Against an ONSET Approach to Hiatus Resolution

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It is a commonplace of phonological theory that languages tend to favor syllabifying consonants as onsets when possible; while one can find languages that disallow codas, none forbid onsets- no language requires codas, while some require onsets. Prince and Smolensky (1993) trace this observation to Jakobson (1962), by way of Clements and Keyser (1983). In order to reflect "the universally unmarked characteristics" of onsets, they posit the constraint ONSET, which disfavors onsetless syllables.

Another generalization that can be made on the basis of cross-linguistic typology is that languages tend to disallow a sequence of two vowels across a syllable boundary. Taken together, the two observations seem to stem from one and the same source; in languages that rank the constraint ONSET high, neither word initial nor word medial onsetless (hiatal) syllables will surface. In fact, many researchers attempting to explain hiatus resolution patterns have taken just this approach (cf. Rosenthall 1994, Casali 1996, though see Ola Orie and Pulleyblank (2000) for a different approach.) Despite the support that ONSET analyses have enjoyed, data problematic for this approach are not hard to find.

In this paper, I discuss such a case. In Yatzachi Zapotec (YZ), an Oto-Manguean language spoken in southeastern Mexico, onsetless syllables are allowed initially, but input hiatus cannot surface in the output[1]. This in itself is a problem for an ONSET analysis, since only in word medial position is the ONSET violation repaired, an eunexpected result if ONSET is high ranked. ONSET style approaches have been taken that get around this problem; for example, McCarthy and Prince (1993) claimed that asymmetrical repair of ONSET violations in Axininca Campa was caused by a high ranked constraint requiring the alignment of the beginning of a root with the beginning of a syllable. This constraint will rule out repair of initial ONSET violations, but not of medial ones. The data I will discuss here is even more difficult to handle under an ONSET approach to hiatus resolution, however; not only are strictly adjacent vowel sequences repaired, but vowels separated by a glottal stop are also "fixed".

In YZ, input vowel sequences cannot survive into the output. To remedy the offending vowel sequences, one of two repair strategies will be followed: coalescence or diphthongization. The choice of repair strategy depends on the identity of the two vowels

[1] The Yatzachi Zapotec data in this paper comes from Butler-Haworth (1980), but any mistakes are most certainly my own. Input regarding the Yatzachi Zapotec data from Rebecca Long and Steve Marlett, both of SIL Mexico, was extremely helpful and is very appreciated. Thanks also to Ellen Broselow, Marie Huffman, Lori Repetti, Harriet Klein, Christina Bethin, Bob Hoberman, Meghan Sumner and Adamantios Gafos for their thoughtful comments and suggestions throughout the development of this paper. Thanks to the audiences of the Long Island Sounds Conference held at NYU May 4, 2001 and the Stony Brook QPW for their insightful comments on intermediate versions of this paper.

and their relation to each other. Interestingly, vowel sequences in which the first is followed by a glottal stop undergo processes which are remarkably similar to those that occur in strictly adjacent cases. In VʔV contexts, the two vowels surface tautosyllabically, with the glottal stop realized as laryngealization. Additionally, abstracting away from superficial differences, the same repair strategies take place in these environments as in the VV contexts:

(1)	a.	zetʃa	+	oʔ	→	zetʃaoʔ	-diphthongization
	b.	tʃʃagnaʔ	+	oʔ	→	tʃʃagnao̰	-diphthongization
	c.	tʃxi	+	oʔ	→	tʃxjoʔ	-dipthongization
	d.	tʃziʔ	+	oʔ	→	tʃzjo̰	-diphthongization
	e.	zetʃa	+	eʔ	→	zetʃeʔ	-coalescence
	f.	tʃʃagnaʔ	+	eʔ	→	tʃʃagneḛ	-coalescence

The similarity that exists between the Zapotec VV and VʔV contexts suggests that they would best be accounted for under the same analysis. However, while the ONSET approach can handle the VV contexts, it has nothing to say about VʔV, for the glottal stop could conceivably syllabify as an onset to the second syllable. Therefore, if we take as our goal to subsume both phenomena under the same analysis, this analysis cannot take ONSET to be the factor motivating repair.

Instead, I propose here that hiatus resolution may occur in a language quite independently of the ranking of the constraint ONSET, and that a VʔV sequence constitutes hiatus. My analysis, which I will elaborate upon in section 2, claims that vowels in hiatus tend to be disfavored because of the marginal status of adjacent vocalic gestures. Thus, while ONSET is violated by onsetless syllables in both initial and medial position, my approach will only prohibit the latter, from whence would derive the asymmetrical treatment of putative ONSET violations in a number of languages, including Yatzachi Zapotec.

After introducing the Zapotec data in section 1, I will discuss my analysis fully in Section 2. Here I will take an approach inspired by the gestural analyses of Browman and Goldstein (1989, et seq.), and particularly the discussion of gestural coordination and coordination constraints in Gafos (2001). I posit a constraint requiring the coordination of a consonant gesture with flanking vocalic gestures, the motivation for which comes from the need to avoid the acoustic realization of a V-to-V gestural transition. In section 3, I wrap up the discussion of Zapotec VV and VʔV sequences, discussing the factors that determine choice of repair strategy.

My analysis makes several predictions regarding the distribution of ONSET repair and hiatus resolution, which I discuss in section 4. This section introduces two exemplars of languages whose asymmetrical treatment of ONSET violations can be explained by my analysis; Yucatec Maya and Axininca Campa. Additionally, I discuss the possible extension of my proposal to cases of feature spreading in vowel harmony systems.

Finally, in section 5, I conclude with a summary of the analysis and its applications to languages other than Yatzachi Zapotec. Following the conclusion are two appendices, the first including the definition of all constraints used in this paper, and the second discussing the predictions that the present analysis makes for possible cross-linguistic hiatus resolution patterns.

I Data

In this paper, I will introduce and explain the patterns that obtain when vowels are input adjacent in Yatzachi Zapotec, created by the affixation of a vowel initial suffix to a vowel final verb. Zapotec verbs may end in any of its five vowels, [i], [o], [e], [a] and [ə][2]. I will discuss data in which the vowel initial suffixes have been affixed to glottal stop final verbal bases in parallel with the strictly adjacent vowel contexts.

For the purposes of this paper, only subject-marking suffixes will be considered. These suffixes may affix to any Zapotec verbal base and must do so when the subject is not otherwise expressed in the clause. Thus, data relating to this issue is abundant. In (2) below are the subject-marking suffixes of Zapotec. For obvious reasons, I will be concerned only with those suffixes that are vowel initial, shown below in bold type.

(2)	a.	**-aʔ**	**1st Singular**	f.	**-eʔ**	**3rd Respectful**
	b.	-to	1st Plural Inclusive	g.	-bo	3rd Familiar
	c.	-cho	1st Plural Exclusive	h.	**-əb**	**3rd Animal**
	d.	**-oʔ**	**2nd Singular**	i.	**-ən**	**3rd Inanimate**
	e.	-le	2nd Plural			

In the remainder of this section, I will introduce all of the Zapotec VV and VʔV data, organizing my discussion according to the type of repair strategy employed (coalescence or diphthongization), for the sake of simplicity.

1.1 Coalescence

In Zapotec, a subset of inputs with adjacent vowels surface having undergone coalescence, resulting in a monomoraic output vowel that is the correspondent of both input vowels. Forms which undergo coalescence include all identical vowels, vowel sequences with schwa and input [a.e] sequences. In the first case, the output segment is a faithful realization of both input vowels, since they are featurally identical. In sequences with schwa, the schwa is lost in favor of the non-schwa vowel, and in [a.e] sequences the resulting output contains only [e]. Examples of these patterns are shown below in (3), (4) and (5):

(3)		V_x	+	V_x	→	V_x
	a.	zetʃa stop	+	-aʔ 1^{st} Sg.	→	zetʃaʔ ‘I stop’
	b.	zo live	+	-oʔ 2^{nd} Sg.	→	zoʔ ‘You live’
	c.	tʃn̲e speak	+	-eʔ 3^{rd} Resp.	→	tʃn̲eʔ ‘He speaks’
	d.	tʃbezə wait	+	-əb 3^{rd} Animal	→	tʃbezəb ‘The animal waits’
(4)		ə	+	V_x	→	V_x
		V_x	+	ə	→	V_x
	a.	tʃbezə wait	+	-aʔ 1^{st} Sg.	→	tʃbezaʔ ‘I wait’
	b.	tʃbezə wait	+	-eʔ 3^{rd} Resp.	→	tʃbezeʔ ‘He waits’
	c.	zo live	+	-əb 3^{rd} Animal	→	zob ‘The animal lives’
	d.	tʃxi clean	+	-əb 3^{rd} Animal	→	tʃxib ‘The animal cleans’
(5)		a	+	e	→	e
	b.	zetʃa stop	+	-eʔ 3^{rd} Resp.	→	zetʃeʔ ‘He stops’

In the case of vowels that are adjacent in the input but for the presence of a glottal stop, coalescence occurs in exactly the same environments as it does in the VV cases. Moreover, in forms in which the input vowels are not identical, the vowel whose features survive into the input are also the same; schwa takes on the features of the non-schwa vowel, and [e] spreads onto a preceding [a]. The only differences between the realization of strictly adjacent input vowels and VʔV vowels are that the result of coalescence in the latter case is a bimoraic vowel instead of a monomoraic one, and that the glottal stop surfaces as laryngealization on the vowel. Both of these contrasts will be explained in

[2] Note that Yatzachi Zapotec lacks the vowel [u]. Butler-Haworth claims that Zapotec’s [o] is “un sonido entre **o** y **u**.”

more detail in sections 2 and 3. The data in (6), (7) and (8) give examples of the VʔV forms that undergo coalescence.

