

Post Obstruent Tensification in Korean¹

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0. Introduction

Coda Neutralization (CN) and Post Obstruent Tensification (POT) are well studied phenomena in Korean Phonology (Avery and Idsardi 2001; Clements and Hume 1995; Kim-Renaud 1974; Lee 1997; Shin 2001; Silva 1992; Sohn 1987; Tak 1997; among others). However, most previous studies treated CN and POT separately. This study aims to show the phonetic evidence that unreleased consonants are glottalized in Korean, and to explain a close relationship between CN and POT: glottalization of unreleased consonants in coda spreads to onset of the following obstruent, i.e., an assimilation of constricted glottis. The Aperture Theory (Steriade 1993) is adopted to present a clear distinction between released and unreleased stops, which is crucial to the analysis of the present study. A formal account of CN and POT is proposed within the framework of Optimality theory (Prince & Smolensky 1993; McCarthy & Prince 1993, 1995) to provide a unified analysis of CN and POT.

This paper is structured as follows. Section 1 provides background information such as the Korean consonant inventory and the Aperture Theory (Steriade 1993). The phonological representations of Korean consonants are proposed with the Aperture nodes. Section 2 presents my analysis of CN within the framework of OT. In section 3, I propose an analysis of POT as an assimilation process. Section 4 concludes the paper.

1. Background Information

1.1. Korean Obstruents

Korean shows a three-way contrast in phonation among the stops and affricates: plain, aspirated and tense, and the fricative /s/ shows a two-way distinction: plain and tense (See Consonant Inventory in 1). All consonants in the inventory except /ŋ/ appear in syllable-initial position. There are stronger restraints on what consonants can come in syllable-final position. In orthography, all obstruents except /p/, /t/ and /c/ can occur in syllable-final position, but only [p[̚]], [k[̚]] and [t[̚]] are realized phonetically. This restriction on what obstruents can occur phonetically in syllable-final position causes obstruents to be altered in both manner and place of articulation, which will be closely discussed in Section 2. All nasals and the lateral occur in coda position.

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(1) Korean consonant inventory

		Bilabial	Alveolar	Palatal	Velar	Glottal
Stop	Plain	p	t		k	
	Tense	p'	t'		k'	
	Aspirated	p ^h	t ^h		k ^h	
Affricate	Plain			c ²		
	Tense			c'		
	Aspirated			c ^h		
Fricative	Plain		s			h
	Tense		s'			
Nasal		m	n		ŋ	
Liquid			l			

1.2 Aperture Theory (Steriade 1993)

In order to represent closure and release, a binary feature [+/- release] has been adopted by some phonologists (Kim-Renaud, 1974; Lee, 1997 etc). Alternative to this is Aperture theory of Steriade (1993). Steriade represents phonetic gestures such as closure and release in terms of aperture nodes in the phonology. Her study is based on the hypothesis that the stop closure followed by a release may be identical in structure to the aperture position carried by an approximant or a fricative. Stops and affricates have two aperture nodes, one representing the closure, and the other the release. Continuants, on the other hand, have only a single node. According to her theory, A_0 represents full closure, total absence of oral airflow, A_f stands for intermediate aperture such as that found in a fricative, and A_{max} is maximal aperture. Given these definitions, the representations of released stops, unreleased stops, affricates, approximants, and fricatives are obtained as in (2).

- (2)
- a. Released stops: A_0A_{max}
 - b. Unreleased Stops: A_0
 - c. Affricates: A_0A_f
 - d. Approximants: A_{max}
 - e. Fricatives: A_f

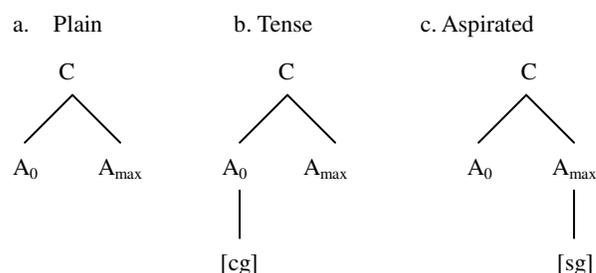
² I use [c] as IPA [tʃ] following a number of Korean linguists (Kang 1999, Kim Renaud 1974, Lee 1997, Lee 1999 among others). [c] has been used to indicate a voiceless palatal affricate in Korean in order to emphasize that it is a single phoneme and due to typographic simplicity, even though [c] stands for a voiceless palatal stop in the IPA.

