

A Landmark Underspecification Account of the Patterning of Glottal Stop

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by

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Abstract of the Dissertation

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This dissertation addresses the asymmetry in patterning between laryngeal and supralaryngeal consonants. In this dissertation, I consider four patterns: (1) required identity-across-glottals (in $V_1\text{?}V_2$, $V_1 = V_2$); (2) hiatus resolution-like processes in $V\text{?}V$ ($V\text{?}V \approx VV$); (3) prohibition of glottal stop from syllable onset or coda; and (4) temporal instability of sequences with glottal stop (e.g. vowel intrusion: $V_x\text{?}C \rightarrow V_x\text{?}^{V_x}C$, coalescence of $C\text{?}$ to C'). I present a unified analysis of these patterns within the framework of Articulatory Phonology (Browman and Goldstein 1986, et seq.), in which utterances are comprised of abstract articulatory gestures (rather than segments or features).

I argue that the exceptional behavior of glottal stop is a function of its acoustic properties: in contrast to oral stop consonants, glottal stop does not condition formant

transitions, and therefore lacks the landmarks of ONSET (marking the beginning of the gesture) and OFFSET (marking the end of the gesture). Based on data on temporal relations within syllables and sequences (e.g. in Browman and Goldstein 2000), I propose that the ONSET and OFFSET landmarks are points of alignment for phasing relations that underlie syllabification and sequentiality. Because it lacks these crucial landmarks (the Landmark Underspecification proposal), glottal stop cannot participate unambiguously in syllabic or sequential phasing relations.

This approach provides an account of each of the patterns described above. Hiatus resolution-across-glottals occurs because the glottal stop cannot satisfy the constraint that requires syllable onsets to be precisely phased with respect to the following vowel; glottal stop is therefore not a satisfactory syllable onset. Languages in which the vowels flanking laryngeal consonants are required to be identical exhibit a subset case of the hiatus resolution pattern, differing only in the strategies employed to repair hiatus. Similarly, glottal stop is disallowed pre- or postvocally in some languages because it cannot obey the constraints on phasing of onset or coda consonants with respect to syllable nuclei. Finally, the lack of clear cues to the temporal position of glottal stop lead underlying sequences with glottal stop to surface non-sequentially, manifested as vowel intrusion or as coalescence of the glottal stop with a vowel or consonant.

Among the languages discussed are Yatzachi Zapotec (Otomanguean), Yucatec Maya (Mayan), Kekchi (Mayan), Arbore (Cushitic), Tukang Besi (Malayo-Polynesian), Kashaya (Pomoan) and Yurok (Algic).

This dissertation is dedicated to:

my father, Edwin Robert Borroff, in thanks for his support,
and in hopes of happiness and good health,

to my mother, Irene N. Borroff, for her unending enthusiasm,

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1.0 Introduction

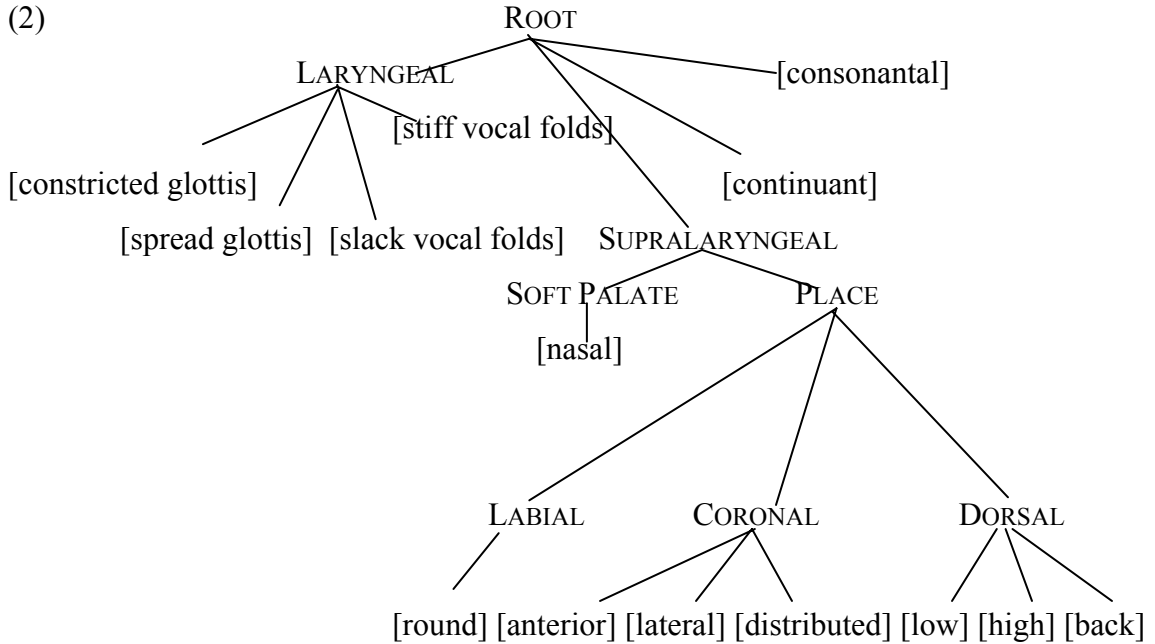
In many languages, laryngeal consonants, and glottal stop in particular, pattern differently from the supralaryngeal consonants. The goal of this dissertation is to provide a unified account of the patterning of glottal stop cross-linguistically.

