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The Effect of Prosody on Glottal Stop Deletion in Capanahua[1]

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1. Introduction

In Capanahua (Panoan; Eastern Central Peru) there exists a process of glottal stop deletion in coda position which is putatively an odd-even alternation. Loos (1969:182) observes that the glottal stop is deleted in the coda of even-numbered syllables counting from the beginning of the word, but it is allowed to remain in the coda of odd-numbered syllables and in mono-syllabic words (see also Safir 1979:112, fn. 4).

(1) Coda of monosyllabic word: Glottal stop remains

a)	/taʔ/	[taʔ]	*Declarative modal*[2]
b)	/ɾaʔ/	[ɾaʔ]	'Probably'

(2) Coda of odd-numbered syllable: Glottal stop remains

a)	/taʔno/	[ˈtaʔ.no]	'Grub'
b)	/ʔiʔsap/	[ʔiʔˈsa]	'Bird'

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[1] Parts of this talk were presented at the 6th meeting of the South Western Optimality Workshop (SWOT) at USC in April 2001. This work benefited from extensive discussion with Rachel Walker. Special thanks to Eugene Loos for his prompt and detailed answers to my questions. Thanks also to Dani Byrd, Beto Elias, Abigail Kaun, Mario Saltarelli, Adam Ussishkin, Kie Zuraw, and the audiences at NELS 32 and SWOT 6 for their comments and suggestions. All errors are of course mine.

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[2] Unless otherwise noted, the Capanahua data in this chapter comes from Loos 1969 and p.c., and Loos and Loos 1998.

c)	/ʔonaniʔki/	[ˈʔo.na.niʔ.ki]	'He knows (verb)'
d)	/ʔoʂakaʔinaiʔki/	[ˈ ʔo.ʂa.ka.ʔi.niʔ.ki]	'He falls asleep (verb)'

(3) Coda of even-numbered syllable: Glottal stop deletes

a)	/βitʃiʔ/	[ˈβi.tʃi]	'I grab (verb)'
b)	/ɾakaʔti/	[ˈra.ka.ti]	'He lies down (verb)'
c)	/honomataʔki/	[ˈho.no.ma.ta.ki]	'It is not a wild pig'[3]

A number of alternations existing in the language show that the glottal stop is underlying. (4) shows a case involving the declarative modal /taʔ/ and the adverb /raʔ/. In (4a), /taʔ/ occurs in the fifth syllable of a word; the glottal stop remains. However, when this suffix occurs in the sixth syllable of a word (4b), the glottal stop is not pronounced; the same happens with /raʔ/.

(4) Alternations: /taʔ/ *declarative modal* and /ɾaʔ/ 'probably'

1 2 3 4 5 6
a) [ʔo.tʃi. ti. -ɾa.- **taʔ.**-ki]
dog –probably -declarative modal-certitude mode
'It is probably a dog'

1 2 3 4 5 6 7
b) [ʔo.tʃi.ti.–ma.-ɾaʔ.- **ta.** -ki]
dog – not –probably -declarative modal-certitude mode
'It is probably not a dog'

If [ʔ] deletion is an alternate syllable-timing effect, the question arises why a phonological process should be based on 'mere' counting, and what counting reflects. Additionally, previous work on closely related Huariapano shows that a process of coda [h] epenthesis in odd-numbered syllables has actually a metrically-related distribution (Parker 1994, 1998).

In this paper, I argue that the observed relationship between glottal stop deletion and even-numbered syllables is not a coincidence; my claim is that foot structure in Capanahua is key to determining the distribution of the glottal stop. Loos' (1969) generalization about the distribution of [ʔ] in Capanahua actually reflects an epiphenomenon of foot structure. Specifically, I argue that the deletion of the glottal stop correlates with the weak position in a foot. While this was suggested in Safir 1979, I explore the relationship between foot structure and the deletion of the glottal stop in Capanahua in more detail. Further, I claim that the deletion of the glottal stop in coda is an instance of prominence-based reduction (Crosswhite 1999 and to appear), since it makes a weak syllable weaker.

The organization of this paper is as follows. Section 2 discusses stress and foot structure in Capanahua, and section 3 explores the conditioning of [ʔ]

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[3] From Shell 1975:39.

distribution by foot structure. In section 4 the opacity of the stress system will be considered. In section 5, apparent counterexamples are discussed. Finally, section 6 is the conclusion.

2. Capanahua stress and foot structure

Capanahua has 16 consonants and 4 vowel phonemes: /a/, /i/, /o/, /ɯ/. There is no contrastive vowel length (Loos 1969). A consonant chart is given in (5); notice that the glottal stop is listed as a phoneme in the language.