As can be seen in (2a) and (2b), released and unreleased stops show a clear distinction: unreleased stops are represented as a simple closure A_0 without release while released stops have a closure A_0 with a release feature A_{max} .

1.3 Phonological Representation of Korean stops

Assuming that Korean obstruents have a three-way distinction underlyingly and that tense consonants are singleton rather than geminate (see Lee 2004 for details), I propose the phonological representations of Korean consonants using Aperture Theory as in (3)

(3) Phonological Representation of Korean consonants.



Notice that the feature [cg] is aligned under the closure portion of the segment. As Korean tense stops are characterized by glottal tension on the closure portion of the segment, rather than release (Martin, 1974)³, aligning [cg] under the closure is more plausible.

2. Coda Neutralization

The three-way laryngeal contrast in obstruents in Korean is neutralized in the coda. The labial and velar stops are always neutralized to their unreleased counterparts [p[̚]] and [k[̚]] respectively, losing their laryngeal distinction. All coronal obstruents are neutralized to unreleased [t[̚]] regardless of whether they are stops, fricatives or affricates. It is difficult to account for a Coda Neutralization (CN) in a uniform way because the CN in Korean involves changes of the place of articulation in the case of affricates as well as neutralizing laryngeal distinctions. The data in (4) show how the obstruents are neutralized.

- (4) a. Labial stops are neutralized to the unreleased [p[̚]].
- | | | |
|--------------------|---------------------|----------------|
| /pap/ | [pap [̚]] | 'steamed rice' |
| /ip ^h / | [ip [̚]] | 'a leaf' |
- b. Velar stops are neutralized to the unreleased [k[̚]].
- | | | |
|----------------------|----------------------|---------------------|
| /pak/ | [pak [̚]] | 'gourd' |
| /nyek ^h / | [nyek [̚]] | 'around (the time)' |
| /pak'/ | [pak [̚]] | 'outside' |

³ Keating (1990) points out that unlike the [+sg] which aligns with the release portion, [+cg] can align only with a closure as in the case of English syllable-final voiceless stops which have glottal constriction.

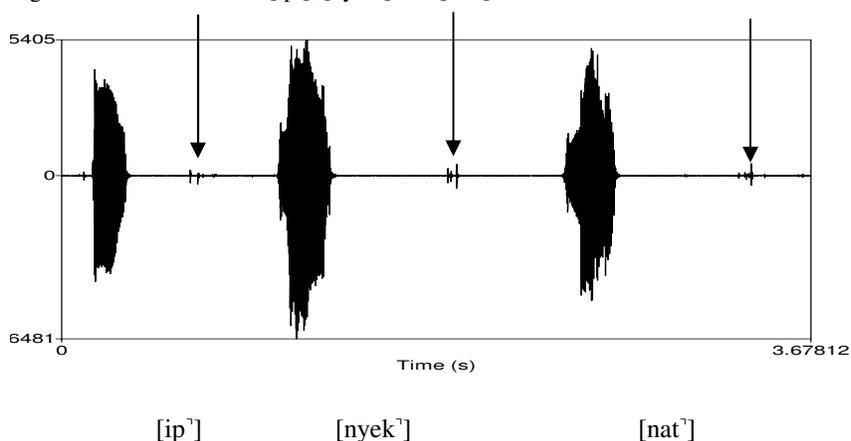
- c. Coronal stops are neutralized into [t̚].
 /kot/ [kot̚] 'instantly'
 /k'itʰ/ [k'it̚] 'a point'
- d. Affricates are neutralized into [t̚].
 /nac/ [nat̚] 'day'
 /nacʰ/ [nat̚] 'face'
- e. Fricatives are neutralized into [t̚].
 /nas/ [nat̚] 'sickle'
 /kas/ [kat̚] 'to go (past)'

2.1 Glottalization of unreleased consonants

Researchers agree that the neutralized consonants in Korean are unreleased (Kim-Renaud, 1974; Silva, 1992; Shin, 2001 among others). The glottalization of these unreleased consonants, however, is controversial. Using phonetic evidence from Sawashima & Park (1979), Kim (1983) argued that these consonants are glottalized. Kim further states that the glottalization of these unreleased stops involves the feature [constricted glottis], and states that this feature spreads to the following onset obstruent, resulting in Post Obstruent Tensification. Baek (1991) and Lee (1997) also assert that Korean unreleased obstruents are glottalized and Lee (1997) represents this with the feature [+Constricted Glottis].

