

The Necessity of Output-Output Correspondence: Evidence from Tunica

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McCarthy (1999) claims that by adopting ANCHOR (Stem, PrWd) as the selector, Sympathy alone is sufficient for those cases that the O-O faith approach can account for. In this study, I will show that the opacity in Tunica provides strong evidence for the necessity of the O-O faith approach. The targeted opacity effect is observed in the interaction between glottal stop epenthesis and vowel deletion. Tunica does not allow adjacent vowels and deletes one of them. At the same time, to satisfy the onset requirement, glottal stops are epenthesized only in word-initial positions. This opacity is accounted for as the result of reconciliation between the BO-faithfulness requirement and the phonological requirements on outputs. Sympathy fails due to its inability to recognize the morphological structure. Furthermore, I also propose that the constraint *VV is independently motivated and cannot be reduced to some other constraints such as ONSET.

1. Introduction

1.1 *The Aim of the Paper*

In a derivational framework, the analysis of opacity requires rule ordering. This method is not compatible with Optimality Theory in the sense that OT does not allow intermediate representations. Opacity is still a problematic area for OT since classic OT cannot handle all the Opacity Effects. Therefore, OT faces the challenge that it has to find a way to explain Opacity while keeping parallel evaluation.

In this paper, we will look at some opacity effects in Tunica, a Native American language. We will show that, by adopting an Output-Output correspondence approach (O-O faithfulness, Benua 1995), we can explain the relevant phonological opacities. We will also compare O-O faithfulness with the Sympathy approach (McCarthy and Prince, 1999). We will see that Sympathy has some shortcomings in solving relevant problems. Therefore, we will conclude that the O-O approach is superior to the Sympathy approach, with respect to the Opacity Effect in Tunica.

1.2 *Basic Phonology of Tunica*

Tunica is a Native American language once spoken in central Louisiana. No speakers currently remain. (Ethnologue: Languages of the World, 14th Edition).

Before we go into the detailed relevant facts, let us first have a look at the phonetic characteristics of Tunica. The Sound Inventory of Tunica can be summarized as follows:

Consonants

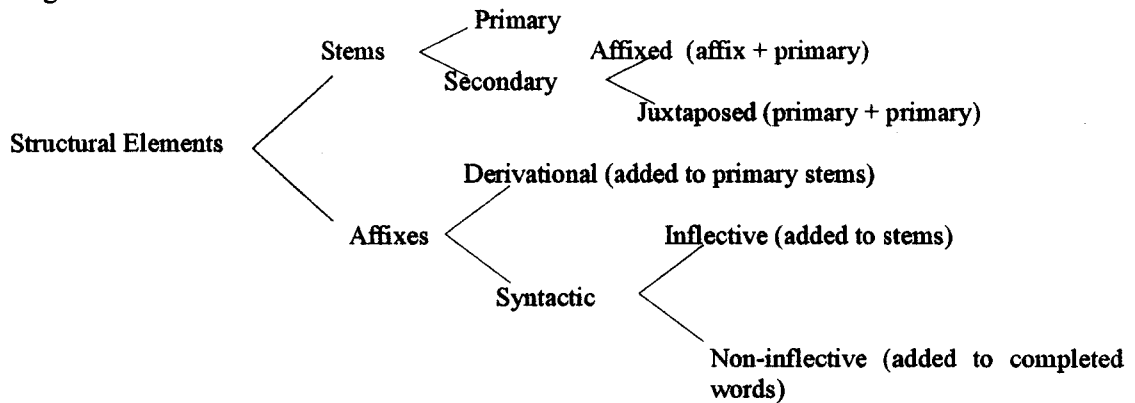
Stops:	p, t, tʃ, k, ?
Fricatives:	s, ʃ, h
Nasals:	m, n
Liquids:	l, r
Glides:	w, j

Vowels¹:

i, u, e, o, a

(Based on Hammond, 1988; Lin 2002)

In Haas (1940), lexical items are categorized as stems and affixes, which are shown in the following diagram:



(Based on the description in Haas, 1940: 35-37)

While the stems must have stress, only certain affixes receive stress. In this paper, I will concentrate on the stress pattern in stems, since they are the ones, which require stress. As we will see in detail later, in some cases, more than one stress can be found in a word. According to Haas, there is no significant difference among those stresses (in one word). In other words, we will not distinguish primary stress from secondary stress. To avoid confusion of terminology, I will adopt Haas' categorization, distinguishing stems and affixes, although they both can be categorized as morphemes. I will use the term 'uncompounded word' for primary stems and 'compounded word' for secondary stems.

2. Output-Output Faithfulness vs. Sympathy

2.1 Stress Patterns in Tunica

2.1.1 Stress Pattern in Uncompounded words

According to Haas (1940), every syllable in Tunica must begin with a single consonant. Furthermore, a word/phrase medial consonant cluster is possible, but may not have more than three consonants. Finally, a phrase final consonant cluster is possible, but may not have more than two consonants. These generalizations suggest that Tunica does not allow complex onsets, but that complex codas are permitted. However, the maximum number of consonants in a complex coda is two.

For uncompounded words, if there is a stress in a primary stem, the first syllable always receives the stress². Furthermore, we also find cases in which, in addition to the initial stress, stress occurs in a later syllable. This pattern can be analyzed as an initial trochee for all words, and a later trochee in the word for some cases. At the same time, the stress assignment is quantity-insensitive. The examples are listed here:

- | | | | | |
|-----|-----|----|-----|----------------------|
| (i) | (σ) | | | |
| | (1) | a. | tʃú | 'to take, to obtain' |
| | | b. | já | 'to do, make' |

¹ For a detailed discussion on mid vowel distribution, see Lin (2002).

² I have to mention that in Tunica, for some bound stems, so-called pre-primo-syllabic stress is assigned. In Haas (1953), the term is employed to describe the case when the bound stem itself does not bare any stress but forces the syllable immediately preceding it to have stress.

