

Deriving Interactions of Complex Stops¹

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1 Introduction

Doubly-articulated stops, a subtype of complex segments, have two separate phonological places of articulation with equal degrees of stricture (Ladefoged and Maddieson 1996: 328). These complex stops are most commonly labial-velar, with labial-palatal and rarely labial-alveolar also reported (Cahill 1999). These segments have the duration of a single segment, and contrast with stop clusters in certain languages (Ladefoged and Maddieson 1996: 335). In an Optimality Theoretic system (Prince and Smolensky 1993/2004), complex stops must then be admitted in GEN and the base. How, then, are these segments treated by CON? This project investigates the idea that constraints make no reference to "complexity" or these types of segments specifically, and that all the phonological interactions of complex stops are derived from independently-motivated universal markedness scales and faithfulness constraints.

In the core system and set of constraints developed in this project, the markedness profile of a complex stop KP is the sum of markedness for K and of markedness for P; thus complex stops are "extra marked" because of their double place. Place markedness is defined along a universal scale with constraints in a stringency relation (de Lacy 2006; Prince 1997; Prince and Smolensky 1993/2004). The constraints *must* be in a stringency relationship and not in a universal fixed hierarchy, due to the special behavior of the markedness constraint that violates against all places: this constraint assigns two violations to complex stops and one violation to all other simple stops, making it possible to militate against all and only complex stops when in the proper ranking configuration. This also means that the constraint set cannot be defined as *lenient* following Gouskova (2003), as the constraint that violates against the least marked place is the only constraint that has this crucial behavior. This project also assumes that all complex stops are labial-dorsal: labial-palatals [CP] have a [dorsal] major place, and that the existence of labial-alveolars is disputed, following recent arguments in Bennett (to appear). These arguments are summarized in section 2.

Even without making specific reference to doubly-articulated complex stops in CON, the core system accounts for the intended presence or absence of complex segments in a given system. The reduction of these complex segments is always to the least marked but still faithful place, subject to a universal markedness hierarchy. Further definitions of voicing markedness and

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faithfulness allow the voicing distinctions of complex stops to be lost on the surface while simple stops retain voicing distinctions. These interactions are all discussed in section 3. Section 4 then extends the core system to capture alternations in Amele and Dagbani. However, the systems here are only a beginning towards a complete phonology of doubly-articulated stops (see Cahill 1999 for an overview of issues). Certain generalizations are not captured here, such as the many languages with [gb] as their only complex stop; a fact that as Cahill (2009) points out is contrary to normal markedness expectations. Additionally, the typology predicts a close relationship between simple palatal stops and labial-palatal stops, CP only if C, which is not supported empirically. These cases are discussed in section 3.4. Sections 5 and 6 conclude and offer general remarks.

2 Background and Definitions

As defined in Ladefoged and Maddieson (1996), complex segments, or doubly-articulated segments, "are those which have two simultaneous articulations of the same degree of stricture" (Ladefoged and Maddieson 1996: 328). These means that stops can be doubly-articulated, but also segments of other degrees of stricture such as approximants. This project, and thus this section, focuses solely on stop consonants. The focus is restricted to stop consonants to both give the project a manageable scope, and also because stops are very well attested as doubly-articulated consonants. Ladefoged and Maddieson (1996: 329) argue that doubly-articulated fricatives do not exist in the world's languages, and that approximants like [w], described as having both labial and velar gestures, "are not parallel to segments with two closures" (Ladefoged and Maddieson 1996: 328). In this work, the term complex refers to the same property as doubly- or multiply-articulated consonants.

This project focuses on the behavior of complex stops. Complex stops are generally those stops that have multiple place features. In this work, discussion is limited to those stops with two equal phonological major place features (double articulation rather than secondary articulation, see van de Weijer 2011). Major place features include [labial], [dorsal], and [coronal], with their normal definitions. The places are equal in a segment if neither has special representational status with respect to the other; all are children of a c-place node (Clements and Hume 1995). All complex stops are assumed to be labial-dorsal, despite previous descriptions of labial-coronals. Instead, these stops are analyzed as labial-dorsals with the minor place feature [–back], indicating that the dorsal element is palatalized. Justification for this is given in the next section. The feature [±back] is considered minor place because it is dependent on a major place feature; in this case, [dorsal]. When voicing is irrelevant, [+back] labial-dorsals are abbreviated KP, and [–back] labial-dorsals are abbreviated CP.

2.1 *Palatalized Labial-Dorsals*

A significant assumption of this project is that all complex stops contain a dorsal place, whether it is velar or palatal. Bennett (to appear) provides a review of phonological and phonetic evidence for the alleged existence of labial-coronals and concludes that they are in fact unattested; this conclusion is assumed here, and the arguments below summarize Bennett's (to appear).

In Dagbani and Nzema, the attested labial-coronals before front vowels (Cahill 1999, 2008; Ladefoged 1968; Olawsky 1999; Wilson and Bendor-Samuel 1969) are shown to be palatals rather than alveolar under more recent phonetic and impressionistic data. Cahill (2008)'s acoustic analysis of Dagbani labial-velars reveals the articulation of the fronted variants to include "palatal closure, labial closure, slow palatal release, labial release" and "palatal friction" (Cahill 2008: 1), with the following narrow transcriptions:

- (1) [cp̠jɪ́ní] 'guinea fowl'
 [ɟbʒíhí] 'to sleep' (Cahill 2008: 1)

Bennett (to appear) confirms these fricated palatal transcriptions with a native speaker of Dagbani (Bennett to appear: 5), in addition to providing additional acoustic analysis of the fricated release. Olawsky (1999) also reports palatal contact for [tp] in Dagbani, although Olawsky does claim that this is in variation with an alveolar articulation. It is not reported whether this is inter- or intra-speaker variation.

In Margi and Bura, following Maddieson (1983, 1987), labial-coronals are found to be sequences of labial and coronal stops, not a single labial-coronal segment. To quote Bennett's summary:

Maddieson (1983, 1987), however, finds that – in both Margi and Bura – these sequences are not complex segments; rather, they are consonant clusters. In Bura, the bilabial portion of such sequences is clearly released before the closure for the alveolar portion begins (Maddieson 1983: 294); the labial and coronal articulations are not in fact simultaneous. These sequences also have a much longer total duration than simplex stops, which is not generally the case for labio-velars (Maddieson 1983: 296; see also Connell 1994 for a review of other earlier studies). (Bennett to appear: 4-5)

Further, the sequence [pt] is heterosyllabic when possible, as evidenced by the shortening of a preceding vowel (Maddieson 1983: 296), and that there is no evidence that initial [pt] clusters should be disallowed, as Bura allows other initial clusters such as [mɪ] (Maddieson 1983: 299).

Based on this, the inventories of Margi and Bura are excluded from the discussion on complex stops as they do not contain complex stops. According to van de Weijer (2011), labial-coronals have "only been demonstrated beyond doubt for Yeletnye (Papua New Guinea)" (van de Weijer 2011: 11). Bennett (to appear) also admits that Yeletnye is still a "plausible example of a language with labio-coronals" (Bennett to appear: 4), but suggests one place may be secondary to the other, and thus not problematic. If Yeletnye includes doubly-articulated segments that are phonologically equally both [labial] and [coronal], they are not only beyond the scope of this project but against the basic premises as well.

2.2 *Palatals as Phonologically Dorsal*

The treatment of CP as phonologically dorsal is based on the idea that (certain) palatals are phonologically dorsal. This treatment is based on Chomsky and Halle (1968: 305), which treats palatals as [–coronal –back], and more recently Hall (1997). Hall (1997), depending on the type of palatal consonant, represents them with a feature [±back] dependent on either [coronal] or

[dorsal]. The complex stops here are assumed to be palatals dependent on [dorsal]. Hall (1997: 77) calls this feature [\pm P] but considers [+P] equivalent to [-back]. This of course assumes as well that CP is palatal and not alveolar. That sounds previously described as [tp] or [pt] are palatal is a point previously argued in Bennett (to appear).

2.3 *Phonetic Background*

The phonological characterization of complex stops as having multiple major place features not only stems from how these segments behave phonologically but also from their phonetics. In complex stops there is complete closure at two different articulators. Labial-velars are the most common complex stop (Ladefoged 1968: 9; Ladefoged and Maddieson 1996: 333). As reported by Ladefoged (1968), labial-velars utilize a variety of airstream mechanisms: pulmonic egressive only; velaric ingressive plus pulmonic egressive; or velaric ingressive plus glottalic ingressive plus pulmonic egressive (Ladefoged 1968: 8). The cause and scope of this variation is not clear; Ladefoged reports one speaker using all three mechanisms within a single utterance (Ladefoged 1968: 9).

3 The Core System and Constraints

This section defines a system capturing behavior of complex stops. It is referred to as the core system KP0 because it deals with single segments in isolation, to generate a typology of possible stop inventories and mappings. The components GEN_{KP0} and CON_{KP0} are defined for this core system. In later sections, when specific languages and alternations are discussed, the system will be augmented to treat full syllables; thus GEN_{KP0} and CON_{KP0} are modified, resulting in new systems. These new systems are defined in turn and share many of the core properties of this system.

3.1 GEN_{KP0}

The focus of this system is to model stop inventories, so stop segments are considered in isolation—segment sequences and prosodic structure such as syllables are ignored at this point. The candidate set for a given input consists of all possible stop segments as defined by the system. All segments have at least one major place feature: [coronal], [labial], and [dorsal]. The only type of complex stop generated are labial-dorsals. Complex stops have two major place features of equal status; each is marked as major c-place. All and only dorsal features, whether in simple or complex stops, are marked as [\pm back]. Velar stop [K] is [+back], palatal stop [C] is [-back]. All segments are also marked for [\pm voice]. Secondary articulation (e.g. [k^w]) is not modeled in this system (but is addressed in Section 4.2). The full candidate set for an input is given below, with the featural specification for each. The reason a geometry of features is assumed is strictly so that c-place can be differentiated between v-place in the representations and constraint definitions. No claims are made about if the v-place and c-place features are on the same tier, or any related issues such.

Major place features are [labial], [dorsal], and [coronal]. Minor place features are features dependent on some major place feature, such as [\pm back] being marked for all dorsals. Primary place refers to those major place features marked as c-place, and secondary place refers to major place features marked as v-place. Secondary place is not introduced until section 4.2.

(2) *Place and Voicing Featural Specifications*

	Major Place	Minor Place	Voicing
t	coronal		–voice
d	coronal		+voice
p	labial		–voice
b	labial		+voice
k	dorsal	+back	–voice
g	dorsal	+back	+voice
c	dorsal	–back	–voice
j	dorsal	–back	+voice
kp	labial, dorsal	+back	–voice
gb	labial, dorsal	+back	+voice
cp	labial, dorsal	–back	–voice
jb	labial, dorsal	–back	+voice

Each possible segment is treated as an input, and the candidate set for each input is the same set of segments.

3.2 CON_{KP0}

3.2.1 *Markedness Constraints*

The markedness constraints for this system are based on the markedness hierarchy below:

- (3) [dorsal] [–back] > [dorsal] [+back] > [labial] > [coronal]
 C > K > P > T
 where > signifies *more marked than*

This hierarchy adds palatals (non-back dorsals) as the most marked place. The general scale is based on a number of similar hierarchies implemented in OT in the literature. Prince and Smolensky (1993/2004: 219) implemented a scale where labials are more marked than coronals. Lombardi (2001) adds the glottal feature to this scale (as least marked place), and de Lacy (2006: 50) utilizes a hierarchy where dorsal is the most marked place over labial. For the purposes of simplicity, glottal place is ignored here, yet it can be implemented as another point on the scale, with the candidate set and constraints modified accordingly. The addition of glottal will not change any of the crucial conclusions of this system, as long as glottal place is treated featurally (as it is in de Lacy 2010 and Lombardi 2001), rather than as the absence of place features. The palatal stop C is above the velar stop K on the scale as in the languages surveyed here, palatal stop C implies velar stop K for a given language. Likewise, CP implies KP in a particular inventory. However, it is not strictly necessary to include reference to minor place features on this scale. Constraints based on the markedness hierarchy $K > P > T$, where K is all [dorsal] segments, plus the additional markedness constraint *[–back], are equivalent to constraints based on the hierarchy in (3).

The hierarchy in (3) is directly related to the constraint definitions in (4-7). For a discussion of the formal relationship between the hierarchy itself and the set of constraints, and the relationship of the hierarchy to substantive definitions of the idea of *markedness*, see de Lacy (2006: 2, 34).

The hierarchy is implemented in the constraints themselves stringently, based on de Lacy (2006: 50). The constraints are crucially in a stringency relation rather than in a fixed hierarchy (see section 5.2, also Prince 1997, de Lacy 2010:24). In the definitions below, PL(S) represents the set of major c-place features for a segment S.

(4) **m:*CKPT**

Assign one violation for every segment S where [dor] ∈ PL(S) & S is [-back]
and

Assign one violation for every segment S where [dor] ∈ PL(S) & S is [+back]
and

Assign one violation for every segment S where [lab] ∈ PL(S)
and

Assign one violation for every segment S where [cor] ∈ PL(S)

(5) **m:*CKP**

Assign one violation for every segment S where [dor] ∈ PL(S) & S is [-back]
and

Assign one violation for every segment S where [dor] ∈ PL(S) & S is [+back]
and

Assign one violation for every segment S where [lab] ∈ PL(S)

(6) **m:*CK**

Assign one violation for every segment S where [dor] ∈ PL(S) & S is [-back]
and

Assign one violation for every segment S where [dor] ∈ PL(S) & S is [+back]

(7) **m:*C**

Assign one violation for every segment S where [dor] ∈ PL(S) & S is [-back]

Each markedness constraint assigns a violation for nonback dorsals [C], as this is the most marked place on the hierarchy. The definitions are defined as conjunctions rather than disjunctions so that a segment with two place specifications, such as labial-dorsals, receive *two* violations. This makes complex stops more marked than simple stops by virtue of their additional place features. The violation profiles of the candidates are shown below.

(8) *Markedness Violation Profiles*

	m:CKPT	m:CKP	m:CK	m:C
t, d	1	0	0	0
p, b	1	1	0	0
k, g	1	1	1	0
c, j	1	1	1	1
kp, gb	2	2	1	0
cp, jb	2	2	1	1

This constraint m:CKPT is necessary to generate grammars where complex stops are neutralized to simple stops, but simple dorsals and labials remain—a great majority of the world's languages. The fact that *CKPT assigns one violation to simple stops, and two to all complex stops, means it can act as a *de facto* constraint militating against complexity. It must assign a violation to all places, even the least marked, for the constraint to have this property. This property is discussed in detail in Section 3.3.3.