(5) Capanahua Consonant Chart (IPA; Based on Loos 1969)

	Bilabial	**Alveolar**	**Post-Alveolar**	**Retroflex**	**Velar**	**Glottal**
Plosive	p	t			k	ʔ
Fricative	β	s	ʃ	ʂ		h
Affricate		ts	tʃ			
Flap		ɾ				
Nasal	m	n				
Approximant	w		j			

Previous accounts of Capanahua report that it has only one stress per word, in either the first or second syllable (Loos 1969). Thus, there is a two-syllable window at the beginning of the word for stress assignment. Pitch normally correlates with stress, so I abstract away from it here. Stress is assigned to a second heavy syllable, or else to the first syllable (Loos 1969, Safir 1979). In other words, stress is assigned to the first light syllable in a sequence of two lights (6a) or to a heavy syllable, either in the first or second syllable (6b, c). Thus, Capanahua is a quantity-sensitive language with moraic trochees of the form (ˈLL) or (ˈH). The foot structure facts of Capanahua are outlined in (7).

(6) Footing in Capanahua: Moraic trochees

a)	(ˈLL)	[(ˈmapo)]	'head'	[(ˈtʃitʃi) ka]	'knife'
b)	(ˈH) L	[(ˈtsis) ti]	'ashes'	[(ˈmeʃ) pi]	'clumsy'
c)	L (ˈH)	[hi (ˈsis)]	'ant'	[βa (ˈkoʃ)]	'foam'

(7) Foot structure facts in Capanahua

- ☐ Feet are moraic trochees; they are formed of two light syllables, or a heavy syllable
- ☐ Left-to-right iterative footing
- ☐ Syllables might be left unparsed

Capanahua has reportedly one stress per word. It could be argued that words in this language have one foot only and that the rest of the syllables in the word are left unparsed. However, the distribution of [ʔ] in coda position suggests footing beyond the first two syllables. This will be considered in more detail in section 3. The following constraints are needed to capture foot structure in Capanahua:

(8)	**FOOT BINARITY-μ**	Feet are binary under a moraic analysis[4]
	RHTYPE=T	Feet have initial prominence (Prince and Smolenksy 1993)
	ALL-FT-LEFT	Align (Ft, Left, PrWd, Left) 'Every foot stands at the left edge of the prosodic word' (McCarthy and Prince 1993)
	PARSE-SYLLABLE	Syllables are parsed by feet (Prince and Smolensky 1993)

In a word with three light syllables, such as [(ˈ tʃitʃi) ka] 'knife', stress falls on the first syllable rather than on the second syllable. This shows that footing starts from the beginning of the prosodic word. The ranking All-Ft-Left>>All-Ft-Right captures this fact. Foot Binarity-μ outranks Parse-Syllable; it is better to create binary feet than leave syllables unparsed (Tableau 2).

Tableau 1: All-Ft-Left>> All-Ft-Right[5]

/tʃitʃi ka/ 'knife'	ALL-FT-LEFT	ALL-FT-RIGHT
☞ a. (ˈtʃitʃi) ka		
b. tʃi (ˈtʃi ka)	*!	

Tableau 2: Foot Binarity-μ >> Parse-Syllable

/tsisti/ 'ashes'	FOOT BINARITY-μ	PARSE-SYLLABLE
☞ a. (tsis) ti		
b. (tsis.ti)	*!	
c. (tsis)(ti)	*!	

Parse-Syllable outranks All-Ft-Left; it is better to parse all syllables than to have all feet aligned with the left edge of the prosodic word (Tableau 3).

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[4] The standard interpretation of the Foot Binarity constraint is that feet are binary under a moraic or syllabic analysis (Prince and Smolensky 1993). Since in Capanahua feet cannot be binary under a syllabic analysis, I assume that the constraint Foot Bin-μ is active in this language rather than the more general Foot-Bin constraint (see also Eisner 1997).

[5] Apart from establishing the importance of All-Ft-Left, the constraint All-Ft-Right will not be relevant in the remainder of the discussion.

Tableau 3: Parse Syllable>>All-Ft-Left

/βana+ska+wu/ 'plant, then'	PARSE-SYLLABLE	ALL-FT-LEFT
☞ a. (ˈβa.na)(ska.wu)		**
b. (ˈβa.na) ska.wu	*!*	

In candidate (a) the rightmost foot is misaligned from the left edge by two syllables. Candidate (b) is perfect as regards All-Ft-left, but two syllables are left unparsed, so this candidate is dispreferred.

Since Ft-Binarity-μ>>Parse-Syllable and Parse-Syllable>>All-Ft-Left, by transitivity Ft-Binarity-μ>>Parse-Syllable>>All-Ft-Left. Assuming that both Rhtype=T and Ft-Binarity-μ are undominated, the ranking so far is Rhtype=T, Ft-Binarity-μ >> Parse- Syllable>>All-Ft-Left. The stress facts of Capanahua are outlined under (9).

(9) Stress facts in Capanahua:

- ☐ There is only one stress per word; no secondary stress reported
- ☐ Second syllable stressed if heavy; otherwise, first syllable stressed
- ☐ Coda consonants contribute weight for the purpose of stress assignment

The lengthening morpheme /n/ provides evidence for the fact that coda consonants contribute weight for stress purposes. When /n/ is added to CV.CV words, stress shifts from the first to the second syllable (10).