(ii)	($\acute{\sigma}\sigma$)			
	(2)	a.	tíra	'cloth'
		b.	?éri	'to lift'
(iii)	($\acute{\sigma}\sigma$) σ^3			
	(3)	a.	híyuhu	'grass'
		b.	lúpiran	'chameleon'
(iv)	($\acute{\sigma}\sigma$)($\acute{\sigma}\sigma$)			
	(4)	a.	ʃílawæya	'tanner'
		b.	rúwifíyu	'bird species'
(v)	($\acute{\sigma}\sigma$) $\sigma\sigma$			
	(5)	a.	-álakafi	'hair of the head'
		b.	páhpahkana	'pleated woodpecker'
(vi)	($\acute{\sigma}\sigma$)($\acute{\sigma}\sigma$) σ			
	(6)		tʃíyatátahka	'lizard species'
(vii)	($\acute{\sigma}\sigma$) $\sigma\sigma\sigma$			
	(7)		wæhatahani	'often, frequently'
(viii)	($\acute{\sigma}\sigma$) σ ($\acute{\sigma}\sigma$)			
	(8)		-étikumáfi	'parent-in-law, child-in-law'

It seems that Tunica is not sensitive to syllable weight. Some other generalizations can be summarized as presented in (9):

- (9)
- a. The first syllable always gets stressed.
 - b. It seems that there exists lexical stress (there is more than one way to stress four and five syllable words).
 - c. If the input does not have a lexical stress, only one stress is assigned.
 - d. The lexical stress is preserved in some cases.

The generalization in (9a) can be qualified in part through the following constraints:

- (10) **ALIGN-Wf-LEFT (ALIGN -Wf-L)**
 The left edge of the word coincides with the left edge of the syllable.
 (after McCarthy and Prince, 1993)

Other generalizations show that we need a set of prosodic constraints to make the stress assignment system work. The following constraints are adopted from Kager (1999):

- (11) **RHTYPE=T (RH-T)**
 Feet have initial prominence.
- (12) **STEM=PRWD (S=Prwd)**
 A stem must be a prosodic word.
- (13) **PARSE-SYL (PAR-S)**
 Syllables are parsed by feet.
- (14) **FOOT-BIN (FT-B)**
 Feet are binary under a syllabic analysis

³ There is only one example for the pattern $\acute{\sigma}\acute{\sigma}$ in Hass (1953):

(i) hkʔihpóta 'to belch'

Notice that this form is also a counter-example for the midvowel distribution.

- (15) **DEP-IO** (DEP)
Every element of the output has a correspondent in the input.
- (16) **MAX-IO** (MAX)
Every element of the input has a correspondent in the output.

We have already established that Tunica is not quantity-sensitive, and because syllabification is relatively straightforward, I will employ abstracted forms instead of real words. I will start with the cases in which lexical stresses are not involved.

Since constraints such as **STEM=PRWD**, **RH-TYPE=T**, and **ALIGN-Wr-L** are never violated, they should be ranked as un-dominated. Tableau (17) shows that **STEM=PRWD** needs to be ranked higher than **FOOT-BIN**:

(17)

/σ/	S=Pwd	RH-T	ALIGN-Wr-L	FT-B
a. σ	*!			
b. <u>σ</u> (σ)				*

At the same time, **DEP-IO** should also be ranked over **FOOT-BIN**, otherwise, impossible candidates such as (σσ) or (σσ) would be allowed to surface (the underlined syllables are epenthetic):

(18) σ = epenthetic syllable

/σ/	S=Pwd	RH-T	ALIGN-Wr-L	DEP	FT-B
a. <u>σ</u> (σ)					*
b. (σ <u>σ</u>)				*!	
c. (σ <u>σ</u>)				*!	

Moving onto three-syllable inputs, we find that to guarantee that the actual output has only one initial stress, we have to rank **FOOT-BIN** over **PARSE-SYL**, as (19) shows. Additionally, the failure of candidates such as (σσ)(σσ) and (σσ)_ in tableau (20) tells us that **DEP-IO** and **MAX-IO** should be ranked higher than **PARSE-SYL**.

(19)

/σσσ/	S=Pwd	RH-T	ALIGN-Wr-L	FT-B	PAR-S
<u>σ</u> (σ <u>σ</u>)σ					*
(σ <u>σ</u>)(σ <u>σ</u>)				*!	

(20)

/σσσ/	S=Pwd	RH-T	ALIGN-Wr-L	DEP	MAX	FT-B	PAR-S
<u>σ</u> (σ <u>σ</u>)σ							*
(σ <u>σ</u>)(σ <u>σ</u>)				*!			
(σ <u>σ</u>)_					*!		

Tableau (22) shows that we need another constraint, namely, **ALL-FT-LEFT**:

- (21) **ALL-FT-LEFT** (A-FT-L)
Every foot stands at the left edge of the PrWd. (Kager, 1999)

(22)

/σσσσ/	S=Pwd	RH-T	ALIGN-Wr-L	DEP	MAX	A-FT-L	FT-B	PAR-S
($\acute{\sigma}\sigma$)($\acute{\sigma}\sigma$)						#!		
σ ($\acute{\sigma}\sigma$) $\sigma\sigma$								**
$\sigma\sigma$ ($\acute{\sigma}\sigma$)			*!			**		**

Now, let us turn to the stems that are assigned lexical stresses. Based on Richness of the Base (Prince and Smolensky, 1993), we cannot predict / restrict the position of the lexical stress. However, we know that the input stress sometimes is preserved⁴, requiring us to adopt the following constraint:

(23) **HEAD-MAX-IO** (= H-MAX-IO)

If $\alpha \in S_1$ is a prosodic head in a word, $\beta \in S_2$ and $\alpha R \beta$, then β is a prosodic head.

(McCarthy, 1995)

If a segment in the input is a prosodic head and this segment stands in correspondence with a segment in the output, the related segment in the output is also a prosodic head.

(Alderete, 1996)

We shall notice that as long as the initial foot is legally established, the lexical stress is preserved. The following hypothetical examples illustrate this observation ($\acute{\sigma}_L$ = lexical stress):

- (24) a. Input: $\sigma(\acute{\sigma}_L\sigma)\sigma$
 Output: $(\acute{\sigma}\sigma_L)(\sigma\sigma)$ * $\sigma(\acute{\sigma}_L\sigma)\sigma$
- b. Input: $\sigma\sigma(\acute{\sigma}_L\sigma)$
 Output: $(\acute{\sigma}\sigma)(\acute{\sigma}_L\sigma)$ * $(\acute{\sigma}\sigma)(\sigma_L\sigma)$
- c. Input: $\sigma\sigma\sigma(\acute{\sigma}_L\sigma)$
 Output: $(\acute{\sigma}\sigma)\sigma(\acute{\sigma}_L\sigma)$ * $(\acute{\sigma}\sigma)(\sigma\sigma_L)\sigma$

We need the following ranking to capture the above data:

ALIGN-Wr-LEFT >> **HEAD-MAX-IO**

(A head may be deleted in order to build an initial foot)

HEAD-MAX >> **ALL-FT-LEFT**

(A head may not be deleted if an initial foot is available)

There are two logical possibilities for the position of the lexical stress in bi-syllabic stems. In the case of $/(\acute{\sigma}\sigma)/$, the current constraints and rankings are sufficient. The tableau in (25) shows the other possibility, $/(\sigma\acute{\sigma})/$. This indicates that **RH-TYPE=T** must dominate **HEAD-MAX**:

(25) $/(\sigma\acute{\sigma})/$ **RH-TYPE=T** >> **HEAD-MAX-IO**

($\sigma\acute{\sigma}_L$)	S=Pwd	RH-T	ALIGN-Wr-L	DEP	FT-B	H-MAX-IO	A-FT-L	PAR-S
($\sigma\acute{\sigma}_L$)		*!						
σ ($\acute{\sigma}\sigma$)								
($\sigma\sigma$)		*!						