For example, glottal stop regularly patterns as transparent to spreading of vocalic and consonantal features across it, as opposed to the supralaryngeal consonants, which are generally opaque to spreading. This fact is illustrated by the data in (1), which show that in Chemehuevi (Uto-Aztecan), Sundanese (Austronesian) and St'át'imcets (Lillooet; Salish), glottal stop alone is transparent to vocalic spreading, nasal spreading, and faucal harmony, respectively:

- (1) Chemehuevi
- | | | | | |
|----|---------------|---|------------------------|-------------|
| a. | /nukwɨjɨʔumi/ | → | [nukwɨjɨʔɨmi] | ‘run (pl.)’ |
| b. | /ɨvɨjuni/ | → | [ɨvɨjuni] / *[ɨvɨjɨni] | ‘ill/bad’ |
- (Press 1979, Steriade 1987)*
- Sundanese
- | | | | | |
|----|---------|---|--------------------|----------------------------------|
| c. | /ɲiar/ | → | [ɲĩār] | ‘say’ (active) |
| d. | /niʔis/ | → | [niʔĩs] | ‘relax in a cool place’ (active) |
| e. | /ɲatur/ | → | [ɲātur] / *[ɲātũr] | ‘arrange’ (active) |
- (Cohn 1993)*
- St'át'imcets
- | | | | | |
|----|------------------------|---|---------------------------|-------------------------|
| f. | /suq ^w m/ | → | [ʃɔq ^w m] | ‘to skin an animal’ |
| g. | /ʔúʔq ^w aʔ/ | → | [ʔóʔq ^w εʔ] | ‘to drink a little bit’ |
| h. | /súsq ^w əm/ | → | [šúšq ^w əm] | ‘to skin small animals’ |
| | | | (*[šššq ^w əm]) | <i>(van Eijk 1997)</i> |

Previous accounts of patterns like those shown in (1) have proposed to explain the distinct patterning of glottal stop in comparison to the supralaryngeal consonants with a representational distinction. One typical approach is to root this distinction in the fact that the laryngeal consonants, unlike other consonants, do not involve contribution from any oral articulator. Within a feature geometric approach, this distinction is exemplified by positing a hierarchical organization among place features such that the SUPRALARYNGEAL node dominates all oral consonantal and vocalic features, but crucially does not dominate the laryngeal features. An example of a feature geometric tree in which glottal stop is shown to lack oral place features is shown in (2), from Sagey 1986

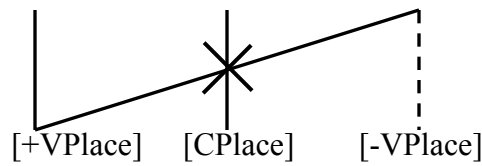
and Bessell 1992. Here, place is necessarily a feature only of supralaryngeal consonants, as place is hierarchically dominated by the node SUPRALARYNGEAL and neither the nodes SUPRALARYNGEAL nor PLACE dominate the node LARYNGEAL.¹



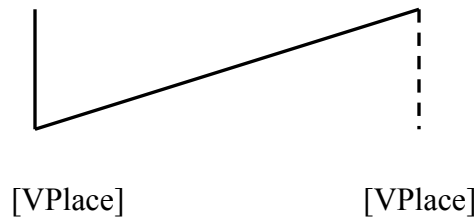
The placeless account of glottal stop can successfully account for the fact that it patterns as transparent, for example as shown in the data in (1). Under this account, spreading of features dominated by the node SUPRALARYNGEAL (e.g. the vocalic and consonantal PLACE features) onto another element is blocked by the presence of an intervening specification for the same node {SUPRALARYNGEAL}. Blocking results from the prohibition on crossing association lines, as illustrated in (3a), in which the presence of an intervening C PLACE node blocks spreading of VPLACE in V_xCV_y . In contrast, the fact that glottal stop lacks a C PLACE node will allow spreading across it, resulting in the observed patterns of transparency.

¹ Examples of placeless approaches to the patterning of glottal stop include Steriade 1987, Cohn 1990, Bessell and Czaykowska-Higgins 1992, Duanmu 1994, Basri 1999, Sumner 1999, Ola Orié and Bricker 2000, Broselow 2001, and Parker 2001, among others.

(3) b. * V t V (e.g. /ɪtu/ → [ɪtu], *[ɪtɪ])



a. V ? V (e.g. /ɪʔu/ → [ɪʔɪ])



The approach sketched above simply restates the generalization that laryngeal consonants pattern distinctly from supralaryngeal consonants because they are not supralaryngeal. A more satisfying analysis of the patterning of laryngeal consonants might give a phonetically grounded explanation of this distinction. Furthermore, while this approach provides an account of the transparency of glottal stop in a number of languages, it is less successful in dealing with patterns of transparency in other languages, as well as a range of other patterns exhibited by glottal stop. In this chapter, I will briefly introduce data from four patterns that distinguish the patterning of glottal stop from the supralaryngeal consonants: (1) translaryngeal harmony and the related pattern of languages that require the vowels flanking laryngeals to be identical; (2) hiatus resolution-like repair of V?V; (3) positions on the syllabic position of glottal stop; and (4) the tendency of underlying sequences with glottal stop to surface non-sequentially.