If we exclude m:*CKPT from the system, following markedness proposals like Gouskova (2003), the constraint m:*CKP *cannot* act as a ban on complexity, as the coronal candidate is better than all others, simple or otherwise. In a system without m:CKPT, simple dorsals and simple labials entail labial-dorsals, and vice versa; this is undesirable. The crucial presence of this constraint is thus contra markedness proposals like *leniency* as defined in Gouskova (2003: 3) which do not allow a constraint to violate against the least marked element on a scale. This point is discussed further in section 5.2.

Additionally, the markedness constraints as implemented here are *not* equivalent to a fixed hierarchy based on the same scale. The following fixed hierarchy of constraints has the same properties of a system without m:CKPT: it cannot disallow complex stops while allowing simple dorsals and labials to realize faithfully:

(9) *Fixed Hierarchy*

m:C » m:K » m:P » m:T

If place faithfulness f:KPT is ranked above m:K, then labials and dorsals are realized faithfully, but so are complex labial-dorsals. Having place faithfulness f:KPT dominate only m:P, complex stops are disallowed, but so are simple dorsals. This is discussed in detail in section 5.2.

Voiced stops are marked based on the following constraint.

(10) **m:*jgbd**

Assign one violation for every [+voice] segment S where [dor] ∈ PL(S) & S is [-back] and

Assign one violation for every [+voice] segment S where [dor] ∈ PL(S) & S is [+back] and

Assign one violation for every [+voice] segment S where [lab] ∈ PL(S) and

Assign one violation for every [+voice] segment S where [cor] ∈ PL(S)

It is defined as m:*CKPT with the condition that the segment is also voiced. This means it also assigns two violations to voiced complex stops [gb] and [jb] but one violation to simple voiced stops. This is crucially different from previous definitions of similar constraints, such as *LAR or *Voice (Lombardi 1999, 2001). While these constraints were not meant to deal with the interaction of complex stops, they would assign one violation to a voiced complex stop like [gb] assuming that violations are assigned based on the voicing values of each segment, irrespective of place. The violation profiles for a standard *Voice constraint and the constraint used here are given below.

(11) *Violation Profiles: *jgbd and *Voice*

	*jgbd	*Voice
p, t, k	0	0
kp, cp	0	0
b, d, g	1	1
gb, jb	2	1

Defining the constraint such that each place in a voiced segment incurs a violation means that an input /gb/ can reduce in place to [b] to reduce the number of violations assigned by *jgbd, while still preserving voicing faithfulness. This is exactly what happens in the Complex Voicing Place Reduced languages (section 3.3.4). The constraint m:*jgbd is in a special/general relationship with *CKPT, as both have the same violation profiles for voiced stops. As will be seen in the analysis of the typology, [gb] can be banned without losing the voicing distinctions among the simple stops of the language—an empirically desired result.

3.2.2 Faithfulness Constraints

Mappings in this system are mediated by three faithfulness constraints: f:KPT, a major place faithfulness constraint, and identity constraints for the features [±back] and [±voice].

The constraint f:KPT assigns violations based on the additions or removals of the privative major place features between the input and output; it is a faithfulness constraint for major place. Because complex stops are admitted in GEN, this constraint can assign 0, 1, or more than one violations per the number of input-output place feature discrepancies based on the definition below.

(12) **f:KPT**

If S1 is a segment in the input, and
S2 is a segment in the output, and
S1 and S2 are in correspondence, and
[cor] or [lab] or [dor] \in PL(S1),
Assign one violation for every x such that:
x \in PL(S1) & x \notin PL(S2) and
Assign one violation for every x such that:
x \in PL(S2) & x \notin PL(S1)
where x \in {[lab], [cor], [dor]}

The violations for the candidate set for the input /kp/ are shown below.

(13) *Violation Profile for f:KPT*

/kp/	f:KPT	Comment
[t]	3	[dor] and [lab] not in output, [cor] not in input
[p]	1	[dor] not in output
[k]	1	[lab] not in output
[c]	1	[lab] not in output
[kp]	0	No change in major place
[cp]	0	No change in major place

The mapping /kp/→[t] incurs the most violations, because there are no major place features in common between the input and output. This is similar to Pater (1999)'s definition for featural identity based on monovalent features. While Pater (1999: (15)) formulates IO and OI faithfulness constraints for the feature [nasal], f:KPT is a single constraint that does the work of IO and OI constraints for the features [dorsal], [coronal], and [labial]. Pater's formulation reduces Ident-style constraints to Max- and Dep-like feature deletion and epenthesis, as is also noted in McCarthy and Prince (1995: 71): "The privative formulation makes it clear that this analyzes Ident into Max- and Dep-like components" (McCarthy and Prince 1995: fn. 40). The constraint here is equivalent to the sum of the violations of six different constraints: IdentIO and IdentOI (under Pater's formulation) for the features [coronal], [dorsal], and [labial]. Because there is no immediate reason to treat these constraints as individual, they are all represented in the single constraint f:KPT. While Max- and Dep-like, such a formulation is not strictly equivalent to correspondence between features (in addition to segments, see Lombardi 2001: (11) an argument for this formulation); this point is taken up in section 5.2. The constraint as defined in (13) is also equivalent to calculating the cardinality of the symmetric difference between the sets PL(S1) and PL(S2).³

The other two faithfulness constraints are identity constraints (McCarthy and Prince 1995: 16) for the binary features [±back] and [±voice].

³ Thanks to Alan Prince for pointing this out.

(14) **f:[back]**

If S1 is a segment in the input, and
S2 is a segment in the output, and
S1 and S2 are in correspondence
Assign one violation if S1 is [α back] and S2 is [$\neg\alpha$ back]

(15) **f:[voice]**

If S1 is a segment in the input, and
S2 is a segment in the output, and
S1 and S2 are in correspondence
Assign one violation if S1 is [α voice] and S2 is [$\neg\alpha$ voice]

Voicing is treated as a binary feature, but this is not crucial here. The feature [\pm back], however, is crucially binary especially in the treatment of palatalization in Dagbani in section 4.2. Segment correspondent pairs where one member is unspecified for back do not incur violations of f:[back]:

(16) Violation Profile for f:[back]

/C/	f:[back]	Comment
[C]	0	Faithful
[K]	1	/C/ is [-back], [k] is [+back]
[T]	0	[T] is undefined for [\pm back]

3.3 Factorial Typology and System Properties

The factorial typology of this system consists of 19 distinct languages. The factorial typology of this system is calculated in OTWorkplace using the FacTyp function (Prince, Tesar, and Merchant 2013). All constraint violations were calculated automatically in OTWorkplace, using either standard regular expressions or VBA code equivalent to the definitions given in the previous section (see also Danis 2014). The results are shown in the table below. The languages in the typology below are given unique names, which are defined in the table in (18).

(17) *KP0 Factorial Typology*

	Inputs->	t	p	k	c	kp	cp	d	b	g	j	gb	jb
Lg. 1	t.cor	t	t	t	t	t	t	t	t	t	t	t	t
Lg. 2	d.cor	t	t	t	t	t	t	d	d	d	d	d	d
Lg. 3	t.lab	t	p	t	t	p	p	t	p	t	t	p	p
Lg. 4	d.lab	t	p	t	t	p	p	d	b	d	d	b	b
Lg. 5	t.dor.s.maj	t	p	k	t	p	p	t	p	k	t	p	p
Lg. 6	d.dor.s.maj	t	p	k	t	p	p	d	b	g	d	b	b
Lg. 7	t.dor.c.maj	t	p	k	t	kp	p	t	p	k	t	kp	p
Lg. 8	d.dor.c.maj.b	t	p	k	t	kp	p	d	b	g	d	b	b
Lg. 9	d.dor.c.maj.gb	t	p	k	t	kp	p	d	b	g	d	gb	b
Lg. 10	t.dor.s.f	t	p	k	c	p	p	t	p	k	c	p	p
Lg. 11	d.dor.s.f	t	p	k	c	p	p	d	b	g	j	b	b
Lg. 12	t.dor.c.f	t	p	k	c	kp	cp	t	p	k	c	kp	cp
Lg. 13	d.dor.c.f.b	t	p	k	c	kp	cp	d	b	g	j	b	b
Lg. 14	d.dor.c.f.gb	t	p	k	c	kp	cp	d	b	g	j	gb	jb
Lg. 15	t.dor.s.min	t	p	k	k	p	p	t	p	k	k	p	p
Lg. 16	d.dor.s.min	t	p	k	k	p	p	d	b	g	g	b	b
Lg. 17	t.dor.c.min	t	p	k	k	kp	kp	t	p	k	k	kp	kp
Lg. 18	d.dor.c.min.b	t	p	k	k	kp	kp	d	b	g	g	b	b
Lg. 19	d.dor.c.min.gb	t	p	k	k	kp	kp	d	b	g	g	gb	gb

From the typology above, certain surface generalizations can be teased out. Every language that has complex stop [gb] has complex stop [kp], so [gb] entails [kp]. Further, the presence of complex stop [cp] entails complex stop [kp]; [cp] entails [kp] as well. This is expected, because based on the constraints of this system, voiced segments are more marked than voiceless, and palatal are more marked than velars. When these predictions are compared against an empirical database (section 3.4), we see that the more marked complex segment [CP], in terms of place, does imply [KP]; however, [gb] does not imply [kp]. There are a number of languages with [gb] as their only complex stop (Cahill 2009). This and other relevant predictions are discussed in detail then.

The names of the languages in the factorial typology reflect the intensional properties (Alber and Prince in progress; Prince 2013) of that language. The notation is explained below:

(18) *Property Notation for Language Names*

Voicing	<i>Voiceless</i>	t
	<i>Voiced</i>	d
Most Marked Major Place	<i>Coronal</i>	cor
	<i>Labial</i>	lab
	<i>Dorsal</i>	dor
Complexity	<i>Simple</i>	s
	<i>Complex</i>	c
Palatal Realization	<i>Faithful</i>	f
	<i>Unfaithful Major Place</i>	maj
	<i>Unfaithful Minor Place</i>	min
Voiced Complex Segments	<i>Reduced Place</i>	b
	<i>Preserved Place</i>	gb

The mappings of the system are summarized below:

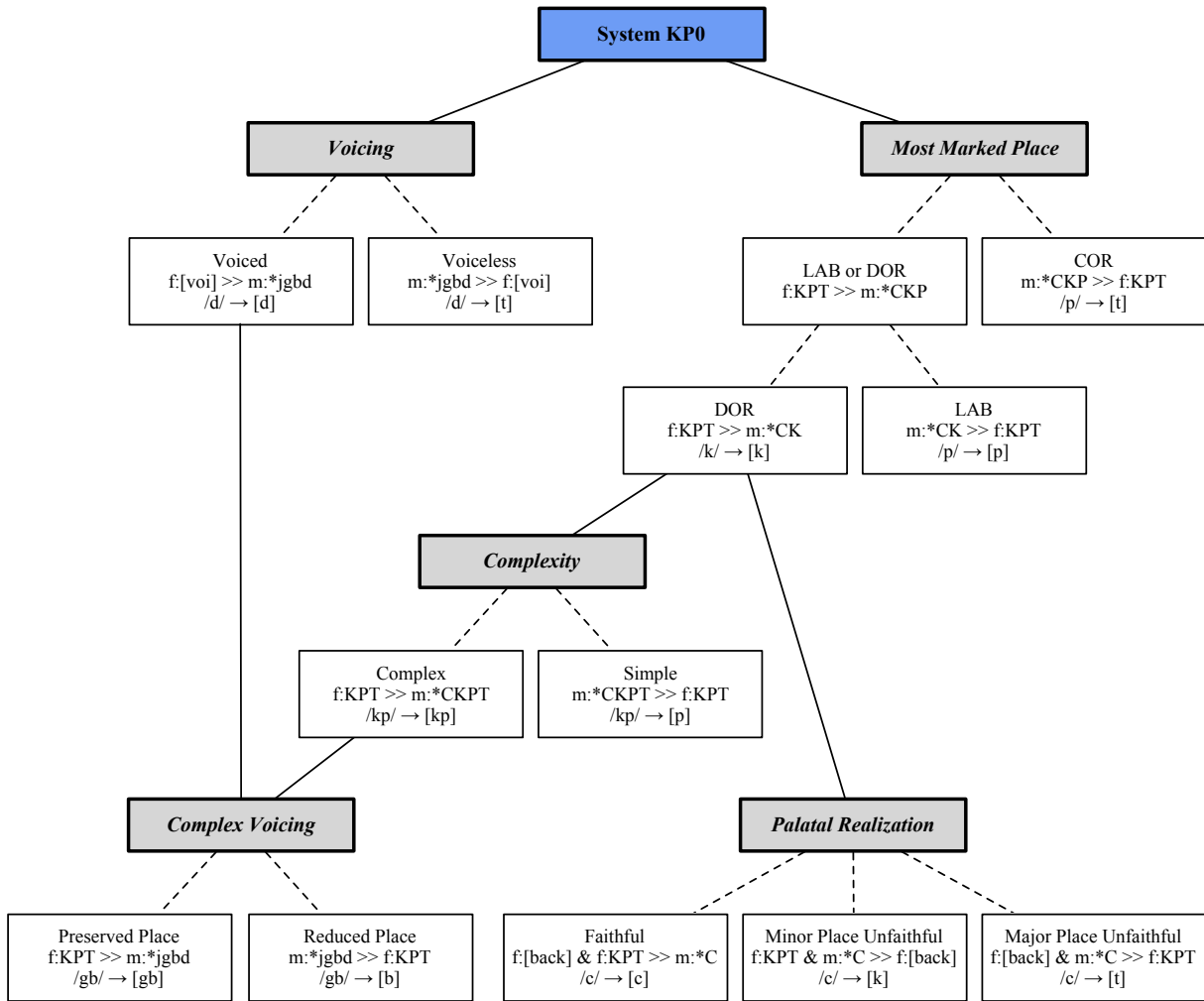
(19) *KP0 Mappings*

Input		Maps to:	Comment		
T, P, K	Voiceless t, p, k	Self			
		t	least marked place		
	Voiced d, b, g	Self			
		Voiceless, faithful place			
		d	least marked place, faithful voicing		
C	Voiceless c	Self			
		k	unfaithful minor place		
		t	least marked place		
	Voiced j	Self			
		g	unfaithful minor place		
		c	unfaithful voicing		
		k	unfaithful voicing, minor place		
		d	least marked place, faithful voicing		
		t	least marked place, unfaithful voicing		
		CP	Voiceless cp	Self	
	kp			unfaithful minor place	
	p			least marked faithful place	
	t			least marked place	
Voiced jb	Self				
	gb		unfaithful minor place		
	cp		unfaithful voicing		
	kp		unfaithful voicing, minor place		
	b		least marked faithful place, faithful voicing		
	p		least marked faithful place, unfaithful voicing		
	d		least marked place, faithful voicing		
	t		least marked place, unfaithful voicing		
	KP		Voiceless kp	Self	
				p	least marked faithful place
t		least marked place			
Voiced gb		Self			
		kp	unfaithful voicing		
		b	least marked faithful place		
		p	least marked faithful place, unfaithful voicing		
		d	least marked place, faithful voicing		
		t	least marked place, unfaithful voicing		

Not all combinations of properties are possible; however. Certain properties are *moot* with respect to others, meaning combinations of these properties either do not result in significant distinctions, or result in ranking contradiction (Alber and Prince in progress; Prince 2013). For instance, a language cannot be COR and also Complex, as Complex implies a labial and dorsal segment; neither of which are realized in a COR language. A COR language with the ranking condition for Complex satisfied (f:KPT \gg m:*CKPT) will have exactly the same mappings as a COR language with the ranking for Simple (m:*CKPT \gg f:KPT) satisfied; in a COR language, these two constraints are not crucially ranked with respect to each other. This mootness is expressed hierarchically in the tree, with Complexity being a child node of DOR. The full

definition of these properties and their structure are discussed in the following subsections. The full property tree of KP0 is shown below.