(10) Coda consonants contribute weight

a.	[ˈhi.wi]	'tree'	vs.	[hi.ˈwin]	'tree (lengthened form)'
b.	[ˈba.ra]	'bullet'	vs.	[ba.ˈran]	'bullet (lengthened form)'
c.	[ˈma.po]	'head'	vs.	[ma.ˈpon]	'head (lengthened form)'

The following constraints are needed to capture stress facts in Capanahua.

(11)	**STRESS PROM**	Maximize stress prominence 'Only one stress per word'
	WEIGHT-BY-POSITION	**(WBP)** Coda Consonants are moraic (Hayes 1989, Sherer 1994)
	LEFTMOST	Align (Hd-Ft, Left, PrWd, Left) 'The head foot (main stressed foot) is leftmost in PrWd' (McCarthy & Prince 1993)

I propose Stress Prom to capture the fact that in many languages there is only one stress per prosodic word, with no secondary stresses (Halle and Vergnaud 1987). Stress Prom is undominated in Capanahua. Weight-By-Position dominates Leftmost; in L (ˈH) cases, the head foot does not coincide with the left edge of the prosodic word, but stress is attracted by the heavy syllable instead[6]. This is shown in Tableau (4). WBP also outranks Parse-Syllable (Tableau 5); it is better to leave a syllable unparsed than to have a non-moraic coda consonant.

Tableau 4: Weight-By-Position >> Leftmost

/hisis/ 'ant'	WEIGHT-BY-POSITION	LEFTMOST
☞ a. hi ('sis)		*
b. ('hi) sis	*!	

Tableau 5: Weight-By-Position >> Parse-Syllable

/hisis/ 'ant'	WEIGHT-BY-POSITION	PARSE-SYLLABLE
☞ a. hi ('sis)		*
b. ('hisis)	*!	

Stress Prom, Rhtype=T and Foot Binarity-μ are undominated. WBP is dominated since coda [ʔ] is non-moraic, and it outranks Leftmost and Parse-Syllable. Parse-Syllable outranks All-Ft-Left. Constraint interaction relative to foot structure and stress in Capanahua is as follows:

(12)	Foot structure facts in Capanahua	Ranking/Undominated Constraint
☐	Feet are moraic trochees	Undominated Rhtype=T, FtBin- μ
☐	Left to right iterative footing	Parse-Syllable>>All-Ft-Left
☐	Syllables might be left unparsed	FtBin- μ >> Parse-Syllable

(13)	Stress facts of Capanahua:	Ranking/Undominated Constraint
☐	There is only one stress per word	Undominated Stress Prom
☐	Second syllable stressed if heavy; otherwise, first syllable stressed	WBP>>Leftmost
☐	Coda consonants contribute weight	High-ranked Weight-By-Position

Below are summary tableaux for ('LL), ('H), L ('H), and ('LL) L cases. There is no evidence of the ranking between Leftmost and Parse-Syllable; I assume they are equally ranked.

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[6] Words with (H)('H) patterns such as [his.'mis] 'looker' are problematic since, unexpectedly, the second syllable is stressed rather than the first. This is due to the historical development of Capanahua. Proto-Panoan three-syllable words reduced to two syllables in Capanahua and a number of other Panoan languages. In such cases, the second syllable has high tone or strong stress, regardless of the H/L status of the first syllable (Shell 1975). The analysis of these exceptional cases is beyond the scope of this paper, but a possible way to handle them is by means of a prespecified lexical accent, along the lines of Inkelas, Orgun and Zoll 1996.

Tableaux 6-9

/mapo/ head'	Stress Prom	Rh=T	FtBin-μ	WBP	Left most	Parse syl	All Ft L
☞ a. (ˈmapo)							
b. (maˈpo)		*!					
c. (ˈma) po			*!				
d. ma (ˈpo)			*!				
e. mapo							
/tsisti/ 'ashes'	Stress Prom	Rh=T	FtBin-μ	WBP	Left most	Parse syl	All Ft L
☞ a. (ˈtsis) ti							
b. tsis (ˈti)			*!				
c. (ˈtsisti)			*!				
d. (tsisˈti)		*(!)	*(!)				
e. tsisti				*!		**	
/hisis/ 'ant'	Stress Prom	Rh=T	FtBin-μ	Wbp	Left most	Parse syl	All Ft L
☞ a. hi(ˈsis)					*	*	*
b. (ˈhi)sis			*!				
c. (hiˈsis)		*(!)	*(!)				
d. (ˈhisis)			*!				
e. hisis				*!		**	
/tʃitʃika/ 'knife'	Stress Prom	Rh=T	FtBin-μ	Wbp	Left most	Parse syl	All Ft L
☞a. (ˈtʃitʃi) ka						*	
b.tʃi(ˈtʃi ka)					*	*!	
c.(ˈtʃi) (ˌtʃika)	*(!)		*(!)				
d. (ˈtʃi)(tʃika)			*!				
e. (tʃi)(ˈtʃi ka)			*!				