For example, consider again the Sundanese and St'át'imcets data in (1c-e) and (1f-h), respectively. In these languages, glottal stop fails to block consonantly conditioned feature spreading. In these data, the impetus to spread lies with the conditioning consonant or the feature that spreads;² the glottal stop itself is not a participant in the spreading process, and does not cause or condition it. However, patterns exist that show surface similarity to the translaryngeal harmony data, and yet challenge the assumption that the presence of glottal stop is incidental to the harmony process. One such pattern is exhibited by the Yucatec Maya (YM) data in (4). In YM, vowels flanking laryngeal consonants must be identical. This requirement holds underlyingly in monomorphemic

² For example, it has been proposed that featural alignment constraints motivate spreading; they require a given feature to be aligned to an edge of phonological unit. For example, the constraint ALIGN RT FEATURE_α, PROSODIC WORD will force rightward spreading of feature_α until the last element in the prosodic word carries this feature. See Kirchner 1993, Smolensky 1993, Pulleyblank 1994, Cole and Kisseberth 1994, Walker 1995, 1996, Ní Chiosáin and Padgett 1997 for the featural alignment approach to feature spreading

roots, as in (4a). (4b) shows that sequences of underlying non-identical vowels flanking glottal stop will undergo assimilation. For comparison, (4c) shows that no spreading occurs in VC_{ORAL}V sequences. At first glance, the patterns exhibited by (4a-c) appear to be classic examples of translaryngeal harmony patterns. However, the data in (4d) show that the picture is a bit more complicated. Here, the offending V_x?V_y sequence is not repaired through spreading, but rather through deletion of the laryngeal accompanied by glide insertion. For ease of discussion, I refer to this pattern as ‘*required identity – across–glottals.*’

(4) Yucatec Maya

- | | | | |
|----|-----------------|-------------------|-------------|
| a. | wi?it | | ‘loincloth’ |
| b. | /hé? im b’ine?/ | → [hí? im b’ine’] | ‘I will go’ |
| c. | kitam | | ‘peccary’ |
| d. | /p’o?-eh/ | → [p’oyeh] | ‘wash it!’ |

(Ola Orié and Bricker’s (2000) (1)-(4))

The data in (4) suggest that translaryngeal spreading in YM occurs independently of an external trigger; it is the V_x?V_y sequence itself that offends. Here, spreading in V_x?V_y occurs because there is an intervocalic glottal stop, not because there is an external impetus to spread. This suggestion is supported by the fact that spreading is not a necessary outcome of a V_x?V_y sequence; (4d) shows that the requirement that all vowels flanking laryngeals be identical can be vacuously satisfied through deletion of the laryngeal.

Perhaps the most striking example of a pattern that cannot be explained by the glottal transparency hypothesis involves the occurrence of hiatus resolution processes in V?V sequences. This pattern is exhibited by YM data in (4d) (glide insertion is YM’s preferred hiatus resolution strategy), as well as by data from a number of languages in which there is an unexpected interaction of the vowels flanking a laryngeal consonant. These languages exhibit a pattern in which the same hiatus resolution processes occur in V?V sequences as occur in VV sequences despite the presence of the glottal stop. For example, consider the data in (5) from Yatzachi Zapotec (YZ) and Yapese.

(5) Yatzachi Zapotec

- | | | | |
|----|-----------------|---------------|--------------|
| a. | /zetʃa + e?/ | → [zetʃe?] | ‘he stands’ |
| b. | /tʃʃagna? + e?/ | → [tʃʃagne?e] | ‘he marries’ |

(Butler-Haworth 1980, Borroff 2003, 2005)

Yapese

- | | | | |
|----|----------------|---------------|---------------------|
| c. | /fai + ng/ | → [fe:ng] | ‘to find something’ |
| d. | /ka+?a+i mi:l/ | → [ke?e mi:l] | ‘he ran first’ |

(Jensen 1977)

In YZ, underlying [a-e] sequences undergo assimilation to [e] in both VV and V?V (c.f. (5a) vs. (5b)). Finally, in Yapese, feature preserving coalescence occurs in [a-i] sequences when these are strictly adjacent (5c), and when the vowels are separated by a glottal stop (5d).

These data are problematic under the traditional assumption that hiatus resolution occurs in response to the need for every syllable to have an onset; in a CVV sequence, the syllable headed by the second vowel will lack an onset. For a V?V sequence, in contrast, the glottal stop itself should syllabify as an onset to the following vowel. Thus, the onset approach to hiatus resolution does not shed any light on the patterning of V?V in these languages.

Furthermore, placeless approaches to the patterning of glottal stop will have some difficulty in handling the full range of data in (5). To illustrate this, let us consider a placeless-? analysis of the YM data in (4d) and (5a) presented in Ola Orié and Bricker 2000. Ola Orié and Bricker (2000) propose that the laryngeal deletion and accompanying glide insertion in these examples is the result of a requirement that syllabic onsets be specified for oral place. This account explains why insertion of an oral glide is required in (4d) and (5a). In fact, the markedness of placeless onsets is suggested to be a factor in the distribution of glottal stop in a number of languages. For example, Broselow 2001 presents data from three Makassarese languages that exhibit a [ʔ] ~ [k] alternation in which coda glottal stop is realized as [k] when affixation of a vowel initial morpheme would result in the glottal stop's being prevocalic. Consider the data in (5) from Standard Makassarese to illustrate this pattern:³

- (5) Standard Makassarese
- | | | | | |
|----|-----------------|---|----------------|-------------|
| a. | bájiʔ | | | ‘good’ |
| b. | bajiʔ-aŋ | → | bajíkaŋ | ‘better’ |
| c. | bajiʔ-a | → | bájika | ‘I am good’ |
- (Broselow 2001)*

Similarly to Ola Orié and Bricker's (2000) analysis of YM hiatus resolution in V?V, Basri 1999, Broselow 2001 proposes that the [ʔ] ~ [k] alternation in the Makassarese

³ For the time being, I present the Standard Makassarese data as representative of the patterns in other Makassarese languages, including Selayarese and Konjo. It should be noted that complications arise when considering the later languages' equivalents of (5c), in which a vowel initial clitic has been affixed to the root. While Makassarese continues to exhibit the [ʔ] ~ [k] alternation in this environment, in both Selayarese and Konjo the glottal stop remains in the output before a vowel initial clitic (e.g. Selayarese *bakkaʔ-a* → *bákkaʔa* ‘I am big’). Broselow 2001 suggests that this pattern is an indication that clitics are outside the prosodic domain of the word. This proposal is further supported by the fact that true suffixes, but not clitics, are counted in stress assignment (Basri 1999, Basri *et al.* 2000, Broselow 2001).

languages results from an Optimality Theoretic constraint that requires all onset consonants to be specified for place (ONSETPLACE).

