NON-INHERENT VOICING AND WAYS TO FIX IT*

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0. Introduction

Cross-linguistic studies have revealed that among plosive sounds, the most common opposition used by the languages of the world is the contrast between plain voiced and voiceless stops. It is therefore not a novelty that both of these stop series are included in the sound inventory of Palenquero, a creole of Spanish and African descent that arose during the eighteenth century in Northern Colombia. Nevertheless, Palenquero is an interesting linguistic scenario in that voiced and voiceless stops pattern asymmetrically in terms of input-to-output mapping. Whereas voiceless stops hardly ever alternate with other sounds, the members of the voiced series participate in numerous alternations with various types of sounds, all of which are endowed with articulatory properties that are more conducive to the production of voicing. Palenquero voiced stops are subject to processes such as spirantization, prenasalization, flapping, and lateralization, which affect them regardless of the syllabic position to which they are assigned. Although all of these processes have been previously studied in other languages, they have always been viewed independently of one another, and rarely in connection with the marked nature of voiced stops.

This paper presents an analysis of the patterns exhibited by Palenquero voiced stops, which reveals that there is a close connection between spirantization, prenasalization, flapping, and lateralization as they embody efficient ways to make underlying voiced stops less effortful to implement. Spirantization, prenasalization, and lateralization are articulatory maneuvers that facilitate the production of voicing by allowing venting through one of the valves that separate the supraglottal cavity from the atmosphere. Flapping, on the other hand, yields this effect by reducing the temporal coordinates of the constriction target. The consequences that these articulatory adjustments have for the production of voicing are formally captured through a system of constraints where the tendency to achieve ease of articulation rivals with the drive to preserve underlying feature specifications.

1. The implementation of stop consonants in Palenquero

Palenquero is a Spanish-lexified creole spoken by approximately 3,000 speakers in the village of San Basilio de Palenque, Colombia. With regard to its sound system, this language inherited the contrast between unaspirated voiceless stops and plain voiced stops that exists in Spanish. The distinctiveness of these two stop series is illustrated by the examples in (1). Escalante (1954), Montes (1962), Patiño Rosselli (1983), and Comité Católico de San Basilio de Palenque (2000) are my data sources.

(1) Two contrastive stop series

	Labial		Coronal		Dorsal	
	/p/	/b/	/t̪/	/d̪/	/k/	/ɡ/
Spanish	part̪íɾ	bat̪íɾ	t̪óðo	d̪ós	kɾíst̪o	ɡɾít̪o
Palenquero	pat̪í	bat̪í	t̪ó	d̪ó	kɾít̪o	ɡɾít̪o
	‘to leave’	‘to shake’	‘all’	‘two’	‘Christ’	‘cry’

The fact that syllable codas are severely restricted in Palenquero has important consequences for the distribution of stop consonants. Because no place-bearing segments are tolerated in the coda, the only chance for a stop consonant to be faithfully preserved is if it is parsed by the syllable onset (e.g. [d̪o.t̪ó] ~ [d̪o^{t}.t̪ó] < *Span.* [d̪ok.t̪óɾ] ‘doctor’). Nonetheless, onset position does not guarantee that the stop consonant will remain identical to its input correspondent. As we will see below, even in syllable-initial position, the output correspondents of underlying voiced stops often lose their identity, whereas in this same position, voiceless stops are rarely unfaithful to their input correspondents.[1]

A common process that causes voiced stops to have unfaithful output correspondents is spirantization. The context in which voiced stops spirantize in Palenquero is post-vocalic position. Notwithstanding, at a very slow speech rate, as when trying to communicate with a foreigner who has little competence in the language, voiced stops may retain their complete oral closure even if they are preceded by a vowel (e.g. [ka.bé.sa] ‘head’). By contrast, in running, connected speech, post-vocalic voiced stops spirantize regularly, (2a). The data in (2b-d) show that in Palenquero spirantization always fails to apply if the voiced stop is preceded by a consonant or a pause. The examples in the rightmost column of (2c) are particularly interesting because they show that the voiced stop resists spirantization even in fast speech, where all apparent traces of a preceding oral consonant disappear as a consequence of simplifying the geminate segment that results from assimilation.

(2) Spirantization in running, connected speech

	Spanish	Palenquero	
a.	V ___		
	[ka.βé.sa]	[ka.βé.sa]	‘head’
	[sa.lu.ðáɾ]	[sa.lu.ðá]	‘to greet’
	[pa.ɤáɾ]	[pa.ɤá]	‘to pay’

b.	N ___				
	[se^{m}.bɾáɾ][2]	[se^{m}.blá]			‘to plant’
	[kwá$^{n̪}$.d̪o]	[kwá$^{n̪}$.d̪o]			‘when’
	[lé^{ŋ}.gwa]	[lé^{ŋ}.gwa]			‘tongue’
c.	C ___				
	[seɾ.βé.sa]	[se^{b}.bé.sa]	~	[se.bé.sa]	‘beer’
	[t̪áɾ.ðe]	[t̪á$^{d̪}$.d̪e]	~	[t̪á.d̪e]	‘late’
	[al.gú.no]	[a^{g}.gú.no]	~	[a.gú.no]	‘someone’
d.	// ___				
	[bo.ɣo.t̪á]	[bo.ɣo.t̪á]			‘Bogotá’
	[d̪o.lóɾ]	[d̪o.ló]			‘pain’
	[ga.náɾ]	[ga.ná]			‘to win’

In addition to spirantization, Palenquero voiced stops are also the target of prenasalization. As the examples in (3) illustrate, underlying voiced stops turn into prenasalized voiced stops when they appear in word-initial position. Being in word-initial position, however, is no guarantee that the voiced stop will prenasalize. Because this process is optional, words that sometimes surface with a prenasalized word-initial voiced stop also have alternative pronunciations. If prenasalization fails to apply in the context of a preceding pause, the underlying word-initial voiced stop surfaces unchanged, (3a); but if preceded by a vowel, it is implemented as a spirant, (3b).

(3) Prenasalization

		Spanish	Palenquero	
a.		// # ___		
		[ból.sa]	[^{m}bó.sa] ~ [bó.sa]	‘bag’
		[d̪ú.ɾo]	[$^{n̪}$d̪ú.lo] ~ [d̪ú.lo]	‘hard’
		[gu.sá.no]	[^{ŋ}gu.sá.no] ~ [gu.sá.no]	‘worm’
b.		V # ___		
		[é.sa βól.sa]	[é.se ^{m}bó.sa] ~ [é.se βó.sa]	‘that bag’[3]
		[es.t̪á ðú.ɾo]	[t̪á $^{n̪}$d̪ú.lo] ~ [t̪á ðú.lo]	‘it is hard’
		[sí^{ŋ}.ko ɤu.sá.nos]	[sí^{ŋ}.ko ^{ŋ}gu.sá.no] ~ [sí^{ŋ}.ko ɤu.sá.no]	‘five worms’

It is also important to note that prenasalization is lexically controlled. The option to prenasalize is only available to voiced stops that are the first segment of words that belong to one of the major grammatical categories: noun, verb, adjective, or adverb. In this regard, Patiño-Roselli (1983) notes that despite its high frequency, the preposition /d̪e/ ‘of’ systematically escapes prenasalization. Furthermore, within the major grammatical categories, only the initial voiced stops of words that contain certain roots may prenasalize. For instance, whereas the voiced stop of the verb /d̪eha/ ‘to let’, and its derived forms, often surfaces as [$^{n̪}$d̪], this is never the case for the voiced stop of the verb /d̪esi/ ‘to say’, or any of its derivatives. Of the 222 roots beginning with a voiced stop that I have gathered from Escalante (1954), Patiño Rosselli (1983), and Comité Católico de San Basilio de Palenque

(2000), only 34, equivalent to 15%, have been attested to participate in prenasalization. Given that 85% of the roots that have an initial voiced stop never fall prey of prenasalization, one must acknowledge that the scope of this process is rather narrow.

In addition to being optional, lexically controlled, and limited to word-initial position, prenasalization is also conditioned by place of articulation. The dorsal voiced stop undergoes the process more often than the coronal voiced stop, which in turn prenasalizes slightly more often than the labial voiced stop. Of the 34 roots whose initial voiced stop is allowed to prenasalize, 17 begin with /g/, 10 begin with /d̪/, and 7 begin with /b/. These numbers correspond to 50% for the dorsal, 29% for the coronal, and 21% for the labial, which indicates that the dorsal voiced stop is considerably more receptive to prenasalization than its coronal and labial counterparts. The examples in (4) show that the initial voiced stop of certain words may be pronounced as a plain voiced stop after a pause, as a spirant after a vowel, or as a prenasalized voiced stop in either of these contexts. For 85% of the words beginning with a voiced stop, however, only the first two possibilities are available.