In order to see whether unreleased stops are glottalized, a very preliminary experiment was conducted by recording the data in (4) with my own pronunciation and the data were analyzed with Praat created by Pau Boersma and Weenink. The waveforms in figure 1 show oral closure followed by spread out pitch pulses (shown by arrows in Figure 1), which is indicative of creakiness, an acoustic cue for the presence of glottal stop (Vayra, 1994; Stevens et al., 2002⁴). I maintain that the Korean unreleased stops [p̚], [k̚] and [t̚] as in [ip̚], [nyek̚] and [nat̚] are glottalized.

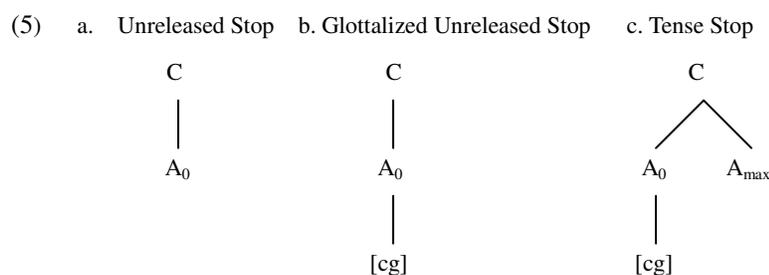
Figure 1. Waveforms for [ip̚], [nyek̚] and [nat̚]



⁴ Vayra (1994) relied on creak as an acoustic cue for the presence of a glottal stop following word-final stressed vowels in phrase-final position. Stevens et al. (2002) also reported that the phrase-final glottalization in Italian accompanied creak.

The glottalization of unreleased final stops is also found in English. Kahn (1976) observes that the English /t/ is unreleased when it is followed by vowels or sonorants as in the case of ‘mat’ and ‘heart’⁵. Cohn (1990) also reports that glottalization is present when the English /t/ is syllable-final.

Unlike the glottalization of the English syllable-final unreleased [t[̚]], the case of the Korean syllable-final unreleased obstruents is complicated because we need to account for syllable-final neutralization as well as glottalization. A natural solution to this problem can be found by adopting the Aperture node model of Steriade. I represent the glottalized and unreleased stops as in (5).



I assume that delinking the release node (i.e. A_{\max} , A_f) triggers neutralization. For example, by delinking A_{\max} in (5c), neutralized unreleased stop is represented with only closure node A_0 as shown in (5b). I presume that (5a) does not occur phonetically in Korean as unreleased stops are glottalized. (5b) and (5c) show a clear difference between glottalized unreleased stops and tense stops; both are glottalized, but tense stops in Korean, which never occur in coda position, are always released. [constricted glottis] under the A_0 node (closure) indicates that an unreleased segment is glottalized. One advantage of above presentation is that it shows that the glottalized unreleased stops have a laryngeal feature. However, the Aperture node representations do not show the changes of places and manners of articulation of coda consonants. In order to complement this defect, the analysis within the Optimality Theory is provided.

2.2 Optimality Theory Account

I account for the CN of obstruents as an interaction between two families of constraints which are revised from Lee (1997). The CODA constraints in (6) trigger a change to the input if they dominate the relevant FAITHFULNESS constraints in (7). Therefore, the ranking shown in (8) forces consonants to be realized as unreleased and glottalized.

⁵ According to Kahn, only the unreleased /t/ is glottalized, and /k/ and /p/ as in ‘Mac’ and ‘map’ are released and not glottalized.

(6) CODA constraints

a. CODA condition : Obs]σ

$$\begin{array}{c} \text{Obs]}\sigma \\ | \\ A_0 \end{array}$$

Coda obstruents must be unreleased.

b. A_0]σ

$$\begin{array}{c} A_0]\sigma \\ | \\ [\text{cg}] \end{array}$$

Unreleased stops in codas must dominate [cg]

(7) FAITHFULNESS constraints

a. MAX-IO (A_{max}): Every A_{max} in the input has a correspondent in the output.

b. MAX-IO (A_i): Every A_i in the input has a correspondent in the output.

c. DEP-IO ([cg]): Every [cg] in the output has a correspondent in the input

(8) CODA constraints >> FAITHFULNESS constraints

With these constraints, I illustrate the account of neutralization of stops, for instance 'pap/ → [pap[̚]] 'steamed rice' in data (4) as shown in Tableau (9).