Many other languages also exhibit prohibitions on laryngeal onsets. Examples of such languages include Macushi (Carib; Hawkins 1950, Abbott 1991, Rose 1996), Carib (Hoff 1968, Peasgood 1972), Tiriyo (Carib; Jones 1972, Meira 1998, 1999), Garo (Tibeto-Burman; Burling 1992, Duanmu 1994) and Chamicuro (Arawakan; Parker 1994, 2001; also see Parker 2001 for a discussion of the cross-linguistic distribution of glottal stop). In his analysis of the distribution of glottal stop in Chamicuro, Parker (2001) takes a similar approach to Ola Orié and Bricker (2000), Basri 1999 and Broselow (2001), positing the constraint HAVEPLACE(onset).

Interestingly, even for languages in which glottal stop appears as pre-vocalic, it is likely to pattern as a coda rather than as an onset (e.g. in V?V, the syllabification is V?.V). For example, Busenitz and Busenitz (1991) report that speakers of Balantak (Central Sulawesi; see discussion in Broselow 2001, 2003) have intuitions that an intervocalic glottal stop is a coda to the preceding vowel. Likewise, in Chickasaw and Choctaw (Western Muskogean), glottal stops syllabify as codas (Ulrich 1993), and coda glottal stops do not syllabify with following vowel initial suffixes (from Pam Munro, as quoted in a summary of responses to a recent Linguist List query by Mark Donohue (Vol-17-3293, posted Nov. 12, 2006)). An additional pattern in which intervocalic glottal stop is treated as a coda is exhibited by the Malayo-Polynesian language of Palu'e, spoken on the Indonesian islands of Palu. Mark Donohue (p.c. 2006) reports that the first vowels in V?V exhibit closed syllable allophones in this language. To illustrate this pattern, consider the data from Palu'e below in (7):

- (7) Palu'e
- | | | |
|----|---------|------------------|
| a. | tu: | 'knee' |
| b. | lǔd.ʒǔn | 'their porridge' |
| c. | věʔi | 'leg' |
- (Donohue, p.c. handout 2006)*

The data in (7a) show that vowel in open syllables surface as tense. In comparison, closed syllables exhibit shorter, laxer variants of the open syllable vowels (7b). (7c) shows that the lax vowel allophones usually associated with closed syllables are also found in V?V sequences. These data suggest that that the intervocalic glottal stop is not syllabified as an onset to the second vowel. A similar pattern is found in Tukang Besi (Malayo-Polynesian), spoken on the Tukang Besi islands of Indonesia (M. Donohue, p.c. 2006).

The failure of pre-vocalic glottal stop to pattern as an onset in languages like Balantak, Chickasaw, Choctaw, Palu'e and Tukang Besi provides a challenge to the general principle of Onset Optimization (all else being equal, languages will syllabify intervocalic consonants as onsets). Seen in the light of the data from these languages, one might reinterpret the data in (5) as further indicating that glottal stop does not syllabify as an onset; it is for this reason that hiatus resolution occurs in V?V in

languages like YM, YZ and Yapese. The question that remains, however, is whether the ONSETPLACE approach suggested for the languages in (4) and (5) will satisfactorily account for the failure of prevocalic glottal stop to pattern as an onset in hiatus resolution-across-ʔ languages.⁴

Further challenges to the placeless analysis of glottal stop arise as we begin to consider the wider range of data regarding its patterning. For example, another common pattern exhibited by languages with glottal stop is a tendency for glottal stop to appear within the span of an underlyingly adjacent segment. Consider the data in (8), which show examples of vowel and consonant overlap over glottal stop.

- (8) Kekchi
- a. kwaʔ + k → kwaʔak ‘to eat (transitive)’
(Campbell 1974, Hall 2003)
- Tukang Besi
- b. /goraʔu/ → [goraʔu] ~ [gora^wʔu] ‘egg’
(Donohue 1999)
- Arbore
- c. /be:k-t-aw/ → [be:ʔtaw] / [beʔetaw] ‘my wound’
(Hayward 1984)
- d. /ʔiy dayʔ-e/ → [ʔiy dajʔje] ‘he guarded’
(Hayward 1984)

The data in (8) show that underlying sequences with glottal stop regularly fail to be realized as sequential in the output. The Kekchi data in (8a) provide an example of vowel intrusion into an underlying ʔC sequence (Hall 2003). The Tukang Besi and Arbore data show that glottal stop sometimes varies in temporal position with respect to underlyingly adjacent vowels, and may also intrude upon the span of a consonant (8d). As it turns out, this pattern is quite common cross-linguistically. For example, a number of languages exhibit reorganization of input Vʔ and Cʔ sequences to simultaneity in the