(4)	Spanish	Palenquero			
	// # ___	// # ___	V # ___	X # ___	
a.	Dorsal				
	[ga.náɾ]	[ga.ná]	[pá ɣa.ná]	[^{ŋ}ga.ná]	‘to win’[4]
	[go.sá]	[go.sá]	[pá ɣo.sá]	[^{ŋ}go.sá]	‘to enjoy’
	[gɾi.t̪áɾ]	[gɾi.t̪á]	[pá ɣɾi.t̪á]	[^{ŋ}gɾi.t̪á]	‘to scream’
	[gló.ɾja]	[gló.ɾja]	[ése ɣló.ɾja]	[^{ŋ}gló.ɾja]	‘glory’

	[ɡi.né.o]	[ɡi.né.o]	[é.se ɣi.né.o]	[^{ŋ}ɡi.né.o]	'plantain'
	[ɡɾá.sja]	[ɡlá.sja]	[é.se ɣlá.sja]	[^{ŋ}ɡlá.sja]	'grace'
b.	Coronal				
	[d̪ó.se]	[d̪ó.se]	[t̪ó ðó.se][5]	[$^{n̪}$d̪ó.se]	'twelve'
	[d̪úl.se]	[d̪ú.se]	[é.se ðú.se]	[$^{n̪}$d̪ú.se]	'sweet'
	[d̪áɾ]	[d̪á]	[pá ðá]	[$^{n̪}$d̪á]	'to give'
	[d̪o.lóɾ]	[d̪o.ló]	[é.se ðo.ló]	[$^{n̪}$d̪o.ló]	'pain'
c.	Labial				
	[bo.sál]	[bo.sá]	[é.se βo.sá]	[^{m}bo.sá]	'muzzle'
	[bí.no]	[bí.no]	[é.se βí.no]	[^{m}bí.no]	'wine'

Unlike the dorsal and labial voiced stops, the coronal voiced stop is subject to several other transformations. An underlying coronal voiced stop may surface as a flap when preceded by a vowel or a pause, (5, 6). When it is preceded by a vowel, the coronal voiced stop is in the context not only for flapping but also for spirantization (e.g. /med̪io/ 'half'). Whether a post-vocalic coronal voiced stop will flap or spirantize is unpredictable, and in many cases, both pronunciations are possible (e.g. [méɾjo] ~ [méðjo] < /med̪io/ 'half'). Nonetheless, there are some words that regularly exhibit flapping (e.g. [aɾjó] < /ad̪ió/ 'good-bye'), whereas others favor spirantization (e.g. [roðá] < /rod̪a/ 'to roll'). In the corpus of Escalante (1954), I found 59 cases of flapping versus 31 cases of spirantization. In Patiño-Roselli (1983), the count was 24 cases of flapping versus 40 cases of spirantization. Yet in

Comité Católico de San Basilio de Palenque (2000), there were 26 cases of flapping and not a single case of spirantization.

(5) Word-internal flapping:

/sused̪e/	→	[su.se.ɾé] ~ [su.se.ðé]	'to happen'
/med̪iko/	→	[mé.ɾi.ko] ~ [mé.ði.ko]	'doctor'
/pad̪ese/	→	[pa.ɾe.sé] ~ [pa.ðe.sé]	'to suffer'

Coronal voiced stops in word-initial position also undergo flapping whether they are preceded by a vowel or a pause, (6). Furthermore, if the root happens to be one of the 34 roots that allow prenasalization, such coronal voiced stop may also surface as a prenasalized voiced stop.

(6) Word-initial flapping:

/d̪a/	→	[ɾá] ~ [$^{\text{n̪}}$d̪á] ~ [d̪á]	'to give'
/d̪eha/	→	[ɾe.há] ~ [$^{\text{n̪}}$d̪e.há] ~ [d̪e.há]	'to let'
/d̪o/	→	[ɾó] ~ [$^{\text{n̪}}$d̪ó] ~ [d̪ó]	'two'

A second process that targets coronal voiced stops to the exclusion of their dorsal and labial counterparts is lateralization. Like flapping, lateralization takes place when the coronal voiced stop is preceded by a vowel or a pause, (7), however, lateralization is far less common. Adding up all of the cases of lateralization reported in my data sources, I found only 19 words that exhibit this change. Despite the few examples, the fact that there are words where [l] is in free variation with [d̪], [^{n}d̪], [ð], and [ɾ] confirms that lateralization is part of Palenquero's active phonology.

(7) a. Word-internal lateralization:

/sabad̪o/	→	[sá.βa.lo] ~ [sá.βa.ðo] ~ [[sá.βa.ɾo]	'Saturday'
/yud̪a/	→	[yu.lá] ~ [yu.ðá] ~ [yu.ɾá]	'to help'
/obed̪ese/	→	[o.βe.le.sé] ~ [o.βe.ðe.sé] ~ [o.βe.ɾe.sé]	'to obey'

b. Word-initial lateralization:

/d̪ole/	→	[lo.lé] ~ [^{n}d̪o.lé] ~ [d̪o.lé]	'to hurt'
/d̪ed̪o/	→	[lé.lo] ~ [d̪é.ðo]	'finger'

On closing this section, it is worth stressing that of all the processes that target voiced stops in Palenquero; spirantization is the only one that is not lexically conditioned. We observed that as long as speech is connected, spirantization applies to all words in which the target is in the appropriate phonological context. By contrast, for the processes of prenasalization, flapping, and lateralization to apply, it is not enough that the target is in the right context. The stop consonant must also belong to a word that is marked to undergo that particular process. Furthermore, because an underlying voiced stop that belongs a marked word may be implemented in several ways, it must also be the case that a single word may be marked for more than one process.

2. Voicing in stops

It is a well-known phonetic fact that voicing is not an inherent property of stop consonants. Phoneticians have observed that whereas in the articulation of sonorants vocal fold vibration comes rather effortlessly, voiced stops require additional muscular effort in order to get the vocal folds to vibrate (van den Berg 1958, Lisker and Abramson 1971, Ohala 1983, Westbury and Keating 1986). This is due to the fact that vocal fold vibration is an aerodynamic event, which in addition to a light adduction of the vocal folds requires air flowing through the glottis from areas of high to low pressure. However, in sounds articulated with a complete oral closure, air pressure builds up in the oral cavity. High pressure above the larynx disrupts the high-to-low-pressure system required for air to flow through the glottis. As air stops flowing through the glottis, the vocal folds stop vibrating and voicing dies out. It is estimated that the vocal folds will cease to vibrate when the transglottal pressure gradient falls below 2000 dyn/cm^2 (Westbury 1983, Westbury and Keating 1986). Because this occurs prior to the end of the average closure duration of stop consonants (80 ms), this sound class is not inherently voiced. In other words, although voicing is not impossible in stop consonants, it is articulatorily more costly because it cannot be maintain passively throughout the entire duration of the closure interval, but has to be actively induced during at least the final portion of the segment.

The non-inherent nature of voicing in stop consonants is a key factor in understanding the set of processes that target voiced stops in Palenquero. It is not an accident that voiced stops are so often changed through various transformations, whereas their voiceless counterparts are rarely altered. The reason for this asymmetry is that their being endowed with a non-inherent property makes voiced stops unstable. Furthermore, a close look at the processes that target voiced stops in Palenquero reveals a natural connection among them: they all serve to change the members of the marked stop series into segments where voicing is inherent. Bringing these facts together, I will argue that Palenquero resorts to the processes of spirantization, prenasalization, flapping, and lateralization because rather than losing the non-inherent voicing of stop consonants, this language chooses to accommodate this marked feature at the expense of being unfaithful to other features. Despite the damage to the identity of voiced stops that these processes cause, they are effective strategies to yield savings in articulatory effort, which makes it less costly for the language to maintain a distinctive opposition between voiced and voiceless stops.

3. Underlying voiced stops or spirants?

The tendency for voiced stops to alternate with spirants, which are more compatible with voicing because their degree of constriction does not result in complete airflow stoppage, suggests that the grammar of Palenquero disfavors sounds whose makeup includes a complete oral closure in combination with vocal fold vibration. Following this line of thought, one can call on the markedness constraint *VDSTOP as the reason why spirants often emerge in the place of voiced stops.

(8) *VDSTOP: Voiced stops are prohibited: *[-sonorant, -continuant, voice][6]

Besides the fact that stops possess the degree of oral closure that is most detrimental to voicing, this constraint is supported by the frequency with which voiced stops appear in sound inventories. Crosslinguistic studies such as Maddieson (1984) have found that voiced stops are less common than voiceless stops. Crucially, while all languages that have voiced stops invariably also have a series of voiceless stops, the reverse of this is not true.

When the faithfulness constraint that prohibits featural unfaithfulness, IDENT(Feature), is outranked by *VDSTOP, underlying voiced stops are forced to change. If [continuant] is the specific feature that is subdued, voiced stops may be avoided by turning them into [+continuant] segments. In other words, the ranking *VDSTOP >> IDENT(continuant) is able to induce spirantization.

(9) IDENT(Feature): Input and output correspondents must agree in their specifications for all features.

(10) IDENT(continuant): Input and output correspondents must agree in their specifications for the feature [continuant].

(11) *VDSTOP >> IDENT(continuant)

	Input: /d̪ole/[7]	*VDSTOP	IDENT(continuant)
☹	a. [d̪o.lé]	*!	
☞	b. [ðo.lé]		*

This ranking, however, not only allows spirants to act as correspondents of voiced stops, (11b), but also prevents voiced stops from ever emerging, (11a). This is certainly an undesirable result because voiced stops do surface in Palenquero, (2b,c,d). In an attempt to avoid the obliteration of all voiced stops, one could resort to positional faithfulness constraints (Beckman 1999), which could neutralize *VDSTOP in certain positions if they took precedence over it in the ranking. Nonetheless, this may not be the case of Palenquero because spirantization does subdue voiced stops parsed in well-known prominent positions such as word, root, and syllable initial, provided that the phonological conditions required for this process are met: speech must be connected, and the voiced stop must be preceded by a vowel, (2a, 3b). Data such those in (2a, 3b) clearly show that, as far as spirantization is concerned, Palenquero does not exhibit any positional faithfulness effects.

Because plain voiced stops such as the one that causes the dismissal of candidate (11a) are indeed possible in Palenquero, the ranking *VDSTOP >> IDENT(continuant) may not be part of the grammar of this language. If IDENT(continuant) were indeed dominated by *VDSTOP, such grammar would not only be unable to produce surface voiced stops, but would also be deprived of underlying voiced stops because spirants would always be selected as the optimal input. This point is illustrated by the following tableau des tableaux, where according to the principle of Lexicon Optimization, the most transparent output-to-input mapping determines the underlying form.