(6)		V_xʔ	+	V_xʔ	→	$V_x\underset{\cdot\cdot}{V}_x$
	a.	tʃʃagnaʔ marry	+	-aʔ 1^{st} Sg.	→	tʃʃagnaa̤[3] 'I marry'
	b.	tʃbeʔ sit	+	-eʔ 3^{rd} Resp.	→	tʃbee̤ 'He sits'
	c.	tʃʃoʔ break (it)	+	-oʔ 2^{nd} Sg.	→	tʃʃoo̤ 'You broke it'
	d.	tʃseləʔ send	+	-əb 3^{rd} Animal	→	tʃseləə̤b 'The animal sends'

(7)		əʔ V_xʔ	+ +	V_x ə	→ →	$V_x\underset{\cdot\cdot}{V}_x$ $V_x\underset{\cdot\cdot}{V}_x$
	a.	tʃseləʔ send	+	-aʔ 1^{st} Sg.	→	tʃselaa̤ 'I send'
	b.	tʃseləʔ send	+	-oʔ 1^{st} Sg.	→	tʃseloo̤ 'You send'
	c.	tʃseləʔ send	+	-eʔ 3^{rd} Resp.	→	tʃselee̤ 'He sends'
	d.	tʃziʔ buy	+	-əb 3^{rd} Animal	→	tʃzii̤b 'The animal buys'

(8)		aʔ	+	eʔ	→	ee̤
	a.	tʃʃagnaʔ marry	+	-eʔ 3^{rd} Resp.	→	tʃʃagnee̤ 'He marries'

[3] The VʔV data show that coalescence results in outputs with long vowels. Additionally, the output form is realized with laryngealization on the part of the vowel. In this paper, I have represented the larygealization as creakiness on the part of the second mora of the vowel. It is important to note, however, that this is an idealization of the data. Zapotec speakers vary as to the amount of laryngealization that occurs and whether it is realized on both moras of the vowel or solely the rightmost one.

1.2 Diphthongization

Diphthongs are created in all Zapotec forms in which this vowel is [i], [o] or [e], both in VV and VʔV contexts. As was the case with the vowel sequences that undergo coalescence discussed above, the VʔVs differ from the VV sequences only in the laryngealization on the correspondent of the second input vowel.

(9)		i, e	+	V_x	→	yV_x
		o	+	V_x	→	wV_x
	a.	tʃxi	+	-aʔ	→	tʃxjaʔ
		clean		1st Sg.		‘You clean’
	b.	zo	+	-eʔ	→	zweʔ
		live		3rd Resp.		‘He lives’
	c.	tʃn̲e	+	-oʔ	→	tʃn̲joʔ
		speak		2nd Sg.		‘You speak’

(10)		iʔ, eʔ	+	V_x	→	yV̤$_x$
		oʔ	+	V_x	→	wV̤$_x$
	a.	tʃxiʔ	+	-aʔ	→	tʃxja̤
		buy		1st Sg.		‘I buy’
	b.	tʃʃoʔ	+	-eʔ	→	tʃʃwe̤
		break (it)		3rd Resp.		‘He broke it’
	c.	tʃbeʔ	+	-oʔ	→	tʃbjo̤
		sit		2nd Sg.		‘You sit’

Diphthongization will also occur in Zapotec forms in which a suffix beginning with [o] is affixed to a verbal base ending in [a]:

(11)		a	+	o	→	ao
	a.	zetʃa	+	-oʔ	→	zetʃaoʔ
		stop		2nd Sg.		‘You stop’

Input [aʔ-oʔ] sequences result in diphthongization of the sequence, with a creaky off-glide. This is shown below in (12).

(12)	aʔ	+	oʔ	→	ao̤
a.	tʃʃagnaʔ	+	-oʔ	→	tʃʃagnao̤
	marry		2nd Sg.		‘You marry’

The data in (3) through (12) show that both strictly adjacent vowel sequences and sequences of vowels flanking a glottal stop undergo the same processes in Yatzachi Zapotec outputs. For ease of comparison of these environments, consider the charts in (13) and (14).

(13) VV sequences

	i	oʔ	eʔ	aʔ	əb, ən
i	-	joʔ	jeʔ	jaʔ	ib, in
o	-	oʔ	weʔ	waʔ	ob, on
e	-	joʔ	eʔ	jaʔ	eb, en
a	-	aoʔ	eʔ	aʔ	ab, an
ə	-	oʔ	eʔ	aʔ	əb, ən

(14) VʔV sequences

	iʔ	oʔ	eʔ	aʔ	əb, ən
iʔ	-	jo̤	je̤	ja̤	ii̤b, ii̤n
oʔ	-	oo̤	we̤	wa̤	oo̤b, oo̤n
eʔ	-	yo̤	ee̤	ja̤	ee̤b, ee̤n
aʔ	-	ao̤	ee̤	aa̤	aa̤b, aa̤n
əʔ	-	oo̤	ee̤	aa̤	əə̤b, əə̤n

It is clear that the output of VV and VʔV parallel each other in almost every respect. Given this similarity, it is reasonable to attempt to account for these phenomena within the same overall analysis. In the following section I propose an analysis of the observed phenomena in both contexts, showing that they can in fact be subsumed under the same explanation. I begin with a summary of the main problem that the Zapotec data poses for previous analyses. Then, I introduce the background of my analysis, discussing the framework of gestural phonology along the lines of Gafos (2001), before continuing on to the analysis proper.

2 The Analysis

2.1 Gestural Phonology

Gestural Phonology sets out to define the relationship between abstract phonology and phonetics; it deals with how outputs of the phonology are realized via the gestures that create them. In this framework, as envisioned by Browman and Goldstein (1989 et seq.), the gestures that produce a sound are considered to be primary- for them, what is specified by the phonological system is the gestures to be made in the production of the sound. In contrast to Browman and Goldstein (1989 ff.), I take the approach that the phonological specifications of a segment (height, backness, roundness etc.) are mapped onto instructions to the articulators regarding a specific target gesture associated with that segment. Both approaches are compatible with the analysis put forth here, however. The aforementioned target gestures are the result of instructions as to the articulators employed in making the gesture, as well as the Constriction Location (CL) and Constriction Degree (CD). For example, the target for the vowel /i/ is "a gesture involving the tongue body (TB)… CL and CD take the values of {palatal} and {narrow.}" (Gafos (2001), pg.6)

Given the specification of a certain target, for example /i/'s TBCL {palatal} and TBCD {narrow}, the articulator, here the tongue body, must implement the movements needed to reach the specified target. Since achievement of a gestural target is necessarily not instantaneous, each gesture involves a number of components sequenced over time. We can roughly describe a gesture as involving movement towards the target, achieving the target, and movement away from the target. In more precise terminology these are subdivided into the onset of movement, achievement of target, c-center, and release. The descriptions of each of these gestural landmarks are given below in (15):

(15)	ONSET:	The onset of movement towards the target gesture
	TARGET:	The point in time at which the gesture achieves its target
	C-CENTER:	The midpoint of the gestural plateau
	RELEASE:	The onset of movement away from the target of the gesture.

(Gafos (2001)'s (5), pg. 10)

Under this framework, every gesture, whether consonantal or vocalic, consists of at least these four components. Note that on this view the target of the gesture is phonologically specified, while the movements that occur before achievement of the gestural target and after the release of the gestures would not be. What movements are made at these points would instead be dependent on other factors, such as the starting position of the articulator and the articulation of surrounding sounds.

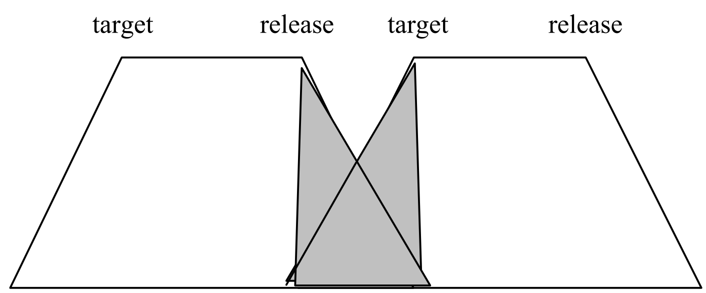
My analysis of Yatzachi Zapotec VV and VʔV phenomena is modeled on Gafos' (2001) characterization of the coordination of gestures, and their relationship to OT constraints. Gafos (2001) argues that not only are the target articulations of segments specified but also their relationship to other segments. According to his proposal, one can state the observed temporal coordination between two gestures as a coordination of the landmarks of those gestures, his *gestural coordination relations*. Furthermore, the more descriptive coordination relation can be translated into an alignment constraint governing the coordination of gestures.

With this very brief introduction, I will turn to my own analysis, which appropriates the notion of gestural coordination to explain the YZ phenomena. Further discussion of this topic, and a practical application of coordination constraints to phonological data from Moroccan Colloquial Arabic, can be found in Gafos (2001).