⁴ Even in languages in which glottal stop does appear to syllabify as an onset, it often does so only in certain restricted environments. For example, glottal stop is inserted prevocalically in English, but only in word- and prosodic phrase initial position (glides are inserted elsewhere). Likewise, in Selayarese (Mithun and Basri 1986), Arabic (Lombardi 2002a) and Kisar (Christiansen and Christiansen 1992), glottal stop is inserted before phrase initial onsetless syllables, but it is lost when morpheme concatenation results in the syllable being non-initial. See Lombardi 2002a and section 4.2 of this work for further discussion of each of these patterns. Chapter 4 addresses these and other possible counterexamples to the possibility that glottal stop *always* fails to syllabify as an onset, a proposal that I develop in chapter 3. Note that an analysis like this approach is more restrictive than the ONSETPLACE proposal, which predicts that at least some languages should allow glottal stop onsets without restriction.

output. This is illustrated by the examples from Kashaya in (9), in which synchronic coalescence of Cʔ sequences to glottalized consonants are shown.⁵

- (9) Kashaya
- | | | | | |
|----|--------------------------|---|-------------------------|------------|
| g. | wólʔwo | → | wol'wo | ‘badger’ |
| h. | s’uwac-ʔk ^h e | → | s’uwac’k ^h e | ‘will dry’ |
- (Buckley 1994)*

A second important fact about the temporal patterning of glottal stop to address is the fact that the temporal position of glottal stop can vary from token-to-token (as in *Tukang Besi* and *Arbore* (8b,c)). Additionally, the position of glottal stop can be influenced by factors like speech rate. For example, vowel intrusion in *Chamicuro* (Arawakan; Parker 1994, 2001, Hall 2003) is more likely in careful speech, and in *Choapan Zapotec* (Oto-Manguean; Lyman and Lyman 1977), it is more likely to occur in fast speech. Finally, the non-sequentiality of glottal stop is not limited to environments of vowel intrusion, but is also exhibited as C overlap over glottal stop in underlying Cʔ sequences as in the *Arbore* example from (8d).

The data in (8) and (9) prove particularly challenging to the autosegmental account of the patterning of glottal stop. First, this account cannot explain the fact that in *Kekchi*, when underlying $V_xʔ$ surfaces as $V_xʔV_x$ the output configuration continues to behave as if V_1 and V_2 formed a single vowel (Campbell 1974, Hall 2003). Second, it is doubtful that the autosegmental approach provides us with the appropriate machinery to account for the temporal properties of glottal stop. For these reasons, I propose a unified account of the patterning of glottal stop that can address the temporal characteristics of ‘segments’. This approach is presented in the framework of Autosegmental Phonology (AP), in which speech sounds are specified in terms of the articulatory gestures that comprise them. Adopting the representational conventions of AP into the framework of OT will allow us to account for the variability in temporal position of glottal stop, as exhibited by the data in (8) and (9). Ultimately, I will show that this theoretical position will also allow an account of each of the other patterns discussed in this section: translaryngeal harmony, required identity-across-glottals, hiatus resolution-across-glottals, restrictions on the syllabic position of glottal stop, and the failure of underlying sequences with glottal stop to be realized as sequential (as exhibited by patterns of vowel intrusion and C-ʔ coalescence). As a background for the development of this proposal, section 1.2 sets out

⁵ Such reorganization might also account for additional patterns of Xʔ coalescence, for example Compensatory Lengthening in Colloquial Tehrani Farsi as conditioned by the loss of glottal stop (Darzi 1991, Sumner 1999, Kavitskaya 2002), and the Vʔ coalescence that has been proposed to be a precursor stage to tonogenesis in some modern tonal Athabaskan languages (for example, in *Kutchin*, *Sarcee*, *Navajo*, *Chipewyan*, *Hare*; Krauss 1979:2005, Leer 1979, 1999, Kingston 2005), and in Ancient Chinese (Egerod 1971, Thongkum 1990). I return to this question in chapter 2.

the assumptions regarding the theoretical frameworks of OT, AP, and the unique properties of their union, which I refer to henceforth as AP in OT.

1.1 Theoretical Frameworks: OT, AP, AP in OT

1.1.1 Theoretical Background; OT

In this dissertation, I take an Optimality Theoretic approach to explaining the patterning of glottal stop cross-linguistically (Prince and Smolensky 1993). In this framework, the phonological grammar is proposed to consist of a set of universal constraints (CON) that conscribe the form of phonological (markedness constraints) outputs as well as the extent to which an output form can differ from an input form (faithfulness constraints).⁶

Within this framework, cross-linguistic variation results from language-specific hierarchical rankings of universal constraints. Candidate outputs for each input are generated (by GEN), and are evaluated against the constraint hierarchy with a metric, EVAL, that weighs constraint violations such that violations of high ranked constraints weigh more than violations of low ranked constraints. If a language ranks constraint X over constraint Y, and they are in conflict, then the output form will be the one that satisfies constraint X at the expense of violating constraint Y. Variations in constraint ranking between languages will result in variations in the phonological patterns observed in these languages, but the extent of variation will be constrained. This result obtains because constraints are universally present in the grammar of every language, and even low-ranked constraints will show their effects in some environments (for example, in effects from the emergence of the unmarked (TETU; for discussion see McCarthy and Prince 1994, among others).

In this dissertation, I suggest that a satisfactory analysis of the patterning of glottal stop is unavailable under a featural approach that attributes the laryngeal/supralaryngeal asymmetry to place of articulation distinctions. Instead, the data discussed above, and in the following chapter, show that a unified explanation of glottal stop's patterning must take into account its temporal characteristics (for example, to explain patterns of vocalic and consonantal overlap of glottal stop). Thus, this study adopts the representational aspects of Articulatory Phonology into the Optimality Theoretic framework.⁷ As a background for this approach, the following section further describes the AP framework.

⁶ In addition to the markedness and faithfulness constraints described here, other constraint types have also been incorporated into the OT grammar. For example, McCarthy and Prince (1993) proposed to include morpho-phonological alignment constraints that constrain the alignment of phonological categories with morphological categories (e.g. ALIGN LEFT (ROOT, PROSODIC WORD): Align the left edge of the root with the left edge of the prosodic word).