(12) Selection of the optimal input

Inputs	Output	*VDSTOP	IDENT(continuant)
a. /b, d̪, g/	☞ a. β, ð, ɤ		*!
☞ b. /β, ð, ɤ/	☞ b. β, ð, ɤ		

Contrary to the result of this evaluation, the existence of a distinctive contrast between voiced and voiceless stops, as evinced by minimal pairs such as those in (1), requires that underlying voiced stops be posited for Palenquero. Another fact that argues against the ranking *VDSTOP >> IDENT(continuant) is that geminate voiced stops also emerge in this language, (2d). Such segments represent an even more blatant violation of the constraint *VDSTOP because their oral closure lasts longer, making it especially costly to sustain voicing throughout the duration of the closure. The crux of the matter is that the ranking *VDSTOP >> IDENT(continuant) contradicts the facts exhibited by the Palenquero data. It is undisputable that both geminate and simplex voiced stops emerge in this language, and that the latter participate in a distinctive opposition with voiceless stops. Taking these facts into account, I claim that the right ranking is IDENT(Feature) >> *VDSTOP, which forces the grammar to generate output forms that contain voiced stops, (13a), and to accept these segments as part of the underlying sound inventory, (14a).

(13) *VDSTOP >> IDENT(Feature)

Input: /d̪ole/	IDENT(Feature)	*VDSTOP
☞ a. [d̪o.lé]		*
b. [t̪o.lé]	[voice]!	
c. [ðo.lé]	[continuant]!	
d. [ⁿd̪o.lé]	[nasal]! [sonorant][8]	
e. [ɾo.lé]	[rhotic]! [sonorant]	
f. [lo.lé]	[lateral]! [sonorant]	

(14) Selection of the optimal input

Inputs	Output	IDENT(Feature)	*VDOBSTR
☞ a. /b, d̪, g/	☞ a. b, d̪, g		***
b. /β, ð, ɣ/	☞ b. b, d̪, g	***!	***

The following sections will reveal that the possibility that certain voiced stops be matched with a non-identical output correspondent, such as the first segment of candidates

(14c-f), does not arise from a general prohibition against voiced stops (e.g. *VDSTOP), but from a drive to reduce their articulatory cost in those contexts where they are most effortful to produce. I argue that this happens in Palenquero because a principle that promotes articulatory ease (e.g. LAZY) is given higher priority than the drive to remain faithful to all feature specifications (e.g. IDENT(Feature)).

4. Deriving spirants from underlying voiced stops

Because the change that spirantization causes on voiced stops has a direct impact on the effort required to yield voicing, this process is most amenable to an effort-based analysis. From an aerodynamic point of view, spirantization is a type of oral venting, which prevents that the rising pressure resulting from forming a complete closure in the oral tract equals the subglottal pressure. This is accomplished by avoiding that the articulators in the oral cavity form a tight seal between them, which allows air to leak through the oral valve. Oral leakage releases supraglottal pressure and helps maintain transglottal airflow constant, thereby preventing the extinguishment of voicing. Put in a different way, when a voiced stop is spirantized, its voicing is implemented upon a constriction that is more conducive to vocal fold vibration. The immediate consequence of this is that the marked feature of the stop is realized at a lower effort cost. From this standpoint, spirantization is clearly an articulatory maneuver that serves to yield effort savings in the articulation of voiced stops by forcing their complete oral closure to ease off (e.g. target undershooting).

I will proceed along the lines of Piñeros (2002) to propose that instead of the markedness constraint *VDSTOP, the spirantization patterns exhibited by Palenquero are provoked by the effort reduction constraint LAZY (Kirchner 1994, 1995, 1998). LAZY is a family of anti-effort constraints that promote articulatory ease by discriminating against effortful articulations.

(15) LAZY: Reduce muscular effort in the articulation of segments.

In order to calculate articulatory effort, Kirchner (1998) posits abstract effort units. As Kirchner stresses, it should be kept in mind that effort units are not actual physical measurements, but estimates of relative effort based on articulatory events and factors such as displacement, impedance, precision, and velocity. By hypothesis, the total effort necessary to articulate a segment can be calculated by adding the efforts required to produce each one of its articulatory gestures. For the purpose of this paper, we will be mostly concerned with the effort dimension where the gestures for vocal fold vibration and stricture intersect.

Westbury (1983:1322) notes that for the vocal folds to vibrate, they must be properly adducted and tensed, and there must be sufficient transglottal pressure gradient for air to flow through the glottis. Although we know that these conditions require a rise in subglottal pressure initiated by the lungs as well as activity of the structures in the larynx, we do not know with precision all of the structures that are involved in these actions, much less can we measure with all accuracy the amount of effort spent in performing each one of them. Although precise effort measurements of all the structures that participate in the production of voicing are beyond our current capabilities, our understanding of the mechanism used to produce voicing allows us to identify conditions that favor vocal fold vibration, which make it less effortful, as well as factors that are detrimental to it and make voicing more effort-consuming. Based on the presence/absence of these factors, we can make estimates of how effortful it is to produce voiced segments.

Taking into account, that complete airflow stoppage is the greatest impediment to voicing (van den Berg 1958, Lisker and Abramson 1971, Ohala 1983, Westbury 1983, Westbury and Keating 1986), I estimate a threshold of 100 effort units for voiced stops as the most effortful voiced segments. I have chosen to use a scale of 0-100 where the lowest value stands for no effort at all (lack of all articulatory gestures), and the highest value is assigned to voiced stops because their articulation requires that both the oral and nasal valves be closed, thereby causing transglottal airflow to cease. In order to maintain voicing under such adverse conditions, active muscular adjustments must be made, which translates into a higher effort cost. By contrast, the cost of producing voiced segments with lesser degrees of constriction decreases according to the degree to which the oral closure is loosened and/or the presence of nasal venting (see Piñeros 2002 for estimates).[9]

Although it seems reasonable to assume that of all voiced segments, voiced stops are the most costly, one must also take into account that sounds are not produced in isolation and that the context in which they appear bears on the actual effort that their articulation requires. Because in running, connected speech, segments influence other segments in the speech signal, the quality of adjacent segments has important consequences for effort reduction. Following Laver (1994:112), I assume that the articulation of any segment has three phases: an onset phase, a medial phase, and an offset phase. The medial phase is the period during which the maximum closure/aperture is achieved. The onset phase embodies the approach of the vocal organs to the medial phase, whereas the offset phase consists of the movement of the organs towards the medial phase of the next segment, and hence constitutes an overlap phase with the onset phase of that next segment. In terms of stricture, if the medial phase of a segment requires an aperture gesture (e.g. /a/), and the medial phase of the following segment requires a closure gesture (e.g. /d/), then the active articulator has to cover a considerable distance during the overlap phase. By contrast, if the medial phases of two adjacent segments involve movements in the same direction (e.g. both involve closure or aperture), then the shorter distance that the active articulator has to travel from one target to the other makes it possible to save some effort. Consequently, the estimated 100 effort units necessary to produce a voiced stop in isolation are actually not all needed when the medial phase of the preceding segment already involves some degree of constriction. Since this constriction brings the active articulator closer to the target of the voiced stop, the displacement and effort necessary to produce the voiced stop are reduced.

By contrast, a constriction during the medial phase of a following segment may not contribute to reduce the effort in articulating the voiced stop because that gesture comes after all three phases of the voiced stop have already been completed. Note that this does not mean that the constriction/aperture of the medial phase of a following segment is irrelevant for effort reduction. Obviously, whenever less displacement is required, less effort needs to be consumed. However, while a following segment may contribute to reduce the total amount of effort invested in the syllable or larger constituents, it has no impact on the effort required to articulate a segment whose articulation has already been fully implemented. This is an inevitable consequence of the temporal organization of segmental units.

Let us assume that a preceding vowel makes no contribution to reducing the effort in producing a voiced stop because this kind of segment has no constriction at all. In making this assumption I am taking into account that although it has been observed that voicing in a stop consonant is facilitated by the presence of two flanking vowels (Westbury and Keating, 1986), it is also true that whenever a stop consonant is preceded by a vowel the aperture of that vowel causes the articulators to move away from the constriction target: the greater the aperture of the vowel, the further the separation from the target. This means that the aperture of a preceding vowel yields an increase in displacement, which demands greater effort consumption on the part of the active articulator in order to travel that greater distance.[10] On these grounds, I assume that the overall effort involved in producing a voiced stop is not automatically reduced by the presence of two flanking vowels because the additional energy consumed by the active articulator as a result of the increase in displacement may cancel out the effort savings contributed by flanking vowels.

We expect, on the other hand, that a consonant, being endowed with some degree of constriction, would contribute to rendering a following voiced stop less effortful according to the degree of its closure: consonants with a low degree of constriction would make a small contribution, whereas consonants with higher degrees of constriction would make greater contributions. Given the phonotactics of Palenquero, however, it will not be necessary for us to engage in a discussion of the specific contributions made by consonants with different degrees of constriction because this language does not allow any consonant that precedes a voiced stop to have its own constriction. This is a consequence of the fact that such consonant could only be parsed as a syllable coda, and Palenquero bars all place-bearing consonants from the right syllable edge (e.g. [a^{g}.go] < *Spn.* [ál.ɣo] 'something'; [t̪á$^{\text{d̪}}$.d̪e] < *Spn.* [t̪áɾ.ðe] 'late'). Rather than yielding effort savings, as it is the case in Spanish spirantization (Piñeros 2002); it turns out that in Palenquero, a preceding oral consonant causes the voiced stop to be more effortful than usual because it falls prey of total assimilation. Although assimilation serves to preserve the structural position of a coda consonant that is under threat of deletion, the geminate voiced stop that emerges from this process consumes greater effort than a simplex voiced stop because it has a longer closure. This certainly makes it harder to sustain voicing while both the oral and nasal valves are closed. My estimate is that this longer closure makes the voiced stop more effortful by 30 units (see table 16 below).