Three-syllable inputs such as $\sigma(\acute{\sigma}\sigma)$ further suggest that **FT-BIN** dominates **HEAD-MAX**. The candidate $/(\acute{\sigma})(\acute{\sigma}\sigma)/$ would not surface due to the violation of **FT-BIN**, even though it satisfies **HEAD-MAX-IO**, which tells us that **FT-BIN** is ranked over **HEAD-MAX-IO**:

⁴ We will see later that the stress can be deleted in certain environments.

(26) /σ (σ^σ)/

σ (σ _L σ)	S=Pwd	RH-T	ALIGN-W _T -L	DEP	FT-B	H-MAX-IO	A-FT-L	PAR-S
σ (σ _L σ)			*!				*	*
σ' (σ _L σ)						*		*
(σ)(σ _L σ)					*!		*	

In four-syllable inputs that have lexical stress, the evaluation of the input /σσ(σ^σ)/ in tableau (27) shows that **HEAD-MAX** dominates **ALL-FT-LEFT**:

(27) /σσ(σ^σ)/ **HEAD-MAX >> ALL-FT-LEFT**

σσ(σ _L σ)	S=Pwd	RH-T	ALIGN-W _T -L	DEP	MAX	FT-B	H-MAX-IO	A-FT-L	PAR-S
σσ(σ _L σ)			*!					*	**
σ'(σ _L σ)								*	**
(σσ)σ							*!		**

Now we can summarize the ranking constraints as the following:

(28) {STEM=PRWD, RHTYPE=T, ALIGN-W_T-LEFT, DEP-IO, MAX-IO} >> FOOT-BIN
>>HEAD-MAX-IO >> {ALL-FT-LEFT, PARSE-SYL}

2.1.2 Stress Patterns in Compound Words

In Tunica, primary stems can be combined to create a secondary stem. This procedure can be applied cyclically:

- (29) a. háhka 'corn'
 b. tómu 'to pound'
 c. -tífi 'gravy'
 d. háhkatómu 'flour'
 e. háhkatómutífi 'gravy'

The data shows that the stresses in the stems are maintained as long as they do not create adjacent stresses. In other words, there is no stress shifting or reassignment:

(i) σ + σ... → σσ..., *σσ...
 (30) ?a + tépi → ?atépi 'together' (each + in)

(ii) σ + σσσ..... → σσσσ... *σσσσ..., *σσσσ...
 (31) tá + ?utʃæhkatónaji → tá + ?utʃæhkatónaji 'old toad woman'

Also, a final syllable may bear stress, as shown below:

(iii) + σ →σ *.....σ
 (32) ʃíla + ?ɔʃka + rá → ʃílʔɔʃkará 'hard footed bug' (bug + foot + hard)

Since the stresses are basically maintained as they were in the primary stems (despite the fact that

compounding is cyclic), we still expect the stress pattern not to change in a larger compound word, and this prediction is confirmed:

(33) háhka + tómu + -tíci → háhkatómufíci 'gravy'

We have seen that the original stress patterns are preserved, unless there is a stress clash. The data in (34) indicates that Tunica adopts rightmost destressing. I will divide the data into two groups so that we can see the reason for destressing:

(34) a. tʃúhki + ?ɔ́ʃta → tʃúhk_?ɔ́ʃta 'live oak' (oak + green)
 b. éhti + ?íra → éht_?íra 'clothes' (? + cloth)

There are two main characteristics of the stress pattern in compound words. The first one is that stresses are not re-assigned/ shifted. The second one is that, when the combination of stems produces a stress clash, one of the stresses is deleted. The fact that the stresses in the primary stems are preserved as much as possible indicates an active faithfulness constraint based on Output-Output correspondence theory (Benua 1995). It is not possible for us to predict relevant patterns by Input-Output faithfulness constraints since, with the exception of the lexical stresses, all the stresses are the results of the interaction of a set of constraints on the stress assignment system. There is no reference to stresses in the inputs. Therefore, the following constraint should be adopted:

(35) **HEAD-MAX (B/O)** (= H-M-BO)
 If a segment in the base form is a prosodic head, and this segment stands in correspondence with a segment in the output, then the related segment in the output is also a prosodic head. (after Alderete, 1996)

Although **HEAD-MAX (B/O)** preserves the original stress, destressing shows that this constraint can be violated. Destressing happens when two stresses are adjacent. It seems that the stress assignment system can automatically avoid adjacent stresses. The crucial constraints are the following:

- RH-TYPE=T** (RH-T)
- FOOT-BIN** (FT-BIN)
- ALL-FOOT-LEFT** (ALL-FT-L)
- HEAD-MAX-BO** (H-M-BO)

Since the constraint **FOOT-BIN** is ranked very highly, every stressed syllable will be followed by an unstressed syllable. There is only one case such that a stem can have a final stress: a one-syllable stem or a foot in which the unstressed syllable is deleted (e.g. by vowel deletion). For either case, we can have an abstracted form such as (36). The tableau in (36) also shows that **HEAD-MAX-BO** needs to be dominated by **RH-TYPE=T**:

(36) ...($\acute{\sigma}$) + ($\acute{\sigma}\sigma$)... → ($\acute{\sigma}\sigma$) σ ...

Input: $\sigma + \sigma\sigma$...	RH-T	FT-BIN	H-M-BO	ALL-FT-L
Base: ($\acute{\sigma}$) + ($\acute{\sigma}\sigma$)...				
...($\acute{\sigma}$)($\acute{\sigma}\sigma$)...		*!		
...($\acute{\sigma}$)($\sigma \sigma$)...		*!		
...($\acute{\sigma}\sigma$) σ ...			*	n
... σ ($\acute{\sigma}\sigma$)			*	n + 1!
...($\sigma\acute{\sigma}$) σ ...	*!			