2.2 Gestural Motivation for Hiatus Resolution

The guiding intuition behind the analysis put forth in this section is that hiatus resolution contexts are intrinsically different from pure ONSET violations in that they involve the juxtaposition of two vowels against one another. In a gestural approach, we can state the problem thus; faithful realization of input hiatus will result in an output in which the gestures of two vowels are adjacent. I propose that this is an undesirable output for reasons that will be discussed below. First, consider the schematic representation of the gestures comprising a sequence of two vowels with no separating consonant, shown below in (16).

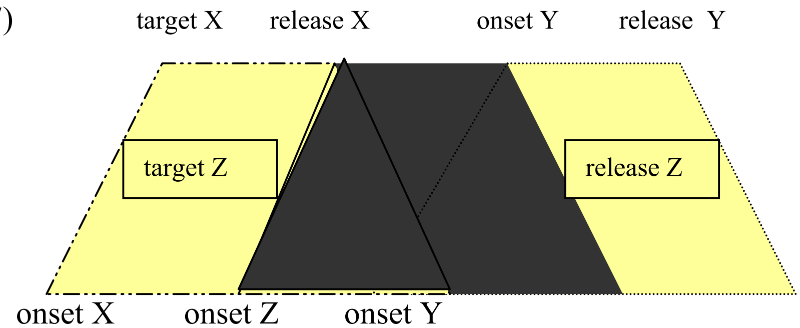
(16)



In the diagram in (16), the target of each of the vowels, X and Y, is phonologically specified by the vowel's features. Other portions of the gesture, such as the onset and release of the vocalic gestures, are not so specified; they should fall out from the physical make up of the articulators involved, the target specification and so on. Consider now the period of time between the release of the first vowel and the achievement of the target of the next (shaded in gray on the diagram). During this period, gestures are being made that do not reflect any additional underlying phonological specification, for they are merely consequences of the physical system.

During this transitional period, acoustic cues may be produced which the hearer must ignore in order to correctly perceive the speech stream; if they do not, they may incorrectly interpret the cues as being the result of an underlying gestural target, an entirely new phoneme. For our schematic example, such confusion could result in an output that is ambiguous between [$X^Z Y$], in which there is an intrusive element (a vowel or glide) [Z], and [XZY] in which [Z] is a member of the input. The latter possibility is shown below in (17).

(17)



Let's now take a more concrete example. Consider a vowel sequence consisting of an [i] followed by an [a], coordinated in the same way as the vowels in (16). During the period when the tongue body is moving away from the narrow constriction at the palate, and moving towards a wider constriction, the canonical targets for neither [i] nor [a] are being articulated. At this point, it is possible that the hearer will perceive the acoustic consequences of the transitional gestures, and attribute to it a phonological representation. In the case of [i] followed by [a], the hearer is likely to perceive an intrusive glide, whether it exists in the input or not. Take, for example, the song "Old MacDonald," in which the refrain is "e, i, e, i, o." In careful speech, this might be pronounced [i. ai. i. ai. oʊ]. In normal speech, however, it would likely be pronounced [i.jai.i.jai.joʊ], with epenthesis of a glide. But for the difference in pronunciation between the two speech rates, it would be a toss up as to whether the glide was perceived as an artifact of the transition between the vowels, or as a fully specified input segment[4].

This situation is surely undesirable; by allowing gestures that are not part of the phonological specification of the prosodic word to be perceived, we are increasing ambiguity. In fact, from a perceptual optimization point of view, it should be an overarching goal to obscure the acoustic realization of any gestures beyond the target to avoid just this difficulty[5].

I propose that languages in which hiatus is resolved place great importance on the need to stop ambiguous transitional cues from being perceptible in the speech stream. My claim is that the ideal gestural coordination relation of a sequence of two vowels is

[4] Thanks to Ellen Broselow (pc), for pointing out this out to me, and to Marie Huffman for suggesting the "Old MacDonald" analogy.
[5] This brings up the question of why languages should freely allow consonantal transitions to be perceived. My answer to this question would be that consonant transitions are so short that they may not be attended to as closely as are vowel transitions. Moreover, some consonants can be perceived only by the period after the release of their target. For example, stop consonants are identifiable by the burst of air accompanying the release of constriction. This distinguishes them from vowels, which are perceptible throughout the production of the target gesture.

shown below in (18). I assume that the gestural coordination relation in (18) holds of the gestures made by each of the articulators involved in the production of the segments.

(18) For any sequence of two vocalic gestures, X & Y, the release of the first vocalic gesture, X, is synchronous with the achievement of the target of a consonant gesture, Z, and the achievement of the target of the second vocalic gesture, Y, is synchronous with the release of the consonant gesture, Z.

(18) describes a relation between the three segments in a VCV sequence identical to that shown above in (17). Note that the area between the release of the first vowel and the achievement of the target of the second is now completely overlapped (and obscured) by the target of the consonant. The gestural coordination relation described in (18) would then be expressed as an Optimality Theory constraint on output like the one in (19):

(19) ALIGN (V_1, RELEASE, C_1, TARGET) & ALIGN (C_1, RELEASE, V_2, TARGET)

We can read the constraint in (19) in prose as 'Align the release of the first vowel in a sequence of vowels with the achievement of the target of a consonant, and align the release of that same consonant with the achievement of the target of the second vowel of a sequence.' For the remainder of this paper, I will refer to this constraint as VCV-COORD[6].

The constraint in (19) requires that any sequence of vowels should have a consonant target aligned with them, in the manner suggested. If the input consists of two vowels that are not separated by a consonant, the actual output will be dependent on the ranking of VCV-COORD in comparison to constraints that prohibit deviating from the input. Consider the tableau in (20), which compares the two possible rankings of the alignment constraint and Dep (C), which rules out epenthesis of consonants.

(20)

Input: i + a	VCV-COORD	DEP(C)
1. i.a	*!	
☞2. i.**C**a		*
	DEP (C)	VCV-COORD
☞1. i.a		*
2. i.**C**a	*!	

[6] All constraints mentioned in this paper are defined explicitly in the Appendix.

The tableau above shows that whether C epenthesis occurs in response to an Alignment violation or not is dependent on DEP's ranking in relation to VCV-COORD. Note, however, that should DEP(C) outrank VCV-COORD, this predicts only that epenthesis will not be a viable repair strategy, not that some other strategy like coalescence or glide formation will not be possible. In Zapotec, VCV-COORD is undominated; input hiatus never survives into the output. The actual constraint ranking that must obtain in Yatzachi Zapotec in order for the exact patterns of hiatus resolution to occur will be discussed further in section 3.

The analysis proposed here can neatly handle the fact that VV sequences in YZ are not permitted to surface faithfully in the output, without reference to ONSET. The original justification for moving away from an ONSET analysis of hiatus resolution lay in the fact that in Yatzachi Zapotec, the same processes occurred in VV as in VʔV cases. The question remains, however, as to why my analysis improves upon the ONSET analysis in dealing with this issue. In YZ, VʔV sequences are not permitted, despite the fact that the glottal stop is aligned appropriately with the vowels according to the constraint in (19). In section 2.3, I discuss this issue and consider the output of hiatus resolution in Zapotec: coalescence, glide formation and diphthongization.

2.3 Gestural Coordination and Glottal Stop

The constraint in (19) seems initially to be problematic for the cases of vowel separated by a glottal stop in Zapotec; these cases undergo hiatus resolution despite the presence of the glottal stop. If glottal stop can play the role of the consonant gesture identified in (18) and (19), then we are left without an explanation of the similarity between the processes occurring in the VV and VʔV environments. However, I suggest that if we consider the nature of glottal stop itself, the solution to the problem will be evident.

It is a generally accepted claim that glottal consonants should be treated as placeless in non-guttural languages, Zapotec included among these. If Zapotec glottal stop is placeless, this would distinguish it from all other consonants in the language. I would like to advance the proposal that this is exactly the way Zapotec glottal stop should be characterized. The idea that glottal stop is placeless in YZ is additionally supported by the ability of spreading to occur across it, a phenomenon limited to [VʔV] contexts, as exemplified by the data shown above in (7) and (8). The permeability of glottal stop to spreading has long been a diagnostic for its placelessness, or at least its divergence from other 'full' consonants (Aoki (1968), Steriade (1987), Bessel and Czaykowska-Higgins (1991), McCarthy (1998), Sumner (1999), Ola Orie and Bricker (2000) and others).

Since glottal stop in Zapotec lacks an oral place specification, it would also lack a target gestural articulation on the place level, and would not have a specification of Constriction Location. Recall, however, that our alignment constraint in (19) requires the release of the initial vowel of a sequence to be aligned with the *achievement of the target of a consonant.* Lacking a fully specified gestural target, glottal stop cannot fulfill the requirements of the alignment constraint in (19), for it does not have a target that can be aligned with the vowels that flank it. In fact, this is an intuitively pleasing result, if we consider the motivation behind this constraint to be the need to obscure perception of transitional gestural cues; glottal stop is so short a consonant that it could not possibly play this role. Glottal stop's lack of a place target means that VʔV contexts violate VCV-COORD just as VV environments do, resulting in repair of both types of sequences.

Now we must consider why the observed hiatus resolution strategies of coalescence and diphthongization constitute appropriate responses to the gestural coordination constraint. On the first count, this is an easy question. Coalescence results in an output vowel that is the correspondent of two input vowels, but this output vowel will have only a single gestural target. This is the case even in the input VʔV environments, where the output result is a long vowel, the second half of which is laryngealized. After coalescence, then, there is no longer a sequence of two vowels, and therefore the alignment constraint is inapplicable.