Despite being assimilated (e.g. [kwá$^{\text{n̪}}$.d̪o] ‘when’), a nasal consonant in the syllable coda can still contribute to making a following voiced stop less effortful because the articulation of nasal segments involves velar lowering, which is an articulatory gesture that has direct consequences for transglottal airflow. By opening the velopharyngeal port, air is allowed to escape through the nasal cavity thereby keeping the supraglottal pressure from rising to levels that preclude vocal fold vibration. This effect is precisely what makes voicing a natural property of nasal consonants, which despite having a complete oral closure, are inherently voiced. Given that in a sequence of a nasal consonant followed by a voiced stop the two segments end up sharing a single constriction via assimilation, the nasality of the nasal consonant cannot help overlapping upon the complete oral closure of the voiced stop. This has the effect of adding nasal venting to that critical period of the articulation of a voiced stop when oral airflow is suspended. With nasal venting occurring simultaneously with its complete oral closure, voicing in a stop consonant becomes as natural as it is in a nasal consonant. I estimate that the presence of nasality during the closure of a voiced stop contributes 50 effort units to reducing its articulatory cost. That is to say that voiced stops in post-nasal position are actually quite affordable since they come at half their cost in isolation.

Similar to a preceding place-bearing consonant, we expect that a preceding pause would make voiced stops less effortful because the resting position of the speech organs most often implies a closure of the vocal tract (Widdison 1997:78). The presence of a pause is comparable to a consonantal constriction in the sense that the closure it implies serves to reduce the displacement of the active articulator when moving to the target of a following voiced stop. I estimate that the oral closure of a preceding pause contributes 30 effort units to reducing the articulatory cost of a voiced stop, which is the same contribution that a preceding stop consonant would yield if it were allowed to have its own constriction (Piñeros 2002). The estimates of the actual effort cost of producing voiced stops in the different contexts where they may appear in Palenquero are summarized in table (16).

(16) Estimated effort costs for voiced stops in context

Context	Stop in isolation		Context contribution		Actual effort
Nasal C ___	100	-	50	=	50
Pause ___	100	-	30	=	70
Vowel ___	100	-	0	=	100
Oral C ___	100	+	30	=	130

In sum, voiced stops are most affordable in post-nasal position because they receive the benefit of nasal venting. By contrast, voiced stops are most costly when combined with a preceding oral consonant into a full geminate because this increases their closure duration. Furthermore, the effort cost of producing voiced stops is reduced by the presence of a preceding pause because it shortens the distance that the active articulator has to travel, whereas a preceding vowel makes no contribution to this effect because even though voicing is facilitated by the presence of two flanking vowels, the aperture of a preceding vowel increases the displacement of the active articulator.

Let us further assume that for each effort threshold there is a LAZY constraint that penalizes those segments whose articulation involves reaching that threshold (e.g. LAZY_{50}, LAZY_{75}, LAZY_{100}, LAZY_{130}). Because high effort thresholds are always more costly to reach than lower ones, these constraints are intrinsically ranked as LAZY_{130} >> LAZY_{100} >> LAZY_{70} >> LAZY_{50}. Within this approach, a language that is not willing to invest the 100 effort units required to articulate voiced stops independently of any contextual contributions corresponds to a grammar where LAZY_{100} takes precedence over featural faithfulness: LAZY_{100} >> IDENT(Feature).

Palenquero is an instance of such grammar. In this language, voiced stops are allowed to emerge because the entire family of IDENT(Feature) constraints dominates *VDSTOP; however, not all voiced stops may be faithfully preserved because some of the IDENT(Feature) constraints are subdued by LAZY_{100}. For instance, whereas IDENT(voice) takes precedence over LAZY_{100}, IDENT(continuant) is dominated by it. This follows from the fact that in order to reduce their effort cost, Palenquero voiced stops never undergo devoicing, (17c,f), but they quite often fall prey of spirantization, (17b). To capture these patterns, one must segregate IDENT(continuant) from the IDENT(Feature) cluster and rank it below LAZY_{100}. As the following tableaux illustrate, the effect of this ranking is not to rule out voiced stops per se, but simply to ban all instances in which they would be implemented without any effort savings.

(17) IDENT(Feature) >> LAZY$_{100}$ >> IDENT(continuant) >> *VDSTOP

	Input: /ese bino/	IDENT (Feature)	LAZY$_{100}$	IDENT (continuant)	*VDSTOP
	a. [é.se.bí.no]		*!		*
☞	b. [é.se.βí.no]			*	
	c. [é.se.pí.no]	[voice]!			
	Input: /bino/				
☞	d. [// bí.no]				*
	e. [// βí.no]			*!	
	f. [// pí.no]	[voice]!			

Whenever a voiced stop is preceded by a vowel, it is too costly to retain all of its feature specifications because the preceding vowel, not being endowed with a closure gesture, is unable to contribute any effort savings to the articulation of the voiced stop. Therefore, the faithful implementation of this segment would consume 100 effort units, which LAZY$_{100}$ does not allow, (17a). By turning the voiced stop into a spirant, a discrepancy in continuancy specifications arises; however, the critical effort threshold is never reached, (17b). This result is in contrast with the evaluation of a form where the voiced stop is in absolute initial position. The oral closure of the preceding pause contributes savings of 30 effort units, which makes the voiced stop not only affordable but also mandatory, so that the next ranking constraint may be satisfied, (17d). Note that spirantizing a voiced stop in a context that contributes to reduce its articulatory cost is unsound because it gives rise to unnecessary violations of featural faithfulness, (17e).

Let us now consider the case of voiced stops in post-consonantal context, where spirantization always fails to affect them. If the consonant that precedes the voiced stop is nasal, spirantization is unnecessary because the addition of nasal venting to the closure phase of the voiced stop makes this segment quite affordable, (18a). Given that nasal venting secures constant transglottal airflow, it comes as no surprise that voiced stops never spirantize post-nasally, where their effort cost is half the critical 100 effort units. Spirantizing such effortless voiced stops is unwarrantable because although it would avoid a violation of the constraint *VDSTOP, it would also give rise to a violation of IDENT(continuant), which is a higher-ranking principle, (18b).

(18) IDENT(Feature) >> LAZY_{100} >> IDENT(continuant) >> *VDSTOP

		Input: /mango/	IDENT (Feature)	LAZY_{100}	IDENT (continuant)	*VDSTOP
☞	a.	[má$^{\text{ŋ}}$.go]				*
	b.	[má$^{\text{ŋ}}$.ɣo]			*!	
	c.	[má$^{\text{ŋ}}$.ko]	[voice]!			

When the preceding consonant is oral, on the other hand, the reason why spirantization fails to apply is not because this segment contributes to bring the effort cost of the voiced stop below the 100-unit effort threshold. Recall that because coda consonants lose their place features as a result of assimilation, they are unable to yield effort savings, unless they are nasals. The actual reason why voiced stops do not spirantize in the context of a preceding oral consonant is because whether the segment resulting from assimilation is a geminate stop or a geminate spirant, its implementation will consume more than 100 effort units, (19a,b). As it was estimated above, a geminate voiced stop consumes 130 effort units because its longer closure is a greater impediment to voicing. With regard to continuant geminates, Kirchner (1998:36) estimates that they are even more effortful than non-continuant ones because unlike the latter, continuant geminates require a prolonged steadystate constriction, which demands that the upward movement of the active articulator be arrested by an antagonistic force (i.e. isometric tension).

(19) IDENT(Feature) >> LAZY$_{100}$ >> IDENT(continuant) >> *VDSTOP

	Input: /algo/	IDENT (Feature)	LAZY$_{100}$	IDENT (continuant)	*VDSTOP
☞	a. [á^{g}.go]	[g≠l]	*		*
	b. [á^{ɣ}.ɣo]	[ɣ≠l]	*	*!	
	c. [á^{k}.ko]	[k≠l], [k≠g]!			

The finalists in this evaluation are candidates (19a) and (19b), which tie with respect to the two highest-ranking constraints. They both run afoul of IDENT(Feature) because they provide an unfaithful output correspondent for the segment /l/, and they both violate LAZY$_{100}$ because they contain voiced geminates, segments that surpass the 100-unit effort threshold due to the greater length of their closure.[11] The tie is broken by IDENT(continuant) in favor of candidate (19a) because although both (19a) and (19b) are unable to preserve all of the features of the segment [l], for it is an illicit syllable coda, only the latter manages to preserve all other segments faithfully.

The fact that losing the structural position of an illicit coda consonant may be avoided by exceeding the 100-unit effort threshold, as evinced by the emergence of geminate voiced stops from assimilation, means that MAX, the faithfulness constraint that prohibits deletion, also outranks LAZY$_{100}$.

(20) MAX(imization): Every segment in the input must have a correspondent in the output.

Adding this constraint to the ranking reveals the reason why a voiced stop that is preceded by an oral consonant at the underlying level may not surface as a simplex spirant. Spirantization fails in that context because it would efface all evidence that both consonants have been preserved in the output; particularly, that the consonant that precedes the voiced stop at the underlying level has not been completely lost, which would amount to a fatal violation of MAX, (21c). Note that if the sequence of an oral consonant followed by a voiced stop surfaces as a geminate voiced stop or as a simplex voiced stop, there is a tangible trace of the presence of both consonants in the output form. If the two consonants are implemented as a geminate voiced stop, the longer duration of this output segment is robust proof that it stands for two input segments, (21a). Likewise, when the geminate voiced stop is reduced to a simplex voiced stop in fast speech, its role as correspondent of two input segments is overtly signaled by the retention of its occlusiveness, (21b). In other words, resistance to undergo spirantization serves as proof that deletion has not taken place. Candidates (21a) and (21b) are optimal output forms because they both spare all input segments and remain faithful to their underlying voicing specifications despite the fact that this requires reaching the critical 100-unit effort threshold.