From (36), we can see that the syllables are re-footed to satisfy both **FOOT-BIN** and **ALL-FOOT-LEFT**. The constraint **ALL-FOOT-LEFT** also forces the direction of destressing to be rightward, which is the desired result. In (37), we complicate the situation. We give the chance for the stressed

monomoraic-syllable to reform a foot with its preceding syllable. As a result of ALL-FOOT-LEFT, it forms a new foot with the following syllable. We expect the following syllable to be distressed and this prediction is borne out:

(37) $(\acute{\sigma}\sigma)\sigma+(\acute{\sigma})+(\acute{\sigma}\sigma)\dots \rightarrow (\acute{\sigma}\sigma)\sigma-(\acute{\sigma}-\sigma)\sigma\dots$

$(\acute{\sigma}\sigma)\sigma+(\acute{\sigma})+(\acute{\sigma}\sigma)\dots$	RHTYPE=T	FOOT-BIN	H-M-BO	A-F-L	PAR-S
$(\acute{\sigma}\sigma)(\acute{\sigma}\sigma)(\acute{\sigma}\sigma)\dots$	*!			n + 1	
$(\acute{\sigma}\sigma)(\acute{\sigma}\sigma)(\acute{\sigma}\sigma)\dots$			*	n + 1!	
$\sigma'(\acute{\sigma}\sigma)\sigma(\acute{\sigma}\sigma)\sigma\dots$			*	n	*

In this section, we find that the stress assignment system correctly avoids adjacent stresses. It requires a strategy of re-footing the syllables to adjust the stress assignment. The interaction between RHTYPE=T, FOOT-BIN and ALL-FOOT-LEFT ensures not only rightward destressing, but also the non-occurrence of adjacent stresses. This is not expected in a rule-based framework. In a rule-based framework, we need two separate sets of rules to take care of stress assignment and destressing. But in OT, destressing is a consequence of the interaction between the constraints. We will see this advantage in the following sections as well. The ranking of the relevant constraints is listed in (38):

(38) RHTYPE=T, HEAD-MAX-BO, FOOT-BIN and ALL-FOOT-LEFT
 RHTYPE=T >> HEAD-MAX-BO

2.2 Vowel-Deletion and Glottal Stop Epenthesis

In this section, I will present the Opacity found in Tunica, which will lead us to an O-O faithfulness analysis rather than a sympathy analysis. Another point of my analysis here is that the constraint ONSET is not sufficient in order to account for vowel hiatus in Tunica. I will show that an independent constraint that bans the VV sequence is needed.

2.2.1 Vowel Deletion

One of the phonological properties of Tunica is that adjacent vowels are not permitted (Haas, 1940). Since every word surfaces as having an onset (even those that have an underlying initial vowel), there is no way to design a situation where two vowels will be adjacent in the case of compounding. In other words, it is hard to see what exact phonological process is applied to 2 adjacent vowels, even in a secondary stem. However, given the Richness of the Base, the grammar must be able to have adjacent vowels in some inputs. In that case, only one vowel can survive to appear in the surface representations. We might expect Tunica to take vowel deletion or consonant insertion as strategies. Which strategy does Tunica actually take? Interestingly, it appears that, both consonant epenthesis and vowel deletion are invoked in this language. The relevant fact is that the glottal stop epenthesis is adopted to satisfy onset requirement (we will discuss this case later in Section 2.2.2). We also find that high vowels sometimes get deleted. However, there is some evidence to support vowel deletion as the solution in this case. We will see that the glottal stop can be found only in the word-initial position, which means that at least glottal epenthesis is not applicable for two adjacent vowels within a word. Also, except for glottal epenthesis, we do not see any other case of consonant epenthesis. It seems that we have enough confidence to assume that deletion happens when there are two adjacent vowels in one input. We will need at least three constraints to account for the vowel deletion:

- (39) *VV
 No adjacent vowels are allowed.
- (40) MAX-IO
 Every element of the input has a correspondent in the output. (Kager, 1999)
- (41) DEP-IO
 Every element of the output has a correspondent in the input. (Kager, 1999)

*VV should be ranked as the highest among the three since it is never violated. Also, to prevent consonant epenthesis, DEP-IO needs to be ranked over MAX-IO.

(42) *VV >> DEP-IO >> MAX-IO

/...VV.../	*VV	DEP-IO	MAX-IO
...VV...	*!		
∅' ...V...			*
...VCV...		*!	

In the next section, we will discuss glottal stop epenthesis in detail. We will see that the above ranking has difficulties with the analysis of glottal stop epenthesis.

2.2.2 Glottal Epenthesis

There is some evidence showing that the glottal stop /ʔ/ only occurs before a vowel, in the initial position of a stem. In other words, it only occurs in morpheme initial positions:

- (43) a. ʔɔʃta 'green'
 b. ʔætʃara 'palmetto'

At the same time, vowel-initial items do not occur, with the exception of some bound stems that always need to be attached to some other stems:

- (44) a. -áhali 'kin, relative'
 b. -éhku 'offspring'

Based on the above generalizations, we can assume that the glottal stop in Tunica is epenthetic. It is epenthesized to satisfy the onset requirement.

Since the motivation of the epenthesis is the condition on syllables that they must have an onset, we want to have the following constraints be operative in Tunica:

- (45) **ONSET**
 Syllables must have onsets. (Prince and Smolensky, 1993)
- (46) **DEP-IO**
 Every element of the output has a correspondent in the input. (Kager, 1999)

We also know that violation of DEP-IO is less serious than violation of ONSET, since the glottal stop epenthesis is possible. It also tells us that MAX-IO is ranked higher than DEP-IO because deleting the initial vowel is an option here:

(47) **ONSET, MAX-IO >> DEP-IO**

#VC...	ONSET	MAX-IO	DEP-IO
VC...	*!		
∅' ?VC...			*
__C...		*!	