⁷ It should be noted that AP, as conceived of in the references discussed in this section, is not simply a theory of representation but also is a theory of the phonology and its relationship to what is traditionally

1.1.2 Theoretical Background: AP

Articulatory Phonology (AP; Browman and Goldstein 1986, 1989, 1990, 1995, among others) is an approach to the phonology/phonetics interface in which the linguistically significant units of speech are the physical gestures underlying speech production, or abstractions thereof. Thus, this approach rejects the tenets of Autosegmental Phonology and Feature Geometry, in which speech sounds are specified as bundles of abstract features organized into discrete segments. In this framework, gestures are specified in terms of target coordinates for a particular constriction in the vocal tract. The particular target task for a gesture depends on the interaction of two vocal tract variables for the gesture. These variables are shown below in (16) following Saltzman's (1995) figure 6.2, p.160.⁸ The model articulator sets identified for each tract variable in (12) correspond to the set of articulators employed in the implementation of the tract variable, including main articulators (e.g. tongue tip for Tongue Tip Constriction Location (TTCL)) and contributing articulators (e.g. tongue body and jaw for TTCL).

considered the phonetic component. In fact, research in this framework has had some success in showing that traditional phonological approaches fare worse than AP in accounting for, for example, gradient phonetic processes when the percept is categorical. See Browman and Goldstein 1990 for discussion of an AP approach to the casual speech processes of assimilation, blending and deletion, and Gafos 2003 for discussion of gradient devoicing in syllable final position. Thus, the strongest version of the AP approach rejects the need for an additional derivational component like OT. However, some research within the framework of AP in OT suggests that phonological processes can either be categorical or gradient, and OT allows us to account for the categorical processes (e.g. those that do not appear to fall out directly from facts about gestures and intergestural relations). See Davidson 2003 for discussion of such a pattern, in which it is argued that the intrusive schwa found in English speaker adaptations of illegal consonant clusters can either be a categorical process (schwa epenthesis) or a gradient one (caused by gestural overlap).

⁸ Note however that the set of tract variables included varies depending on the source, and changes with the evolution of the theory. For example, Browman and Goldstein 1989 do not include 'Lower Tooth Height' as a vocal tract variable. Further changes might also be expected; for example, Browman and Goldstein (1989) note a suggestion from Ladefoged and Halle (1988) that Tongue Root be included as a vocal tract variable, but as late as 1995 this was not included by some researchers (see Saltzman 1995). However, as this thesis deals with the patterning of the laryngeal consonants, and this is itself closely related to the patterning of pharyngeal consonants, I do present the Tongue Root variable here.

(12) Vocal Tract Variables, following Saltzman's (1995) figure 6.2, p.160

	Tract Variables	Model Articulators
LP	Lip Protrusion	upper and lower lips
LA	Lip Aperture	upper and lower lips, jaw
LTH	Lower Tooth Height	Jaw
TTCL	Tongue Tip Constriction Location	tongue tip, body, jaw
TTCD	Tongue Tip Constriction Degree	tongue tip, body, jaw
TDCL	Tongue Dorsum Constriction Location	tongue body, jaw
TDCL	Tongue Dorsum Constriction Degree	tongue body, jaw
TRCL	Tongue Root Constriction Location	tongue root, body, jaw
TRCD	Tongue Root Constriction Degree	tongue root, body, jaw
VEL	Velic Aperture	Velum
GLO	Glottal Aperture	Glottis

Browman and Goldstein (1989) suggest that the specifications for constriction degree and location are as shown below in (13). Here, each specification for degree (13a) corresponds to a manner of articulation feature in traditional phonologies (e.g. closed = stop, critical = fricative, narrow = a high vowel or approximant, etc.).⁹

- (13) a. CONstriction DEGREE descriptors: closed critical narrow mid wide
 b. CONstriction LOCATION descriptors: protruded labial dental
 alveolar postalveolar palatal
 velar uvular pharyngeal

⁹ Interestingly, Browman and Goldstein 1990 specify that each individual tract variable is modeled as its own dynamic system that is specified to be coextensive with the associated variable (e.g. TTCL with TTCD). However, under this sort of approach it seems difficult to explain why coordination among the tract variables for a single gesture doesn't appear to exhibit the same variability as that between gestures. Empirical data will have to be brought to bear on the question of whether tract variables are separable, and whether they do vary in overlap in the same ways as the larger gestures do.

Gestures are abstractly defined by the particular specification for, e.g. constriction degree and location of constriction for a model articulator. This creates a target for each gesture that is subsequently implemented/modeled as a dynamical system, which uses a dynamical equation to model the change in a system over time based on the initially specified variables.¹⁰ Using dynamical equations to model movement has precedent in previous research on the coordination of non-speech movements, which have also been modeled as dynamical systems. This approach to the modeling of speech production has had favorable consequences in terms of explaining certain phonetic and phonological patterns, for example increased intergestural overlap in fast speech. I return to discuss other implications of the AP and Task Dynamic approaches in chapter 3, in particular the application of dynamical principles to account for patterns of syllabification. Readers who wish to find a more in-depth discussion of these issues should see, Browman and Goldstein 1986, Saltzman 1995, Goldstein and Fowler 2003 and references therein including Saltzman 1991, Saltzman and Kelso 1987, Saltzman and Munhall 1989, among others.