(20) *KP0 Property Tree*



Dotted lines indicate mutually exclusive choices among those sibling nodes. The Complex Voicing node is child to both Voiced and Complex. This indicates that the choice for this property is significant only if the language is both Voiced and Complex. These properties and ranking conditions are discussed in the sections below.

Each language in the typology must make a choice of properties for those that are child of the root note, System KP0. Every language therefore is either Voiced or Voiceless, and every language has a Most Marked Place. If the most marked place present in the surface inventory is coronal, then the choice is COR; else, it is labial or dorsal, as indicated in the tree. The choices of properties continue down the tree until every possible selection has been made. The full combination of choices in this way results in the exact number of languages in the factorial typology above. The properties and ranking conditions are explained in turn in the sections below.

The analysis of the properties and structure of the typology are based on shared ranking information among those languages, where shared ranking information is determined via the Merchant Join operation (Merchant 2008).

(21) **Merchant Join operator example (Merchant 2008: 88)**

		C1	C2	C3	C4
1	ERC1	W	L	e	L
2	ERC2	e	W	L	L
3	1⊕2	W	W	e	L

The above table shows the result of calculating the join of two individual ERCs. Here, the join is calculated over ERC sets, which involves certain extensions of this operator into a specific algorithm. See Merchant (2008, 2011) where the details of this algorithm is laid out. All calculations here are done in OT Workplace (Prince, Tesar, and Merchant 2013) using the JOIN functions. What is crucial is that the join of two ERC sets produces "exactly the shared ranking information of the two original ERC sets" (Merchant 2011: §5).

Applied here, for a set of languages in the typology that seem to share some property—for example, voicing distinctions—the join of those languages (ERC sets) is calculated. As is seen below, every language with voicing distinctions has the ranking $f:[\text{voi}] \gg m:*\text{jgbd}$. Further, this join is *conservative*: no other language has such a ranking. Therefore, the property can be defined as follows: a language is Voiced iff $f:[\text{voi}] \gg m:*\text{jgbd}$. Using these methods; the structure of the property tree in (20) is deduced. A language is thus Simple only if it is DOR *and* lacks complex stops in its surface inventory. The LAB and COR languages are *not* considered part of the intensional property Simple because they do *not* share the ranking information $m:*\text{CKPT} \gg f:\text{KPT}$. The full set of properties are defined and discussed in the following sections.

3.3.1 Voicing

Languages in KP0 either have voicing contrast or lack voicing contrast. Languages where $f:[\text{voi}]$ dominates $m:*\text{jgbd}$ show voicing distinctions. These are the languages whose names begin with "d." in the factorial typology. The voicing property is transparent from the optimum of the /d/ candidate set; if [t] is optimal, the language lacks voicing contrast.

The voiced and voiceless languages are shown in the table below, with their shared ranking information.

(22) **No Voicing Distinctions**

m:*jgbd » f:[voi]

Inputs->		t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 1	t.cor	t	t	t	t	t	t	t	t	t	t	t	t
Lg. 3	t.lab	t	p	t	t	p	p	t	p	t	t	p	p
Lg. 5	t.dor.s.maj	t	p	t	k	p	p	t	p	t	k	p	p
Lg. 7	t.dor.c.maj	t	p	t	k	p	kp	t	p	t	k	p	kp
Lg. 10	t.dor.s.f	t	p	c	k	p	p	t	p	c	k	p	p
Lg. 12	t.dor.c.f	t	p	c	k	cp	kp	t	p	c	k	cp	kp
Lg. 15	t.dor.s.min	t	p	k	k	p	p	t	p	k	k	p	p
Lg. 17	t.dor.c.min	t	p	k	k	kp	kp	t	p	k	k	kp	kp

(23) **Voicing Distinctions**

f:[voi] » m:*jgbd

Inputs->		t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 2	d.cor	t	t	t	t	t	t	d	d	d	d	d	d
Lg. 4	d.lab	t	p	t	t	p	p	d	b	d	d	b	b
Lg. 6	d.dor.s.maj	t	p	t	k	p	p	d	b	d	g	b	b
Lg. 8	d.dor.c.maj.b	t	p	t	k	p	kp	d	b	d	g	b	b
Lg. 9	d.dor.c.maj.gb	t	p	t	k	p	kp	d	b	d	g	b	gb
Lg. 11	d.dor.s.f	t	p	c	k	p	p	d	b	j	g	b	b
Lg. 13	d.dor.c.f.b	t	p	c	k	cp	kp	d	b	j	g	b	b
Lg. 14	d.dor.c.f.gb	t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 16	d.dor.s.min	t	p	k	k	p	p	d	b	g	g	b	b
Lg. 18	d.dor.c.min.b	t	p	k	k	kp	kp	d	b	g	g	b	b
Lg. 19	d.dor.c.min.gb	t	p	k	k	kp	kp	d	b	g	g	gb	gb

3.3.2 *Most Marked Place*

The property of Most Marked Place reflects the most marked major place based on the place hierarchy in (3) that is faithfully realized in the language. A language is thus either marked as COR, LAB, or DOR. A LAB language implies coronals as well, and a DOR language implies labials and coronals. This is clear via an examination of the typology.

The necessary ranking that COR languages share is m:*CKP » f:KPT. m:*CKP is the markedness constraint violating against all dorsals and labials, but not coronals. There are exactly two COR languages: that with voicing contrast and that without.

(24) **COR languages**

m:*CKP ≫ f:KPT

Inputs->		t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 1	t.cor	t	t	t	t	t	t	t	t	t	t	t	t
Lg. 2	d.cor	t	t	t	t	t	t	d	d	d	d	d	d

In these languages, every non-coronal input maps to a coronal output, with voicing preserved in the Voiced language (Lg. 2).

LAB and DOR languages form a natural class in this typology as they both share the ranking f:KPT ≫ *CKP—the opposite ranking for the COR property. Having major place faithfulness f:KPT dominating the constraint banning dorsals and labials will mean that at least some non-coronal segment will be realized faithfully.

Like with the COR languages, there are only two LAB languages: one which preserves voicing, and one which does not.

(25) **LAB Languages**

m:*CK ≫ f:KPT

Inputs->		t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 3	t.lab	t	p	t	t	p	p	t	p	t	t	p	p
Lg. 4	d.lab	t	p	t	t	p	p	d	b	d	d	b	b

Here, all coronal and labial inputs are mapped faithfully with respect to place; all simple dorsals map to the least marked place (coronal), while complex stops map to the least-marked but still faithful place, labial.

The bulk of the languages in the typology are DOR languages, as the DOR property contains a number of subproperties that must be chosen: Complexity, Complex Voicing behavior, and C-Behavior.

(26) **DOR Languages**
 f:KPT » *CK

	Inputs->	t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 5	t.dor.s.maj	t	p	t	k	p	p	t	p	t	k	p	p
Lg. 6	d.dor.s.maj	t	p	t	k	p	p	d	b	d	g	b	b
Lg. 7	t.dor.c.maj	t	p	t	k	p	kp	t	p	t	k	p	kp
Lg. 8	d.dor.c.maj.b	t	p	t	k	p	kp	d	b	d	g	b	b
Lg. 9	d.dor.c.maj.gb	t	p	t	k	p	kp	d	b	d	g	b	gb
Lg. 10	t.dor.s.f	t	p	c	k	p	p	t	p	c	k	p	p
Lg. 11	d.dor.s.f	t	p	c	k	p	p	d	b	j	g	b	b
Lg. 12	t.dor.c.f	t	p	c	k	cp	kp	t	p	c	k	cp	kp
Lg. 13	d.dor.c.f.b	t	p	c	k	cp	kp	d	b	j	g	b	b
Lg. 14	d.dor.c.f.gb	t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 15	t.dor.s.min	t	p	k	k	p	p	t	p	k	k	p	p
Lg. 16	d.dor.s.min	t	p	k	k	p	p	d	b	g	g	b	b
Lg. 17	t.dor.c.min	t	p	k	k	kp	kp	t	p	k	k	kp	kp
Lg. 18	d.dor.c.min.b	t	p	k	k	kp	kp	d	b	g	g	b	b
Lg. 19	d.dor.c.min.gb	t	p	k	k	kp	kp	d	b	g	g	gb	gb

All and only the LAB languages have *CK dominating f:KPT. *CK is a markedness constraint that assigns violations to all and only dorsals, so this constraint dominating the general place faithfulness will prohibit all dorsals in the language. The DOR languages have the reverse ranking: general place faithfulness dominates the markedness constraint violating against all dorsals, so these languages have at least some dorsals in their surface inventory, in addition to complex stops. Recall again that because all complex stops are assumed to include a dorsal element, complex stops do not emerge in the system until dorsal place is allowed at all. As will be shown in the next section, the behavior of the fronted dorsal C is subject to further ranking conditions.

3.3.3 Complexity

The Complexity property refers to whether the language contains complex stops or not. In terms of mappings, (at least some) complex inputs in Complex languages map to complex stops. The crucial rankings for Simple and Complex languages fall out from the unique behavior of the *CKPT markedness constraint. This constraint not only assigns violations to segments of all places, but assigns *two* violations to segments with multiple place features, i.e. complex stops. Because it is an assumption in GEN that a segment will contain at least one place feature (e.g. no segment with zero place features), this constraint assigns either 2 or 1 violations. Lombardi (2001: 11) reaches a similar conclusion that every segment must have some place feature. Effectively, the constraint m:*CKPT can act as a *de facto* ban on complexity. Its violation profile is repeated below:

(27) *Violation Profile for m:*CKPT*

	*CKPT
t, d	1
p, b	1
k, g	1
c, j	1
kp, gb	2
cp, jb	2

This constraint is, effectively, assigning a violation to complex stops without assigning a violation to simple stops (1 versus 0). With this constraint dominating major place faithfulness f:KPT, it is possible for a language (such as English) to ban all complex stops while still allowing simple stops of all major places. The crucial ranking that all simple languages share is that *CKPT dominates f:KPT. Likewise, because complex stops are admitted in GEN, a language must have faithfulness f:KPT dominating markedness *CKPT in order for complex stops to be optimal. These languages are shown below.

(28) **Simple Languages**m:*CKPT \gg f:KPT

	Inputs->	t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 5	t.dor.s.maj	t	p	t	k	p	p	t	p	t	k	p	p
Lg. 6	d.dor.s.maj	t	p	t	k	p	p	d	b	d	g	b	b
Lg. 10	t.dor.s.f	t	p	c	k	p	p	t	p	c	k	p	p
Lg. 11	d.dor.s.f	t	p	c	k	p	p	d	b	j	g	b	b
Lg. 15	t.dor.s.min	t	p	k	k	p	p	t	p	k	k	p	p
Lg. 16	d.dor.s.min	t	p	k	k	p	p	d	b	g	g	b	b

Notice that the COR and LAB languages are *not* included in the table above, even though there are no complex stops in their surface inventories. This is because the fact that they lack complex stops is predictable from the fact that they ban all dorsals. Thus, they are simple due to different crucial rankings. These languages are moot with respect to complexity for this reason. While there may be extensional reasons to group LAB/COR together here, intensionally they do not form a class with the Simple languages above. There are exactly six Simple languages above, from the combination of the Voicing property (2 choices) and the C-behavior property (3 choices).

A crucial characteristic of the Simple languages is that labials and dorsals can be preserved while labial-dorsals are not. Dominating place faithfulness f:KPT in the Simple languages is the constraint m:*CKPT. While this constraint does assign violations to labials and dorsals (and coronals), it only *differentiates* between complex stops and simple stops, as shown above in (27). When this constraint dominates f:KPT, the complex stops KP and CP are removed from being possible optima, leaving the simple stops. Then, the remaining ranking conditions determine what simple stops remain in the simple languages. All Simple languages will include coronals and labials, because the Most Marked Place implies all other places, and the C-Behavior property will determine the mapping of /C/.

(29) **Complex Languages**

f:KPT » m:*CKPT

Inputs->		t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 7	t.dor.c.maj	t	p	t	k	p	kp	t	p	t	k	p	kp
Lg. 8	d.dor.c.maj.b	t	p	t	k	p	kp	d	b	d	g	b	b
Lg. 9	d.dor.c.maj.gb	t	p	t	k	p	kp	d	b	d	g	b	gb
Lg. 12	t.dor.c.f	t	p	c	k	cp	kp	t	p	c	k	cp	kp
Lg. 13	d.dor.c.f.b	t	p	c	k	cp	kp	d	b	j	g	b	b
Lg. 14	d.dor.c.f.gb	t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 17	t.dor.c.min	t	p	k	k	kp	kp	t	p	k	k	kp	kp
Lg. 18	d.dor.c.min.b	t	p	k	k	kp	kp	d	b	g	g	b	b
Lg. 19	d.dor.c.min.gb	t	p	k	k	kp	kp	d	b	g	g	gb	gb

Complex languages preserve complex inputs via major place faithfulness dominating m:*CKPT, the markedness constraint that militates against complex stops. As [kp] is the least marked complex stop, every Complex language has at least [kp] in its surface inventory. Complex languages can choose freely between Voiced and Voiceless, as neither of these properties is dependent on the other. All languages above that begin with "d." are Voiced, and the three that begin with "t." are Voiceless. The three Voiceless languages vary on the behavior of fronted dorsals C, which is explained in a later section. The Voiced languages differ along this dimension in addition to how place is preserved in voiced complex segments.

3.3.4 *Complex Voicing*

The Complex languages vary among another dimension that the Simple languages do not: that of the voicing distinctions of the complex stops themselves. This section will first define the Complex Voicing property, and then add discussion on its place in the hierarchical organization of the system properties. However, unlike the Voicing property, voicing distinctions in complex stops are reduced not via devoicing but via reduction of a voiced complex stop to a voiced simple stop.