3. Foot structure and glottal stop deletion

Now that the basic stress and foot structure patterns of Capanahua have been identified, the connection between foot structure and glottal stop deletion can be seen more clearly. I propose that the generalization that coda [ʔ] is allowed only in monosyllabic words or odd-numbered syllables is an epiphenomenon of foot structure. Below is my distributional summary for glottal stop deletion in Capanahua.

(14) Glottal stop deletion in Capanahua is conditioned by foot structure:

Coda [ʔ] remains in an unfooted syllable or a strong syllable within a foot
Coda [ʔ] is never pronounced in coda of a weak syllable within a foot

The distribution of the coda glottal stop in this language is consistent with the foot structure pattern of the language, as (15-17) show. (15) shows that a coda [ʔ] occurs in unfooted syllables, both in monosyllabic words (15a, b) and elsewhere (15c). (16) shows that the coda glottal stop remains in strong syllables. This is clearly seen in (16a), where the relevant syllable is stressed.

(15) Coda [ʔ] stays in an unfooted syllable

a)	/taʔ/	[taʔ]	*declarative modal*
b)	/ɾaʔ/	[ɾaʔ]	'probably'
c)	/ʔiʔsap/	[ʔiʔ(ˈsa)]	'bird'

(16) Coda [ʔ] stays in a strong syllable in a foot

a)	/taʔno/	[(ˈtaʔ.no)]	'grub'
b)	/ʔonaniʔki/	[(ˈʔo.na)(niʔ.ki)]	'he knows (verb)'
c)	/ʔoʂakaʔinaiʔki/	[(ˈʔo.ʂa) (ka.ʔi) (niʔ.ki)]	'he falls asleep (verb)'

I posit that the underlined syllables in (16b, c), although unstressed, are prosodically strong because they occur foot-initially (feet have initial prominence in Capanahua). [ʔ] is not pronounced in the second syllable of a foot formed of two lights (17); this corresponds to the weak or unstressed footed syllable. Note that the underlined syllable in (17c) is weak because it occurs foot-finally.

(17) Coda [ʔ] deletes coda of weak syllable within a foot

a)	/βitʃiʔ/	[(ˈβi.tʃi)]	'I grab (verb)'
b)	/ɾakaʔti/	[(ˈɾa.ka) ti]	'he lies down (verb)'
c)	/honomataʔki/	[(ˈho.no) (ma.ta) ki]	'It is not a wild pig'

The distribution of the glottal stop in coda provides evidence for footing beyond the two first syllables in the word, and thus for iterative parsing. This is clearly seen in alternations involving morphemes with coda [ʔ]. Moraic trochee footing reveals that [ʔ] is not pronounced in a weak footed syllable, but that it is kept in a strong syllable.

(18) Alternations

a) [(ˈʔo tʃi) (ti **ɾa**) (**ta**ʔ ki)] ‘It is probably a dog’
dog –probably -declarative modal-certitude mode

b) [(ˈʔo tʃi) (ti ma) (**ɾa**ʔ **ta**) ki] ‘It is probably not a dog’
dog – not –probably -declarative modal-certitude mode

The facts of stress and footing structure in Capanahua are coherent with [ʔ] distribution in Capanahua. However, in order to decide between an odd/even alternation analysis and a foot structure analysis, crucial examples such as the following would need to be found.

(19) Hypothetical crucial cases

```
       1    2 3
a.    (H) (L L)          Odd-numbered syllable. Prediction: [ʔ] remains
             |           Weak syllable within a foot. Prediction: [ʔ] deletes
             ʔ]σ
       1 2   3   4 5
b.    (L L) (H) (L L)    Even-numbered syllable. Prediction: [ʔ] deletes
                 |       Strong syllable within a foot. Prediction: [ʔ] remains
                 ʔ]σ
```

In both cases, a heavy syllable disrupts footing. In (19a), the prediction under an odd/even alternation analysis is that the coda [ʔ] should remain, since it occurs in an odd-numbered syllable. Under a foot structure analysis [ʔ] should not occur, since it appears in a weak syllable. In (19b), under an odd/even alternation analysis, the prediction is that a coda [ʔ] would be deleted in this position, since the syllable is even-numbered. Under a foot structure analysis, the prediction is that a coda [ʔ] in this position would be pronounced, since it would occur in a strong syllable.

Unfortunately, cases such as this one are not found in Capanahua, where there exists a distributional gap in the existence of heavy syllables disrupting the process of coda [ʔ] deletion (Safir 1979, Loos p.c). A question is what underlies the absence of such structures in Capanahua. One hypothesis is that the relevant forms from Proto-Panoan were lost. Interestingly, the absence of such forms appears to be related to the apparent coincidence between footing and syllable counting for [ʔ] distribution.