(21) MAX, IDENT(Feature) >> LAZY_{100} >> IDENT(continuant) >> *VDSTOP

	Input: /algo/	MAX	IDENT (Feature)	LAZY_{100}	IDENT (continuant)	*VDSTOP
☞	a. [á^{g}.go]		[g≠l]	*		*
☞	b. [á.go][12]		[g≠l]	*		*
	c. [á.ɣo]	*!			*	

According to this analysis, the markedness constraint *VDSTOP has no weight on the determination of whether an underlying voiced stop will be faithfully preserved or not. It has been shown that Palenquero does not prohibit voiced stops per se. Rather, this language seeks to achieve ease of articulation by weakening their complete oral closure in those contexts where they would be too effortful to implement. Nonetheless, we have also observed that there are times when the tendency to make voiced stops less effort consuming is overridden. This happens when the reduction of effort would cause losing an input segment or being unfaithful to features other than [continuant].

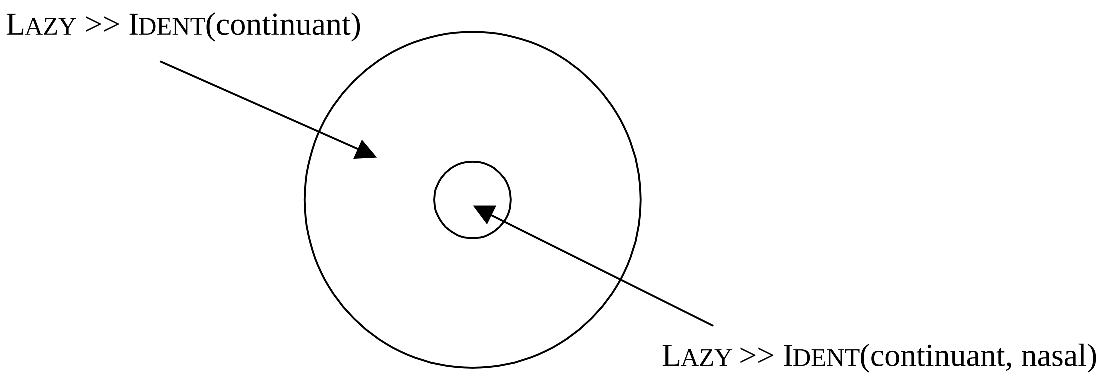
5. Effort reduction through nasal venting

Despite the apparent unrelatedness between spirantization and prenasalization, if we compare these processes in terms of the kind of articulatory adjustments involved in spirantizing or prenasalizing a voiced stop, it becomes evident that they are actually quite germane. Like spirantization, prenasalization is an articulatory maneuver that relies on venting in order to prevent the complete stoppage of transglottal airflow in segments that are endowed with a complete oral closure. Phoneticians have observed that opening the velopharyngeal port during the closure phase of a voiced stop has the effect of releasing supraglottal pressure, which contributes to maintain the transglottal pressure gradient necessary for air to flow through the glottis. This maneuver makes the production of voicing considerably less effortful, and as noted by Ohala and Ohala (1991), it does not cause the voiced stop to become completely nasal as long as the velum is raised prior to the release. From this standpoint, the difference between spirantization and prenasalization is simply which one of the two valves that separate the supraglottal cavity from the atmosphere is used for the purpose of venting. Whereas spirantization allows air leakage through the oral valve, prenasalization does so through the velopharyngeal valve.

Henton, Ladefoged and Maddieson (1992:71) observe that a prenasalized voiced stop is phonetically not distinct from a sequence consisting of a nasal consonant plus a voiced stop because they exhibit the same timing pattern for velar activity. In both cases, the velum descends and remains down for the majority of the closure, but rises shortly before the release. This parallelism means that whether nasality is a feature added to the closure phase of the voiced stop (e.g. prenasalization) or a feature dominated by a placeless root node in a homorganic nasal-plus-voiced-stop sequence (e.g. nasal place assimilation), the production of voicing in both of these structures is equally facilitated by the presence of nasal venting. According to this, I estimate that like pos-nasal voiced stops; prenasalized voiced stops come at the low effort cost of 50 units.

Recall that unlike spirantization, the prenasalization process that affects voiced stops in Palenquero is optional, lexically controlled, and limited to one particular linguistic position. Because only the initial voiced stops of words that contain certain roots may prenasalize, we are forced to posit a lexical mark for those special roots, 34 in total. Within this approach, the reason why the words [ɡló.ɾja] ‘glory’, [ɡlo.ɾi.fi.ká] ‘glorify’ may also be pronounced as [^{ŋ}ɡló.ɾja] and [^{ŋ}ɡlo.ɾi.fi.ká] is because they contain the root /*^{PN}ɡloɾi/, which is assigned the diacritic ‘*^{PN}’ to signal that it is licensed to participate in prenasalization. This type of root contrasts with the great majority of Palenquero roots beginning with a voiced stop (e.g. /ɡaɾɡan̪t̪/ ‘throat’), which must be deprived of such mark since their initial voiced stop always escapes prenasalization; although it may fall prey of spirantization when preceded by a vowel (e.g. [ɡa^{g}.ɡán̪.t̪a] ‘throat’ ~ [má ɣa^{g}.ɡán̪.t̪a] ‘throats’). I assume that words that inherit the prenasalization mark from their root belong to a special lexical class, whose optimal output form is selected by an alternative constraint ranking. This alternative ranking may be construed as a co-grammar, a restricted domain within the general grammar, in which not only IDENT(continuant) but also IDENT(nasal, sonorant) is subdued by LAZY.

(22) Co-grammar: a restricted grammar within the general grammar



In the restricted grammar, LAZY$_{70}$ must outrank IDENT(nasal, sonorant)[13] because even post-pausal voiced stops, which consume only 70 effort units, undergo prenasalization, (23b). Under this ranking, voiced stops must also prenasalize when preceded by a vowel given that their effort cost also surpasses the 70-unit effort threshold, (23d).

(23) LAZY$_{100}$ >> LAZY$_{70}$ >> IDENT(nasal)

	Input: /*^{PN}gloɾia/	LAZY$_{100}$	LAZY$_{70}$	IDENT (nas, son)	LAZY$_{50}$
	a. [gló.ɾja]		*!		
☞	b. [^{ŋ}gló.ɾja]			**	*
	Input: /ku *^{PN}gloɾia/				
	c. [ku gló.ɾja]	*!	*		
☞	d. [ku ^{ŋ}gló.ɾja]			**	*

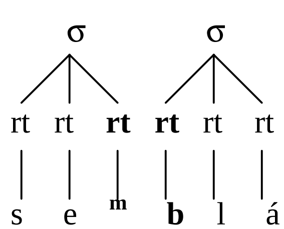
The fact that prenasalization never affects word-internal voiced stops suggests that an additional faithfulness constraint is at large. Following work by McCarthy and Prince (1995), I propose that O-CONTIG(Wd), which penalizes the insertion of word-internal segments, is the principle that limits prenasalization to word-initial position.

(24) O-CONTIG(Wd): "No intrusive segments within the word"

The output string standing in correspondence with an input word must form a contiguous string.

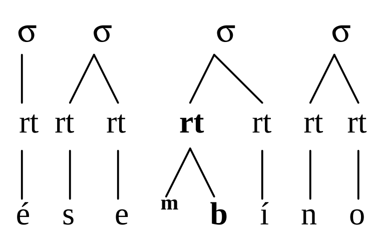
Taking into account the observation made by Henton, Ladefoged and Maddieson (1992:71) that a prenasalized voiced stop, (25b), is indistinguishable from a sequence consisting of a nasal consonant plus a voiced stop, (25a), one must conclude that the constraint O-CONTIG(Wd) will object against the outcome of prenasalization whenever this process applies within word boundaries given that the nasal portion of the prenasalized voiced stop can be interpreted as an intrusive segment (e.g. *[ha^{m}blá] vs. [ha.βlá] < /habla/ 'to speak'). This side effect of adding the feature [nasal] to the closure phase of a stop consonant is most likely due to the fact that nasality does not need to appear in combination with oral features in order to project a root node, hence the natural tendency for nasals to be placeless in positions where they do not need to be released (e.g. the syllable coda).

(25) a. NC as two root nodes



'to plant'

b. NC as a single root node



'that wine'

With O-CONTIG(Wd) dominating LAZY_{100}, the effort cost of producing a voiced stop may be reduced through prenasalization when this segment is edgemost within the word, (26c), but not when it is word-internal, (26f). Note that although in both (26c) and (26f) the nasal portion of the prenasalized voiced stop may be interpreted as a segment in itself, only the prenasalized voiced stop that is in word-initial position may be uncontroversially said not to result in a violation of O-CONTIG(Wd) because although in both cases the added nasality may be interpreted as an epenthetic segment, such segment is word-internal in (26f), but certainly not in (26c). Also note that even within the restricted grammar, a word-internal voiced stop in post-vocalic position can be rendered less costly than 100 effort units through spirantization because IDENT(continuant) is outranked by LAZY_{100} throughout the entire grammar, (26e).

(26) O-CONTIG(Wd) >> LAZY_{100} >> IDENT(cont) >> LAZY_{70} >> IDENT(nas, son)

	Input: /*^{PN}bino/	O-CONTIG (Wd)	LAZY_{100}	IDENT (cont)	LAZY_{70}	IDENT (nas, son)
	a. [bí.no]				*!	
	b. [βí.no]			*!		
☞	c. [^{m}bí.no]					**
	Input: /kabesa/					
	d. [ka.bé.sa]		*!			
☞	e. [ka.βé.sa]			*		
	f. [ka^{m}bé.sa]	*!				**

In order to account for the optional character of prenasalization, I assume that words containing one of the 34 roots that are licensed to undergo prenasalization do not always have to undergo the process because their output forms may be generated either through the general grammar, (27), or through the restricted grammar, (28). This follows from the fact that whereas words that contain a root that lacks the lexical mark for prenasalization are inadmissible inputs for the restricted grammar, those words that inherit such mark from their root are admissible inputs not only for the restricted grammar, but also for the general grammar, given that the latter does not require that the input bear any particular lexical mark, nor that it does not bear one.