(30)	Input	Output	Properties of Language
	/gb/	→ [gb]	Voiced + Complex + Complex Place Preserved
		→ [b]	Voiced + Complex + Complex Place Reduced
		→ [kp]	Voiceless + Complex

In a Voiceless, Complex language, /gb/ maps to [kp] due to m:*jgbd dominating f:[voi]. However, in a language with voicing distinctions, where f:[voi] dominates m:*jgbd, /gb/ can be mapped to [b] in a language where m:*jgbd dominates f:KPT. In the surface inventory of such a language, it appears that voicing distinctions of complex stops are lost in that the language will contain [kp] as well as voiced and voiceless simple stops, but it is not because /gb/ is realized with unfaithful voicing. This is due to the fact that m:*jgbd interacts with major place faithfulness f:KPT; because m:*jgbd assigns violations per place of voiced segments, one way to satisfy the constraint is to have fewer places.

Based on the definition of the constraint that assigns violations to voiced segments, $m:*\text{jgbd}$, the voiced complex stops are more marked than voiced simple stops, which in turn are more voiced than all voiceless stops.

(31) *Violation Profile for $m:*\text{jgbd}$*

	$m:*\text{jgbd}$
t, p, k, kp, cp	0
d, b, g	1
gb, jb	2

Based on the definition of the constraint $m:*\text{jgbd}$, the voiced complex stops are more marked than voiced simple stops, which in turn are more voiced than all voiceless stops. This is crucial to get the empirical set of languages with [kp] as the only complex stop while preserving voicing distinctions in the simple stops. The languages where the place of voiced complex stops is preserved are shown below.

(32) **Voiced Complex Place Preserved**

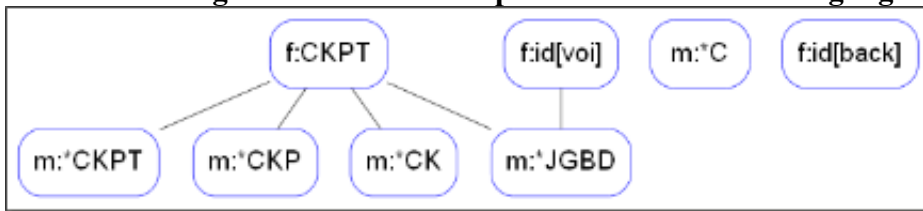
$f:\text{KPT} \gg m:*\text{jgbd}$

Inputs->		t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 9	d.dor.c.maj.gb	t	p	t	k	p	kp	d	b	d	g	b	gb
Lg. 14	d.dor.c.f.gb	t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 19	d.dor.c.min.gb	t	p	k	k	kp	kp	d	b	g	g	gb	gb

The crucial mappings to examine here are for the /jb/ and /gb/ candidate sets. Notice that for /gb/, the stop is realized faithfully in every language. The realization of /jb/ is further subject to the C-behavior property, yet this input is realized fully faithfully in language 14, and faithfully with respect to major place in language 19. The reason why it is reduced to a simple stop in language 9 is not because of the Voiced Complex property, but because all [-back] dorsals are realized as coronal in this language. Because there are no labial-coronals (assumption in GEN_{KP0}), [db] is not an available candidate, and [b] is the optimum for [jb] in this language.

Only those languages that are both Voiced and Complex must make a choice for the Complex Voicing property. Thus all languages in the above table share the following ranking. The remaining constraints, $m:*C$ and $f:[\text{back}]$ are ranked depending on the C-Behavior property, explained in the following section.

(33) **Shared Ranking for all Voiced Complex Place Preserved languages**



As being Voiced and being Complex are both prerequisites for the Complex Voicing choice to be made, all languages above have $f:[\text{voi}]$ dominating $*\text{jgbd}$ (Voiced), and $f:\text{KPT}$ dominating

m:*CKPT (Complex). Because all Complex languages are Dorsal, the ranking conditions for DOR are also met (f:KPT \gg m:*CKP & m:*CK).

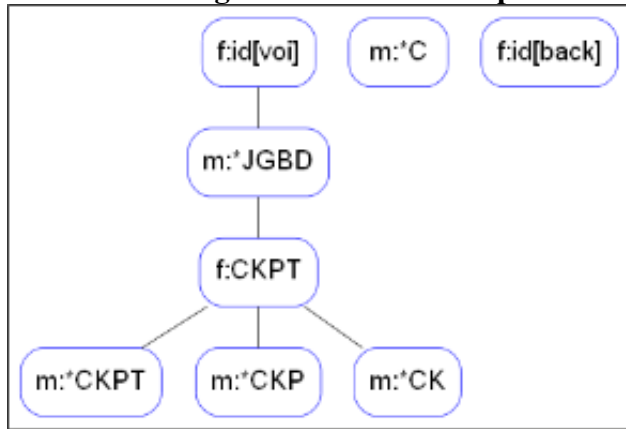
The Voiced Complex Place Reduced languages share all of the same rankings as above, except that m:*jgbd dominates f:KPT, causing voiced complex stops to reduce in place. These languages, and their shared rankings, are shown below.

(34) **Voiced Complex Place Reduced**

Inputs->		t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 8	d.dor.c.maj.b	t	p	t	k	p	kp	d	b	d	g	b	b
Lg. 13	d.dor.c.f.b	t	p	c	k	cp	kp	d	b	j	g	b	b
Lg. 18	d.dor.c.min.b	t	p	k	k	kp	kp	d	b	g	g	b	b

Again, the crucial candidate sets are for /jb/ and /gb/. The output across all languages for these inputs is [b]. In these languages, f:[voi] is undominated, so there must be voicing faithfulness in the optima. This rules out all voiceless candidates shown in (31). The constraint f:[voice] immediately dominates m:*jgbd; now, the only remaining possible optima are voiced simple stops and voiced complex stops. Because simple stops receive one violation, and complex stops two, the complex stops are ruled out as possible optima. Voiced simple stops remain, and [b] is the least marked but still faithful simple stop remaining. This is decided by the scaled markedness constraint and the major place faithfulness constraint f:KPT. The full shared ranking of these languages is shown below.

(35) **Shared Ranking for all Voiced Complex Place Reduced languages**



The property of Complex Voicing has a unique status within the current system: it is a subproperty of both Voiced languages and of Complex languages. In the property tree in (20), this is represented by Complex Voicing being a child node of both Voiced and Complex.

This is confirmed via two ways: the Merchant Join for all Voiceless Complex languages (listed above) is conservative, but the join for all languages with [kp] anywhere in the surface inventory (i.e. Voiceless Complex + Voiceless) is *not* conservative. Further, the mappings of the input /gb/ differ between Voiceless languages and Complex Voiceless languages.

If the typology is searched for languages where the only complex stops in the surface inventories are voiceless, the following group of languages is the result:

(36) **Languages whose only complex stops are voiceless**

	Inputs->	t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 7	t.dor.c.maj	t	p	t	k	p	kp	t	p	t	k	p	kp
Lg. 8	d.dor.c.maj.b	t	p	t	k	p	kp	d	b	d	g	b	b
Lg. 12	t.dor.c.f	t	p	c	k	cp	kp	t	p	c	k	cp	kp
Lg. 13	d.dor.c.f.b	t	p	c	k	cp	kp	d	b	j	g	b	b
Lg. 17	t.dor.c.min	t	p	k	k	kp	kp	t	p	k	k	kp	kp
Lg. 18	d.dor.c.min.b	t	p	k	k	kp	kp	d	b	g	g	b	b

When the join of these languages is calculated, the only shared ranking information among them is that f:KPT dominates m:*CKPT, m:*CKP, and m:*CK. The properties defined by this ranking are DOR and Complex—no shared information about the behavior of voiced elements can be deduced, because there is no ranking shared among *all* the languages.

(37) **Shared ranking information for the languages in (36)**



The fact that no information relating to f:[voi] or m:*jgbd can be deduced is also clear from the mappings themselves. In Voiceless languages, where *jgbd \gg f:[voi], /gb/ \rightarrow [kp] (languages 7, 12, and 17 above). However, in Complex Voiceless languages, where f:[voi] \gg *jgbd \gg f:KPT, /gb/ \rightarrow [b] (languages 8, 13, and 18 above). Thus, in the Complex Voiceless, the inputs /gb/ and /jb/ are not realized unfaithfully with respect to voicing, but rather with respect to place. This is transparent from the crucial ranking conditions: f:[voi] is undominated in the Voiceless Complex language, but *jgbd, a constraint that assigns more violations to voiced complex stops rather to voiced simple stops, dominates major place faithfulness. Thus, f:[voi] will be satisfied not by a mismatch in voice, but a mismatch in place.

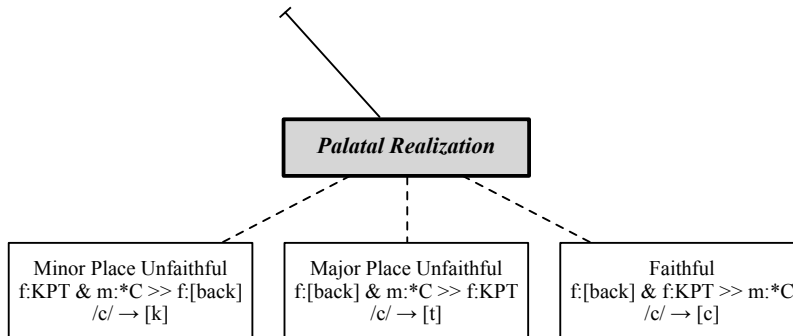
As mentioned previously, a language needs to be both Voiced and Complex in order for it to choose between Voiced Complex and Voiceless Complex. The prerequisite for complexity is enforced via Complex Voicing being both a subproperty of the Complex languages and of the Voiced languages. The distinction of Complex Voicing is pared down to whether f:KPT dominates *jgbd (Complex Voiced), or vice-versa (Complex Voiceless).

3.3.5 Palatal Realization

The Palatal Realization property reflects how the inputs /c/ and /j/ are realized with respect to place. Note that C as used here represents any dorsal specified as [-back]. These inputs also have

implications for the realization of /cp/ and /jb/, if these inputs are still realized as complex stops. For example, in a Complex language where /c/ → [k], then /cp/ → [kp].

(38) **Palatal Realization Subtree**



The input /c/ and its voiced counterpart /j/ are realized in one of three ways with respect to place: fully faithful, with an unfaithful value of [back], or with an unfaithful major place.

(39) **Possible /C/ mappings**

/C/	→	[C]	Faithful
	→	[K]	Unfaithful [back] value
	→	[T]	Unfaithful major place

For /c/ to be realized faithfully, both f:[back] and f:KPT must dominate m:*C. The constraint f:[back] assigns violations based on mismatches in the [back] value, which in this system is a subfeature of only dorsals. Major place faithfulness f:KPT does not assign a violation for /c/ → [k] as both of these segments have a major place of [dorsal]. The Palatal Realization property is a ternary choice, as no two choices form a conservative join.

The Faithful languages are shown below.

(40) **Faithful Palatal Languages**

f:[back] & f:KPT ≫ m:*C

	Inputs->	t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 10	t.dor.s.f	t	p	c	k	p	p	t	p	c	k	p	p
Lg. 11	d.dor.s.f	t	p	c	k	p	p	d	b	j	g	b	b
Lg. 12	t.dor.c.f	t	p	c	k	cp	kp	t	p	c	k	cp	kp
Lg. 13	d.dor.c.f.b	t	p	c	k	cp	kp	d	b	j	g	b	b
Lg. 14	d.dor.c.f.gb	t	p	c	k	cp	kp	d	b	j	g	jb	gb

As this is a subproperty of DOR, all languages above have dorsals (as C itself is dorsal). Complexity is an independent choice, so the languages above are either Simple (10, 11) or Complex (12, 13, 14). Likewise, they are either Voiced (11, 13, 14) or Voiceless (10, 12).

The ranking condition for a Faithful language above has both types of place faithfulness, f:[back] and f:KPT, dominating the markedness constraint m:*C. If m:*C dominates just one of these faithfulness constraints, /C/ is realized unfaithfully. If m:*C dominates f:[back], then /C/ → [K], with major place preserved. However, if m:*C dominates f:KPT, then /C/ → [T], reducing to the least marked place. These describe the Minor Unfaithful and Major Unfaithful subproperties of the Palatal Realization property, respectively.

(41) **Minor Place Unfaithfulness**

f:KPT & m:*C ≫ f:[back]

Inputs->		t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 15	t.dor.s.min	t	p	k	k	p	p	t	p	k	k	p	p
Lg. 16	d.dor.s.min	t	p	k	k	p	p	d	b	g	g	b	b
Lg. 17	t.dor.c.min	t	p	k	k	kp	kp	t	p	k	k	kp	kp
Lg. 18	d.dor.c.min.b	t	p	k	k	kp	kp	d	b	g	g	b	b
Lg. 19	d.dor.c.min.gb	t	p	k	k	kp	kp	d	b	g	g	gb	gb

In these languages, the behavior of /c/ and /j/ mirrors exactly the behavior of complex stops /cp/ and /jb/. If /C/ is realized as [K], then /CP/ is realized as /KP/.

(42) **Major Place Unfaithfulness**

f:[back] & m:*C ≫ f:KPT

Inputs->		t	p	c	k	cp	kp	d	b	j	g	jb	gb
Lg. 5	t.dor.s.maj	t	p	t	k	p	p	t	p	t	k	p	p
Lg. 6	d.dor.s.maj	t	p	t	k	p	p	d	b	d	g	b	b
Lg. 7	t.dor.c.maj	t	p	t	k	p	kp	t	p	t	k	p	kp
Lg. 8	d.dor.c.maj.b	t	p	t	k	p	kp	d	b	d	g	b	b
Lg. 9	d.dor.c.maj.gb	t	p	t	k	p	kp	d	b	d	g	b	gb

Because non-dorsals are not specified for [back], any dorsal mapping to a non-dorsal does not receive a violation from f:[back]; this constraint is only violated when inputs and outputs have opposite values for [back]. Thus, when m:*C and f:[back] dominate f:KPT, as is the case with the Major Place Unfaithfulness languages above, the optimal mapping is /C/ → [T]. This is clear from the candidate sets of the simple palatals /c/ and /j/. The input /CP/, in these languages, maps to [P], as [TP] is excluded in GEN.

3.4 *Predictions of the System*

The system as defined in this section makes a number of predictions with respect to stop inventories and complex stop distributions that can be tested against empirical languages. The predictions and results of these prediction compared against an empirical database are explained in the following sections. A simplified table of the factorial typology is given below, showing surface inventories instead of specific input-out mappings, with attested languages listed on the right. The table shows surface inventories, not mappings, so the languages with identical surface inventories have been collapsed. Only the complex languages are included.