The distribution of [ʔ] deletion cannot be attributed to positional faithfulness to stressed syllables (Beckman 1999), since there is only one main stress per word in Capanahua. It cannot be attributed to positional faithfulness to the strong or first syllable in a foot either since coda [ʔ] also occurs in unfooted syllables. I propose that

[ʔ] deletion is an instance of prominence-based reduction (Cf. Crosswhite 1999 and to appear), whereby weak syllables are made weaker in the language. In order to account for the distribution of the glottal stop, I propose the constraints in (20):

(20)	**MAX-IO**	Every element of the input has a correspondent in the output (McCarthy & Prince 1995)
	* ʔ | μ	(***MORAIC** [ʔ]) Glottal stops are non-moraic (González, to appear)
	$*C]_\sigma$	(**NO-CODA**) Syllables are open (Prince & Smolensky 1993)
	$*C]_{\sigma\ \text{WEAK}}$	Weak syllables in a foot are open (González 2001)

The relative sonority of laryngeals varies crosslinguistically (Clements 1990). In Capanahua, a coda [ʔ] does not make a syllable heavy (whereby *Moraic [ʔ]); a possible reason might be its reduced sonority, as in the case of glottalized sonorants in Kwakwala (Zec 1994). Additionally, the lower the sonority of a segment, the less able it is to support a mora (Zec 1994, 1995; Blevins 1999). $*C]_{\sigma\ \text{WEAK}}$ is a markedness constraint that bans marked structure from non-prominent positions (Cf. De Lacy 2001 and Smith 2000). $*C]_{\sigma\ \text{WEAK}}$ is the mirror image of Stress-to-Weight (21); while Stress-to-Weight enforces heaviness of stressed syllables, $*C]_{\sigma\ \text{WEAK}}$ enforces weakness of non-stressed syllables[7]. Weakness in this case is enforced not in moraic, but in segmental terms, since [ʔ] lends strength to a syllable even if it is non-moraic.

(21)	**STRESS-TO-WEIGHT**	If stressed, then heavy (Myers 1987, Riad 1992)

Additionally, the ranking of $* C]_{\sigma\ \text{WEAK}}$ over $* C]_\sigma$ (No Coda) is a case of a specific constraint ranking over a more general constraint. The ranking among the constraints in (18) is $* C]_{\sigma\ \text{WEAK}}$,* MORAIC [ʔ] >> MAX-IO >> NO CODA; tableaux (10, 11) below show how this ranking captures both examples where the glottal stop remains in strong syllables, and cases where it deletes in weak syllables. Note that a comparison between candidates (a) and (b) in Tableau 10 shows that MAX-IO >>NO CODA. Similarly, a comparison between candidates (a) and (b) and (a) and (c) in Tableau 11 shows, respectively, that $* C]_{\sigma\ \text{WEAK}}$ >> MAX-IO, and *MORAIC [ʔ]>> MAX-IO.

Tableau 10: [ʔ] remains in strong syllable within foot

/taʔno/ 'grub'	$* C]_{\sigma\ \text{WEAK}}$	* MORAIC [ʔ]	MAX-IO	NO CODA
☞ a. (ˈtaʔ.no)				*
b. (ˈta.no)			*!	
c. (ˈtaʔ) no		*!		*

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[7] I thank Adam Ussishkin for his helpful comments on the constraint $* C]_{\sigma\ \text{WEAK}}$.

Tableau 11: [ʔ] deletes in weak syllable within foot

/βitʃiʔ/ 'I grab'	* C] $_{\sigma \text{ WEAK}}$	* MORAIC [ʔ]	MAX-IO	NO CODA
☞ a. (ˈβi.tʃi)			*	
b. (ˈβi.tʃiʔ)	*!			*
c. βi (ˈtʃiʔ)		*!		*

My proposal is that coda [ʔ] deletion makes weak syllables weaker in Capanahua. [ʔ] remains in unfooted syllables because a strong/weak contrast is not relevant in that position. Coda [ʔ] deletion achieves rhythmicity in Capanahua and compensates for lack of secondary stresses. A question is why the glottal stop is targeted rather than any other segment. Two different possibilities exist; the glottal stop is targeted because it has no place features, or because it does not contribute to weight in Capanahua (Cf. Parker 1998).

4. Opacity of the Stress System

The connection between foot structure and [ʔ] deletion in Capanahua has not been explored in detail before. One possible reason is the opacity of its stress system. In Capanahua, there is a coda condition against most consonants; a summary of this coda condition is provided in (22) below:

(22) Permissible codas: /s, ʃ, ʂ/
Impossible codas: /h, w, j/; /ts, tʃ/; /p, t, k/[8]

Previous descriptions state that stress is assigned underlyingly, and that it is ordered before the deletion of underlying codas (Loos 1969). I will refer to this as the *rule-based approach*. In derivational terms, the fact that a coda assigns stress even if deleted in the surface produces *opacity*. The following derivation shows the proposed ordering between stress assignment and the coda condition in [maˈpo] 'clay' and [ˈmapo] 'head', a minimal pair differing only in stress. The word [ˈmapopan] 'clay (subject)' provides evidence that there is an underlying final /p/ in [maˈpo] 'clay'.