(27) General grammar: the lowest IDENT constraint outranks the 70-unit effort threshold

	Input:	/*PNd̪eha/	IDENT (Feature)	LAZY$_{100}$	IDENT (continuant)	LAZY$_{70}$
☞	a.	[d̪e.há]				*
	b.	[t̪e.há]	[voice]!			
	c.	[ðe.há]			*!	
	d.	[ⁿd̪e.há]	[nasal]!			

(28) Restricted grammar: IDENT(nas, son) is outranked by the 70-unit effort threshold

	Input:	/*PNd̪eha/	IDENT (Feature)	LAZY$_{100}$	IDENT (cont)	LAZY$_{70}$	IDENT (nas, son)
	a.	[d̪e.há]				*!	
	b.	[t̪e.há]	[voice]!				
	c.	[ðe.há]			*!		
☞	d.	[ⁿd̪e.há]					**

This analysis dovetails with the observation made by Patiño-Rosselli (1983) that being optional, prenasalization in Palenquero represents a sociolinguistic option used by the bilingual speakers of this community to signal the channel they are choosing for their communication. For instance, the use of [ⁿd̪e.há] vs. [d̪e.há] 'to let', signals unequivocally that the speaker has selected the creole, as opposed to the Spanish channel. On this view, the linguistic competence of Palenquero speakers comprises both a general grammar, which is similar to the variety of Spanish spoken in most of the Northern Coast of Colombia, and a restricted grammar, which governs linguistic structures and processes specific to the creole. In this regard, it is worth stressing that only forms that are lexically marked are allowed to enter the restricted grammar, where in addition to spirantization, there are various other processes (e.g. prenasalization), which serve to render voiced stops less effortful.

The greater propensity to prenasalization exhibited by dorsal voiced stops as opposed to their coronal and labial counterparts is also related to the effort required to yield their voicing. Although any major constriction is detrimental to voicing, it has been observed that the further back the constriction takes place, the sooner the stoppage of transglottal airflow will occur (Westbury 1983, Westbury and Keating 1986, Ohala 1983). This is due to the fact that posterior articulations leave a smaller wall surface area between the glottis and the point of the constriction than anterior articulations. With a smaller wall surface area, the potential for passive cavity enlargement is considerably reduced.

As Westbury (1983:1324) notes, pressure-actuated expansion of the supraglottal cavity is possible because the walls of the vocal tract are not rigid, but compliant, and thus will yield to pressures acting upon them. The effect of enlarging the supraglottal cavity is that a greater volume of air may be accommodated. This, in turn, makes it possible to retard the complete stoppage of transglottal airflow given that the supraglottal pressure does not rise as fast when this cavity has been expanded. By contrast, when the constriction is closer to the glottis, this leaves less wall surface area for passive cavity enlargement. In this smaller cavity, pressure builds up faster, and this causes the transglottal pressure differential to be extinguished sooner.

Consequently, voicing will die out faster if the constriction is coronal than if it is labial, but the cessation of voicing will occur the fastest when the constriction is dorsal. That is to say that coronal voiced stops are more dependent on active voicing than labial voiced stops, however, it is dorsal voiced stops that depend the most on it. Because dorsal stops are the most prone to require active muscular adjustments in order to be voiced throughout their closure, it is to be expected that they will also be the most susceptible to prenasalization as a means to reduce their effortfulness. This explains why in 50% of the Palenquero roots that participate in prenasalization the initial voiced stop is dorsal. The reason why the percentages for coronal (29%) and labial (21%) voiced stops are not very far apart from one another is that Palenquero voiced stops are dental, rather than alveolar, which makes them closer to labials in the sense that there is a gain in wall surface area when coronals are articulated against the upper teeth than when they are articulated against the alveolar ridge.

6. Effort reduction by shortening the duration of the closure

Although it may appear that flapping has nothing in common with either spirantization or prenasalization, this process is actually another articulatory maneuver that may be used in order to reduce the effort cost of implementing voiced stops. By shortening the temporal coordinates of the constriction target, the closure phase of the voiced stop becomes so brief that it may be completed before the transglottal pressure gradient has dropped below the critical level for voicing (2000 dyn/cm^2). In other words, because transglottal airflow dies out progressively, not abruptly, it is possible that even a segment whose articulation involves a complete oral closure be completely voiced without having to resort to active voicing if the entire duration of its closure is shorter than the period during which the transglottal pressure gradient has not yet fallen below 2000 dyn/cm^2. As noted by Westbury (1983:1324), this period varies depending on how rigid the vocal tract walls are: the laxer the walls, the longer the period of non-active closure voicing. This is due to the fact that laxer walls allow greater passive enlargement of the supraglottal cavity, which as explained above, has the effect of retarding the equalization of supraglottal and subglottal pressures.

Westbury (1983) estimates that voicing may continue past occlusion for 7 ms if the vocal tract walls are rigid, roughly 30 ms if they are “tense”, slightly more than 60 ms if they are ‘moderate’, and easily a full 80 ms if they are “lax”. According to this, even if the vocal tract walls are not completely lax, a segment whose closure interval lasts 30 ms or less will be largely voiced without having to make any muscular adjustments. Flaps, which are characterized by the brevity of their closure, are precisely such segments. In this regard, Catford (1977) reports that the closure duration of flaps ranges between 1-3 centiseconds (10-30 ms), which is well within the non-active closure-voicing period even if the vocal tract walls were tense. Taking these observations into account, I estimate that turning an underlying voiced stop into a flap reduces its effort cost from 100 to 50 units since voicing throughout such brief closure is mainly passive.

For flapping to yield such effort savings, however, it is necessary that the active articulator be especially agile so that it may reach the constriction target and move away from it at an extremely fast speed. This ballistic manner of articulation is most compatible with the tongue tip than with the lips or tongue dorsum, which being more massive articulators are considerably slower. This appears to be the reason why coronal, but not other voiced stops undergo flapping in Palenquero. In this regard, one must consider that although it might be possible to force the lips or tongue dorsum to reach the high speed necessary for flapping, this is probably too costly because the displacement of such organs in a ballistic manner, being a task for which massive articulators are not well fit, will only be possible through an intensification of muscular effort. Consequently, the effort savings that would be obtained by reducing the duration of the closure would be cancelled out by the additional effort invested in speeding up the lips or tongue dorsum. This would justify that with only one type of voiced stop undergoing flapping, such segment is not the dorsal but the coronal voiced stop, which is not what one would expect knowing that it is in the case of posterior articulations that voicing is the most challenging.

After work by Hall (1997), I adopt the feature [flap] in order to distinguish between consonants whose complete oral closure lasts between 10-30 ms (e.g. flaps such as [ɾ]), and those whose complete oral closure is approximately twice as long (e.g. stops such as [d̪]). As Hall argues, the distinctive contrast between flaps and oral stops may not hinge on the feature [continuant] because both of these sound classes involve a complete oral closure, which causes them both to be [-continuant]. Because the actual contrast between these two consonant types crucially hinges on the duration of their oral closure, [flap] is a more suitable feature for capturing the change /d̪/ → [ɾ].

Considering that it is only in certain words that a coronal voiced stop may surface as a flap (e.g. [mé.ɾi.ko] ~ [mé.ðí.ko] < /med̪iko/ 'physician'), it seems reasonable to assume that flapping is another process limited to the restricted grammar, as it requires that those special words that are affected by it be assigned a lexical mark. For instance, the reason why the

Palenquero word for ‘physician’ may be pronounced either as [mé.ɾi.ko] or [mé.ðí.ko] is because it contains the morpheme /*FLmeḓik/, which being endowed with the diacritic ‘*FL’, is licensed to enter the restricted grammar to undergo flapping. By contrast, the coronal voiced stop of an unmarked word such as /saluḓa/ ‘to greet’ may only fall pray of spirantization (e.g. [sa.lu.ðá]), because it belongs to the morpheme /saluḓ/, which being deprived of this diacritic can only serve as input to the general grammar, where the only strategy that is permitted to make voiced stops less effortful is spirantization.

Furthermore, given that not only post-vocalic (e.g. [mjé.ɾo] < /mieḓo/ ‘fear’), but also post-pausal coronal voiced stops (e.g. [ɾó.se moná] < /ḓose mona/ ‘twelve children’) may be turned into flaps, the constraint LAZY$_{70}$ must outrank IDENT(flap). That is to say that within the effort-based approach proposed here, flapping ensues simply from separating IDENT(flap) from the IDENT(Feature) cluster and grouping it with the set of feature faithfulness constraints that is subdued by the 70-unit effort threshold, (30).

(29) General grammar: the lowest IDENT constraint outranks the 70-unit effort threshold

	Input:	/*FLmeḓiko/	IDENT (Feature)	LAZY$_{100}$	IDENT (continuant)	*LAZY$_{70}$
	a.	[mé.ḓi.ko]		*!		*
	b.	[mé.t̪i.ko]	[voice]!			
☞	c.	[mé.ði.ko]			*	
	d.	[méⁿḓi.ko]	[nas]! [son]			
	e.	[mé.ɾi.ko]	[flap]! [son]			

(30) Restricted grammar: IDENT(nas, flap, son) is outranked by the 70-unit effort threshold

	Input: /*^{FL}med̪iko/	O-CONT (Wd)	IDENT (Feat)	LAZY 100	IDENT (cont)	LAZY 70	IDENT (nas, flap, son)
	a. [mé.d̪i.ko]			*!		*	
	b. [mé.t̪i.ko]		[voice]!				
	c. [mé.ði.ko]				*!		
	d. [mé^{n}d̪i.ko]	*!					**
☞	e. [mé.ɾi.ko]						**

Tableau (29) shows that a word-internal coronal voiced stop belonging to a marked word such as /*^{FL}med̪iko/ will surface as a spirant if it is fed as input to the general grammar, (29c). Because [flap] and all other features except for [continuant] are subsumed by the top-ranking constraint IDENT(Feature), spirantization is the only strategy available to reduce the effortfulness of the coronal voiced stop in the general grammar. By contrast, when the same word is fed to the restricted grammar, flapping is favored instead because it yields greater effort savings that make it possible to bring the cost of providing an output correspondent for the coronal voiced stop below the 70-unit effort threshold, (30e). Furthermore, note that although prenasalization is able to yield the same effect, (30d), this option is ruled out not only because the word /*^{FL}med̪iko/ does not bear a mark for this process, but also because it would introduce an intrusive segment within the word, which is sanctioned by the top-ranking constraint O-CONTIG(Wd).