The issue of diphthongization is slightly more complicated, and requires explicit consideration of the gestures that make up a diphthong. Diphthongs are contour segments, characterized by the fact that in their articulation the tongue moves from the position for one vowel to the position for another. As such, the distinction between diphthongs and adjacent vowels dims a bit, at least with regards to our VCV coordination constraint- diphthongs are often considered to be tautosyllabic sequences of vowels. This approach would be problematic for the present analysis, for it would predict that the coordination constraint would be equally violated by diphthongization as by hiatus, an undesirable result. I propose instead that we should think of diphthongs in a somewhat different manner.

In the discussion of coalescence, I suggested that a coalesced form is a single correspondent of two input vowels but has only a single gestural target. In the Zapotec cases considered here, the result of coalescence is always exactly identical to at least one of the input correspondents. It seems clear that the output of coalescence 'inherits' its phonological specification from the input segments with which it is associated. Let's now consider diphthongs. Diphthongs also inherit their features from their input correspondents. I propose that diphthongization creates a segment that unites the features of its input correspondents in a single output correspondent, just like coalescence. Consider now the examples of coalescence and diphthongization from Zapotec shown in (21).

(21)	a.	zetʃa$_1$	+	e$_2$ʔ	→	zetʃ**e**$_{1,2}$ʔ	-coalescence
	b.	zetʃa1	+	o$_2$ʔ	→	zetʃ**ao**$_{1,2}$ʔ	-diphthongization

I have indicated by the use of subscript that the bold-faced element is the correspondent of both input vowels. As you can see, the difference between diphthongization and coalescence is minimal; the diphthongized form will show the features of both input vowels, while the coalesced form shows the features of only one vowel. In the next section, I discuss the factors that determine which vowels are allowed to diphthongize and which coalesce. To preview, diphthongization of {zetʃa$_1$ + e$_2$ʔ} is ruled out by a constraint prohibiting near-level sonority contours, so while the form in (21a) cannot diphthongize, the one in (21b) is free to do so.

Above I said that diphthongs and coalesced vowels inherit the features of their input correspondents. In the case of coalescence, the output is required to be featurally faithful to only one of the vowels. I assume that because the sonority countour constraint is undominated in Zapotec, a form like (21a) is allowed to surface despite violating input-output faithfulness. Diphthongs, on the other hand, are required to be featurally faithful to the input. Assuming that diphthongs are a *single* correspondent of the input vowels, how can they have the features of both input segments? I propose that diphthongs are forced by input-output faithfulness constraints to carry the phonological specifications of both input vowels. So, in the case of (21b) the diphthong will have an unordered set of features like [+HIGH, +LOW…]. Under the assumption that the gestural target for a segment is read from its phonological specifications, the gestural target for a diphthong like (21b) would, for example, include instructions for Tongue Body Constriction Degree (TBCD) like [NARROW, WIDE].[7] Here we arrive at a conflict; how can a single segment be both [NARROW] and [WIDE] at the same time? The only way for the articulators to implement the conflicting instructions is to sequence the achievement of the target so that it is first [WIDE] then [NARROW].[8] Despite the apparent temporal sequencing of the gesture that forms a diphthong, it is the result of a single gestural target. Because a diphthong has only a single gestural target, the VCV-COORD constraint does not apply for it requires a consonant gestural target to be aligned *between* two vocalic gestural targets. Where there is only a single gesture, there is no violation.

An interesting result of this discussion is that diphthongization begins to look like a form of coalescence that surfaces when the constraint hierarchy conspires to require input-output faithfulness. When no input-output faithfulness is required then canonical coalescence is free to occur, barring interfering factors. This approach might shed light on languages in which coalescence of the sort shown in (22) occurs.

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[7] I am making a number of non-trivial assumptions here; the first is that input segments have phonological specifications like [HIGH, LOW, BACK, FRONT, ROUND, SPREAD]. The second is that those features are mapped into instructions to the articulators as to i) articulators involved (lips for [LABIAL] etc.) ii) constriction degree and iii) constriction location. Here I differ from Browman and Goldstein (1989, et seq.), who would claim that a segment's only specifications are the instructions as to the gestures that form them. Finally, I assume that the phonological features [HIGH] and [LOW] match up with gestural targets for constriction degree [NARROW] and [MID] respectively.

[8] I assume that some sort of CONTIGUITY constraint could determine the order in which the diphthong achieves each portion of its gestural target. Some interesting consequences arise from the assumption that a diphthong has a gestural target with an unordered set of specifications like [NARROW] and [WIDE], though. If this CONTIGUITY constraint is low ranked, input [a + o] could conceivably be realized as diphthongal [oa], rather than [ao]. If we bring into the mix the gestural target for another articulator, for example, the lips, then we have an additional possibility. For input [a + o] we might get a correct ordering of Tongue Body CD [NARROW, WIDE] but a metathesized ordering of Labial CD [NARROW, WIDE], resulting in an output like [ɑɯ]. If full or partial metathesis occurs, then it could be support for the assumption that a diphthong has a gestural target whose specifications are temporally unordered. Additionally, if this were the case, partial metathesis would not constitute a violation of IDENT, but would violate CONTIGUITY.

(22) a. w**a**-**i**nkosi → w**e**nkosi
‘of the chiefs’

b. n**a**-**i**mpendulo → n**e**mpendulo
‘with the answer’

c. w**a**-**u**mfazi → w**o**mfazi
‘of the woman’

d. n**a**-**u**m-ntu → n**o**mntu
‘with the person’

(Casali (1996), from Aoki (1974))

In these examples from Xhosa, the features of both input vowels have been preserved, but the result is not a diphthong, an output which Casali calls “height coalescence”. Following Rosenthal (1994) and Casali (1996), I propose that height coalescence occurs due to the need for feature preservation. In cases like the ones in (22), input-output faithfulness constraints will be ranked high, but so will a constraint like NODIPHTHONG. The result of this ranking is that the features of the input vowels will be preserved as much as possible without creating a diphthong.

In this section, I proposed an analysis of hiatus resolution that can account for the Zapotec data without recourse to the constraint ONSET. I showed here that the constraint will predict repair not only when two vowels are strictly adjacent, but also when they are adjacent across a glottal stop, given an understanding of glottals in non-guttural languages as placeless. In the following section, I will wrap up the remaining issues that will help explain the Zapotec data, before continuing in section 4 to extend my analysis to data from Yucatec Maya and Axininca Campa.

3 Additional Issues in Explaining Zapotec VV and VʔV data

In section 2, I discussed the fact that the motivation behind the observed phenomena in Yatzachi Zapotec vowel sequences was a constraint requiring the target gesture for a consonant to overlap the transition between two adjacent vowels. In Zapotec, this constraint is highly ranked, and thus forces repair of both strictly adjacent sequences of vowels, and vowels that are gesturally adjacent across a glottal stop. What remain to be discussed, however, are the factors that determine what the output of this repair will look like; in other words, what determines which repair strategies will take place in response to VCV-COORD. In this section, I will briefly address this issue to complete the discussion of Zapotec vowel sequences.

3.1 Determining the Repair Strategy Chosen

In determining the repair strategy chosen as a means of avoiding a violation of VCV-COORD, I propose that considerations of the sonority of syllable nuclei are crucial factors. As a background to my discussion, consider the relative sonority hierarchy of Zapotec vowels shown below in (23), adapted from discussion in Kenstowicz (1994).

(23) i, o[9] < e < ə < a
-------------- *rising sonority*----------- >

If vowels do, in fact, differ in sonority, then there are three possible sonority contours that might obtain in a vowel sequence. These are rising sonority, falling sonority and level sonority. Nevertheless, all options are not equal. Zapotec allows only the former two contours; Zapotec diphthongs may be either rising [ja], [we] or falling [ao]. However, Zapotec syllable nuclei may never have level sonority unless the nucleus consists of a single member[10]. Moreover, YZ does not allow nuclei to surface into the output whose difference in sonority is less than two steps on the sonority scale in (23). I propose that the constraint shown in (24) prohibits syllabic nuclei with level sonority.

(24) SONORITYDISPERSION$_{(\text{NUCLEUS})}$ (SONDISP$_{(\text{NUC})}$): the members of a syllable nucleus should be maximally distant in sonority.

In Zapotec, this constraint is never violated, and may be ranked indefinitely high. The ranking predicts that, in choosing between coalescence and diphthongization, the former strategy will be preferred when diphthongization would result in an output that violated SONDISP$_{(\text{NUC})}$. This is due to the fact that while coalescence results in a syllable nucleus with a single sonority value, diphthongization results in a syllable with a sonority contour across the nucleus, and thus may only occur when the result is a syllable whose members are maximally distant in sonority. Consider the tableaux in (25) and (26), which show that different outputs are predicted in input [a.e] (which violates SONDISP) sequences than are predicted in input [a.o] sequences (which does not violate SONDISP.