(23) Derivation of [maˈpo] 'clay', [ˈmapopan] 'clay (subject)', and [ˈmapo] 'head'

UR	/mapop/	/mapop-an/	/mapo/
STRESS ASSIGNMENT	ma(ˈpop)	(ˈmapo) pan	(ˈmapo)
CODA CONDITION	ma(ˈpo)	________	______
SR	ma(ˈpo)	(ˈmapo) pan	(ˈmapo)

---

[8] Nasals are allowed in coda before a [-continuant] segment. In all other cases, the nasal is not pronounced. For further details see Loos 1969.

The rule-based approach towards opacity is called into question by advances in phonological theory such as Optimality Theory (Prince and Smolensky 1993). Another possible approach to explain opacity is that stress is lexical; however, stress is predictable from the (underlying) coda consonant in this language. Alternatively, the output structure might contain unpronounced structure. An input like /mapop/ maps to an output [maˈpo], where the last syllable is footed in apparent violation of footing structure in Capanahua. *Turbidity* (Goldrick 2000, Goldrick and Smolensky 2000) was proposed as a possible way to handle these types of cases.[9] Turbidity states that some outputs have a covert or 'turbid' structure, and that any unpronounced material can influence the pronunciation of other parts of the output (Goldrick 2000). The idea is that there is a single but complex output representation rather than intermediate stages in a derivation.

Turbidity includes two types of output associations: projection, and pronunciation. Projection is a structural or abstract relation between a segment/feature in the output with respect to its input. Pronunciation is an output relation describing the surface realization of the structure. Projection is represented in Goldrick 2000 with an upward-pointing arrow ↗, while pronunciation is indicated with a downward-pointing arrow ↘. When both pronunciation and projection hold, a solid line | is used. In this paper I use a simpler representation. I indicate segments not pronounced but present in the output within angle brackets <> (see (24)) – as in containment theory (Prince & Smolensky 1993). Pronounced output segments lack angle brackets. Additionally, moraic consonants are indicated with the symbol μ.[10]

(24) /maˈpop/→ [ma (ˈpo<p>)] Where <p> is not pronounced
| |
μ μ but projects a mora

The constraints needed to capture opacity are shown in (25).

(25)	**CODA CONDITION:**	Do not pronounce a coda consonant unless it is a coronal continuant sibilant (González 2001)
	PRONOUNCE-μ:	All moras must be Pronounced (Goldrick 2000)
	PROJECT WBP:	All codas must Project their own mora (based on Goldrick 2000, Hayes 1989, Sherer 1984)
	Reciprocity^{X}Y:	$(R\ ^{X}Y)$ If Y projects to X, then X must pronounce Y (Goldrick 2000)

Project WBP is equivalent to WBP and will replace it from here on. I propose the Coda Condition as a tentative and descriptive undominated constraint; it outranks Max-IO, as Tableau 12 shows. There is no direct evidence about the ranking of Max-IO and Project WBP, so I assume they are equally ranked. These constraints are respected at the expense of Pronounce-μ and Reciprocity.

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[9] Another alternative to handle opacity cases is Sympathy Theory (McCarthy 1998, 1999).

[10] I assume that vowels project moras, but I won't represent them in the outputs for simplicity.

Tableau 12: Coda Condition>>Max-IO

/mapop/ 'clay'	CODA CONDITION	MAX-IO
a.ma ('pop)	*!	
☛ b. ma (' po)		*

Tableau (13) shows the best possible output candidates for /mapop/ 'clay'. The undominated constraint Foot-Bin-μ is also included in the comparison among the different candidates. Candidate (a) is the actual winner, since it has an unpronounced coda consonant projecting a mora, and thus violates low-ranked Pronounce-μ and Reciprocity. Candidates (b, c, d, e, h, i) fall out under undominated Foot-Binarity-μ and/or Coda Condition. Candidate (f) shifts the stress to the first syllable, parsing the two syllables into a foot and deleting the coda consonant. This constitutes a violation of Max-IO, so the candidate loses. Finally, candidate (g) violates Project-WBP, since its coda consonant is non-moraic and stress has shifted to the first syllable. Note that a comparison among candidates (f), (g) and (a) show that Max-IO and Project-WBP outrank both Pronounce-μ and Reciprocity.

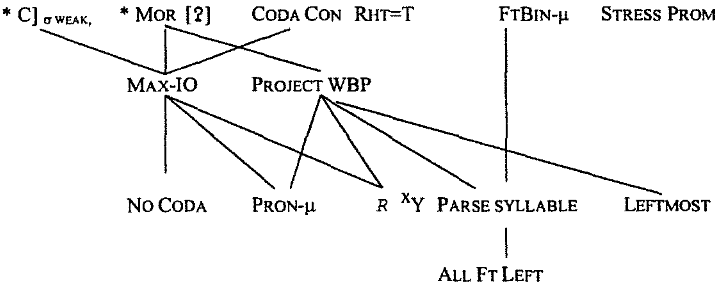
Tableau 13: /mapop/ 'clay'

/mapop/ 'clay'	FT-BIN-μ	CODA COND	MAX-IO	PROJECT WBP	PRON-μ	*R* ^{X}Y
☛a.ma('po<p>) | μ					*	*
b.ma(' po<p>)	*!			*		
c. ma (' pop) | μ		*!				
d. ma (' pop)	*(!)	*(!)		*		
e. ma (' po)	*!		*			
f. (' mapo)			*!			
g.(' mapo<p>)				*!		
h.(' mapo<p>) | μ	*!			*	*	*
i. (' mapop)		*!		*		

A diagram of the ranking among all constraints discussed is provided in figure (1) below. So far I have provided an OT analysis of the foot and stress system of

Capanahua, including opaque effects between stress and the coda condition. This is an improvement over previous accounts, which failed to make a connection between foot structure and stress opacity in Capanahua.