(43) *Annotated FacTyp of Complex Languages (Surface Inventories)*

Surface Inventory →	t	p	k	c	kp	cp	d	b	g	j	gb	jb	Attested Languages
t.dor.c.maj/min	t	p	k		kp								Bora, Lama, Lokpa (Cahill 2009)
t.dor.c.f	t	p	k	c	kp	cp							
d.dor.c.maj/min.b	t	p	k		kp		d	b	g				Late, Sekpele, Krachi (WAPS)
d.dor.c.f.b	t	p	k	c	kp	cp	d	b	g	j			
d.dor.c.maj/min.gb	t	p	k		kp		d	b	g		gb		Soso, Mende, Dagbani, Bantonu, Ga, Ewe, Avatime (Siya), Siwu (Lolobi), Ge, Bini, Ora, Ijaw (Upper), Kambari, Tiv, Krio (WAPS)
d.dor.c.f.gb	t	p	k	c	kp	cp	d	b	g	j	gb	jb	Dagbani (Olawsky 1999)

Many attested languages are excluded from this table; these are discussed in the subsections to follow, along with the specific predictions why certain languages are included or excluded.

Certain predictions of the typology as defined previously are discussed in the following sections. The system captures implicational relationships between the presence of CP in relation to KP, but not CP in relation to C. The system also captures certain interactions related to voicing, but not all: voicing can be preserved among the simple stops while lost with the complex stops, but languages where [gb] is the only complex stop present are absent from the typology. In KP0, [gb] entails [kp].

3.4.1 Methodology and Data

The empirical basis for this section is collected from two main sources, which themselves are surveys of existing language descriptions. The first is Ladefoged's (1968) *Phonetic Survey of West African Languages* (henceforth WAPS), and the second are the stop inventories surveyed in Cahill (2009). Both of these surveys focus on which sounds are contrastive in those languages; in OT the idea of contrast is slightly different (but still exists, see Tesar 2013:281 for a recent definition of contrast in OT), and a sound not listed in some particular language description in the collection here may still exist in that language's phonetic or surface inventory. The amalgamated survey consists of 89 languages, and is included as an appendix.

Further, it should be stressed that this is a collection of language *descriptions*, some of which will have the same name in the "Language" column, but with ultimately different segments listed for their inventories. For instance, the WAPS description of Krachi includes [g], but the description from Cahill (2009) lacks [g]. A number of reasons could cause these discrepancies: different dialects, different analytical conclusions, or simply an accidental gap of data. The descriptions themselves come from a variety of sources (grammars, articles, unpublished elicitations) and can vary from impressionistic data and data collected instrumentally. Thus weight should not be put on the claim that, say, Efik fits into some particular spot in the currently typology, but rather *x* number of descriptions fit into some spot on the current typology. It is hoped that the number of existing language descriptions that fit into the predicted typology correlates with the actual number of natural languages that fit into said spot. Throughout this section, the discussion will still refer to simply *languages* for simplicity's sake.

3.4.2 Place Interactions

One of the driving ideas behind the design of KP0 is that it does not make reference to anything called "complex" place; the effect of these segments fall out of the definitions of constraints that make reference to specific features. This results in a number of interactions between segments of similar or overlapping place in the typology; these are discussed in this section.

- (44) **Prediction:** If a language has CP, it necessarily has KP
Empirically Supported: Yes

The only languages in KP0 that have CP are those that are Dorsal, Complex, and C-Faithful. If a language is Dorsal and Complex, it will therefore have KP. This is also the case empirically based on the collected survey, even if there are only a paucity of languages with CP (n=2: Dagbani and Nzema). It is reemphasized that what has traditionally been transcribed as [tp] or [pt], that is, a labial-coronal, is assumed here to be a labial-dorsal that has been fronted, based on the arguments presented in section 2.1.

There are in fact two languages surveyed in WAPS that are said to have [tp] (CP) but not [kp]: Margi and Bura. These are repeated below:

- (45) *Attested inventories for Margi and Bura:*

Language Name	p	t	k	c	b	d	g	ɟ	kp	gb	tp (cp)	db (ɟb)
Bura	p	t	k	c	b	d	g	ɟ			tp	
Margi	p	t	k	c	b	d	g	ɟ			tp	db

Maddieson (1983), however, provides phonetic evidence demonstrating "that the so-called labial-alveolars are in fact a simple sequence of bilabial and an alveolar articulation, and we will argue that a segmental interpretation is the correct analysis from a phonological point of view as well" adding "there is every reason to believe that the conclusions presented apply to Margi and the other languages involved" (Maddieson 1983:287-288). The conclusions for Margi are confirmed in Maddieson (1987). See also Bennett (to appear) for further discussion on these points. I accept these arguments and exclude Margi and Bura from the set of languages that have CP.

- (46) **Prediction:** If a complex input is realized as a simple output, it is never of the more marked place.
Empirically Supported: Yes

This prediction falls out from the definition of both the markedness constraints and the place faithfulness constraint f:KPT. In effect, the complex input /kp/ has three levels of outputs in terms of major place faithfulness: completely faithful [KP/CP], simple-but-faithful [K/C] and [P], and unfaithful (all other candidates). As is shown below, however, the candidate /kp/→[p] harmonically bounds /kp/→[k], as [p] is less marked than [k].

(47) *Violation profiles of /kp/→[p] vs. /kp/→[k]*

input	output	1:m:*CKPT	2:m:*CKP	3:m:*CK	4:m:*C	5:f:KPT	6:f:[back]	7:m:*jgbd	8:f:[voil]
kp	t	1	0	0	0	3	0	0	0
	p	1	1	0	0	1	0	0	0
	k	1	1	1	0	1	0	0	0
	kp	2	2	1	0	0	0	0	0

All other candidates not included above are bounded as well. Crucially here, outputs [k] and [p] both receive one violation from f:KPT as each has one major place feature in the input not realized in the output (column 5). Because of the scaled markedness constraints, output [p] receives no violations from *CK, while output [k] does (column 3); this is the crucial (and only) difference in violations that causes [k] to be bounded in this candidate set.

Because this prediction involves alternations specifically, and not just surface distributions of segments, it cannot be tested against a survey of segment inventories. This prediction is discussed in detail in Section 4.1, where phonotactic and paradigmatic alternations of the relevant type are discussed.

The next prediction involves the behavior of complex palatals with respect to simple palatals.

(48) **Prediction:** A Complex language has C iff it has CP
Empirically Supported: No

This prediction arises from the fact that, for a DOR language, the C-Behavior property and the Type property (Complex or Simple) are independent choices, and that the C-Behavior property affects how C is realized whether in a simple stop or a complex one. Thus if the language is Complex, and /c/ → [c], then it must be the case that /cp/→[cp], and vice versa. In other words, the behavior of minor place is predicted to be linked between simple and complex segments, when empirically minor place behavior is independent between complex and simple place.

The following are attested language with at least one complex stop, the simple palatals (either [c] or [j]), and no CP:

(49) *Complex, C but no CP*

Language Name	p	t	k	c	b	d	g	ɟ	kp	gb	tp (cp)	db (ɟb)	Source
Idoma (Western)	p	t	k	c	b	d	g	ɟ	kp	gb			WAPS
Igbo	p	t	k	c	b	d	g	ɟ	kp				WAPS
Kutep	p	t	k	c	b				kp				WAPS
Logba	p	t	k	c	b	d	g	ɟ	kp	gb			WAPS
Loko	p	t	k	c	b				kp				WAPS
Ngwo (Widekum)	p	t	k	c	b	d	g	ɟ	kp	gb			WAPS
Nkonya	p	t	k	c	b	d	g		kp				WAPS
Sisala	p	t	k	c	b	d	g	ɟ	kp	gb			WAPS
Urhobo	p	t	k	c	b	d	g	ɟ	kp	gb			WAPS

These languages are impossible in the typology of KP0. There is no constraint that specifically militates against palatal complex stops CP. The only constraint that differentiates between simple stops and complex stops is m:*CKPT (and it's voicing counterpart m:*jgbd). These constraints do not differentiate between KP and CP, however. The behavior of CP is entirely up to the faithfulness constraints f:[back] and f:KPT, and the markedness constraint m:*C, as defined in Section 3.2.1.

The next prediction concerns the general relationship between a complex stops and its simple counterparts. The simple counterparts of a complex stop are defined as the set of segments each with place feature of the original complex stop; so, the simple counterparts of [kp] are [k] and [p].

- (50) **Prediction:** If a language has complex segment XY it necessarily has simple segments X and Y
Empirically Supported: No

To test this prediction, it is broken down into all possible versions:

- (51) a. If a language has [kp], then it necessarily has [k] and [p] = False
 b. If a language has [gb], then it necessarily has [g] and [b] = False
 c. If a language has [cp], then it necessarily has [c] and [p] = Unclear
 d. If a language has [ɟb], then it necessarily has [ɟ] and [b] = Unclear

The following languages have [kp] but lack [p]:

(52) *Languages that have [kp] but lack [p]*

Language Name	p	t	k	c	b	d	g	ɟ	kp	gb	tp (cp)	db (ɟb)	Source
Anum		t	k		b	d	g		kp				WAPS
Balanta		t	k			d			kp				Cahill 2009
Effutu		t	k		b	d	g		kp	gb			WAPS
Efik		t	k		b	d			kp				WAPS
Efik		t	k		b	d			kp				Cahill 2009
Fo		t	k		b	d	g		kp	gb			WAPS
Kyerepong		t	k		b	d		ɟ	kp				WAPS
Makaa		t	k		b	d	g		kp				Cahill 2009
Nzima		t	k	c	b	d		ɟ	kp		tp		WAPS
Usaghade		t	k		b	d			kp				Cahill 2009

There are no languages that have [kp] but lack [k]. These languages are impossible in KP0 because being a Complex language implies being a DOR language; all DOR languages have simple dorsal stops.

The following languages have [gb] but lack [g] or [b]:

(53) *Languages that have [gb] but lack either [g] or [b]*

Language Name	p	t	k	c	b	d	g	ɟ	kp	gb	tp (cp)	db (ɟb)	Source
Krahn	p	t	k		b	d				gb			Cahill 2009
Limba, W. Central	p	t	k		b	d				gb			Cahill 2009
Owa	p	t	k							gb			Cahill 2009
Sherbro	p	t	k		b	d				gb			Cahill 2009
Sicite	p	t	k		b	d				gb			Cahill 2009
Temne	p	t	k		b	d				gb			WAPS
Temne	p	t	k		b	d				gb			Cahill 2009

The only language above that lacks [b] also lacks [g]; in fact, it lacks all voiced simple stops (Owa). It should also be noted that the above languages are also impossible in KP0 because they have [gb] as the only complex stop—as will be discussed next, in KP0 [gb] always implies [kp].

3.4.3 Voicing Interactions

Voicing interactions in KP0 are governed primarily by the interaction of the two constraints f:[voi] and m:*jgbd, as is seen in the discussion of the Voicing property in Section 3.3.1. However, the voicing markedness constraint also interacts with the major place faithfulness constraint f:KPT, as m:*jgbd assigns voicing violations based on the number of places. This results in some nonobvious mappings and predictions, which are discussed in this section.

- (54) **Prediction:** A language can have kp without gb, but with voicing distinctions among simple stops
Empirically Supported: Yes

This prediction is due to the fact that the voicing of complex segments is a separate property of the voicing of simple segments. Remember that this property, Complex Voicing, is only available to those languages that are both Voiced and Complex. A language can have voicing distinctions in the simple stops, but still ban [gb]. In these languages, [gb] is neutralized to [b], instead of to [kp] as it is in the fully Voiceless languages. In WAPS there are three such languages: these languages have [kp] as their only complex stops, but have [p t k] and [b d g]. These are shown below.

- (55) *Voiced, Complex, Voiceless Complex*

Language Name	p	t	k	c	b	d	g	ɟ	kp	gb	tp (cp)	db (ɟb)	Source
Krachi	p	t	k		b	d	g		kp				WAPS
Late	p	t	k		b	d	g		kp				WAPS
Sekpele (Likpe)	p	t	k		b	d	g		kp				WAPS

Based on surface inventory, these languages fit exactly into the d.dor.b group of languages; property of C must be unfaithful, but beyond that the type of unfaithfulness cannot be deduced from this data. In the current system, which is based on a strict markedness hierarchy, if a language has dorsal sounds, it also has coronal and labial sounds. This implication holds for voiced segments as well: a voiced dorsal implies a voiced coronal and a voiced labial. There are a number of languages, mostly in Cahill's (2009) survey, which have gaps in their simple inventories. If the prediction is generalized beyond the current system, there are number of languages that lack voicing distinctions of complex stops but preserve certain voicing distinctions among their simple stops; these languages are marked as "excluded" in the appendix because of their gaps but are repeated below.

(56) *Voicing distinctions for simple stops, not for complex stops*

Language Name	p	t	k	c	b	d	g	ɟ	kp	gb	tp (cp)	db (ɟb)	Source
Anum		t	k		b	d	g		kp				WAPS
Balanta		t	k			d			kp				Cahill 2009
Chumburung	p	t	k		b	d			kp				Cahill 2009
Ditammari	p	t	k		b	d			kp				Cahill 2009
Efik		t	k		b	d			kp				WAPS
Efik		t	k		b	d			kp				Cahill 2009
Ibibio	p	t	k		b	d			kp				Cahill 2009
Igbo	p	t	k	c	b	d	g	ɟ	kp				WAPS
Kabiye	p	t	k			d			kp				Cahill 2009
Kissi	p	t	k		b	d			kp				WAPS
Krachi	p	t	k		b	d			kp				Cahill 2009
Kutep	p	t	k	c	b				kp				WAPS
Kuwaa	p	t	k		b	d			kp				Cahill 2009
Kyerepong		t	k		b	d		ɟ	kp				WAPS
Larteh	p	t	k		b	d			kp				Cahill 2009
Loko	p	t	k	c	b				kp				WAPS
Makaa		t	k		b	d	g		kp				Cahill 2009
Nkonya	p	t	k	c	b	d	g		kp				WAPS
Nkonya	p	t	k		b	d			kp				Cahill 2009
Nzima		t	k	c	b	d		ɟ	kp	tp			WAPS
Sekpele	p	t	k		b				kp				Cahill 2009
Usaghade		t	k		b	d			kp				Cahill 2009
Waama	p	t	k		b	d			kp				Cahill 2009

It can be concluded that, even though these languages are excluded because the current system cannot account for gapped inventories, the fact that the voicing of simple stops can be preserved while it is lost for complex stops is a desirable result.

In KP0, there is an implicational relation between the presence of [gb] and that of [kp]:

- (57) **Prediction:** If a language has [gb], it necessarily has [kp]
Empirically Supported: No

In terms of markedness, [gb] is more marked than [kp] because it receives two violations from m:*jgbd, while [kp] receives none. All other markedness violations of these segments are equal; this is the only difference in their violation profiles. Because there is no constraint that prefers [gb] but not [kp], the presence of the more marked element implies the presence of the less marked element in this system. This is not the case empirically, as a number of languages have [gb] but lack [kp]. If this is a true phonological gap, then the core system KP0 cannot capture this generalization. However, in Cahill (2009), the so-called gb-only languages are discussed extensively, and Cahill concludes that [kp] is lost historically due to a merger with [gb].