(9) Input: pap]σ

$$\begin{array}{c} \wedge \\ A_0 \quad A_{\text{max}} \end{array}$$

Candidates	CODA con	A_0 [cg]	MAX (A_{max})	DEP ([cg])
a. [pap] $\begin{array}{c} \wedge \\ A_0 \quad A_{\text{max}} \end{array}$	*!	*		
b. [pap [̚]] $\begin{array}{c} \\ A_0 \end{array}$		*!	*	
^{LS} c [pap [̚]] $\begin{array}{c} \\ A_0 \\ \\ [\text{cg}] \end{array}$			*	*

(9a) is faithful to the input, fatally violating CODAcon which prohibits the release feature in the coda. (9b) satisfies CODAcon, but it violates the A_0 -[cg] as the syllable-final A_0 is not aligned with [cg]. (9c) comes out victorious at the expense of violating the lower-ranked faithfulness constraints in the low-ranked in the hierarchy.

As can be seen in data (4e), fricatives /s/ and /s'/ are neutralized into the unreleased [t[̚]]. If the airflow has stopped while articulating fricatives, they end up as the unreleased stop [t[̚]], which has the same place of

articulation as [s]. Thus, delinking A_f results in an unreleased stop by default. The datum ‘/nas/ → [nat̚]’ ‘sickle’ in (4e) can be accounted for as illustrated in (10).

In the tableau below, (10a) crucially violates CODA constraints. (10b) satisfies CODAcon, but it violates A_0 -[cg] failing to assign [cg] to the unreleased consonant. (10c) only violates the low-ranked faithfulness constraints.

(10) Input: nas]σ
 \downarrow
 A_f

Candidates	CODA con	A_0 [cg]	MAX (A_f)	DEP (A_0)	DEP ([cg])
a. [nas] \downarrow A_f	*!	*			
b. [nat̚] \downarrow A_0		*!	*	*	
1.5c [nat̚] \downarrow A_0 \downarrow [cg]			*	*	*

A more elaborated account is needed for analyzing CN of affricates since affricates involve a change of the place of articulation (i.e. /c/ and /c^h/ are realized as [t̚]). I propose a constraint *C]σ - [-ant] shown in (11) and a FAITHFULNESS constraint MAX-IO ([-ant]) in (12) in order to forbid palatal stops, which do not exist in Korean, to be realized as an optimal output.

(11) *C]σ
 \downarrow
 [-ant]

Coda consonants must not be [-anterior].

(12) MAX-IO ([-ant]): Every([-ant]) in the input has a correspondent in the output.

With this constraint, ‘/nac/ → [nat̚]’ ‘day’ in (4d) can be achieved as in the tableau below.

(13) Input: /nac/
 $\swarrow \searrow$
 $A_0 \quad A_f$

Candidates	CODA con	A ₀ [cg]	*C]σ [-ant]	MAX (A _f)	MAX ([-ant])	DEP ([cg])
a. [nac] A ₀ A _f	*!	*	*			
b. [natʰ] A ₀		*!		*	*	
c. [natʰ] A ₀ [cg]				*	*	*
d. [nacʰ] A ₀ [cg]			*!	*		*

(13a) violates the CODA constraints which are high-ranked in the hierarchy, thus it is ruled out. (13b) satisfies *C]σ – [-ant] as palatal consonant becomes alveolar, but it violates higher ranked A₀-[cg] which requires glottalization. (13d) satisfies the dominant constraints, but it is ruled out violating *C]σ – [-ant]. (13c) is an optimal output at the expense of violating faithfulness constraints.

3. Post Obstruent Tensification

Tensification, in general, refers to the phenomenon in which plain consonants /p, t, k, c, s/ are changed into tense consonants [pʰ, tʰ, kʰ, cʰ, sʰ] after an obstruent, a nasal, or a lateral. Tensification is classified into Post Obstruent Tensification (POT), Post Nasal Tensification (PNT), and Post Lateral Tensification (PLT), depending on the consonant before the plain obstruent. PNT and PLT require morphological structure (Lee 1997; Shin 2001; Sohn 1987). This study investigates only POT as it applies across the board without reference to any morphological conditioning. I argue that tensification of the plain obstruents in syllable-initial position is triggered by the addition of [cg] to the preceding syllable-final obstruent after neutralization. In other words, POT is an assimilation process in which an obstruent in onset obtains the feature [constricted glottis] from the unreleased consonant in a preceding coda.

