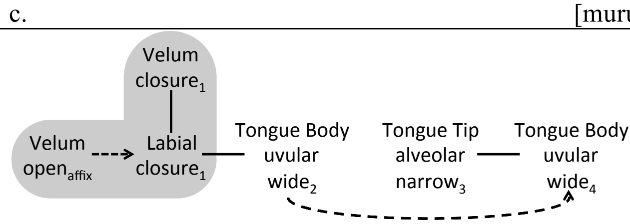
The first person affix that results in nasalization of the first consonant of a root form is a velum opening gesture. Note, however, that the addition of this velum opening gesture does not simply produce a nasal stop. Rather, the root-initial consonant becomes a prenasalized stop. It is proposed here that the reason for this is that in Articulatory Phonology and in TADA, its computational implementation (Nam, Goldstein, Saltzman, & Byrd 2004), the closure gesture for a stop is accompanied by a gesture calling for velum closure. Affixation of a velum opening gesture will only result in a fully nasal stop root-initially if the root consonant’s accompanying velum closure gesture is deleted. This is presumably protected by MaxGest(root)-IO, as was seen in the case of Zoque palatalization. However, it is also not possible for the oral closure gesture of a stop to be coupled to both a velum opening and velum closure gesture. The following gestural co-occurrence constraint prevents such coupling:

> *Velum Opening—Oral Closure—Velum Closure: Assign a violation mark for any consonantal gesture that is coupled in-phase to both a velum opening gesture and a velum closure gesture.

Note that this constraint specifies that only in-phase (synchronous) coupling of these gestures is prohibited. Anti-phase (sequential) coupling, on the other hand, allows for the avoidance of a violation of *Velum Opening—Oral Closure—Velum Closure, while still preserving both velum gestures in the output, satisfying MaxGest(root)-IO and MorphReal. The tableau in (8) demonstrates.

In Candidate A [b̃uru], both velum gestures are coupled in-phase (synchronously) with the consonantal gesture, violating *Velum Open—Oral Closure—Velum Closure and creating what is likely a phonetically impossible form. Candidate B [buru] fails to realize the gestural affix, violating MorphReal, while Candidate C [muru] deletes the velum closure gesture of the root-initial consonant, resulting in a full nasal consonant and violating MaxGest(root)-IO. In the winning Candidate D [^{m}buru], the velum opening gestural affix is coupled anti-phase (sequentially) to the root-initial consonantal gesture, resulting in a prenasalized stop. This alternative coupling relation between root and affix gestures ensures that all gestures present in the input are preserved without violating *Velum Open—Oral Closure—Velum Closure. As can be seen here, the adoption of gestures and their coupling relations as phonological primitives allows for a straightforward analysis of prenasalized stop formation.

(8) Alternative coupling of a velum opening gestural affix

Input: Velum open$_{affix}$ | Labial closure$_1$ / Velum closure$_1$ | Tongue Body uvular wide$_2$ | Tongue Tip alveolar narrow$_3$ | Tongue Body pharyngeal wide$_4$ (N$_{affix}$) (b$_1$ u$_2$ r$_3$ u$_4$)	*VelOpen —C— VelClo	MORPH REAL (N$_{affix}$)	MAXGEST (root)-IO
a.  [b̃uru]	*!		
b.  [buru]		*!	
c.  [muru]			*!
☞ d.  [^{m}buru]			

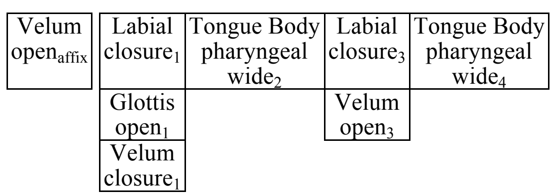
4.2.2 Root gesture deletion

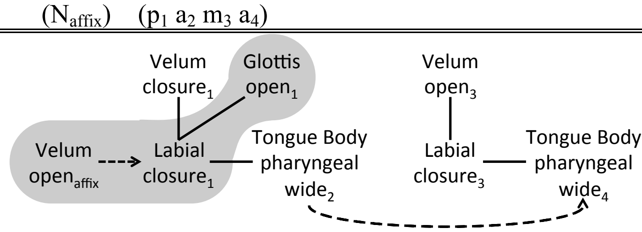
Affixation of a velum opening gesture in Zoque demonstrates another instance of marked structure avoidance for voiceless prenasalized stops. Note in (7c) and (7d) that unaffixed root forms [pama] and [tatah] begin with voiceless stops, but forms bearing the third person affix, [^{m}bama] and [^{n}datah], begin with voiced prenasalized stops. The glottal opening gesture responsible for the voicelessness of the root-initial consonant is lost when the consonantal gesture is also coupled to a velum opening gesture. The following gestural co-occurrence constraint captures this ban on voiceless prenasalized stops:

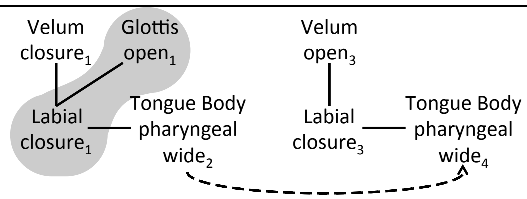
> *Velum Opening—Oral Closure—Glottal Opening: Assign a violation mark for any consonantal gesture that is coupled to both a velum opening gesture and a glottal opening gesture.