4 Alternations

While the number of languages containing complex stops is a small subset of all natural languages, and the number of *those* languages with alternations involving complex stops is even smaller, a variety of alternations exist, and these are discussed in the following sections. The

mappings of KP0 often involve complex stops being mapped to simple stops, as is the case for every Simple language and the Complex Place Reduced languages, or complex stops neutralizing to voiceless stops, as is the case in the Voiceless languages. Dagbani and Nzema are languages where KP is in an alternation with CP.

Each subsection below defines a new system, which is an augmentation of KP0. However, this is only for argument's sake: it is envisioned that all are subsystems of some super-GEN and super-CON that can generate grammars for the intended languages. They are broken up here into their parts to pinpoint the crucial interactions at play for each language type.

4.1 *Complex to Simple*

There are languages that show evidence of complex inputs being realized as simple outputs. Amele (Papua New Guinea) has a paradigmatic alternation where a morpheme containing a complex stop is realized either faithfully or reduced to a simple stop (Roberts 1987). Welmers (1973) cites Efik as a language where [p] appears only in codas and [kp] only in onsets, putting the two in a phonotactic alternation. This section focuses on Amele, but the ideas can be extended to Efik and other languages with similar alternations.

In Amele (Papuan, Papua New Guinea), the complex stop [gb] is realized as [p] in coda position. This is part of a more general devoicing pattern observed in Roberts (1987: 346).

(58) In final position:

/d/	→	[t]
/b/, /gb/	→	[p]
/g/	→	[k]

Roberts (1987) analyzes this as a word-final alternation, but as clusters are extremely rare (found only in certain proper nouns, and a verb plus certain clitics, Roberts 1987: 347), it is presented here as coda devoicing.⁴ The scope of the prosodic domain this alternation is sensitive to is not crucial for the analysis here, but the syllable is settled on for simplicity's sake.

The paradigmatic alternation is seen in the data below, from Roberts (p.c.). The ordering of syntactic morphemes differs between the two sets of data; when the person-number morpheme /ogb/ is realized finally, the stop is realized as [p], but as [gb] when the morpheme is word-internal.

⁴ Roberts reports the form [tugbdo?], p. 346, as evidence for word-final neutralization rather than syllable-final. If this generalizes beyond one datum, it is still not crucial which prosodic domain is at play for the analysis here, only that there is *some* prosodic position where voiced complex stops are neutralized.

(59) a. [gb] realized faithfully in onsets (person-number morpheme is word internal):

/h+ogb+ona/	[ho'.gbɔ.nə]	'we are coming' (present)
/f+ogb+ona/	[fo'.gbɔ.nə]	'we are seeing' (present)
/h+ogb+a/	['ho.gbə]	'we came' (today)
/f+ogb+a/	['fo.gbə]	'we saw' (today)
/h+ogb+an/	[ho'.gbæn]	'we came' (yesterday)
/f+ogb+an/	[fo'.gbæn]	'we saw' (yesterday)
/h+ogb+an/	[ho'.gbæn]	'we will come' (future)
/f+egb+an/	[fe'.gbæn]	'we will see' (future)
/h+ogb+a/	['ho.gbə]	'we are about to come' (prospective future)
/f+egb+a/	['fe.gbə]	'we are about to see' (prospective future)

b. [gb] neutralizes to [p] when in coda position (person-number morpheme is word-final):

/h+ol+ogb/	[hɔ'.lɔp]	we used to come' (past habitual)
/f+ol+ogb/	[fɔ'.lɔp]	we used to see' (past habitual)
/h+um+egb/	['hu.mɛp]	we come and (we) ...' (SS.sequential)
/f+im+egb/	['fi.mɛp]	we see and (we) ...' (SS.sequential)
/h+uf+egb/	['hu.fɛp]	if we come and (we) ...' (SS. conditional)
/f+if+egb/	['fi.fɛp]	if we see and (we) ...' (SS. conditional)
/h+ogb/	['hɔp]	as we come and (we) ...' (SS.simultaneous.punctual)
/f+ogb/	['fɔp]	as we see and (we) ...' (SS.simultaneous.punctual)

(underlying forms, surface forms, and translations are all from Roberts p.c.)

In order to account for the alternation in Amele, a new system based on KP0 is constructed, called KP1/PF, with the addition of *positional faithfulness* for place and voicing. These are defined below, and are based on Beckman (1998), Lombardi (1999), among others.

(60) **f-ons:KPT**

If S1 is a segment in the input, and
 S2 is a segment in the output, and
S2 is in the onset position, and
 S1 and S2 are in correspondence, and
 [cor] or [lab] or [dor] ∈ PL(S1),
 Assign one violation for every x such that:
 x ∈ PL(S1) & x ∉ PL(S2) and
 Assign one violation for every x such that:
 x ∈ PL(S2) & x ∉ PL(S1)
 where x ∈ {[lab], [cor], [dor]}

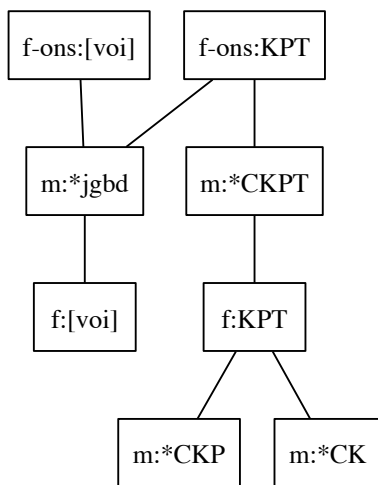
- (61) **f-ons:[voi]**
 If S1 is a segment in the input and
 S2 is a segment in the output and
S2 is in the onset position, and
 S1 and S2 are in correspondence,
 assign one violation:
 if S1 is [voice] and S2 is not [voice]
 or
 if S1 is not [voice] and S2 is [voice]

Additionally, GEN has changed to now allow syllabified consonants and vowels. To focus on the interaction of codas and onsets, and to keep candidate sets simple, the only syllable types discussed are CV or VC

With this new system, a grammar representing Amele can be constructed. This grammar neutralizes [gb] to [p] in coda positions through the use of the added positional faithfulness constraints. The grammar also prohibits CP/C from occurring anywhere in the language as this is not a part of Amele's surface inventory.

With respect to the properties of KP0, the target Amele grammar is Voiced, Complex, Complex Voicing Preserved in onset position, and a Voiceless, Simple language in coda position. The exact behavior of palatals is not known for Amele, /C/ maps unfaithfully as there is no [C] in the surface inventory, but it is not clear if it neutralizes to [T] or [K].

(62) *Necessary Amele ranking*



This ranking ensures the following crucial mappings for Amele:

(63)

Input:	Onsets	Codas
b, d, g	b, d, g	p, t, k
gb	gb	p

The unfaithful mappings are shaded. Onsets in Amele are Voiced, Complex, and Voiced Complex Place Preserved, so the following rankings must hold:

- (64) f-ons:[voi] » m:*jgbd Voiced (Onsets)
 f-ons:KPT » m:*CKP & m:*CK DOR (Onsets)
 f-ons:KPT » m:*CKPT Complex (Onsets)
 f-ons:KPT » m:*jgbd Voiced Complex Place Preserved (Onsets)

In codas, the target mappings are Voiceless, DOR, and Simple. Thus, the following rankings must hold:

- (65) m:*jgbd » f:[voi] Voiceless
 f:KPT » m:*CKP & m:*CK DOR
 m:*CKPT » f:KPT Simple

These rankings produce the Hasse diagram in (62). Note that the constraints m:*C and f:[back] are not shown here. The desired C-Behavior property for Amele is not known, so these constraints have been left out. However, it must be the case that /C/ is realized unfaithfully, either as [K] or [T]. Thus, based on the KP0 property definitions, m:*C must dominate either f(-ons):KPT or f:[back]. This is why the ranking in (62) is labeled as necessary, but is not sufficient.

It must be emphasized that the system dealing with Amele, KP1/PF, is a *different* system from KP0 and thus it is not automatic that the properties and definitions from KP0 transfer directly to the new system. However, in this specific case, because the only addition is reference to onsets, the properties now must be set both generally and in onset position. No new properties emerge *per se*, but the choice of *where* these properties appear emerges.

4.2 Complex to Complex

The purpose of this section is to further augment the core system KP0 with constraints and changes to GEN which results in a possible Dagbani-type grammar. Secondary articulation is now added; in addition to a consonant having multiple c-place features, and minor place features dependent on those, a consonant can now have v-place features. In addition, a constraint is added that prefers palatalization before front vowels, called simply m:pal.

In all Complex languages that have unfaithful minor place [\pm back] for palatal inputs /C/, the complex stop /CP/ is realized as [KP]. There are two languages mentioned in the literature that have a KP~CP alternation: Dagbani and Nzema (Cahill 1999:158, reported there as a KP~TP alternation, but with palatal articulation). In these languages, consonants have palatal articulation before front vowels (Cahill 1999, Cahill 2008, Olawsky 1999, Bennett to appear), although Olawsky (1999: 260) does describe variation with alveolar articulation.

The Dagbani palatalization process is described as optional and adds secondary articulation to simple coronals and labials, and changes labial-velars to labial-palatals, when occurring before front vowels. It is not clear what the effect is on simple dorsal onsets is.

(66) Dagbani:

/n-kpi/	[n tpi], [cpi]	'die'	
/n-gbi/	[n dbi], [ɟbi]	'dig'	
/n-ɲme/	[n ɲme], [nme]	'hit'	(Olawsky 1999: (509))

/kpíni/	[cp̄jíní]	'guinea fowl'	/pini/	[pjíní]	'gifts'
/kpíà/	[cp̄jà]	'sheanut'	/pía/	[pía]	'ten'
/kpè/	[cp̄jè]	'to enter'	/pè/	[p'è]	'to milk'
/gbíhi/	[ɟbɜ́íhí]	'to sleep'	/bíhi/	[bíhí]	'children'
/gbéli/	[ɟbɜ́éli]	'glare at'	/béli/	[b'éli]	'accompany'
/gbíàɣú/	[ɟbɜ́iàʔú]	'forehead'	/bíáɣú/	[bíáʔú]	'day'

(Cahill 2008: (2))

All underlying forms and transcriptions above are the respective original author's.

A new system, KP2/PAL, is constructed. Once again GEN_{PAL} is modified to include consonant-vowel sequences. To keep things simple, only onset-nucleus combinations are generated, as it is onsets that undergo palatalization in Dagbani. The two possible vowels are represented U and I: I being a front vowel and U being a back vowel. Featurally, both vowels are [dorsal], and I is [-back], and U [+back]. As voicing does not play a crucial role, voicing distinctions are ignored (also again for simplification). The data above shows that this process is active in both voiced and voiceless consonants. Consonants are represented similarly, with T, P, K, and C representing [coronal], [labial], [dorsal, +back] and [dorsal, -back], respectively. The symbol J now stands for secondary palatal articulation of a consonant. The feature specification of candidate TJI is shown below for explication.

(67)

	TJ	I
C-place	V-place	V-place
[coronal]	[dorsal, -back]	[dorsal, -back]

For CON_{PAL}, place faithfulness is now sensitive to the differences in c-place and v-place features; C-PL(S) is a function that takes a segment S and returns that segment's c-place features, and likewise for V-PL(S). An upper bound of two major place features per segment is imposed, so no segment has two c-place features and a v-place feature: no complex stop has secondary articulation.

(68) **f-c:KPT**
 If S1 is a segment in the input, and
 S2 is a segment in the output, and
 S1 and S2 are in correspondence, and
 $[\text{cor}]$ or $[\text{lab}]$ or $[\text{dor}] \in \mathbf{C-PL}(S1)$,
 Assign one violation for every x such that:
 $x \in \text{PL}(S1) \ \& \ x \notin \mathbf{C-PL}(S2)$ and
 Assign one violation for every x such that:
 $x \in \text{PL}(S2) \ \& \ x \notin \mathbf{C-PL}(S1)$
 where $x \in \{[\text{lab}], [\text{cor}], [\text{dor}]\}$

(69) **f-v:KPT**
 If S1 is a segment in the input, and
 S2 is a segment in the output, and
 S1 and S2 are in correspondence, and
 $[\text{cor}]$ or $[\text{lab}]$ or $[\text{dor}] \in \mathbf{V-PL}(S1)$,
 Assign one violation for every x such that:
 $x \in \text{PL}(S1) \ \& \ x \notin \mathbf{V-PL}(S2)$ and
 Assign one violation for every x such that:
 $x \in \text{PL}(S2) \ \& \ x \notin \mathbf{V-PL}(S1)$
 where $x \in \{[\text{lab}], [\text{cor}], [\text{dor}]\}$

The constraint f-v:KPT acts as faithfulness for secondary articulation.

(70) **f-c:[back]**
 If S1 is a segment in the input, and
 S2 is a segment in the output, and
 S1 and S2 are in correspondence
 Assign one violation if
 $\exists x$ s.t. $x \in \text{C-PL}(S1)$ and x is $[\alpha\text{back}]$
 and
 $\exists x$ s.t. $x \in \text{C-PL}(S2)$ and x is $[\neg\alpha\text{back}]$

(71) **f-v:[back]**
 If S1 is a segment in the input, and
 S2 is a segment in the output, and
 S1 and S2 are in correspondence
 Assign one violation if
 $\exists x$ s.t. $x \in \mathbf{V-PL}(S1)$ and x is $[\alpha\text{back}]$
 and
 $\exists x$ s.t. $x \in \mathbf{V-PL}(S2)$ and x is $[\neg\alpha\text{back}]$

The extended definitions for [back]-faithfulness for both c-place and v-place is necessary to ensure that, for example, any value for [back] under c-place does not affect the faithfulness violation counting for v-place faithfulness f-v:[back].

Some constraint must prefer consonants to palatalize before front vowels. The following constraint *m:pal* does exactly this. It is similar to a standard local Agree type constraint, but is slightly more nuanced to account for the *v*-place and *c*-place features in addition to the possible absence of a [back] feature all together (as [back] is still assumed to be dependent on only [dorsal]).

- (72) **m:pal**
 If S1 and S2 are adjacent segments in the output
 Assign one violation if
 S1 or S2 is [-back] and
 either S1 or S2 is not [-back]

If a segment has the feature [-back] anywhere in its representation, then a violation is assigned if *both* segments do not have [-back] anywhere in their representations. The violation profiles for *m:pal* for the full candidate set is shown below.