As can be seen in (14), tensification occurs after stops, affricates, and fricatives. Preceding coda consonants are unreleased losing their laryngeal distinction.

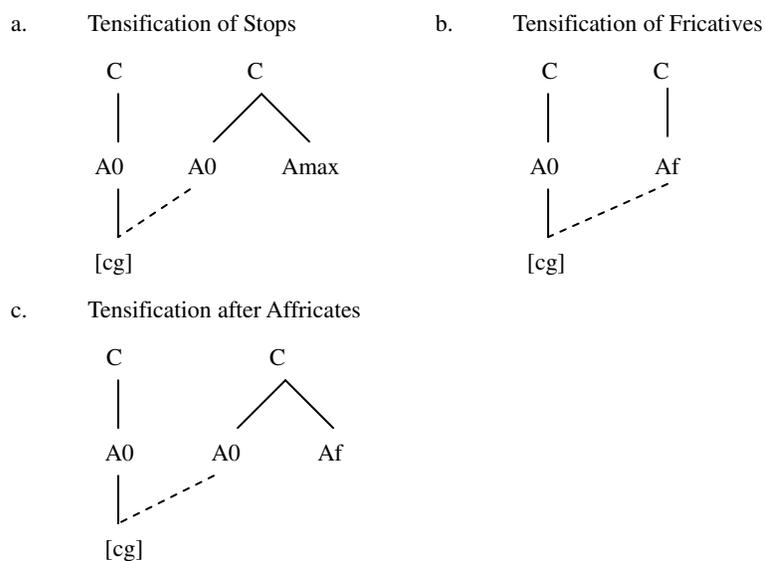
- (14) a. Tensification after labial stops
 /ip .sul/ [ipʰ .sʰul] 'lips'
 /ipʰ .kwa/ [ipʰ .kʰwa] 'a leaf and'
- b. Tensification after velar stops
 /pak .si/ [pakʰ .sʰi] 'gourd seed'
 /pu.əkʰ .kwa/ [pu. ə kʰ .kʰwa] 'kitchen and'

	/pak' . kwa/	[pak'.k'wa]	'outside and'
c.	Tensification after coronal stops		
	/kot . caŋ/	[kot'.c'aŋ]	'instantly'
	/k'it ^h .caŋ/	[k'it'.c'aŋ]	'end'
d.	Tensification after affricates		
	/nac.pam/	[nat'.p'am]	'day and night'
	/nac ^h .kwa/	[nat'.k'wa]	'face and'
e.	Tensification after fricatives		
	/nas.cil/	[nat'.c'il]	'sickling'
	/kas.ta/	[kat'.t'a]	'went'

3.1 Representations of Tensification (Aperture Node)

I claim that POT is a result of an assimilation of the glottalization which results from the coda neutralization. The relation between CN and POT is well captured by the representations of Tensification using Aperture Nodes in (15): The feature, constricted glottis of the neutralized consonant in coda position spreads to the following onset. In other words, Post Obstruent Tensification is the result from glottalization of the preceding unreleased obstruent.

(15) Representation (Aperture node)



3.2 Optimality Theory Account

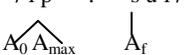
In order to show the assimilation process within the framework of Optimality Theory, I propose a constraint, SHARE (Laryngeal node) in (16).

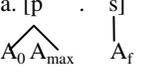
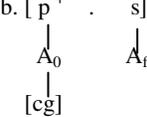
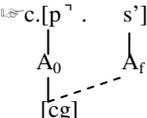
- (16) SHARE (laryngeal node)⁶
Adjacent obstruents share laryngeal features.

In addition to the constraints for accounting for CN in the previous section, SHARE (Laryngeal node) allows the feature [cg], in the glottalized coda, to spread to a following obstruent. Abiding by this constraint, the obstruent in the onset is realized as tense, obtaining its tenseness from the preceding neutralized consonant. SHARE (laryngeal node) must dominate faithfulness constraints as shown in (17).