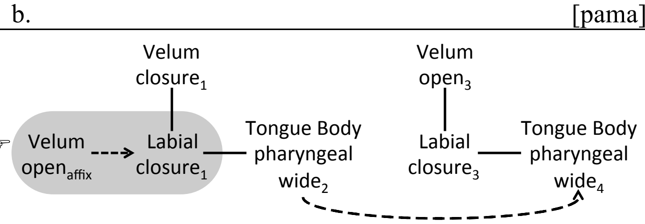
Note that this constraint does not specify the type of coupling relation between gestures in this marked structure—any coupling between these three gestures will violate it. This means that the alternative coupling of the velum opening gesture, resulting in a prenasalized stop, will not avoid violation of *Velum Opening—Oral Closure—Glottal Opening. Instead, some gesture within the marked structure must be deleted. In this case, it is the glottal opening gesture of the root rather than the velum opening gesture of the affix, indicating that MORPHREAL is ranked above MAXGEST(root)-IO. The following tableau demonstrates this.

(9) Deletion of a root gesture

<table>
<tr><td>Input:


(N$_{affix}$) (p$_1$ a$_2$ m$_3$ a$_4$)</td><td>*VelOpen —C— GlotOpen</td><td>MORPH REAL (N$_{affix}$)</td><td>MAXGEST (root)-IO</td></tr>
<tr><td>a. 

[^{m}pama]</td><td>*!</td><td></td><td></td></tr>
<tr><td>b. 

[pama]</td><td></td><td>*!</td><td></td></tr>
<tr><td>☞ c. 

[^{m}bama]</td><td></td><td></td><td>*</td></tr>
</table>

In Candidate A [^{m}pama], a voiceless prenasalized stop, while preserving all gestures present in the input, violates *Velum Opening—Oral Closure—Glottal Opening. Candidate B [pama] deletes the velum opening gestural affix, violating MorphReal. The winning Candidate C [^{m}bama] deletes the glottal opening gesture of the root, violating MaxGest(root)-IO in order to satisfy *Velum Opening—Oral Closure—Glottal Opening, and resulting in a voiced prenasalized stop.

The examination of morphological consonant mutation in Zoque undertaken here has demonstrated several types of avoidance of marked structures caused by gestural affixation, all of them motivated by gestural co-occurrence constraints. Palatalization eliminates a marked structure by deleting a gestural affix, while preanasalization does so either through the use of alternative coupling of gestures or by deleting a root gesture.

4.2.3 Prenasalized stops in featural/segmental theory

A segmental alternative to the representation of prenasalized stops relying on Aperture Theory was previously developed in Steriade (1993). According to Aperture Theory, stops have two ordered aperture positions for the stop's closure and release. Prenasalized stops are represented by a [nasal] specification for the closure, but not the release, of the stop. The following figure illustrates the differing representations of prenasalized and nasal stops, with A_0 referring to the stop's closure portion, and A_{max} to its release.

Figure 5: Representations of prenasalized and nasal stops in Aperture Theory

However, it is unclear why the affixation of a [nasal] feature in Zoque would only attach to one aperture position of a root-initial stop. Presumably this could be captured by positing a constraint protecting only the non-nasality of the release aperture position, but why this should be so is not explained. Alternative coupling, on the other hand, is easily explained as the result of a co-occurrence restriction against the synchronicity of incompatible velum gestures.

In addition, the development of Aperture Theory points to the need within segmental theory to appeal to special mechanisms, such as multiple aperture positions for a single consonant, in order to capture temporally complex phenomena. The representation of prenasalized stops requires a richer representation of time than a typical segment-based framework's simple linear ordering can provide. Such a representation of time is well within the range of Articulatory Phonology's representational abilities, however. There is no need to appeal to special mechanisms to deal with certain phenomena, as coupling relations between gestures are inherent to the theory of Articulatory Phonology.

5 Conclusion

The inspection of cases of morphological consonant mutation has shed light on some of the advantages of adopting gestural representations in phonology. Gestural affixation provides a better typological fit to attested phonological units that may act as morphemes than is provided by a segmental or featural representation of consonant-mutating affixation. Furthermore, the ability to make use of coupling relations between gestures makes capturing affixation involving complex timing between root and affix elements fairly simple. The ability to appeal to coupling relations between gestures also allows for a straightforward analysis of variations in gestural affix coupling as the avoidance of structures that are banned by gestural co-occurrence constraints. These advantages suggest that phonology makes use of gestures, rather than segments or features, as primitives, in keeping with the tenets of Articulatory Phonology.

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