One challenge for the Articulatory Phonology framework is how to represent the gestures of speech as they unfold in time. It is apparent that the symbolic system of autosegmental phonology is insufficient to express the extended activation interval of gestures or gestural overlap. Additionally, a single IPA symbol is associated with multiple gestures, and in reality each gesture associated with a single ‘segment’ may have different edges (different starting point, different length, etc.). In response to the need to reflect the temporal extent of gestures and their relative phasing, Browman and Goldstein 1989 developed the ‘Gestural Score,’ in which the gesture is represented as unfolding in time along the horizontal axis, and overlap is denoted by vertical placement. (14) shows a gestural score for the word “palm”, adapted from a similar diagram in Browman and Goldstein (1989). Note that the pronunciation presented here is an ‘l’-less variant of the word “palm.” Some dialects of English retain the [l], and thus these forms would include an additional tongue tip gesture.

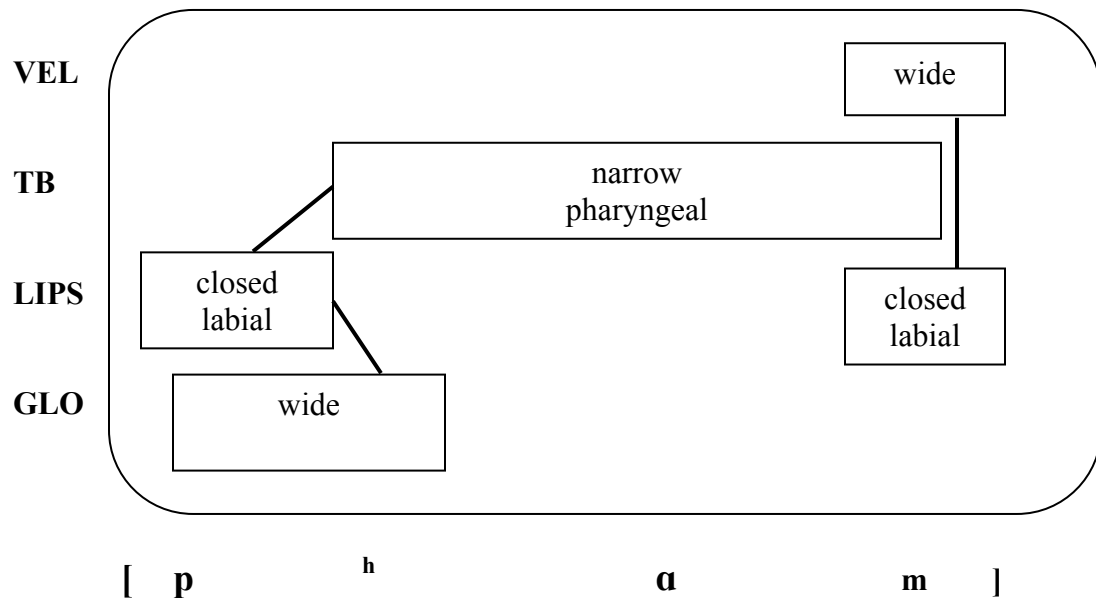
In the diagram in (14), each rectangle represents the time span between the point at which the articulators begin moving for a particular gesture to the point at which they stop moving for that gesture. To the left of the gestural score the tier for each gesture is identified, including the Velic, Tongue Body, Lip and Glottal tiers. Within the box representing the activation interval of each gesture, the Constriction Location and Constriction Degree for each gesture is identified. For example, labial closure for ‘p’ and for ‘m’ is indicated by the specifications for {closed} constriction degree and {labial} constriction location for the gestures on the LIPS tier. The horizontal axis denotes the passage of time; the length of the activation interval of a gesture is indicated by the length

¹⁰ An example of a dynamical equation for speech is shown below, repeated from Browman and Goldstein 1986 (p. 238):

i. $m\ddot{x} + k(x-x_0) = 0$
 where m = mass of the object
 k = stiffness of the spring
 x_0 = rest length of the spring
 x = instantaneous position of the object
 \ddot{x} = instantaneous acceleration of the object

of the associated box. Overlap between gestures is indicated by their co-occurrence in the same vertical space; for example, the overlap of the velum opening and labial closure gestures associated with ‘m’ is indicated by the fact that one gesture is directly above the other in the diagram. This diagram also shows the phonologically specified temporal relations among gestures via association lines, for example between the labial closure gesture for the ‘p’ and the tongue body gesture for ‘a’. Finally, on the line directly below the gestural score, IPA symbols show the percept that results from the particular coordination among gestures exhibited by the utterance.

(14) Gestural score for ‘palm’, with phasing association lines

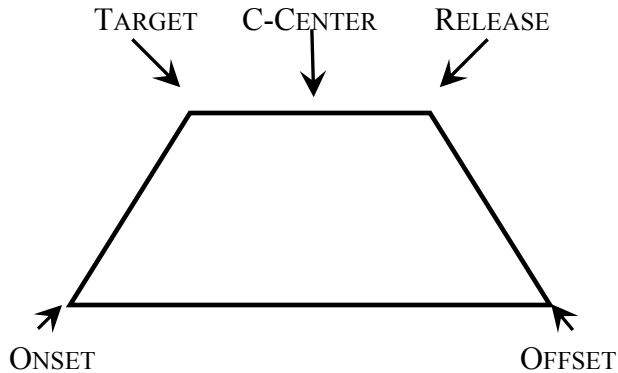


The main assumptions of the AP framework that I propose to incorporate into OT include: (a) that utterances are specified in terms of the abstract gestures; (b) that gestures are targets for constriction in the vocal tract; and (c) that a gesture’s target constriction results from specifications for the various vocal tract variables (model articulator, and constriction location and degree). The next section goes on to discuss a theoretical approach that unifies the derivational aspects of OT with the insights of AP; henceforth, AP in OT. In particular, we discuss proposals within the framework of AP in OT that are innovations from both parent frameworks.