Here we have a serious ranking problem. In the preceding section, we have already shown that DEP-IO must dominate MAX-IO since Tunica chooses vowel deletion to avoid the VV sequence. Here we see that MAX-IO has to dominate DEP-IO for the reason that glottal stop epenthesis is preferred rather than deleting the initial vowel. In other words, to solve this problem, we need to know why different strategies are employed in these two cases⁵. Notice that we only find one instance of consonant

⁵ This problem arises only if we assume that the glottal stop is epenthesized as one independent element. However,

epenthesis in Tunica. In this case, the epenthetic consonant is glottal stop. We might want to separate the DEP constraint into two separate constraints:

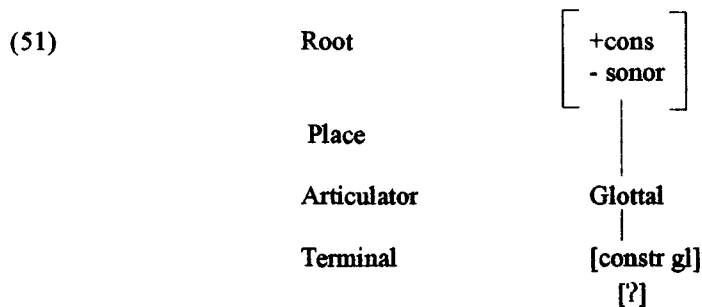
- (48) **DEP-IO-C**
Every consonant (except glottal stop) of the output has a correspondent in the input.
- (49) **DEP-IO-no place**
Every placeless consonant of the output has a correspondent in the input.

By separating DEP and ranking DEP-IO-C as a non-violable constraint, we are now able to predict that only a glottal stop can be the epenthetic consonant. However, a problem still remains. The following tableau illustrates the problem explicitly:

(50)

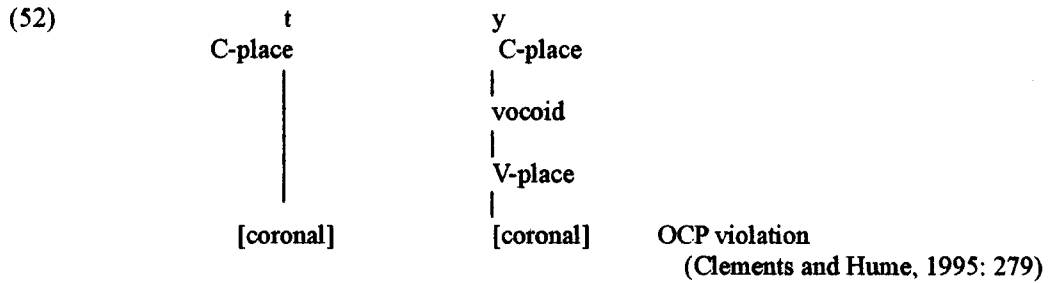
/#VC.../	ONSET	*VV	DEP-C	MAX-IO	DEP-no place
a. VC...	*!				
b. \emptyset ?VC...					*
c. C...				*!	
/...VV.../	ONSET	*VV	DEP-C	MAX-IO	DEP-no place
d. ...VV...		*!			
e. \emptyset ...V...				*	
f. \otimes V?V					*

Although the ranking in (50) predicts the right winner for glottal stop epenthesis, the same ranking wrongly chooses (50f) as the winner instead of (50e), the actual winner. Now, the question can be rewritten as follows: why is the epenthetic glottal stop unable to solve the problem of the VV sequence? To answer this question, we need to have a close look at the properties of a glottal stop. Under the assumption that a glottal stop is placeless (Clements and Hume 1995, Kenstowicz 1994, among others), the question of why it is chosen as an epenthetic consonant can be explained. It is chosen because it has the minimum influence on the inputs yet makes the outputs fit the phonological markedness requirement. We can consider the feature tree of the glottal stop as follows:



Clements and Hume (1995) proposes that each articulator feature of a given category should be assigned to the same tier whether it is a consonant or a vowel:

the epenthetic glottal stop can be found only in onset position. This gives us some alternative interpretation of this ?. It is possible that the glottal stop and the following vowel should be interpreted as glottalized vowels. In that case, the glottal stop is not an independent element, which will not violate DEP-IO. Therefore, the conflict of ranking does not exist here. Although there is no access to phonetic resource for us to confirm it, the possibility of the glottalized vowel cannot be excluded.



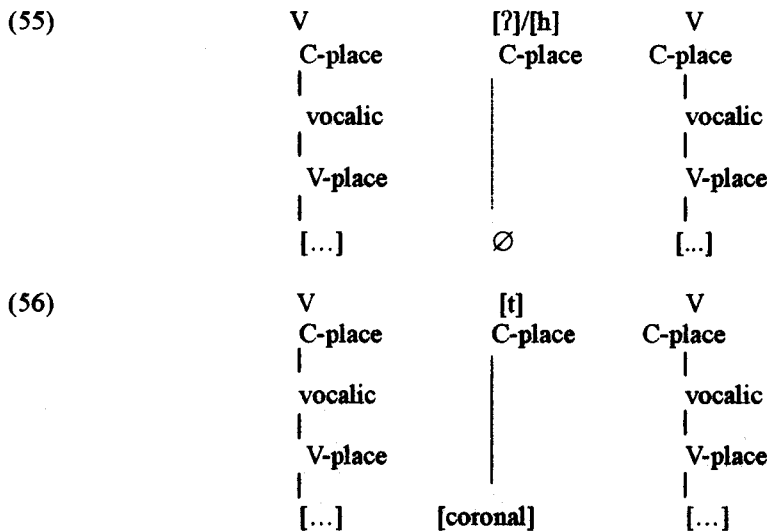
Let us re-think the case of vowel deletion. Apparently, the prohibition on adjacent vowels is a case of OCP (Glodsmith, 1976), which generally forbids two adjacent identical constituents:

- (53) **Obligatory Contour Principle**
Adjacent identical elements are prohibited.

We can understand the vowel deletion in the same way as (53). The sequence of two adjacent vowels needs to be broken by the consonants that have place nodes⁶. However, Tunica does not allow consonant epenthesis other than glottal stop. Therefore, deletion becomes the only resolution for a VV sequence. Let us reformulate *VV as follows:

- (54) ***VV**
No adjacent vocalic place nodes are allowed.