[9] This vocalic sonority scale differs from that proposed in Kenstowicz (1994) in that I have grouped [o] with [i] rather than [e]. My motivation for doing so is based on the fact that Zapotec's [o] is intermediate between [o] and [u] according to Butler-Haworth, and that it patterns with [i] rather than [e] in Zapotec. This suggests it should be closer in sonority to [i] than Zapotec's [e]. An additional difference between the scale in (21) and that in Kenstowicz (1994), is that the latter did not include [ə]. Since, for him, the vowels seem to pattern along height lines, he might claim that [ə] is equivalent in sonority to [e, o]. I suggest that schwa is more sonorous than [e, o]. This proposal is based on the Zapotec data as well as consideration of the articulatory properties of schwa (the mouth is significantly more open in the production of schwa than of the other mid vowels).

[10] For the purposes of this paper, I consider long vowels to satisfy the requirement of being a single unit, and thus may have level sonority. Diphthongs, which I consider to have a single dynamic gestural specification, must have a non-level sonority contour.

(25)

Input: zetʃa + eʔ	VCV-COORD	SON DISP
1. zetʃaeʔ		*!
☞2. zetʃeʔ		
3. zetʃa.eʔ	*!	

(26)

Input: zetʃa + oʔ	VCV-COORD	SON DISP
☞1. zetʃaoʔ		
2. zetʃa.oʔ	*!	

As the tableaux in (25) and (26) show, the ranking of the constraints VCV-COORD and SONDISP as undominated forces an input [a.e] sequence to be realized somehow other than diphthongization (here, coalescence occurs). On the other hand, since diphthongization of an input [a.o] sequence does not violate any of the aforementioned constraints, it is a freely available repair of the VCV-COORD constraint.

Having determined that diphthongization is not available as a repair strategy for VCV-COORD just in case SONDISP is violated, we can now turn to discussing the choice of coalescence over diphthongization in cases where SONDISP does not rule out the latter repair.

In comparing the forms that cannot undergo diphthongization, we can see that the only forms that don't become a diphthong have either [ə] or [a] in first position[11]. Rosenthall (1994) observes that cross-linguistically [ə] and [a] are unlikely to have glide counterparts. He proposes the constraint {A}= V, defined roughly in (27a). Because Rosenthall (1994) makes use of particle phonology (each vowel is made up of vocalic particles {I}, {U} and/or {A}), unlike the present analysis, I will reformulate the constraint as shown in (27b, c).

(27) a. {A}= V: input segments with {A} particles must surface as vowels
b. PEAK$_{SYLL}$ [a]: output correspondents of input [a] should be moraic
c. PEAK$_{SYLL}$ [ə]: output correspondents of input [ə] should be moraic

[11] Sequences of identical vowels also do not undergo glide formation, presumably because of the need to avoid a violation of IDENT V when possible.

The constraints in (27) share the property of requiring [a] and [ə] to be moraic, and are essentially identical in this respect. This would preclude glide-formation of these vowels, so they could not be the on-glide into a diphthong. Note that insofar as (27a) applies to [ə], it would also apply to [e] and [o] (which are considered to be made up of {I, A} and {U, A} particles respectively), an undesirable consequence of constraints making reference to vowel particles.

Furthermore, (27b, c), from Kenstowicz (1994) and Prince and Smolensky (1993) can be seen to be derived from the sonority hierarchy introduced above. In his discussion of the aforementioned PEAK$_{SYLL}$ constraints, Kenstowicz (1994), following Prince and Smolensky (1993), proposes that they should be ranked hierarchically in relation to one another as shown in (28).

(28) PEAK$_{SYLL}$ a > e, o > i, u> …. > p, t, k

Kenstowicz (1994) p. 3

The hierarchy in (28) is meant to reflect the cross-linguistic generalization that [a] is a better nucleus than [e, o], which in turn are better than [i, u]. The worst syllable nucleus would be a voiceless stop, [p, t, k]. The hierarchy itself derives from a segmental sonority scale that ranks segments in terms of their overall sonority. The reader will most likely be familiar with the consonant sonority scale shown in (29), and (30) shows the vocalic sonority hierarchy previously introduced.

(29) obstruents < nasals < liquids < glides < vowel
------------------- *rising sonority*-------------------- >

(30) i, o < e < ə < a
--------------- *rising sonority*----------- >

Since PEAK$_{SYLL}$[a, ə] are both unviolated in Zapotec, they are also undominated. We can then propose that dipthongization would be the preferred outcome of input-adjacent vowel sequences, but for the fact that [a] and [ə] are required to be syllable nuclei. Coalescence, a violation of the constraint UNIFORMITY[12], which requires all output segments to have at most one input correspondent, is only possible when the first vowel in the sequence does not have a glide counterpart, or when no input features are lost through coalescence (as is the case with identical vowels).

The constraint ranking we have arrived at in this discussion is thus the one shown below in (31).

[12] De Lacy attributes the formulation of this constraint to McCarthy and Prince (1995) and LaMontagne and Rice (1995)

(31) VCV-COORD, SONDISP, $\text{PEAK}_{\text{SYLL}}$ [a, ə] >> UNIFORMITY >> IDENT (V) >> NODIPHTHONG

The constraint ranking in (31) can account for all the Yatzachi Zapotec data introduced in section 1. The tableaux in (32) and (33) show that the constraint ranking given can handle both VV and VʔV data:

(31)

Input: zetʃa + eʔ	VCV-COORD	SONDISP	$\text{PEAK}_{\text{SYLL}}$[a]	UNIFORMITY	IDENT V
1. zetʃa.eʔ	*!				
2. zetʃaeʔ		*!			
3. zetʃjeʔ			*!	*	
☞4. zetʃeʔ				*	*

(32)

Input: tʃʃagna + eʔ	VCV-COORD	SONDISP	$\text{PEAK}_{\text{SYLL}}$[a]	UNIFORMITY	IDENT V
1. tʃʃagna.e̤	*!				
2. tʃʃagna.ʔe	*!				
3. tʃʃagnae̤		*!			
4. tʃʃagnje̤			*!	*	
☞ 5. tʃʃagnee̤				*	*

Before going on to discuss the predictions that the proposal regarding VCV-Coordination makes for how we should analyze other languages, I will discuss one way in which VV and VʔV sequences differ; coalescence in the latter case results in nuclei which are bimoraic rather than monomoraic.

3.2 MorphReal and RootFaith

A question that might arise when dealing with, for example, identical vowels across a glottal stop, is why we don't see total haplology of the final syllables; [tʃʃagna$_1$ʔ$_2$ + a$_3$ʔ$_4$] → *[tʃʃagna$_{1,3}$ʔ$_{2,4}$]. This would be another way in which VCV-Coord could be satisfied, and we would preserve the greatest degree of parallelism between VʔV and VV, because both would reduce to monomoraic syllables. It is not immediately apparent why the VV cases couldn't also surface as bimoraic.

I propose to account for this divergence in the patterning of the VV and VʔV environments with the constraint shown in (33).

(33) MorphReal: Every morpheme in the input should have a unique phonetic realization in the output.[13]

This constraint demands that the morphological make-up of the input be recoverable in the output.

Let's now consider the role that MorphReal plays in deciding the output candidate in both VV and VʔV contexts:

(34)	a.	Input:	zetʃa	+	-aʔ
	b.	Output:	zetʃaʔ		
(35)	a.	Input:	tʃʃagnaʔ	+	-aʔ
	b.	Output:	tʃʃagnaa		
	c.	Haplology:	tʃʃagnaʔ		
			tʃʃagnaʔ		

In (34) and (35), morpheme correspondence between input and output is indicated by the type of underline; correspondents of root segments are singly underlined, while correspondents of the suffix are marked with a double underline. In (34), we can see that each input morpheme has its own output realization, [zetʃa] and [ʔ], respectively. Thus

[13] This constraint and its definition come from de Lacy (1999). He attributes its origin to Samek-Lodovici (1993).

MORPHREAL is satisfied because both input morphemes have a uniquely identifiable realization in the output. Likewise for the VʔV example in (35b). However, if haplology were to occur in the VʔV example, (35c) shows that the resulting output would be morphologically ambiguous. Each version is identical to the uninflected verbal base; there is no uniquely identifiable output realization of the suffix, hence a violation of MORPHREAL. Thus, the bimoraicity of the vowel in VʔV contexts falls out as a response to the need to satisfy MORPHREAL; the suffix will have its phonological realization in the second mora of the output vowel.

MORPHREAL comes into play in determining the output of other forms as well. Consider the example in (36) in which the two input vowels have coalesced, resulting in the loss of the features of the root vowel:

(36)	a.	Input:	zetʃa$_1$	+	-e$_2$ʔ
	b.	Output:	zetʃe$_{1,2}$ʔ		

The situation that (36) illustrates is one in which faithfulness to the vowel of the affix is more important than faithfulness to the root vowel. This result seems to contradict the claim that ROOTFAITH harmonically outranks AFFIXFAITH, cross-linguistically (Alderete 1998). The Zapotec data needn't be problematic for Alderete's assumption, however. With MORPHREAL as the constraint that forces preservation of the suffix vowel as opposed to the root vowel, this fact is a consequence of the need for every morpheme to have a phonological realization. It says nothing about the morphological status of the morpheme (root or affix); it should apply in equally to all morphemes.