In word-initial position, the coronal voiced stop of a word such as /*$^{PN/FL}$d̪ose/ ‘twelve’, which is marked for both prenasalization and flapping, may be implemented either as a flap or as a prenasalized voiced stop when such word is fed as input to the restricted grammar, (31e,d).

(31) Restricted grammar: IDENT(nas, flap, son) is outranked by the 70-unit effort threshold

	Input: /*$^{PN/F}$d̪ose/	O-CONTIG (Wd)	IDENT (Feat)	LAZY 100	IDENT (cont)	LAZY 70	IDENT (nas, flap, son)
	a. [d̪ó.se]					*!	
	b. [t̪ó.se]		[voice]!				
	c. [ðó.se]				*!		
☞	d. [ⁿd̪ó.se]						**
☞	e. [ɾó.se]						**

This contrasts with the evaluation illustrated in tableau (32), where the same word is fed as input to the general grammar. Unlike the restricted grammar, the general grammar allows the faithful preservation of the initial coronal voiced stop of a marked word such as /*$^{PN/FL}$d̪ose/ if this segment is preceded by a pause, because it succeeds at sparing some effort in order to bring its cost below 100 units, and this is accomplished without violating any of the feature faithfulness constraints, (32a).

(32) General grammar: the lowest IDENT constraint outranks the 70-unit effort threshold

	Input: /*$^{PN/F}$d̪ose/	IDENT (Feature)	LAZY$_{100}$	IDENT (continuant)	*LAZY$_{70}$
☞	a. [d̪ó.se]				*
	b. [ðó.se]			*!	
	c. [t̪ó.se]	[voice]!			
	d. [ⁿd̪ó.se]	[nas]! [son]			
	e. [ɾó.se]	[flap]! [son]			

In partial summary, it has been shown that in addition to spirantization, the processes of prenasalization and flapping are also articulatory maneuvers that occur in the grammar of

Palenquero as different ways to accommodate the feature [voice] in segments where voicing is not inherent throughout the entirety of their duration due to the presence of a complete oral closure (e.g. voiced stops). Nevertheless, unlike spirantization, prenasalization and flapping are bound to a restricted domain of the grammar, to which only lexically marked forms have access. Furthermore, it has been argued that neither prenasalization nor flapping affects voiced stops across the board because, in the case of prenasalization, the ability of nasals to be placeless segments results in the emergence of an intrusive segment within the word; while in the case of flapping, this ballistic manner of articulation is only compatible with an exceptionally agile articulator such as the tongue tip.

7. Effort reduction through lateral venting

The last articulatory maneuver that Palenquero uses to preserve the voicing of underlying voiced stops at the expense of being unfaithful to other features is lateralization (e.g. [ke.lá] ~ [ke.ðá] < /ke̪da/ 'to remain'). Like flapping, lateralization affects the coronal, but not the labial or dorsal voiced stops. It is also important to note that like flapping and prenasalization, lateralization may be interpreted as the addition of a manner feature (e.g. [flap], [nasal], and [lateral] respectively) to the articulation of an underlying voiced stop, which besides facilitating its voicing, has the side effect of turning the input segment into a sonorant.

With regard to lateral sounds, phoneticians have observed that their articulation involves lowering the mid section of the tongue at both sides or at only one side. As a consequence of this, air is able to escape out of the mouth through the area near the molar teeth. Ladefoged and Maddieson (1996) further note that in lateral sounds 'the tongue is contracted in such a way as to narrow its profile from side to side so that a greater volume of air flows around one or both sides than over the center of the tongue'. Relating these articulatory events to the difficulty involved in maintaining voicing throughout the closure of stops, it becomes clear that the change /d̪/ → [l] is simply an adjustment made to the configuration of the mid section of the tongue for the benefit of voicing. The goal in making this adjustment is to create a side passage for the purpose of venting. With air escaping through one or both sides of the tongue, it is certainly much easier to maintain transglottal airflow above 2000 dyn/cm^2 despite the fact that there is still an occlusion in the central region of the oral passage.

From this standpoint, lateralization is a type of oral venting, which differs from spirantization in that instead of undershooting the constriction target, it modifies the aspect of the tongue body in order to secure constant airflow throughout the time that the tongue tip is in full contact with the target. Taking this into account, I assume that like nasal venting and central oral venting, the presence of lateral oral venting reduces the cost of producing a voiced stop from 100 to 50 effort units. Due to the fact that voicing in a coronal voiced stop is much easier to produce when lateral oral venting is added, it is not surprising that in other languages of the world (e.g. Yaka, Bantu family), the sounds [d] and [l] are in complementary distribution as allophonic variants of the phoneme /d/ (Ruttenberg, undated; cited by Patiño-Rosselli 1983).

With this background, it is easy to see how the constraint apparatus that has been assembled in the previous sections accounts for lateralization. The approach is the same as that used to account for prenasalization and flapping. Within the restricted grammar, the constraint IDENT(lateral) is segregated from the IDENT(Feature) cluster and ranked below

LAZY$_{70}$ as part of the set of bottom-ranking feature faithfulness constraints. This has the effect of allowing words that carry the lexical mark '*^{LA}' to take [l] as the optimal output correspondent of an underlying /d̪/, whereas words that do not bear any lexical marks may only resort to spirantization in order to reduce the effort cost of implementing a coronal voiced stop.

(33) General grammar: the lowest IDENT constraint outranks the 70-unit effort threshold

Input: /$^{FL/LA}$sabad̪o/		IDENT (Feature)	LAZY$_{100}$	IDENT (continuant)	*LAZY$_{70}$
a.	[sá.ba.d̪o]		**!		**
☞ b.	[sá.βa.ðo]			**	
c.	[sá.βa.t̪o]	[voice]!			
d.	[sá.βa.^{n}d̪o]	[nasal]! [son]			
e.	[sá.βa.ɾo]	[flap]! [son]			
f.	[sá.βa.lo]	[lateral]! [son]			

(34) Restricted grammar: IDENT(nas, flap, lat, son) is outranked by the 70-unit threshold

Input: /$^{FL/LA}$sabad̪o/		O-CONTIG (Wd)	IDENT (Feat)	LAZY 100	IDENT (cont)	LAZY 70	IDENT(nas, flap, lat, son)
a.	[sá.ba.d̪o]			*!		*	
b.	[sá.βa.ðo]				**!		
c.	[sá.βa.t̪o]		[voice]!				
d.	[sá.βa.^{n}d̪o]	*!					**
☞ e.	[sá.βa.ɾo]				*		**
☞ f.	[sá.βa.lo]				*		**

Tableau (33) shows that although the Palenquero word for 'Saturday' is endowed with lexical marks for both flapping and lateralization (e.g. /$^{FL/LA}$sabad̪o/), when fed as input to the general grammar, the coronal voiced stop contained in this word may only surface as a spirant because IDENT(continuant) is the only feature faithfulness constraint that may be violated to facilitate the voicing of underlying voiced stops, (33b). This contrast with the results of tableau (34), where the same word is fed to the restricted grammar. The lexical marks '*$^{\text{FL/LA}}$' grant this word access to this restricted domain, where [ɾ] and [l] are preferred over [ð] as the optimal output correspondent for the segment /d̪/, because they serve to achieve greater articulatory ease, (34e,f).

Consider now the case of a word like /*$^{\text{PN/FL/LA}}$d̪olo/ 'pain', which bears lexical marks for prenasalization, flapping and lateralization. When fed to the restricted grammar, the coronal voiced stop of this word may surface as a prenasalized voiced stop, flap, or lateral, (35d-f). Nonetheless, if this same word is fed as input to the general grammar, the coronal voiced stop will surface as a plain voiced stop, if preceded by a pause, (36a); and as a spirant, if preceded by a vowel, (37c).

(35) Restricted grammar: IDENT(nas, flap, lat, son) is outranked by the 70-unit threshold

Input: /*$^{\text{PN/FL/LA}}$d̪olo/	O-CONTIG (Wd)	IDENT (Feat)	LAZY 100	IDENT (cont)	LAZY 70	IDENT(nas, flap, lat, son)
a. [d̪o.ló]			*!		*	
b. [t̪o.ló]		[voice]!				
c. [ðo.ló]				*!		
☞ d. [^{n}d̪o.ló]						**
☞ e. [ɾo.ló]						**
☞ f. [lo.ló]						**

(36) General grammar: the lowest IDENT constraint outranks the 70-unit effort threshold

	Input: /*$^{PN/FL/LA}$d̪ole/	IDENT (Feature)	LAZY$_{100}$	IDENT (continuant)	*LAZY$_{70}$
☞	a. [d̪o.ló]				*
	b. [t̪o.ló]	[voice]!			
	c. [ð̌o.ló]			*!	
	d. [ⁿd̪o.ló]	[nasal]! [son]			
	e. [ɾo.ló]	[flap]! [son]			
	f. [lo.ló]	[lateral]! [son]			

(37) General grammar: the lowest IDENT constraint outranks the 70-unit effort threshold

	Input: /ese *$^{PN/FL/LA}$d̪ole/	IDENT (Feature)	LAZY$_{100}$	IDENT (continuant)	*LAZY$_{70}$
	a. [é.se d̪o.ló]		*!		*
	b. [é.se t̪o.ló]	[voice]!			
☞	c. [é.se ð̌o.ló]			*	
	d. [é.se ⁿd̪o.ló]	[nasal]! [son]			
	e. [é.se ɾo.ló]	[flap]! [son]			
	f. [é.se lo.ló]	[lateral]! [son]			

With regard to the immunity of dorsal and labial voiced stops to lateralization, it is important to note that because this maneuver depends on the action of the mid section of the tongue, it is physiological impossible to produce lateral sounds whose point of articulation is labial. This provides an explanation for the fact that the labial voiced stop never undergoes lateralization in Palenquero; but it does not rule out the possibility that the dorsal voiced stop become lateral, since despite the general tendency for lateral sounds to be coronal, there are a number of languages (e.g. English, among them) which have a velar lateral, [ʟ]. It has been argued, however, that [ʟ] patterns as a coronal segment (Blevins 1994), and that its velar quality is only a secondary articulation since it is also against the alveolar ridge that the tongue makes full contact in this segment (Laver 1994). In other words, [ʟ] is essentially a coronal lateral, which in addition to its primary coronal constriction also exhibits raising of the tongue dorsum as a secondary articulation (Laver 1994). As a doubly articulated segment, [ʟ] is more marked than [l] or [l̪], which are the two most common lateral sounds across the languages of the world. On this view, the reason why the dorsal voiced stop does not become [ʟ] in Palenquero is because this change would require incurring a violation of the constraint IDENT(place) since [ʟ] is not only dorsal, but also coronal. Because IDENT(place) is part of the cluster of IDENT(Feature) constraints that are undominated, [ʟ] may never be the optimal output correspond of an underlying /g/ despite the partial identity in place features that exists between these two segments.