(73) *Violation Profiles for m:pal*

		output	m:pal	Comment
Palatalized Stops	Front Vowels	CI	0	Both C and I are -back
		CPI	0	Both CP and I are -back
		TJI	0	Both TJ and I are -back
		PJI	0	Both PJ and I are -back
		KJI	0	Both KJ and I are -back
		CJI	0	Both CJ and I are -back
	Back Vowels	CU	1	U is +back, C is -back
		CPU	1	U is +back, CP is -back
		TJU	1	U is +back, TJ is -back
		PJU	1	U is +back, PJ is -back
		KJU	1	U is +back, KJ is -back
		CJU	1	U is +back, CJ is -back
Non-palatalized Stops	Front Vowels	TI	1	I is -back, T is undefined for back
		PI	1	I is -back, T is undefined for back
		KI	1	I is -back, K is +back
		KPI	1	I is -back, KP is +back
	Back Vowels	TU	0	U is +back, T is undefined for back
		PU	0	U is +back, P is undefined for back
		KU	0	U is +back, K is +back
		KPU	0	U is +back, KP is +back

As can be seen in the table above, every form that is assigned zero violations either has both segments as [-back] (e.g. [CI]), or neither as [-back] (e.g. [TU]). The forms that are assigned one violation have one segment that is [-back], and one segment that is either undefined for [back] (those segments with no [dorsal] place) or is [+back].

The additional assumptions to GEN_{KP0} and CON_{KP0} as made above result in a new system. The addition of the constraint $m:pal$ adds new properties that cannot be directly ported from $KP0$ or the Amele system. This section forgoes a complete analysis of the system $KP2/PAL$, but instead focuses on the grammars generated that result in a Dagbani-like system.

The crucial mappings for a Dagbani-like system are shown below:

- (74) /KPI/ → [CPI]
 /TI/ → [TJI]
 /PI/ → [PJI]

The complex stop KP is realized with a palatal instead of velar articulation, and the coronal stop T and labial stop P are realized with palatal secondary articulation, all before front vowels. In the typology of $PAL1$, there are four languages with such mappings. These are shown below. Again, all calculations are done in OT Workplace.

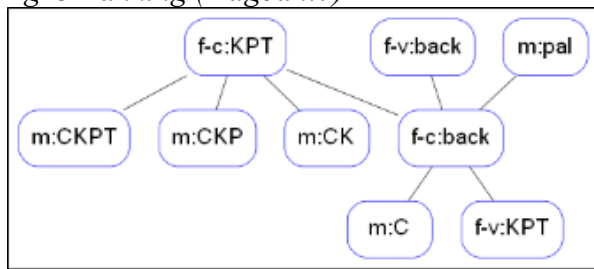
(75) *Dagbani-like Languages in $KP2/PAL$*

Inputs:	TI	PI	KI	CI	KPI	CPI	TJI	PJI	KJI	CJI	TU	PU	KU	CU	KPU	CPU	TJU	PJU	KJU	CJU
Lg#1	TJI	PJI	CI	CI	CPI	CPI	TJI	PJI	KJI	KJI	TU	PU	KU	KU	KPU	KPU	TU	PU	KU	KU
Lg#2	TJI	PJI	CI	CI	CPI	CPI	TJI	PJI	KJI	CJI	TU	PU	KU	KU	KPU	KPU	TU	PU	KU	KU
Lg#3	TJI	PJI	KJI	CI	CPI	CPI	TJI	PJI	KJI	CJI	TU	PU	KU	KU	KPU	KPU	TU	PU	KU	KU
Lg#4	TJI	PJI	KJI	KJI	CPI	CPI	TJI	PJI	KJI	KJI	TU	PU	KU	KU	KPU	KPU	TU	PU	KU	KU

The differences in these languages are in the realizations of simple dorsals before front vowels. Keep in mind that a stop with secondary articulation is still considered simple, for the sake of discussion here. Because the behavior of simple dorsals before front vowels in Dagbani is not known, the discussion here will focus on language 3, partially arbitrarily, partially because this has faithful realizations of /CI/ and /CJI/, with /KI/ mapping to [KJI], gaining secondary articulation. The input /CPU/ is realized as [KPU] as well, as [CPU] violates undominated $m:pal$. The generalization that [kp] and [cp] are in complementary distribution is captured in these languages.

The ranking for Lg#3 is shown in the Hasse diagram below.

(76) *Lg#3 Ranking (Dagbani?)*



While the full set of properties for $KP2/PAL$ is crucially changed with the addition of new constraints and structures, there are some vestiges of $KP0$ properties present. For instance, Lg#3

allows complex stops because f-c:KPT dominates m:CKPT. In fact, f-c:KPT is undominated, so stops of all places are in the surface inventory of the language.

The necessary rankings for the palatalization of complex stops are shown in the comparative tableau below. This CT shows all winner~loser pairs for the /KPI/ candidate set.

(77) /KPI/ Comparative Tableau

ERC#	Input	Winner	Loser	5:f-c:KPT	7:f-v:back	9:m:pal	1:m:CKPT	2:m:CKP	3:m:CK	6:f-c:back	4:m:C	8:f-v:KPT
5.6>11	KPI	CPI	TU	W	W		L	L	L	L	L	
5.6>12	KPI	CPI	PU	W	W		L	L	L	L	L	
5.6>1	KPI	CPI	TI	W		W	L	L	L	L	L	
5.6>2	KPI	CPI	PI	W		W	L	L	L	L	L	
5.6>4	KPI	CPI	CI	W			L	L				
5.6>7	KPI	CPI	TJI	W			L	L	L	L	L	W
5.6>8	KPI	CPI	PJI	W			L	L	L	L	L	W
5.6>15	KPI	CPI	KPU		W					L	L	
5.6>5	KPI	CPI	KPI			W				L	L	

Observe the last two ERCs. The vowel does not change quality, so f-v:back dominates f-c:back and m:*C (ERC 5.6>15). Likewise, /KPI/ does not remain fully faithful. The faithful form violates m:pal, and loses, so m:pal dominates f-c:back and m:*C (ERC 5.6>5). The input /KPI/ is not realized as [PJI], even though [PJI] contains a labial place, a dorsal place, and satisfies m:pal. However, the dorsal place in [PJI] is a v-place feature. The input has no v-place feature, so the addition of this feature violates f-v:KPT, and the lack of the dorsal c-place feature in the output violates f-c:KPT, so this form does worse than the winner [CPI] with respect to both types of place faithfulness.

The comparative tableau for the input /TI/ shows necessary rankings for the addition of secondary palatal articulation to simple stops.

(78) /TI/ Comparative Tableau

ERC#	Input	Winner	Loser	5:f-c:KPT	7:f-v:back	9:m:pal	1:m:CKPT	2:m:CKP	3:m:CK	6:f-c:back	4:m:C	8:f-v:KPT
1.7>4	TI	TJI	CI	W				W	W		W	L
1.7>11	TI	TJI	TU		W							L
1.7>1	TI	TJI	TI			W						L

In this case, the optimal candidate does have secondary articulation. This is a v-place faithfulness violation, so m:pal must dominate f-v:KPT (ERC 1.7>1). The other candidates lose because the

vowel is never unfaithful (f-v:back undominated) and the simple stop is not realized as a more marked simple stop to satisfy m:pal (ERC 1.7>4).

The minimal support as calculated by OT Workplace for this ranking is shown below.

(79) *Support for Lg#3*

ERC	Input	Winner	Loser	5:f-c:KPT	7:f-v:back	9:m:pal	1:m:CKPT	2:m:CKP	3:m:CK	6:f-c:back	4:m:C	8:f-v:KPT
1	KPI	CPI	TJI	W			L	L	L	L	L	W
2	KPI	CPI	KPU		W					L	L	
3	KPI	CPI	KPI			W				L	L	
4	KI	KJI	CI							W	W	L
5	CI	CI	KJI							W	L	W

The constraint m:pal is undominated, so all optima satisfy m:pal. The faithfulness constraint f-v:back is also undominated, so the vowel /I/ is always faithful; it is never realized as [U] in this language. ERCs 1, 2 and 3 above are winner~loser pairs for the input /KPI/. This input does not neutralize to the least marked place, so place faithfulness must dominate all place markedness constraints. Nor does the vowel change to satisfy m:pal.

The crucial aspects of this language are that major place is never unfaithful, so labial-dorsals are still realized as labial-dorsals. However, the minor place feature of the dorsal feature is realized unfaithfully to satisfy m:pal. Notice also that the input /CPU/ is realized as /KPU/ to satisfy m:pal. This puts [KP] and [CP] in complementary distribution in the rankings in line with the original language description. The labial-velar [KP] appears always and only before back vowels, and the labial-palatal [CP] appears always and only before front vowels. This is true for all consonants in the 4 languages listed above: palatalized consonants always precede front vowels, non-palatalized consonants always precede back vowels.

4.3 *Summary*

The systems used in this section are summarized in the table below. A mark indicates the presence of that constraint for that system.

(80) *System Summary*

	m:CKPT	m:CKP	m:CK	m:C	m:*jgbd	m:pal	f(-c):KPT	f(-c):[back]	f:[voice]	f-ons:[voice]	f-ons:KPT	f-v:KPT	f-v:[back]	Description
KP0	x	x	x	x	x		x	x	x					Core System
KP1/PF	x	x	x	x	x		x	x	x	x	x			Place/voice neutralization
KP2/PAL	x	x	x	x		x	x	x				x	x	Palatalization

The set of constraints in KP1 is a superset of the set of constraints in KP0. The addition of positional faithfulness constraints in system KP1/PF allow a ranking for the pattern of place and voice neutralization in Amele, where /gb/ neutralizes to [p] in coda position. The markedness constraint m:pal and the addition of secondary articulation in KP2/PAL are necessary in the analysis of Dagbani and similar languages to capture the alternation between [KP] and [CP]. While KP2 is not strictly a superset of KP1, making it such does not crucially change the system. Voicing constraints, positional faithfulness constraints, and related candidates are not included in KP2 to focus on the analysis of the palatalization of segments before front vowels, yet these constraints and candidates can be added without altering the crucial interactions discussed here.

5 Remarks

5.1 Faithfulness

Faithfulness is crucially defined such that a complex stop can be realized as a simple stop with one place feature of the input as more faithful than a simple stop that shares no features with the input. This is significant for complex stops because there exist robust phonological alternations where complex stops are realized as partially faithful, such as in Amele. This is summarized below.

- (81) /kp/ → [kp] fully faithful
 → [p], [k] partially faithful
 → [t] least faithful

The violation profiles for f:KPT reflect this in the violation counts:

(82) *Example Violations for f:KPT*

/kp/	f:KPT
[kp]	0
[p], [k]	1
[t]	3

This is more than strict equality between place features. A definition that assigns zero violations for identical input/output place features, and one violation for anything else, cannot capture the relationship between input /KP/ and outputs [P] or [K]. For instance, Lombardi (1999: 270) utilizes a faithfulness constraint for laryngeal features, IDLar: "consonants should be faithful to

underlying laryngeal features" (Lombardi 1999: (4)). While in the system discussed there, this does the work of voicing faithfulness, the constraint is defined in terms of faithfulness for the entire laryngeal node. It is not clear how a voiced, [+constricted glottis] segment fares in terms of faithfulness relative to a voiceless, [-constricted glottis] segment.

Cahill (2000, 2008) uses two faithfulness constraints, Max[lab] and Max[dor], to mediate place faithfulness of complex stops (called Faith[lab/dor]_{cons} in Cahill 2008: 8). The ranking Max[lab] » Max[dor] ensures that KP will be realized not only as a faithful simple stop, but [P] instead of [K], which is the intended result. Unless these rankings are assumed to be fixed universally, it is possible for a labial-dorsal to neutralize as a simple dorsal under the opposite ranking. In the system here, the choice of place is mediated by the markedness constraint definitions; there is no ranking in the typology of KP0 which allows /KP/ to map to a simple dorsal segment.

The Max-style place faithfulness constraints also assume correspondence between features, in addition to correspondence between whole segments. In KP0, Max and Dep constraints are not considered and every candidate is assumed to be in correspondence with the input. If feature correspondence were assumed, the candidate set would be significantly enlarged, not only would /K₁P₂/ → [P₂] be a candidate in GEN, but /K₁P₂/ → [P₃] (where these subscripts represent correspondence between *place features*, not segments) would be as well, and so on for every possible combination of correspondence-place pairs. Additionally, under Lombardi's (2001) definitions, segment deletion (Max-segment violation) also incurs a violation of Max-feature, while Max-segment deletion does not incur a violation of f:KPT as defined here, as the condition of there being an output correspondence would not be met.

These considerations are not fatal, however; it is unclear what effect this has on the system as a whole, but it should be noted that feature-correspondence Max/Dep[feature] constraints are not strictly equivalent to segment-correspondence IdentIO[feature] and IdentOI[feature] constraints as defined by Pater (1999) or McCarthy and Prince (1995: 71). Because it is not necessary to assume feature correspondence, any complications are avoided by assuming only segment correspondence.

5.2 *Stringency Relationship vs. Fixed Universal Hierarchy*

A significant and crucial property of the KP0 system is the presence of a markedness constraint that bans all places. This constraint effectively militates against complex segments, as it only differentiates between segments with one place and those with two places. If this constraint is not present, or if the markedness hierarchy is implement via fixed ranking conditions, the typology of the system no longer has necessary empirical coverage. Specifically, Simple DOR languages are absent; these are languages which have dorsal stops such as [k] and [g] but lack complex stops altogether.

In a fixed hierarchy, each markedness constraint refers to only one place in its definition. There is no $m:*\text{CKPT}$, for instance; instead, there is $m:*\text{C}$, $m:*\text{K}$, $m:*\text{P}$, and $m:*\text{T}$. In order to implement the markedness hierarchy in (3), these constraints are in a fixed ranking. For every language in the typology of the fixed hierarchy system, the following ranking holds:

$$(83) \quad m:*\text{C} \gg m:*\text{K} \gg m:*\text{P} \gg m:*\text{T}$$

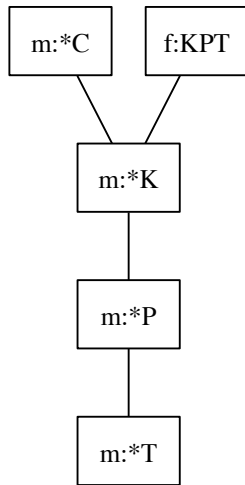
Thus, C is the most marked place because the constraint violating against C is highest ranked. The table below is the typology of a system equivalent to KP0 except with a fixed hierarchy rather than stringency relations among constraints.