In fact, we can see that ROOTFAITH outranks AFFIXFAITH even in Zapotec. Consider the example in (37):

(37)	a.	Input:	tʃxi$_1$	+	-əb$_2$
	b.	Output:	tʃxi$_{1,2}$b		
	c.		*tʃxjəb		

(37a,b) shows that given the input {tʃxi + -əb}, the constraint MORPHREAL does not force the suffix vowel to remain in the output. This is because, even without the suffix vowel, the identity of the suffix is recoverable from the retention of the final consonant of the suffix [b][14]. As soon as we are not required to keep the suffix vowel, the ranking of

[14] Retention of the suffix final glottal stop in, for example, (ib) is not sufficient to satisfy MORPHREAL, resulting in the observed output being one that has undergone coalescence, (ic).

i. a. zetʃa + eʔ
b. zetʃaʔ
c. zetʃeʔ

I assume this to be true as a result of ambiguity caused by retention of only the glottal stop of the suffix; three out of the five suffixes discussed in this paper end in a glottal stop. Preserving the glottal stop at the expense of the suffix vowel would lead to an output that was indeterminate as to which morpheme (*-aʔ,*

ROOTFAITH >> AFFIXFAITH will force us to coalesce, (37b), rather than diphthongize, (37c), because changing the features of the root vowel incurs a now fatal violation of ROOTFAITH.

One final way in which the VV and VʔV contexts differ is that VʔV forms exhibit laryngealization on the output vowel. I will consider this to be the result of coalescence of the glottal stop with the following vowel. Coalescence of this sort is proposed in Sumner (1999) to account for the fact that compensatory lengthening in Colloquial Farsi occurs following loss of glottal consonants, which she considers to have been coalesced with the lengthened vowel. For Sumner, it is the very fact that glottal stop is placeless, a key assumption in the present analysis, that allows it to coalesce with a vowel. In the case of Zapotec, this coalescence must be accompanied by laryngealization to preserve the [+glottal] feature of the input consonant. Thus, a high ranking IDENT (C) constraint will predict that the surface realization of VʔV involves laryngealization of an output vowel.

Having arrived at a fully articulated analysis of all the Zapotec data introduced in section 1, I now turn to consider the possibility of applying my analysis to languages beyond Zapotec whose hiatus resolution patterns can be straightforwardly handled by the VCV-COORD approach, including Yucatec Maya and Axininca Campa.

4 Extending the Analysis to Other Languages

4.1 Yucatec Maya

In Yucatec Maya, (YM) a language unrelated to Zapotec but also spoken in Mexico, glottal consonants, [h] and [ʔ], act as placeless. Accordingly, they pattern differently from other consonants in the language (Ola Orie and Bricker 2000).
As the data in (38) show, glottals may delete when they are surrounded by non-identical vowels, unlike other YM consonants, which do not delete. Glottals may be deleted at morpheme junctures in which illegal consonant clusters are formed, (39), regardless of whether they are members of the suffix or affix. In the case of non-glottal consonants, the deleted consonant is always part of the affix. Additionally, full consonants never delete when there is a glottal that could do so.

(38)	Input	Output	Gloss[15]
	a. kin c’ah ik	kin c’ayik	I give it.
	b. sih eh	siyeh	present it!
	c. tʃiʔ eh	tʃiyeh	bite it!
	d. p’oʔ eh	p’oyeh	wash it!

-oʔ, or *-eʔ)* was present in the input.

[15] The “y” that surfaces in these examples in place of the glottal stop is considered by Orie and Bricker (2000) to be the result of the normal hiatus resolution processes of Yucatec Maya; [j] is regularly epenthesized between two input adjacent vowels.

(Ola Orie and Bricker 2000's (6))

(39)

	Input	Output	Gloss
	a. uy-ʔal	uyal	the heavy one
	b. tʃoʔ-b'	tʃoʔob/ *tʃoʔo	be clean[16]
	c. uy-heʔel k'uʔ	uyeʔel k'uʔ	the nest's egg
	d. ʃeh-b'	ʃeʔeb/ *ʃeʔeʔ	be vomited
	e. uy-tʃitʃ	u-tʃitʃ	the hard one
	f. tʃin-b'	tʃiʔib'	be bent

(Ola Orie and Bricker 2000's (8) & (9))

The data in (38) and (39) support the conclusion that glottals in YM are placeless. On analogy from the discussion of Zapotec glottal stop, we can predict that a glottal consonant that intervenes between two vowels will not satisfy VCV-COORD. Consider now the data in (40) and (41). (40) shows that in adaptations of vowel initial Spanish loans, a glottal stop is epenthesized word initially. Ola Orie and Bricker (2000) state that this is due to a requirement that all roots both begin with and end with a consonant (this constraint is described in Ola Orie and Bricker (2000)'s words in (40a)):

(40) a. INITIAL C: roots and words must begin in a consonant

	Spanish	Yucatec Adaptation	Gloss
b.	arroz	ʔáaroz	rice
c.	anita	ʔáan	Anne
d.	estevan	ʔées	Steven
e.	ojo	ʔòohoh	eye

As (40) shows, glottal stop is employed as an epenthetic consonant in response to Ola Orie and Bricker (2001)'s INITIAL C constraint, which requires roots to begin with a consonant. Note that the same result would be achieved were we to substitute ONSET for INITIAL C.

Turning to the data in (41), we see that when two non-identical vowels are separated by a glottal stop, regressive assimilation (spreading) of the rightmost vowel onto the one preceding the glottal stop occurs.

[16] The fact that the output of [tʃoʔ-b'] cannot be [tʃob'] can be seen as a result of a requirement that words in YM be minimally bimoraic.

(41)

	Input	Output	Gloss
a.	heʔ im b'ineʔ	hiʔ im b'ineʔ	'I will go'
b.	heʔ a b'ineʔ	haʔ a b'ineʔ	'You will go'
c.	heʔ u b'ineʔ	huʔ u b'ineʔ	'He will go.'

(Ola Orie and Bricker (2000) pg. 288)

Given that the constraint VCV-COORD is independently necessary to account for the Zapotec patterns, I propose to apply it to the Yucatec Maya data as well. I propose that spreading of the rightmost vowel onto the one preceding the glottal stop is forced by the constraint VCV-COORD. Spreading of the vocalic features of one vowel onto the other, in essence coalescence of the two vowels, creates an output in which there is a single vowel gesture across the glottal stop. Thus VCV-COORD is not violated, for there is only a single gestural target.

The situation presented in (40) and (41) is very interesting within the framework of my analysis; they show that while epenthesis of a glottal stop before vowel initial roots will satisfy the constraint ONSET, having a glottal stop between two vowels does not satisfy the constraint VCV-COORD. Considering the requirements of the two constraints, this conclusion is expected; ONSET merely requires words to begin with a consonant, but VCV-COORD requires the *target* of a consonant to be aligned in a particular manner. Having previously determined that glottal stop in YM acts as placeless, lacking an oral target, its presence does not satisfy VCV-COORD in this language. Therefore, spreading must occur in order to satisfy VCV-COORD.[17] In fact, Ola Orie and Bricker (2000, p. 291) anticipate such an analysis in a suggestion that "because laryngeals lack a place node, at the place level, the place nodes of flanking vowels are adjacent, hence, in hiatus." (The word "hiatus" should be considered as descriptive of the phenomena here, not as indicating that VʔV in Yucatec Maya incurs a violation of ONSET.)

In Yucatec Maya, we saw an example of a language that treated glottal stop differently depending on the environment in which it was found. The treatment of glottal stop in Yucatec Maya is consistent with what would be expected under the VCV-COORD. Additionally, we saw that the repair strategy employed in a response to VCV-COORD violation with glottals was coalescence of the two vowels flanking the glottal stop- surfacing as regressive spreading of the rightmost vowel[18]. In the next subsection, I turn to Axininca Campa, a language in which putative onset violations are treated differently depending on whether they are word initial or word medial.

[17] It is apparent from the data shown in (38) that another way in which Yucatec Maya satisfies VCV-COORD is to delete the glottal segment, replacing it with a "y". The choice of the two strategies is presumably based on other factors, I'll leave to others to determine.
[18] Note that VCV-COORD violations without a glottal stop are fixed by epenthesis of a glide as the onset to the second syllable.

4.2 Axininca Campa

Axininca Campa, an Arawakan language spoken in Peru, exhibits an interesting asymmetry of onset repair; initial ONSET violations are allowed to surface into the output, while medial onset violations must be repaired through epenthesis of a coronal stop. In fact, according to McCarthy and Prince (1993), all syllables must have onsets with the exception of the initial syllable. This asymmetry poses a direct challenge to an ONSET analysis of hiatus resolution; in order to get repair of adjacent vowel sequences, this approach would require ONSET to be highly ranked, but that ranking should also rule out initial onsetless syllables. In this section, I discuss the Axininca Campa data, as well as an analysis of the data proposed by McCarthy and Prince (1993). I then propose that the Axininca Campa pattern can straightforwardly be accounted for using the present VCV-COORD analysis.

The data in (42a, b) shows examples of epenthesis into hiatus contexts in Axininca Campa. All examples in (42) show the possibility of initial onsetless syllables.

(42)	Input	Output	Gloss
	a. i-N-koma-i[19]	iŋkoma**T**i	'he will paddle again'
	b. oti-aanc^{h}I	oti**T**aanc^{h}i	'to put in"
	c. i-N-tʃ^{h}ik-i	iɲtʃ^{h}iki	'he will cut'
	d. *iraniri	iraniri	'his son-in-law'

(From McCarthy and Prince (1993))

McCarthy and Prince (1993) propose that the constraint ONSET is high ranked in Axininca Campa. Epenthesis occurs in word medial position as a result of the need to satisfy this constraint. McCarthy and Prince (1993) seek to analyze the fact that ONSET violations are not repaired word initially. They claim that syllable structure constraints and prosodic constraints interact with those determining morpheme structure and position. For the case of the asymmetrical treatment of ONSET violations, they propose an alignment constraint that requires the left edge of a stem to be aligned with the left edge of a prosodic word, which outranks ONSET. Their constraint is shown below in (43).