The following diagram might help us to better understand the [V ? V] deletion case:



(55) is a simplified feature tree for the sequence of [V ?/h V]. Compare this to (56). In (55)'s diagram, we can see that the vowels' nodes of Place are still adjacent, because there is no Place node for the glottal stop. This can be considered as the motivation of the vowel deletion in a VV sequence. In other words, the adjacency is evaluated on the place tier. Since the laryngeal consonants are not 'visible' in the place

⁶ Also, Halle (1992) proposes that [+consonantal] should dominate the oral cavity. The consequence of this restriction is that pharyngeals and laryngeals will pattern as [-consonantal] glides. This proposal further supports our claim.

tier, a sequence such as [V ?/h V] is still computed as a violation of *VV. McCarthy (1988) argues that there are OCP effects on the laryngeal node occur as well. In Seri, glottal stops are subject to a dissimilatory process. Generally [ʔ] is permitted at syllable initial and syllable final position. When the syllable takes [ʔ V ʔ] form, the second [ʔ] is deleted. McCarthy suggests that this rule is 'evidently responding to the OCP violation of having adjacent identical specification' (McCarthy, 1988:90). What interests us here is that this rule provides evidence showing that OCP effects related to glottal stops and vowels are licensed in different domains. This is exactly what we expected. If the OCP effect of glottal stops and the OCP effects of vowels in Seri were evaluated on the same tier, we would expect the vowel to block the deletion of the glottal stop. From a phonetic point of view⁷, the vowel formant transition gives us positive evidence. According to Kent and Read (1992), glottal stops and [h] basically cause no formant transitions. In other words, we can argue that there still is a great adjacency of vowels with an intervening [ʔ] or [h].

According to our suggestion, we expect the laryngeal consonant [h] to behave the same way as [ʔ] and this prediction is born out; the vowel deletion happens to the [V hV] sequence too⁸:

- (57) a. máru + hótu + tíhtʃi → már_hotuhtʃ_
 'to pick up' 'to finish' '3FS' 'when she finished clearing'
 b. ʃími + hihki → ʃím_hihki
 'to play' '2FS' 'you(FS) played' (Haas 1940: 24)

Now we have a tableau with the same constraints as (58), but with a different evaluation status:

(58)

/...VV.../	ONSET	*VV	DEP-C	MAX-IO	DEP-ʔ
d. ...VV...		*!			
e. ø...V...				*	
f. VʔV		*!			*

In this section, I argued that the puzzle presented by the conflict between the ranking of MAX-IO and DEP-IO can be explained by investigating the phonetic property of the glottal stop. We concluded that, due to the character of the glottal stop, mainly that it does not have a place node, forces the grammar to choose deletion as the resolution for a VV sequence. The implication of our claim is that *VV needs to be established as an independent constraint. Tunica shows that a constraint such as ONSET cannot substitute with *VV. We have seen that although glottal epenthesis can satisfy ONSET, it cannot help a VV sequence escape the restriction on adjacent vowels.

2.2.3 Interaction between Vowel Deletion and Glottal Stop Epenthesis

We have already seen in the destressing pattern section that vowel deletion happens very often in this language. I will take one of the cases of vowel deletion as the main object of the observation, namely the case in which the glottal stop is involved. The fact is that the unstressed vowels usually get deleted before [ʔ]. The rule can be written as in (59). (60) and (61) display some concrete examples:

- (59) VʔV → __ʔV

⁷ Thanks to Dani Byrd for pointing out this possibility to me.

⁸ Hammond (1988), although he did not give a detailed analysis, gives a syncope rule to summarize the phenomenon of vowel deletion:

(i) V → ø / __ ([+glot]) V

- (60) a. lápu + ?aha → láp_?aha ‘wrong’ (good + neg.)
 b. kóhina + ?æsa → kóhin_?æsa ‘plate’ (clay vessel + flat)
 c. há!ʔukini + ?atæhkala → há!ʔukin_?atæhkala ‘heaven’ (town + between)
 d. káta + hótu → kát_hotu ‘everywhere’ (where + all)
- (61) kúwa + tohku+ tá + ?éhtu → kúwatoh_tá?éhtu
 duck dim. the quick movement redheaded woodpecker

From the previous section, we have already established that the glottal stop is epenthetic. It is introduced to function as an onset. At first glance, the Opacity here then is that glottal stop epenthesis and vowel deletion are in a counter-bleeding relationship:

(62)

A		B	
UL	lapu + aha	UL	lapu + aha
? epenthesis	láp_?aha	vowel deletion	láp_aha
vowel deletion	láp_?aha	? epenthesis	-----
SR	láp_?aha	SR	* lapaha

Here we see that glottal stop epenthesis must be applied first. For a rule-based theory to fit this case, we must allow [láp_?aha] to have a very special underlying form. The grammar somehow should be able to recognize the underlying as having independent cycles. The phonological rules need to be applied to each cycle first. We should keep this in mind as we look at the problem in a different way. The problem we are dealing with will become clearer in the following tableau:

(63)

láp_?aha	*VV	ONSET	DEP-C	MAX-IO	DEP-?
a. lapuaha	*!				
b. ☹ láp_aha				*	
c. ☞ láp_?aha				*	*
d. lapu?aha	*!				*

As (63) shows, the candidates that only involve one operation, vowel deletion, are judged as better than the actual winner. The input /láp_?aha/ has the typical environment for vowel deletion but glottal stop epenthesis needs to be applied anyway. In the previous section, we explained that glottal stop epenthesis cannot solve the VV sequence problem. Here, we have a different situation. This time, it seems that we do not need glottal stop epenthesis at all. Why, then do we still have to epenthesize the glottal stop? Classic OT has difficulties answering this question, as we have seen in (63). In the next section I will propose an O-O faithfulness analysis to solve this problem.

2.2.4 O-O Faithfulness Analysis of Glottal Stop/ Vowel Deletion

To answer the question posed in the previous section, we have to think about the motivation of glottal stop epenthesis. If the appearance of the glottal stop is only licensed by the status of “onset,” then there must be something which forces the glottal stop to keep its status from the primary stem to the secondary stem, i.e. a compound word. Since there is no such onset, namely a glottal stop, in the input, it must obtain its onset status from some other forms. Apparently, the ‘some other form’ must be the related un-compounded forms, or ‘base.’ Now the answer for the question becomes clear. We see that the glottal stop in the middle of a word is an instance of faithfulness to the related bases, with respect to the onsets. Now the opacity we see in (63) is no longer a mystery. Its explanation does not require the ordering of the rules. Rather, it is triggered by the interaction between markedness constraints (for instance, *VV,

ONSET, etc.) and some output-output faithfulness constraints (since the compound words are faithful to their base).

Our next task is to figure out why the deletion is *leftward* in the [V ? V] sequence. This direction is not decided in the discussion of a general vowel deletion case. Let us see what syllabification will look like in both cases; i.e. leftward deletion and rightward deletion. In (64), column A shows the result of leftward deletion and column B shows the result of rightward deletion.