9. Conclusion

This paper has focused on the set of voiced stops of Palenquero and the processes that cause them to alternate with various other sounds. It is not a mere accident that the voiced stops of this language behave asymmetrically with respect to voiceless stops in terms of input-to-output mapping. Unlike voiceless stops, voiced stops are subject to several transformations, which cause them to have unfaithful output correspondents even when they are parsed in strong linguistic positions such as syllable and word initial. Because the only difference between the two stop series that exist in Palenquero is voicing, the reason for the much higher propensity to change exhibited by the members of the voiced series must be related to their being endowed with vocal fold vibration. Stop consonants are at odds with voicing because the rise in supraglottal pressure that a complete oral closure generates will eventually cause transglottal airflow to drop below the level necessitated for the vocal folds to vibrate (2000 dyn/cm^2). To secure voicing throughout the closure interval of a stop consonant, active muscular adjustments must be made at least during its final portion. Therefore, voiced stops are more effort consuming than their voiceless counterparts because part of their voicing is actively induced.

Although there are languages that choose to exclude voiced stops from their sound inventories because of their additional cost (e.g. Hawaiian), Palenquero has chosen to include them so that it may exploit their distinctiveness from voiceless stops in order to encode different meanings (e.g. [pá.so] 'step' vs. [bá.so] 'glass'). Nevertheless, this language also employs various strategies in order to make voiced stops less effortful to implement. I have argued that the processes of spirantization, prenasalization, flapping, and lateralization represent various articulatory maneuvers that Palenquero uses to accommodate the non-inherent voicing of underlying voiced stops, despite the detriment to other features that the changes resulting from these maneuvers give rise to.

In spirantizing a voiced stop, the spatial coordinates of the oral closure are reduced to prevent that the articulators in the oral tract form a tight seal between them. This results in venting through the oral valve, which helps prevent the drop of transglottal airflow below the critical level for voicing. To obtain the benefit of this maneuver, however, faithfulness to the feature [continuant] must be sacrificed. Voicing also benefits from prenasalization because by opening the velopharyngeal port during the closure phase of a voiced stop, nasal venting ensues. Air leakage through the nasal valve serves to secure constant transglottal airflow at the expense of being unfaithful to the feature [nasal], but it also has the side effect of turning the stop consonant into a sonorant, which is a side effect caused by flapping and lateralization as well. In flapping, there is no venting involved, but the voicing of the underlying voiced stop is facilitated because its complete oral closure is rendered so brief that it is completed within the period that the transglottal pressure has not yet dropped below 2000dyn/cm^2; therefore, its voicing is produced passively. Such manner of articulation, however, requires the action of an exceptionally fast and agile articulator such as the tongue tip, which is why labial and dorsal voiced stops, being produced by slower articulators, do not undergo flapping. Finally, the way in which lateralization makes the non-inherent voicing of an underlying voiced stop less effortful to produce is by adjusting the aspect of the tongue body at its mid section in order to create a lateral passage for oral venting. Nevertheless, because lateralization depends on the action of the mid section of the tongue, this maneuver is not available to the labial voiced stop, and although this does not preclude the application of lateralization to the dorsal voiced stop, it does not occur in Palenquero because [place] features may never be altered, which is a change that would result from turning /g/ into [L], given that the latter is a coronal segment whose velar quality is there only as a secondary articulation.

These phenomena, as they occur in the grammar of Palenquero, have been captured through a system of constraints embodying two main forces: the tendency to promote ease of articulation (e.g. LAZY), and the drive for correspondent segments to remain faithful to one another (e.g. IDENT(Feature)). In Palenquero, voiced stops may only alternate with closely related sounds because the only features that may be altered for the sake of articulatory ease are [continuant], [nasal], [flap], [lateral], and [sonorant]. In fact, not all of the features of this set may be changed throughout the grammar of the language. This follows from the fact that whereas prenasalization, flapping, and lateralization are unpredictable and limited to a minority of words, spirantization may apply to any word where the voiced stop is in the appropriate phonological context. This difference in scope has been captured by splitting the grammar into a general and a restricted domain. Spirantization is the most widespread process because in the general grammar IDENT(continuant) is the only feature faithfulness constraint that is outranked by LAZY_{100}, which represents the effort threshold that is reached in producing a voiced stop without any effort savings contributed by contextual factors. In the restricted grammar, by contrast, not only IDENT(continuant), but other feature faithfulness constraints as well (e.g. IDENT(nasal, flap, lateral, sonorant)) have been overtaken by LAZY_{100}, and even by the lower effort threshold represented by LAZY_{70}, since voiced stops may undergo prenasalization, flapping, or lateralization even after a pause.

On this view, the linguistic competence of Palenquero speakers is structured in two co-grammars, one that is closely related to Spanish, a language where spirantization is also the main strategy used to accommodate the non-inherent voicing of underlying voiced stops (Piñeros 2002), and another one that is specific to this creole, where prenasalization, flapping, and lateralization are additional strategies used to reduce the effort required to implement underlying voiced stops. These additional strategies, however, are only operative under lexical control, which is what makes them so limited in scope. The fact that the constraint ranking enforced by the restricted grammar is a subset of the ranking enforced by the general grammar is consistent with this view. To put it in a different way, the restricted grammar proposed here is a morpho-phonological domain where the drive to achieve ease of articulation is pushed further forward than it is in the general grammar; the latter being an exclusively phonological domain.

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Notes

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1 The only process that affects voiceless stops in the syllable onset is post-nasal voicing, which is limited to word-internal position and occurs only as a sociolinguistic option (e.g. [t̪jé^{m}.bo]] ~ [t̪jé^{m}.po] < Span. [t̪jé^{m}.po] 'time'). Furthermore, post-nasal voicing only occurs in a limited set of marked words. Of the 110 words I was able to identify where a word-internal voiceless stop is preceded by a nasal consonant, only 19 undergo this change. Because voiceless stops are affected by this unfaithful mapping only in word-internal position and in such small number of words, the existence of this process does not invalidate the generalization that voiceless stops tend to be faithfully preserved when assigned to the syllable onset.

2 The superscript is used to denote that the segment so transcribed is deprived of place features of its own.

3 Because Palenquero lacks gender and number agreement, [é.se] acts as the masculine, feminine, singular and plural forms of the demonstrative. This contrasts with the Spanish use of [é.se] 'that, sg. msc.' [é.sos] 'those, pl. msc.', [é.sa] 'that, sg. fem.', and [é.sas] 'those, pl. fem.'.

4 [pá] is the Palenquero version of the Spanish preposition [páɾa] 'to, in order to'.

5 [t̪ó] is the Palenquero equivalent of Spanish [t̪ó.ðos] 'all'.

6 This constraint is a more specific version of *VDOBSTR (Beckman 1999), which militates against non-inherent voicing in all obstruent sounds: *[-sonorant, voice].

7 Because the final /r/ of Spanish infinitives never surfaces in Palenquero, I assume that this segment is absent from the underlying representation.

8 I assume that prenasalized voiced stops are not obstruents but sonorants. This is supported by the fact that they are produced with nasal venting throughout their closure duration, which keeps the supra-glottal pressure from reaching the high-pressure levels typical of obstruent sounds.

9 Sibilant fricatives are exceptional in that despite the fact that they have a lesser degree of constriction than stops, voicing is not more natural in them. This is because they have more exacting aerodynamic requirements. Ohala 1983 points out that they require that the oral pressure be low in order to yield their voicing. But on the other hand, the high air velocity necessary to yield their frication requires that the oral pressure be high. 'Meeting both of these requirements may be difficult. To the extent that the segment retains voicing it may be less of a fricative, and if it is a good fricative it runs the risk of being devoiced' (Ohala 1983:201).

10 In this regard, it is worth noting that in certain Spanish dialects, voiced stops tend to weaken to the point of deletion, especially when they are flanked by non-high vowels (e.g. [práo] < /prad̪o/ 'lawn'). This happens whether the flanking non-high vowels are identical or not (e.g. [káa] < /kad̪a/ 'each', [láo] < /lad̪o/ 'side').

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[11] Note that these two candidates also violate LAZY constraints higher than LAZY_{100}, but because the critical threshold for spirantization is that of 100 effort units, such violations have no consequences for the evaluation.

[12] The segment [g] is underlined to indicate that it has multiple input correspondents.

[13] The reader is reminded that prenasalized voiced stops are assumed to be sonorant segments because they lack turbulent airflow throughout their closure interval. Furthermore, like all sonorant segments, they are inherently voiced.