(84) *KP0 with Fixed Markedness Hierarchy*

Inputs->	t	p	c	k	cp	kp	d	b	j	g	jb	gb	MMP	Complexity
t.cor	t	t	t	t	t	t	t	t	t	t	t	t	COR	
d.cor	t	t	t	t	t	t	d	d	d	d	d	d	COR	
t.lab	t	p	t	t	p	p	t	p	t	t	p	p	LAB	
d.lab	t	p	t	t	p	p	d	b	d	d	b	b	LAB	
t.dor.c.maj	t	p	t	k	p	kp	t	p	t	k	p	kp	DOR	Complex
d.dor.c.maj.b	t	p	t	k	p	kp	d	b	d	g	b	b	DOR	Complex
d.dor.c.maj.gb	t	p	t	k	p	kp	d	b	d	g	b	gb	DOR	Complex
t.dor.c.f	t	p	c	k	cp	kp	t	p	c	k	cp	kp	DOR	Complex
d.dor.c.f.b	t	p	c	k	cp	kp	d	b	j	g	b	b	DOR	Complex
d.dor.c.f.gb	t	p	c	k	cp	kp	d	b	j	g	jb	gb	DOR	Complex
t.dor.c.min	t	p	k	k	kp	kp	t	p	k	k	kp	kp	DOR	Complex
d.dor.c.f.min.b	t	p	k	k	kp	kp	d	b	g	g	b	b	DOR	Complex
d.dor.c.min.gb	t	p	k	k	kp	kp	d	b	g	g	gb	gb	DOR	Complex

The language names are given based on the extensional properties as also seen in KP0. The first thing to notice in this system immediately is that there are no **Simple, DOR** languages. The most marked place in a language is [dorsal] iff that language also allows complex stops. The reason why is clear when investigating the necessary rankings for DOR and Complex in this system. The Hasse digram below shows all the shared rankings among the DOR/Complex languages in the typology above.

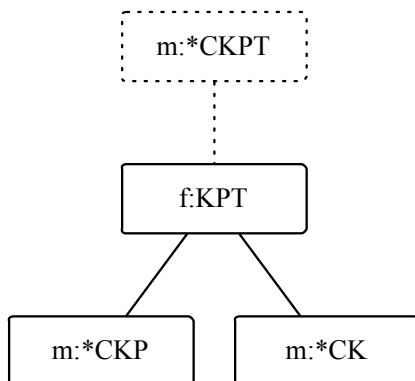
(85) *Ranking for DOR/Complex Languages with Fixed Hierarchy*



In order for dorsal segments to be realized faithfully, either simple or complex, f:KPT must dominate m:*K. However, because m:*K is universally ranked above m:*P, any time f:KPT dominates m:*K it also dominates m:*P. This ranking allows the complex stop KP to surface. There is no ranking that allows simple dorsals but not complex stops. The conditions for allowing complex stops and for allowing dorsals in general are inextricably linked.

The same problem occurs when the stringency relationship among constraints remains but the constraint banning all places, here m:CKPT, is removed from the system. Such a step might be taken to make the constraints *lenient*, as defined by Gouskova (2003: 2): "at least one non-null structure will not violate any markedness constraints on a given dimension of markedness". m:*CKPT is the only constraint that assigns a violation to coronals, so by removing m:*CKPT, the constraint set fits the definition of leniency. The typology for such a system is in fact exactly the same as in (84) above: languages with dorsals entail languages with complex stops.

(86) *Ranking for DOR/Complex Languages with m:*CKPT removed*



Here, major place faithfulness dominates all markedness constraints banning dorsal K and labial P. This allows complex stops to realize faithfully, yet it is also the only way to allow any dorsals in general. The dotted lines show where m:*CKPT needs to be ranked for complex stops to be

banned. If this constraint violating against the least marked place is removed from the system, simple dorsal languages cannot be captured.

One patch is to stipulate a constraint like *Complex, which assigns violations to complex stops. This is against the general aim of the project here, in that this is a specific reference to complexity, but the result would be the same. The idea in the present work of avoiding constraints specific to a standalone notion of complexity is favored over the property of the constraints adhering to a definition of leniency.

In summary, the typologies of systems with a fixed ranking or with stringent constraints lacking $m:*\text{CKPT}$ are crucially not equivalent to the typology of the system that includes $m:*\text{CKPT}$. As mentioned in Section 3.3.3 and confirmed here, the constraint $m:*\text{CKPT}$ is crucial to rankings where complex stops are banned but all places are allowed in simple stops.

6 Summary

Many crucial interactions of complex stops are captured without making specific reference to "complexity" or any other special representational status for stops with multiple place. The interactions fall out from explicitly-defined markedness and faithfulness constraints, with markedness constraints based on a universal hierarchy. These constraints are crucially stringently related, and crucially include the constraint violating against the least marked element on the scale. This constraint is what militates against complexity.

The generalization that a labial-dorsal never neutralizes to [K] or [C] is captured through markedness constraint: a labial-dorsal neutralizes to [P] because this is the least-marked but still faithful segment. Faithfulness is defined such that the non-realization of certain features is more faithful than the non-realization of all place features. A stringent definition of markedness constraints derives a constraint that militates against all complex stops. This is beneficial for languages that have all places in their inventories, but lack complex stops altogether. Systems with a fixed universal hierarchy cannot capture this result, and likewise with systems identical except without a markedness constraint banning the least marked place. The core system here is augmented to capture specific alternations in languages like Amele and Dagbani, where complex stops neutralize to simple stops, or where a labial-velar alternates with a labial-palatal, confirming the predictions about neutralization patterns in the core system. All complex stops are assumed to be labial-dorsals, but the interaction of labial-palatals with respect to simple palatals is incomplete and makes false predictions in the current system.

The only specific reference to complex stops are made in GEN of these systems; their behavior with respect to markedness and faithfulness constraints is derived from the definitions of those constraints and no *ad hoc* constraints governing complex stops are needed. Moving towards a full phonological analysis of doubly-articulated stops, certain interactions still require proper analysis. The independent behavior of simple palatals and labial-palatals, the fact that voiced labial-velar [gb] can be the sole complex stop in an inventory, and other issues remain unsolved here. However, the present assumptions provide not only a new analysis of known alternations, but also new insight in terms of markedness into these phonological processes.

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7 Appendix: Full Segment Database

Language Name	p	t	k	c	b	d	g	ɟ	kp	gb	tp (cp)	db (ɟb)	Comments	Source	Typological Generalization
Amele		t	k		b	d	g			gb			Roberts 1987, p is not contrastive	Cahill 2008	excluded: gb-only
Anum		t	k		b	d	g		kp				g is labialized	WAPS	excluded: lacks p
Avatime (Siya)	p	t	k		b	d	g		kp	gb				WAPS	d.dor.c.gb
Baga Sitemu	p	t	k		b	d	g			gb			Ganong 1998	Cahill 2008	excluded: gb-only
Balanta		t	k			d			kp				Wilson 1961a	Cahill 2008	excluded: lacks g, p, b
Bambara, Southern (Manding)	p	t	k		b	d	g			gb			Welmers 1973:48	Cahill 2008	excluded: gb-only
Bantonu	p	t	k		b	d	g		kp	gb				WAPS	d.dor.c.gb
Bau	p	t	k		b	d	g			gb			Vander Meer & Vander Meer 2002	Cahill 2008	excluded: gb-only
Bini	p	t	k		b	d	g		kp	gb				WAPS	d.dor.c.gb
Bora	p	t	k						kp				Thiesen & Thiesen 1975	Cahill 2008	t.dor.c
Bulu		t	k		b	d							SALA, Yanes & Moise	Cahill 2008	excluded: lacks g, p
Bura	p	t	k	c	b	d	g	ɟ			tp		See Maddieson, Bennett, etc	WAPS	excluded: cp-only but see Maddieson
Chumburung	p	t	k		b	d			kp				Snider 1990	Cahill 2008	excluded: lacks g
Dagbani	p	t	k		b	d	g		kp	gb			has non-contrastive C, CP	WAPS	d.dor.c.gb
Ditammari	p	t	k		b	d			kp				SALA, Sambieni 2005	Cahill 2008	excluded: lacks g
Effutu		t	k		b	d	g		kp	gb			kp~p alternation, see original source, gb rare	WAPS	excluded: lacks p
Efik		t	k		b	d			kp				p allophone? see Welmers	WAPS	excluded: lacks g, p
Efik		t	k		b	d			kp				UPSID, Ward 1933, Cook 1969	Cahill 2008	excluded: lacks g, p
Ewe	p	t	k		b	d	g		kp	gb				WAPS	d.dor.c.gb
Fo		t	k		b	d	g		kp	gb				WAPS	excluded: lacks p
Ga	p	t	k		b	d	g		kp	gb				WAPS	d.dor.c.gb
Ge	p	t	k		b	d	g		kp	gb			language name is nasalized epsilon vowel	WAPS	d.dor.c.gb
Iai	p	t	k		b	d	g			gb			UPSID	Cahill 2008	excluded: gb-only

Ibibio	p t k b d	kp	Boys 1979, Essien 1990	Cahill 2008	excluded: lacks g
Idoma (Western)	p t k c b d g	J kp gb		WAPS	excluded: has c no cp
Igbo	p t k c b d g	J kp		WAPS	excluded: has c no cp
Ijaw (Upper)	p t k b d g	kp gb		WAPS	d.dor.c.gb
Isoko	p t k b d g	J kp gb		WAPS	excluded: has j no jb
Itsekiri	p t k b d g	J kp gb		WAPS	excluded: has j no jb
Jiru	p t k b d g	gb	Shiziru 1971	Cahill 2008	excluded: gb-only
Kabiye	p t k d	kp	Lebikaza 1999	Cahill 2008	excluded: lacks g, b
Kalabari	p t k b d g	J kp gb		WAPS	excluded: has j no jb
Kambari	p t k b d g	kp gb		WAPS	d.dor.c.gb
Kar	p t k b d g	gb	Wichser 1994	Cahill 2008	excluded: gb-only
Kissi	p t k b d	kp		WAPS	excluded: lacks g
Krachi	p t k b d g	kp		WAPS	d.dor.c.b
Krachi	p t k b d	kp	Snider 1990	Cahill 2008	excluded: lacks g
Krahn	p t k b d	gb	Marchese 1978m 1989	Cahill 2008	excluded: gb-only
Krio	p t k b d g	kp gb		WAPS	d.dor.c.gb
Kutep	p t k c b	kp		WAPS	excluded: lacks g, d, has c no cp
Kuwaa	p t k b d	kp	Marchese 1978	Cahill 2008	excluded: lacks g
Kyerepong	t k b d	J kp	kp "probably velarized p"	WAPS	excluded: lacks g, p
Lama	p t k	kp	SALA	Cahill 2008	t.dor.c
Larteh	p t k b d	kp	Ladefoged 1968, Snider 1990	Cahill 2008	excluded: lacks g
Late	p t k b d g	kp		WAPS	d.dor.c.b
Limba	p t k b d g	gb	k and g not contrastive	WAPS	excluded: gb-only
Limba, Central	W. p t k b d	gb	Anderson 1976, SALA	Cahill 2008	excluded: gb-only
Logba	p t k c b d g	J kp gb	p "is rare"	WAPS	excluded: has c no cp
Loko	p t k c b	kp		WAPS	excluded: lacks g, d, has c no cp
Loko	p t k b d g	gb	Innes 1964	Cahill 2008	excluded: gb-only
Lokpa	p t k	kp	SALA	Cahill 2008	t.dor.c
Mahou	p t k b d g	gb	Derive 1983	Cahill 2008	excluded: gb-only
Makaa	t k b d g	kp	Heath 2003	Cahill 2008	excluded: lacks p

Mandinka	p	t	k	b	d	g		gb	Calvet 1967, SALA	Cahill 2008	excluded: gb-only		
Maninja-Kan		t	k	b	d	g		gb	Welmers 1973	Cahill 2008	excluded: gb-only		
Manya		t	k	b	d	g		gb	Manessy 1964 d is implosive	Cahill 2008	excluded: gb-only		
Margi	p	t	k	c	b	d	g	ɟ	tp	db	See Bura notes	WAPS	excluded: cp-only but see Maddieson
Mbato	p	t	k	b	d	g		gb	Grassias & Bole-Richard 1984	Cahill 2008	excluded: gb-only		
Mende	p	t	k	b	d	g		kp	gb		WAPS	d.dor.c.gb	
Mofu-Gudur	p	t	k	b	d	g		gb	SALA	Cahill 2008	excluded: gb-only		
Nateni	p	t	k	b	d				Neukom 1995, Sambieni 2005	Cahill 2008	excluded: lacks g		
Ngwo (Widekum)	p	t	k	c	b	d	g	ɟ	kp	gb		WAPS	excluded: has c no cp
Nkonya	p	t	k	c	b	d	g		kp		kp "probably velarized p", g "is rare"	WAPS	excluded: has c no cp
Nkonya	p	t	k	b	d			kp	Lear & Peacock (ms)	Cahill 2008	excluded: lacks g		
Nzima		t	k	c	b	d		ɟ	kp	tp	involves alternations	WAPS	excluded: lacks g, p
Ono	p	t	k	b	d	g		gb	Phinnemore 1985	Cahill 2008	excluded: gb-only		
Ora	p	t	k	b	d	g		kp	gb		WAPS	d.dor.c.gb	
Owa	p	t	k					gb			Cahill 2008	excluded: gb-only	
Sekpele	p	t	k	b				kp	Andrew Ring p.c. (cf. WAPS)	Cahill 2008	excluded: lacks g, d		
Sekpele (Likpe)	p	t	k	b	d	g		kp			WAPS	d.dor.c.b	
Sherbro	p	t	k	b	d			gb	Anderson 1976	Cahill 2008	excluded: gb-only		
Sicite	p	t	k	b	d			gb	Garber 1987, 1991	Cahill 2008	excluded: gb-only		
Sisala	p	t	k	c	b	d	g	ɟ	kp	gb	palatal segments have frication	WAPS	excluded: has c no cp
Sissala	p	t	k	b	d	g		gb	SALA	Cahill 2008	excluded: gb-only		
Sissala, Western	p	t	k	b	d	g		gb	Moran 2006	Cahill 2008	excluded: gb-only		
Siwu (Lolobi)	p	t	k	b	d	g		kp	gb		WAPS	d.dor.c.gb	
Soso	p	t	k	b	d	g		kp	gb		WAPS	d.dor.c.gb	
Susu	p	t	k	b	d	g		gb	Houis 1963, SALA	Cahill 2008	excluded: gb-only		
Temne	p	t	k	b	d			gb			WAPS	excluded: gb-only	

Temne	p	t	k	b	d			gb	UPSID, Wilson 1961b, Anderson 1976	Cahill 2008	excluded: gb-only
Tenyer	p	t	k	b	d	g		gb	SALA	Cahill 2008	excluded: gb-only
Tepo	p	t	k	b	d	g		gb	Dawson 1975, Thalman 1980	Cahill 2008	excluded: gb-only
Tiv	p	t	k	b	d	g	kp	gb	Tiv	WAPS	d.dor.c.gb
Toussien	p	t	k	b	d	g		gb	Prost 1964	Cahill 2008	excluded: gb-only
Urhobo	p	t	k	c	b	d	g	ɟ kp		WAPS	excluded: has c no cp
Usaghade		t	k	b	d			kp	Connell 1995	Cahill 2008	excluded: lacks g, p
Waama	p	t	k	b	d			kp	SALA, Sambieni 2005	Cahill 2008	excluded: lacks g
Wojenakakan	p	t	k	b	d	g		gb	Derive 1983	Cahill 2008	excluded: gb-only
Yoruba		t	k	b	d	g	ɟ	gb		WAPS	excluded: gb-only