(64)			A		B
(i)	...V.CV + ?V.CV...	→	...VC. __ -?V.CV...		* ...V.CV-? __ CV...
(ii)	...V.CV + ?VC.CV...	→	...VC. __ -?VC.CV...		* ...V.CV-? __ C.CV...
(iii)	...VC.CV + ?V.CV...	→	...VCC. __ -?V.CV...		* ...VC.CV-? __ CV...
(iv)	...VC.CV + ?VC.CV...	→	...VCC. __ -VC.CV...		* ...VC.CV-? __ C.CV...

As we can see in (64), the rightward deletion always has to syllabify the glottal stop as the coda (or a part of it), since complex onsets are not allowed in Tunica. In contrast, leftward deletion results in the glottal stop as a simple onset of the syllable. This can be captured by a constraint in (65):

- (65) **ALIGN-BASE-L**
The left edge of the base coincides with the left edge of a syllable.

Interestingly, this constraint also captures the fact that the epenthetic glottal stop needs to be preserved from the Base to the actual output. We also need a markedness constraint ***COMPLEX^{ONS}**:

- (66) ***COMPLEX^{ONS}**
Onsets are simple. (Kager, 1999)

Since vowel deletion does occur here, we know that ***VV** must be higher than **MAX-IO**. Although there is no crucial candidate showing the ranking among **ALIGN-STEM-L**, ***COMPLEX^{ONS}** and **MAX-IO**, we might want to consider ***COMPLEX^{ONS}** to be highly ranked since it is never violated.

- (67) Input: /lapu + aha /
Base Form: [lapu] + [ʔaha]

Input lapu + aha Base [lapu] + [ʔaha]	*VV	ONSET	ALIGN-BASE-L	* COMPLEX ^{ONS}	DEP-C	MAX-IO
a. la.pu.-a.ha	*!		*			
b. la.pu.-ʔa.ha	*!					
c. ^ʔ lap. __-ʔa.ha						*
d. la.pu.-ʔ ha				*!		*
e. la.pu-ʔ. ha			*!			*
f. la.p __-a.ha			*!			*

Recall that we have argued that [ʔ] and [h] share some similarities, namely, they are both placeless consonant. Therefore, we expect them to behave similarly. Actually, we can find examples in which vowel deletion happens with [h]:

- (68) máru + hótu + tíhtʃi → már_hotutíhtʃ_
'to pick up' 'to finish' '3FS' 'when she finished clearing' (=57a)

In this case, the set of constraints given in (67) chooses the correct output:

(69)

Input maru + hotu Base [máru] + [hótu]	*VV	ONSET	ALIGN-BASE-L	* COMPLEX ^{ONS}	DEP-C	MAX-IO
a. ma.r <u>u</u> .-ho.tu	*!		*			
b. [⊗] ma.r <u>u</u> .-ho.tu						*
c. ma.r <u>u</u> .-h <u>u</u>				*!		*
d. ma.r <u>u</u> .-h <u>u</u>			*!			*

In this section, I proposed an O-O faithfulness analysis for the Opacity observed from the interaction between glottal stop epenthesis and vowel deletion. The O-O faithfulness analysis explains why we can find glottal stops in word-internal positions. We shall notice that the grammar does not solve the same problem twice. Actually, it solves two different problems, one is the requirement of onset and the other is the VV sequence. I also showed that cases of [V?V] and [VhV] should be treated in a uniform way. In the next section I will compare the Sympathy analysis with our O-O faithfulness analysis.

3. Comparison with Sympathy Analysis

In this section, we will examine the Sympathy analysis. We will see that it has some potential problems and therefore cannot be considered as an appropriate way to account for the relevant Opacity.

To refresh our memory, the separated rules and OT constraints are demonstrated in (70), (71) and (72):

(70) Vowel Deletion

a. Rule: $V \rightarrow / (V) _ (V)$

b. Constraints and Ranking: *VV >> DEP-C >> MAX-IO

(71) Glottal stop epenthesis

a. Rule: $_ \rightarrow ? / \# _ V$

b. Constraints and Ranking: ONSET >> MAX- >> DEP-?

(72) *VV, ONSET >> DEP-C >> MAX- >> DEP-?

The tableau in (73) illustrates the relevant opacity:

(73)

l <u>á</u> pu + aha	*VV	ONSET	DEP-C	MAX-IO	DEP-?
a. l <u>á</u> puaha	*!				
b. [⊗] l <u>á</u> p <u>u</u> aha				*	
c. [⊗] l <u>á</u> p <u>u</u> ?aha					*
d. l <u>á</u> pu?aha	*!				*

To make the Sympathy work for this case, we have to select a sympathy candidate which the actual output resembles. We know that the sympathy candidate must include a glottal stop like [lápu?aha]. This sympathy candidate should be selected by some faithfulness constraint. Since DEP-C is not violated by any relevant candidate here, MAX-IO naturally becomes the selector constraint. However, we can see that this selector constraint will not select [lápu?aha] as the sympathy candidate. Instead, [lápuaha] will be selected:

(74)

lápu + aha	*VV	ONSET	DEP-C	★MAX-IO	DEP-?
a. ⊗ lápuaha	*!				
b. ⊗ láp_aha				*	
c. ⊗ láp_?aha				*	*
d. lápu?aha	*!				*

As shown in (74), it is not possible for us to find a faithfulness constraint as the selector within the constraints in (73). A possible way to solve the problem is to employ some other constraint as the selector. One might think that defining the alignment constraint in a different way would be desirable:

(75) **ALIGN-STEM-R**

The right edge of the stem coincides with the right edge of a syllable. (Kager 1999)

Let us first put it in the tableau and see if it can substitute **ALIGN-BASE-L**:

(76)

lápu + aha	*VV	ONSET	ALIGN-STEM-R	DEP-C	MAX-IO	DEP-?
a. lá.pu-a.ha	*!		*			
b. ⊗ láp_-a.ha			*		*	
c. ⊗ láp_-?aha			*		*	*
d. lápu-?aha	*!					*
e. ⊗ lápa-?._ha			*		*	*

The tableau in (76) shows that we still get opacity even if we use **ALIGN-STEM-R**. But, does it help the Sympathy account? Again, the selector must be **MAX-IO**. Since the actual winner differs from the sympathy candidate only in one vowel, the sympathy constraint should be **MAX-⊗O**:

(77) **MAX-⊗O**

Every segment in the sympathy candidate must have a correspondent in the output.