Figure 1: Constraint diagram



5. Apparent counterexamples

In previous sections it has been shown that glottal stop distribution is consistent with foot structure in Capanahua. A question is whether counterexamples exist. In fact, there are two cases which could be considered to go against the generalization that coda [ʔ] remains in unfooted or strong position but not in weak syllables.

First, some suffixes always keep their glottal stop, no matter their position in the word (Loos 1969 & p.c.). This is a problem for a foot structure analysis, because in this case the glottal stop would surface not only in strong syllables, but also in weak syllables. This is also problematic for an odd/even alternation as well, since a coda [ʔ] would be allowed not only in odd-numbered positions, but also in even-numbered positions. The suffix suffix /ʂaʔn/ *future subjunctive* keeps its glottal stop in both strong and weak position (26b and c respectively).

(26) Apparent counterexample I

a)	/ʂaʔn/	[ʂaʔ]	*Future subjunctive*
b)	/ka tan ʂaʔn wɯ/	[ka (ˈta) (ʂaʔ.wɯ)]	'Go over there sometime soon'
	go-there-future subjunctive-imperative		
c)	/wɯ ɾa ja ʂaʔn wi/	[(ˈwɯ.ɾa) (ja.ʂaʔ) wi]	'Push it sometime'
	push-future subjunctive-imperative		

The solution to this problem draws on the opacity of stress in Capanahua. As seen before, outputs in Capanahua are complex, and the interaction between constraints enforcing deletion of segmental material and constraints enforcing projection of moraic consonants generally resolves in mora projection of coda consonants. Thus, for the future subjunctive suffix /ʂaʔn/, the /n/ projects a mora in the output; the output representation for this suffix would be [ʂaʔ<n>]. As a consequence, /ʂaʔn/ is a foot on its own. No matter its position in the word, this suffix is always heavy, and the glottal stop will be always kept because /ʂaʔn/ will always be a strong position. The revised footing and output structure for this suffix is provided in (27).[11]

(27) Revised footing for /ʂaʔn/

a) /ʂaʔn/ [ʂaʔ<n>] *Future subjunctive*
b) /ka.tan.ʂaʔn.wɯ/ [ka (ˈta [n]) (ʂaʔ<n>) wɯ]
go-there-future subjunctive-imperative ‘Go over there sometime soon’
c) /wɯ.ɾa.ja.ʂaʔn.wi/ [(ˈwɯ.ɾa) ja (ʂaʔ<n>) wi]
push-future subjunctive-imperative ‘Push it sometime’

Second, in some suffixes the glottal stop appears to delete in strong position (Loos 1969 and p.c). Consider the examples below.

(28) Apparent counterexample II

a) /ni.tʃi/ [(ˈni.tʃi)] ‘To walk’
b) /βe + ni.tʃi/ [(ˈβe.ni) tʃi] ‘To walk on the surface’
c) /nitʃ + we/ [(ˈniʔ.we)] ‘Walk(imperative)’
d) /βe + nitʃ + ɾiʔβi/ [βe (ˈni)(ɾiʔ.βi)] ‘To walk on the surface again’
surface -to walk-again

(28a, b) show that ‘walk’ has /tʃ/ in the input, and that it is kept as an affricate in onset. (28c) shows that /tʃ/ has a glottal stop allophone in coda position. Note that this derived [ʔ] is kept in strong position in a foot in this case. (28d) is puzzling. The syllable with the input /tʃ/ is stressed, which means that it forms its own foot; however, the [ʔ] that would be expected as an allophone of /tʃ/ does not occur.

Under a rule-based approach, this is not problematic; [ʔ] is not pronounced in precisely the second position in the word, an even position. Derivationally, after stress assignment, an affricate in coda position turns into a glottal stop, and then the glottal stop falls to the glottal stop deletion rule, as (29) shows.

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[11] However, when such a suffix precedes a vowel, the final consonant of the suffix resyllabifies as an onset. This happens to the final /k/ of the future indicative /ʂiʔk/ in examples like /βana+ʂiʔk+i/ [(ˈβa.na) (ʂiʔ.ki)] ‘Will cause to plant’ (cf. with /ʔaʔno+ʂiʔk/ [(ˈʔaʔ.no) ʂiʔ] ‘Will do’). My analysis in terms of mora projection by the final consonant is problematic in such cases, since onsets do not project moras, and [ʔ] still surfaces in such suffixes. It is plausible that in these and other cases, morpheme alignment to foot boundaries is enforced. I leave this matter for further investigation.