(43) ALIGN-L $[_{\text{STEM}} = [_{\text{PRWD}}$: Align the left edge of a stem with the left edge of a prosodic word.

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[19] For the purposes of these examples, N = a nasal unspecified for place that agrees with a following consonant in the output, **T**= an epenthetic coronal consonant, conventions for describing Axininca Campa based on their use in McCarthy and Prince (1993). The example in (42d) was taken from McCarthy and Prince (1993), who did not identify its input form. The asterisk denotes that the input is a reconstructed one.

The constraint shown in (43) will require that no epenthetic elements be added preceding the left edge of the stem. Thus, initial onsetless syllables will surface into the output unchanged because ALIGN-L outranks ONSET; the ONSET violation is tolerated because repairing it would incur a fatal violation of the alignment constraint in (43). In the case of medial syllables, however, ALIGN-L should not be at issue. The constraint ranking they arrive at is ALIGN-L >> ONSET >> DEP(C) (FILL for the authors).

While the McCarthy and Prince (1993) analysis can handle the Axininca Campa data, I propose to approach it in the same manner as Yatzachi Zapotec. The analysis I propose to take is that Axininca Campa ranks VCV-COORD very high- it is undominated. The high ranking status of this constraint forces epenthesis in medial hiatus contexts. This suggests that we should rank VCV-COORD above DEP(C). No repair is predicted by VCV-COORD in initial position, since we do not have the requisite juxtaposition of vocalic gestures. Instead of ranking ONSET high and explaining why it doesn't apply in initial position, we can demote it in favor of VCV-COORD. The constraint ranking for Axininca Campa is thus VCV-COORD >> DEP(C) >> ONSET. The tableau in (44) shows that this new constraint ranking can account for both the fact that initial onsetless syllables survive into the output and that medial ones do not:

(44)

Input: iN-koma-i	VCV-COORD	DEP(C)	ONSET
☞1. …ma.**T**i		*	
2. …ma.i	*!		*
	VCV-COORD	DEP(C)	ONSET
☞1. iŋ			*
2. **T**iŋ…		*!	

The tableau in (44) shows that by applying the VCV-COORD constraint, which was independently necessary for Zapotec, we can explain the Axininca Campa data without recourse to McCarthy and Prince's prosodic alignment constraint. This is a desirable result because it explains the Axininca Campa data with a constraint which I have argued to be independently necessary to account for data from Yatzachi Zapotec. This is not to say, however, that prosodic alignment constraints do not have useful application elsewhere.

In the next section, I turn to cases of vowel harmony in which the features of one vowel spread onto the next across an intervening consonant, and suggest that VCV-COORD might shed some light on this issue.

4.3 Vowel Harmony Systems

In this section, I discuss the possibility that feature spreading in vowel harmony systems occurs for the same reason as spreading in Yucatec Maya - in order to satisfy the VCV-COORD constraint. In Vowel Harmony Systems, a subset of the features of one vowel spreads onto one or more other vowels in the word, resulting in agreement in those features across the word. In many Optimality Theory analyses of Vowel Harmony, the source vowel spreads onto the target vowel as a result of the action of a constraint of the sort shown in (45):

(45) ALIGN-RT/LFT, (FEATUREα, PRWD): Align the feature α with the right/ left edge of a prosodic word

The constraint in (45) will require progressive/regressive spreading of the feature [α] from the source vowel to the target vowel.

Under the assumption that (45) motivates harmonizing, any vowel to the right/left of the source vowel that does not agree in α will incur a violation of ALIGN RT/LFT. Consider now the forms in (46), which are examples of vowel harmony in Turkish.

(46)	Input	Output	Gloss
a.	son-Vn	son-un	‘end-genitive’
b.	kɨz-Vn	kɨzɨn	‘girl-genitive’
c.	köy-Vn	köyün	‘village-genitive’
d.	el-Vn	elin	‘hand-genitive’

(from Ní Chiosáin and Padgett (1998))

In (46), the genitive suffix is a vowel specified only as high and takes on its backness and rounding feature from the source vowel. We see here that spreading in Turkish occurs across consonants.

In Gafos and Lombardi (1998), among others, it is argued that when features are spread from one segment onto the next, all intervening segments must necessarily also participate in the spreading. In fact, studies of consonant-vowel coarticulation support this constraint. In these studies, researchers have examined speech signals and speech production in order to determine the influence of vowels on consonants (Browman and Goldstein (1990), Boyce et al. (1991), Cohn (1993), Keating (1988)). The studies showed that even when intervening consonants were not deemed to be phonologically affected by the vowels on either side, their articulation was influenced by flanking vowels. This supported the idea that when spreading occurs, it must not skip any segment intervening between the source and the target. A consonant that allows spreading to occur across it is called *transparent* to spreading[20].

The question arises here as to what it means for a consonant to be transparent to spreading, and why certain consonants are more permeable to spreading than others. McCarthy (1998) gives the following typology of consonants that allow spreading across them:

(47) Consonants that Accept Spreading of Vocalic Place in VCV

a. Laryngeals ʔ, h	Aoki 1968: Nez Perce Steriade 1987: many cases
b. Gutterals ʔ, h, ʕ, ħ, χ, ʁ	McCarthy 1991: many cases
c. (b) plus coronal sonorants l, r, s	McCarthy 1991: Bedouin Arabic
d. Coronal continuants l, r, s	Makassarese, Selayarese, Konjo
e. Liquids l, r	Paradis and Prunet 1989: Mau
f. Various Coronals	Paradis and Prunet 1989: Gere Paradis and Prunet 1989: Fula
g. All consonants	Clements & Hume 1995: Servigliano Italian

Additionally, he discusses a markedness hierarchy of consonants according to their compatability with having vocalic place superimposed on them (48) through spreading.

(48) Pharyngeals > Coronals > Labials, Dorsals

That pharyngeals allow spreading across them could be explained along the same lines as I have explained spreading across Zapotec's glottal stop, which I will return to in a moment. In discussing coronals, which are primarily articulated with the tongue tip-blade, Gafos (1999) states that "the tongue tip-blade is relatively independent from the tongue body- the major articulator for vowels," and second, "the precise … posture of the tip-blade has no significant effects on the acoustic quality of the vowel." (pg. 7) From these generalizations, he derives two factors that explain when apparently non-local spreading can occur: articulatory independence and acoustic irrelevance. Note that coronals differ from labials and dorsals in that the latter two are not articulatorily independent of vowels; labials involve the lips, and articulator manipulated for producing phonemic rounding contrasts on vowels and dorsal gestures involve the tongue body/ back, "the major articulator for vowels." (pg. 7)

[20] I am using the word transparent to refer to consonants who allow spreading across them but do not show any affect of the spreading, at least phonologically. This distinguishes them from consonants that participate in the harmony, themselves taking on the spread feature.

We should expect, in general, that consonants that tend to allow spreading across them are a) made with articulators not manipulated by the segment that spreads and b) spreading should not perturb the acoustics of transparent element. Consider now glottal stop in this light. A glottal stop is made with closure at the glottis, but involves no additional articulators. Thus, glottal stop is articulatorily independent of surrounding vowels, which are articulated using the tongue body. Similarly, the acoustics of a glottal stop should not be affected by gestures taking place in the mouth during its production. Assuming these generalizations, we predict that vowel spreading occurs freely across the glottal stop, because in a VʔV context, glottal stop meets both 'requirements' for transparency; articulatory independence and acoustic irrelevance. This suggestion is supported by research by Aoki (1968) and Steriade (1987), who note that glottal stop is the most likely consonant to allow spreading across it.

In this paper, I have taken an approach that can provide an explanation for the observations discussed in Gafos (1999) that if a feature spreads across a segment, the segment is articulatorily independent of the articulation of the spreading feature. I assume the following generalization: if a segment is produced without involvement of a particular articulator, then that segment has no phonologically specified gestural target for that articulator. I propose that in exactly those cases when one segment lacks a target for an articulator manipulated in the production of another, the two segments can be said to be articulatorily independent of one another. The fact that spreading occurs only across articulatorily independent segments falls out straight forwardly if we take a VCV-COORD approach to vowel harmony; articulatorily independent segments lack a target that can satisfy the requirements of VCV-COORD. Thus, spreading must occur to remedy this problem. Moreover, while previous analyses explained the fact that spreading *could* occur across a glottal stop, they couldn't explain cases, like Yucatec Maya, in which full spreading *had to* occur. In this analysis the reason glottal stop allows spreading across it is identical to the reason Yucatec Maya forces spreading across it; glottal stop lacks a gestural target for the tongue body.

I propose that vowel harmony systems can also fall under the VCV-COORD approach, with no recourse to a constraint like (44). Instead, the constraint in (46) will predict spreading of features across an intervening consonant whenever that consonant lacks a target, in a manner analogous to the glottal stop case.