(78)

lápu + aha	*VV	ONSET	ALIGN-STEM-R	MAX-⊗O	★MAX-IO	DEP-?
a. lá.pu-a.ha	*!		*	*		
b. láp_-a.ha			*	**	*	
c. ⊗ láp_-?aha			*	*	*	*
d. ⊗ lápu-?aha	*!					*
e. ⊗ lápa-?._ha			*	*	*	*

It seems that we might be able to achieve the task of selecting the sympathy candidate. But we immediately notice that (78) will not give us the actual winner directly. The reason is that the actual winner (78c) is not the only one to satisfy (77), (78e) does as well. Moreover, (78c) and (78e) have exactly the same violations. In other words, the constraints we have in (78) with **MAX-⊗O** cannot distinguish the direction of the deletion. The sympathy analysis looks un-functional here.

I have argued that sympathy has some difficulty in relevant Opacity. The key point is that we must guarantee the epenthetic glottal stop to be the left edge of a syllable in the output. By adopting this approach, we not only capture the fact that glottal stop epenthesis is necessary, but also the fact that the direction of the vowel deletion is leftward. Notice that this operation, i.e. keeping the epenthetic glottal stop as the left edge of a syllable, cannot be achieved in a Sympathy analysis. Clearly, according to *Consistency of Exponence*⁹, the glottal stop has no morphological affiliation, which means that in a

⁹ McCarthy and Prince (1993) discussed a principle called *Consistency of Exponence*:

Sympathy analysis, the epenthetic glottal stop is invisible.

Through the above discussion, we have seen that Sympathy fails crucially because of the constraint **ALIGN-STEM-R**. We need **ALIGN-STEM-R** to predict the direction of the deletion. It requires that the glottal stop have a morphological affiliation, which is not compatible with a Sympathy analysis, due to the *Consistency of Exponence*. However, there is actually one alternative way to predict the direction of the deletion. Let us return to the diagram (62), which is repeated as (79):

- (79)
- | | | A | B |
|-------|-----------------------|------------------------|-------------------------|
| (i) | ... V.CV + ?V.CV... | → ... VC. _ -?V.CV... | * ... V.CV-? _ CV... |
| (ii) | ... V.CV + ?VC.CV... | → ... VC. _ -?VC.CV... | * ... V.CV-? _ C.CV... |
| (iii) | ... VC.CV + ?V.CV... | → ... VCC. _ -?V.CV... | * ... VC.CV-? _ CV... |
| (iv) | ... VC.CV + ?VC.CV... | → ... VCC. _ -VC.CV... | * ... VC.CV-? _ C.CV... |

I have argued that column B is ungrammatical due to the requirement on alignment. We may notice that the alignment requirement is not the only analysis here¹⁰. It might be the effect of a simple restriction on the coda:

- (80) * ?]σ
 Glottal stop is not allowed as a coda.

If we substitute **ALIGN-STEM-L** with * ?]σ, we have the following tableau:

(81)

lapu + aha	*VV	ONSET	* ?]σ	MAX-⊗O	★MAX-IO	DEP-?
a. la.pu-a.ha	*!					
b. lap -a.ha				*	*	
c. * lap -?aha					*	*
d. ⊗ lapu-?aha	*!					
e. lapa-? _ ha			*!		*	*

The above tableau shows that the same selector constraint **MAX-IO** chooses [lapu-?aha] as the sympathy candidate. The sympathy constraint **MAX-⊗O** rules out [lap -a.ha] since the glottal stop is missing. The candidate [lapa-? _ ha] is no longer a threat to the sympathy analysis. It cannot compete with the winner because of the restriction on the coda.

It seems that by adopting * ?]σ, the Sympathy analysis does not have a problem in handling the opacity. In this respect, it seems that there is no way to tell which approach is more advantageous. However, we have already assumed that the vowel deletion in both [?] and [h] cases should be treated uniformly. Although * ?]σ can substitute **ALIGN-STEM-R** in the case of [?], it cannot help us in the case of [h]:

“No changes in the exponence of a phonologically-specified morpheme are permitted.” (McCarthy and Prince, 1993: 21). McCarthy and Prince (1993) further explain the principle in the following way: “Consistency of Exponence means that the phonological specification of a morpheme (segments, moras, or whatever) cannot be affected by Gen. In particular, epenthetic segments posited by Gen will have no morphological affiliation, even if they are bounded by morphemes or wholly contained within a morpheme....Thus, any given morpheme’s phonological exponents must be identical in underlying and surface form, unless the morpheme has no phonological specifications at all...” (McCarthy and Prince, 1993: 22).

¹⁰ Thanks to Elliott Moreton for bringing this analysis to my attention.

(82)

maru + hotu	*VV	* COMPLEX ^{ONS}	* ?] _G	MAX-⊗O	★MAX-IO	DEP-?
a. ⊗ ma.ru.-ho.tu	*!					
b. ⊗ mar. -ho.tu					*	
c. ma.ru.-h tu		*!			*	
d. ⊗ ma.ru.-h tu					*	

As shown in (82), without **ALIGN-STEM-R**, we again cannot predict the direction of deletion in the case of [h]. In other words, **ALIGN-STEM-R** allows us to give a unified account for the [V?V] and [VhV] cases. This task cannot be accomplished by a Sympathy analysis. In a sympathy analysis, we have to treat these two cases separately. For the [V?V] case, * ?]_G is adopted to determine the direction of deletion. The similar goal needs to be achieved by some alignment constraint¹¹ in the [VhV] case. The Sympathy analysis fails to capture the similarities we found in [?] and [h]: they are both laryngeals, they behave similarly in vowel harmony and vowel deletion¹². On the other hand, an O-O faithfulness analysis enables us to capture these similarities. Therefore, we can say that O-O faithfulness is the preferred one in this respect.

4. Summary

In this paper, we have examined a set of phonological facts in Tunica. We discussed the ranking conflict in glottal epenthesis and vowel deletion. Our conclusion is that the glottal stop is not feasible for breaking up the linking of adjacent vowel place nodes. Many phonologists argue that it is the requirement of **ONSET** that leads to OCP in adjacent vowels. However, as we have seen in Tunica, the epenthesis of glottal stop satisfies the onset requirement but fails to repair the OCP effect. Therefore, we have to consider ***VV** and **ONSET** as two independent constraints.

¹¹ Since [h] is not epenthetic in Tunica, a basic alignment is sufficient:

(i) **ALIGN-L**

The left edge of the Grammatical Word coincides with the left edge of the PrWd. (Kager, 1999).

¹² An alternative constraint such as “*CODA-no place” might help sympathy to capture the similar behavior of [?] and [h] regarding to the vowel deletion. However, there is some evidence showing that [h] is a legal coda in Tunica:

(i) a. tʃáh.ki ‘flying squirrel’ b. háh.pa.ya ‘noise’

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