(29) Derivation of [niʔ.we] 'Walk!' and [βeˈni. ɾi tʃ.βi] 'To walk on the surface again'

UR	/nitʃ we/	/βe nitʃɾitʃβi /
STRESS ASSIGNMENT	ˈnitʃ.we	βe ˈnitʃ.ɾi tʃ.βi
CODA / tʃ/→ [ʔ]	ˈniʔ.we	βe ˈniʔ.ɾiʔ.βi
CODA [ʔ] DELETION (EVEN)	_______	βe ˈni.ɾiʔ.βi
SR	[ˈniʔ.we]	[βe ˈni.ɾiʔ.βi]

Under a foot structure analysis, the absence of [ʔ] in strong positions such as in (28d) is problematic. This example then appears to support the claim that [ʔ] distribution relates to an odd/even generalization rather than to foot structure (Loos 1969). However, this apparent contradiction occurs only when an input /tʃ/ is involved. Consider the case of the suffix /ɾiʔβi /, a lexicalized combination of [ɾitʃ] 'yet' and emphatic [βi] (Loos, p.c.); again, this suffix involves an input /tʃ/.

(30) Suffix /ɾiʔβi / 'again'

a) /his + ɾitʃ.βi +we/ [his (' ɾi) (βi.we)]
to look-again-imperative 'Look again'

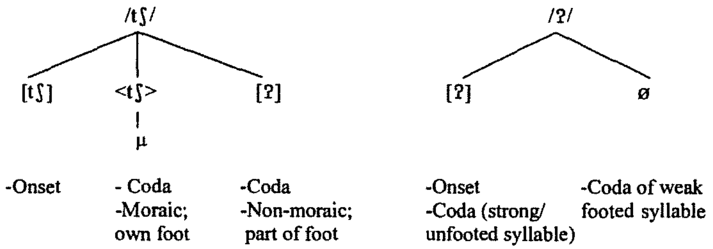
b) / βe +his + ɾitʃ.βi +we/ [βe (' is) (ɾiʔ.βi) we]
face-to look-again-imperative 'Look him in the face again'

c) /nitʃ + ɾitʃ.βi +we/ [niʔ (' ɾi) (βi.we)]
to walk-again-imperative 'Walk again'

As seen before, coda affricates are disallowed in Capanahua. It seems that there is a conflict for /tʃ/ between mora projection and pronunciation of its segmental content. /tʃ/ either projects a mora or turns into a glottal stop. When /tʃ/ projects a mora, as in (30a), no consonant is pronounced, but the syllable forms its own foot. If /tʃ/ turns into a glottal stop, the syllable is part of a bigger foot (30b). When exactly each of this occurs is a matter still under investigation. One possibility is that stress and footing factors are responsible for this split.

There are then two different types of glottal stop in Capanahua. One is phonemic; it is present in the input, and it is pronounced everywhere except in coda of a weak syllable in a foot. The second is an allophone of /tʃ/ and it is found in coda of certain syllables (see figure 2 below). Considering both instances of the glottal stop as similar explains the generalization that the glottal stop occurs in odd-numbered positions only. Separating both cases, the connection between foot structure and glottal stop deletion is clearly seen. However, the problematic case of allophonic [ʔ] remains to be studied further.

Figure 2: Allophones of /tʃ/ and /ʔ/ in Capanahua



6. Conclusion

This paper has shown that the previous description of glottal stop deletion in Capanahua as an alternate-timing effect actually reflects an epiphenomenon of a foot-conditioned process. Coda [ʔ] delete in weak syllables within a foot in order to make weak syllables weaker. The glottal stop does not delete in unfooted syllables since the strong/weak contrast is not relevant in such positions. The fact that [ʔ] has this function is related to its placeless nature and the fact that it is not moraic.

It has also been shown that Capanua is a moraic trochee system, and that the thorny question of opacity between stress and coda consonants can be explained through the idea of complex outputs (Turbidity). It is precisely the analysis of Capanahua as an opaque moraic trochee system which is needed before tackling the issue of glottal stop deletion as a foot structure phenomenon.

A foot structure analysis of [ʔ] deletion in Capanahua has two main advantages over an odd/even alternation analysis. First, the foot structure analysis obtains both the distribution of coda glottal stop and the stress system of the language. Second, together with the turbidity approach, the foot structure analysis explains apparent counterexamples of the distribution of [ʔ] in coda position. Remaining questions are the differences between the phonemic and allophonic glottal stop and the absence of hypothetical crucial forms to distinguish between a footing and an odd/even alternation analysis. Further research includes other so-called alternate-timing processes in related Panoan languages, such as plosive nasal release in even-numbered syllables in Amahuaca and vowel harmony in even-numbered syllables in Shipibo (Loos 1979:149-150, 1999: 232-234), and a cross-linguistic examination of foot-conditioned phenomena.

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