(46) VCV-COORD: ALIGN (V_1, RELEASE, C_1, TARGET) & ALIGN (C_1, RELEASE, V_2, TARGET)

Additionally, recall that VCV-COORD is understood to require a consonant's gestural target to be aligned between every sequence of vowels, for every articulator. With this constraint, we can predict partial vowel harmony in addition to full coalescence, since it allows us to evaluate the desired gestural coordination relation for every feature (e.g. rounding, backness, nasality etc…). Which features spread would depend on where VCV-COORD falls in the hierarchy in relation to constraints requiring identity between the input and output, for example $\text{IDENT}_{\text{I-O}}$ [ROUND], $\text{IDENT}_{\text{I-O}}$ [BACK], $\text{IDENT}_{\text{I-O}}$ [NASAL].

An implicit assumption of the VCV-COORD approach to spreading/coalescence in YZ and YM is that it cannot be considered the result of an imperative to spread; it is simply a repair strategy implemented in order to avoid a violation of VCV-COORD. In this way, the present analysis differs crucially from most OT approaches to vowel harmony that posit a constraint like the one shown in (44) in order to motivate feature spreading. Under the present analysis, feature spreading that occurs in vowel harmony languages does not accidentally pass through intervening consonants, it *must* do so. One consequence eliminating the imperative to spread is that we must assume that certain segments are impermeable to spreading because they *do* have a target specification that can fulfill the requirements of VCV-COORD. Thus spreading would incur a gratuitous violation of, say IDENT, one that was not motivated in any way by the need to satisfy a higher ranked constraint.

5. Conclusion

In this paper, I have argued that hiatus resolution should not be seen as motivated by the requirement that all syllables have ONSETS, but rather by a requirement that vowel gestures not be contiguous, without an overlapping consonantal gesture. The motivation behind this constraint was to obscure ambiguous transitional gestures between two adjacent vowels. Thus, this analysis provides a functional grounding for the notion of syllable structure constraints discussed previously in the literature.

With a distinction drawn between the motivations for the repair of ONSET violations and repair of so-called hiatus violations, we are at once able to explain cases in which there exists an asymmetry between the treatment of ONSET violations depending on position within the word. Languages in which initial onsetless syllables survive into the output but medial onsetless syllables do not (Yatzachi Zapotec, Axininca Campa) are thus explained by ranking VCV-COORD >> REPAIR >> ONSET. With this ranking, only VCV-COORD is high ranked enough to motivate repair. ONSET is too low ranked to be repaired.

The picture presented here accounts for data from Yatzachi Zapotec regarding the remarkable similarity between strictly adjacent contexts and VʔV environments. My account predicts repair in YZ VʔV contexts because VCV-COORD requires the *target* of a consonant to overlap the transition between two vowels. Following Bessell and Czaykowska-Higgins (1991), Sumner (1999), Ola Orie and Bricker (2000) and others, I claimed that Zapotec glottal stop was placeless, and therefore lacking a target appropriate to satisfy VCV-COORD. The observed similarity is predicted to occur because both VV and VʔV forms violate the same constraint. ONSET analyses, in contrast, cannot predict any repair in the VʔV forms because ONSET is not violated in these forms. Data from Yucatec Maya also showed that glottal stop figures differently in medial position than it does in other environments, namely word initial position. In Yucatec Maya, glottal stop is considered a good candidate to satisfy ONSET, but it cannot fulfill the requirement of

VCV-COORD. This fact suggests that the VCV-COORD constraint differs from ONSET in requiring a coordination of gestural targets rather than simply of segments, as has been proposed in this paper.

Finally, I suggested that VCV-COORD might also be able to account for feature spreading in vowel harmony systems. The analysis I sketched indicated that the motivation for vowel harmony is the need to minimize gestures across those consonants whose articulation does not include gestural targets for the relevant articulators, for example, the lips for rounding harmony. In response to the violation of VCV-COORD, spreading must occur to minimize the gestural transition across the offending consonant. We might say that it is not an accident that some consonants are permeable to spreading, rather that feature spreading is a direct consequence of their transparency. This approach would do away with constraints demanding spreading, for it sees spreading as a repair strategy for VCV-COORD rather than a goal in itself. How this suggestion should be implemented, as well as the consequences that would result remains an interesting topic for future work.

APPENDIX 1: CONSTRAINTS AND DEFINITIONS:

- **{A}= V**: input segments with {A} particles must surface as vowels. (Rosenthall 1994)
- **AFFIXFAITH:** The output should be faithful to the input features of affixes. (Alderete 1998)
- **ALIGN-L** $[_{STEM} = [_{PRWD:}$ Align the left edge of a stem with the left edge of a prosodic word. (McCarthy and Prince 1993)
- **ALIGN-RT, (FEATUREα, PRWD):** Align the feature α with the right edge of the word.
- **DEP$_{(I-O)}$ (C):** All output segments should have input correspondents; avoid epenthesis.
- **IDENT$_{(I-O)}$ (V):** Output correspondents of input vowels should agree in features with the input correspondent.
- **INITIAL C**: roots and words must begin in a consonant. (Ola Orie and Bricker 2000)
- **INITIAL AND FINAL C**: roots and words must begin and end in a consonant (Ola Orie and Bricker 2000)
- **MORPHREAL:** Every morpheme in the input should have a unique phonetic realization in the output. (Samek-Lodovici 1993, de Lacy 1999)
- **NODIPHTHONG**: Do not create diphthongs.
- **ONSET**: All syllables should have onsets. (Prince and Smolensky 1993)
- **PEAK$_{SYLL}$ [a]**: output correspondents of input [a] should be the peak of a syllable. (Prince and Smolensky 1993, Kenstowicz 1994)
- **PEAK$_{SYLL}$ [ə]**: output correspondents of input [ə] should be the peak of a syllable. (Prince and Smolensky 1993, Kenstowicz 1994)
- **ROOTFAITH**: The output should be faithful to the input features of affixes (Alderete 1998).
- **SONORITYDISPERSION$_{(NUCLEUS)}$ (SONDISP$_{(NUC)}$)**: the members of a syllable nucleus should be maximally distant in sonority.
- **UNIFORMITY:** Output segments should have at most one input correspondent; avoid coalescence. (McCarthy and Prince 1995, Lamontagne and Rice 1995, de Lacy 1999)
- **VCV-COORD- ALIGN (V_1, RELEASE, C_1, TARGET) & ALIGN (C_1, RELEASE, V_2, TARGET)**: 'Align the release of the first vowel in a sequence with the achievement of the target of a consonant, and align the release of that same consonant with the achievement of the target of the second vowel of a sequence.'

APPENDIX 2: PREDICTIONS MADE BY THE ANALYSIS

The present analysis makes a number of interesting predictions as to what languages should be possible. If we take all of the logically possible rankings of ONSET, VCV-COORD, and two repair constraints X and Y, (for example epenthesis of a consonant, deletion of a vowel, coalescence etc) then we can identify all patterns expected to be present cross-linguistically. These are shown in (47) – (51) below, organized according to outcome.

(49) No Repair of ONSET (#V, NO VV)

a. Y >> VCV-COORD >> X >> ONSET
b. X >> VCV-COORD >> Y >> ONSET
c. VCV-COORD >> X >> Y >> ONSET
d. VCV-COORD >> Y >> X >> ONSET

(50) No Repair of VCV-COORD (VV, NO #V)

a. ONSET >> X >> Y >> VCV-COORD
b. ONSET >> Y >> X >> VCV-COORD
c. Y >> ONSET >> X >> VCV-COORD
d. X >> ONSET >> Y >> VCV-COORD

(51) Repair of neither ONSET nor VCV-COORD (#V, VV)

a. Y >> X >> VCV-COORD >> ONSET
b. X >> Y >> VCV-COORD >> ONSET
c. Y >> X >> ONSET >> VCV-COORD
d. X >> Y >> ONSET >> VCV-COORD

(52) Repair of both ONSET and VCV-COORD (NO #V, NO VV)

a. ONSET >> X >> VCV-COORD >> Y
b. ONSET >> Y >> VCV-COORD >> X
c. ONSET >> VCV-COORD >> Y >> X
d. ONSET >> VCV-COORD >> X >> Y
e. Y >> ONSET >> VCV-COORD >> X
f. Y >> VCV-COORD >> ONSET >> X
g. X >> ONSET >> VCV-COORD >> Y
h. X >> VCV-COORD >> ONSET >> Y
i. VCV-COORD >> ONSET >> X >> Y
j. VCV-COORD >> ONSET >> Y >> X
k. VCV-COORD >> X >> ONSET >> Y
l. VCV-COORD >> Y >> ONSET >> X

The most interesting possible outcomes among those sketched above are cases in which only one environment gets repaired; such a language would serve as more evidence that we were justified in differentiating the constraints ONSET and VCV-COORD. Note, however, that in any case in which ONSET is higher ranked than VCV-COORD and at least one repair strategy, we should expect to see repair of both initial and medial ONSET violations. This would possibly obscure the differences between an environment in which both constraints are repaired and one in which ONSET is the only motivating factor, for we will not be able to tell which constraint is motivating the repair. A language with this ranking, (49 a-d) for example, will not exhibit repair of VʔV contexts while those with the rankings of (51a-e, g) might do so. It is important to notice that we should never expect a case in which both ONSET and VCV-COORD are repaired in different ways, for, as can be seen in (51), the lowest ranked repair strategy should always be chosen.
One goal of future research would be to determine if the predictions made by the proposal in this paper are actually borne out.

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