- (17) CODA CONSTRAINTS, SHARE (laryngeal node) >> FAITHFULNESS CONSTRAINTS

With these constraints and the ranking, the datum (14a) /ip.sul/ → [ipˀ.sʰul] ‘lips’ can be accounted for as in tableau (18)

- (18) Input: / i p . s u l /


Candidates	CODA con	A ₀ [cg]	SHARE (lary)	MAX (A _{amx})	DEP ([cg])
a. [p . s] 	*!	*			
b. [pˀ . s] 			*!	*	*
c. [pˀ . sʰ] 				*	*

Candidate (18a) is faithful to the input, crucially violating CODAcond whose effect is to forbid the release feature in syllable-final position. (18b) satisfies two higher-ranked constraints for CN, but it is excluded as it violates SHARE (lary). (18c) emerges as the optimal output through the evaluation procedure: the coda-onset cluster shares the [cg] at the expense of violating the faithfulness constraints.

With respect to the tensification after fricatives, I assume that DEP-IO(A₀) is low-ranked in the hierarchy. Other than that, the evaluation procedure is the same as the tableau in (18).

⁶ In the same vein, Pulleyblank (1997) proposed IDENTICAL CLUSTER CONSTRAINTS, which requires identical featural properties of consonant clusters.

(19) /nas/ + /cil/

$\begin{array}{c} \text{A}_f \\ | \\ \text{[s]} \end{array}$ + $\begin{array}{c} \text{A}_0 \text{ A}_f \\ \diagdown \quad / \\ \text{[c]} \end{array}$

Candidates	CODA con	A ₀ [cg]	SHARE (Lary)	MAX (A _f)	DEP ([cg])	DEP (A ₀)
a. $\begin{array}{c} \text{[s]} \quad \text{[c]} \\ \text{A}_f \quad \text{A}_0 \text{ A}_f \end{array}$	*!	*				
b. $\begin{array}{c} \text{[t}^\text{h}] \quad \text{[c]} \\ \text{A}_0 \quad \text{A}_0 \text{ A}_f \\ \text{[cg]} \end{array}$			*!	*	*	*
20c. $\begin{array}{c} \text{[t}^\text{h}] \quad \text{[c']} \\ \text{A}_0 \quad \text{A}_0 \text{ A}_f \\ \text{[cg]} \end{array}$				*	*	*

In order to analyze the tensification after affricates such as /nac/+pam/ → [nat^h.p'am] 'day and night' in data (14d), ranking *C]σ – [-ant] over MAX ([-ant]) is necessary as shown in (19).

(19) CODAcon, A₀-[cg] >> *C]σ – [-ant], SHARE (laryngeal node) >> FAITHFULNESS constraints

In the Tableau below, the candidate (20c) comes out victorious at the cost of the faithfulness constraints.

(20) Input: /nac/ + /pam/

$\begin{array}{c} \text{A}_0 \text{ A}_f \\ \diagdown \quad / \\ \text{[n]} \end{array}$ + $\begin{array}{c} \text{A}_0 \text{ A}_{\text{max}} \\ \diagdown \quad / \\ \text{[p]} \end{array}$

Candidates	CODA con	A ₀ [cg]	*C]σ [-ant]	SHARE (lary)	MAX (A _f)	MAX ([-ant])	DEP ([cg])
a. $\begin{array}{c} \text{[c]} \quad \text{[p]} \\ \text{A}_0 \text{ A}_f \text{ A}_0 \text{ A}_m \end{array}$	*!	*	*				
b. $\begin{array}{c} \text{[t}^\text{h}] \quad \text{[p]} \\ \text{A}_0 \quad \text{A}_0 \text{ A}_m \\ \text{[cg]} \end{array}$				*!	*	*	*
20c. $\begin{array}{c} \text{[t}^\text{h}] \quad \text{[p']} \\ \text{A}_0 \quad \text{A}_0 \text{ A}_m \\ \text{[cg]} \end{array}$					*	*	*
d. $\begin{array}{c} \text{[c}^\text{h}] \quad \text{[p']} \\ \text{A}_0 \quad \text{A}_0 \text{ A}_m \\ \text{[cg]} \end{array}$			*!		*		*

4. Conclusions

This study has accounted for Post Obstruent Tensification, showing the correlation between Coda Neutralization and POT from the interaction of constraints in the sense of Prince & Smolensky (1993) and McCarthy & Prince (1993, 1995). It is meaningful to capture the correlation between those different phenomena in that a syllable-initial obstruent always undergoes Tensification when following an unreleased obstruent. In this analysis, the language-particular phonological phenomenon, POT receives a very natural account as an assimilation process.

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