1.1.3 AP in OT

Gafos (2002) proposes that gestures are comprised of abstract gestural landmarks corresponding to physical events in the time-course of a gesture (e.g. beginning of articulator movement, achievement of target constriction, and so on). These are shown schematically and defined in (15) (his (3), p. 276 and (5), p. 279).

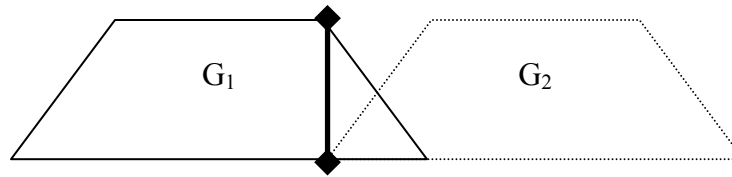
(15)



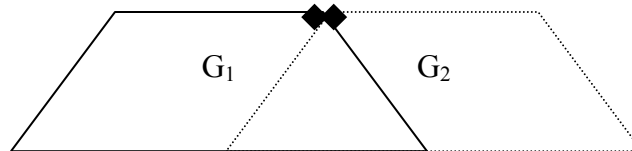
Definition of Gestural Landmarks:	(Gafos 2002)
ONSET:	The onset of movement towards the target gesture
TARGET:	The point in time at which the gesture achieves its target
C-CENTER:	The mid-point of the gestural plateau
RELEASE:	The onset of movement away from the target of the gesture
OFFSET:	The end of all movement associated with the gesture

The landmarks in (15) are abstract phonological entities relating to the concrete states of the articulator in the production of a gesture. These landmarks provide the phonology with a means of referring not only to the gesture itself, but also to particular stages in the production of a gesture. Importantly, the introduction of gestural landmarks allows the OT grammar to constrain the temporal coordination between gestures in a fine-grained manner. For example, a constraint might require that the OFFSET landmark of one gesture (G_1) be aligned to the ONSET landmark of a second gesture (G_2) (Gafos 2002). The resulting temporal coordination between these gestures is shown in (16a) below. (16b) shows an example of a different temporal relation between two gestures, in which the RELEASE of G_1 is aligned to the TARGET of G_2 . Note that henceforth I adopt the trapezoidal representation of gestures from Gafos (2002) (shown in (15) above and (16)), in order to more clearly represent each gesture as unfolding in time as a sequence of 4 separate landmarks.

(16) a. G_1 RELEASE –to– G_2 ONSET



b. G_1 RELEASE –to– G_2 TARGET



In considering the intergestural coordination relations sketched in (16), we can see that a differing alignment between the landmarks of two gestures can have important consequences. For example, if G_1 and G_2 are consonantal gestures then the configuration in (16a), C_1 RELEASE –to– C_2 ONSET, will result in there being a period of time at which there is an open vocal tract between the release of the first constriction and the achievement of the second. Thus, this sort of configuration might be associated with an audible release of G_1 , or an intrusive vocalic element. In fact, Gafos (2002), Davidson (2003) and Hall (2003) have each employed similar configurations to account for intrusive vowels in consonant clusters (in Moroccan Colloquial Arabic, English adaptation of phonotactically illegal consonant clusters, and in vowel intrusion, respectively). In comparison, the configuration in (16b) will not be susceptible to vowel intrusion because the close coordination of G_1 RELEASE –to– G_2 TARGET does not allow for an open vocal tract between the consonantal constrictions.

Thus, in order to reflect differences in the temporal patterning of gestures, the OT grammar constrains the temporal coordination of two gestures as a temporal alignment of the landmarks of those gestures.¹¹ Gafos (2002) suggests a template for constraints on intergestural coordination as shown below:

¹¹ Similar approaches were taken in Kingston 1985 and Huffman 1989 to explain the characteristic within-segment temporal coordination between sub-segmental features and major consonantal or vocalic constriction. For example, Kingston (1985) suggests that laryngeal contrasts for non-continuant consonants (oral stops, ejectives and implosives) are bound to the release of consonantal closure to explain the comparatively stable patterning of these consonants (e.g. ejectives are mostly postglottalized). Huffman (1989) suggests that the temporal implementation of targets for nasality is linked to certain articulatory events, for example to release of constriction for oral stops, to achievement and release of closure for nasals, and to vowel midpoint (for both oral and nasal vowels). In AP terms, these patterns would result from specified phasing relations holding between the gestures corresponding to main oral constriction for the ‘segment’ and the glottal and velic gestures.

(17) Gafos 2002, p. 284

- a. ALIGN (GESTURE¹, landmark¹, GESTURE², landmark²): Align landmark¹ of GESTURE¹ to landmark² of GESTURE²

Interestingly, the incorporation of coordination relations between gestures into OT gives it the power to account for certain temporal characteristics of speech, for example contextual changes in gestural overlap caused by changes in speech rate. Thus, one benefit of AP in OT over traditional OT is that it can account for patterns associated with casual or fast speech in addition to those associated with careful speech. See Gafos (2002) and Hall (2003) for discussion of accounting for the effects of speech rate on intrusive vowels.

In the approach described here, OT constraints underlie precedence relations between gestures. An important aspect of this approach is that it posits OT constraints that make reference to the gesture, rather than to the segment or to the feature. In fact, I suggest that this is a necessary condition of any AP in OT approach; in order for the grammar to be coherent, there must be commensurability between the units of phonological representation and those employed by the constraint set. For example, if phonological inputs and outputs are specified in terms of gestures, then it is meaningless to posit a constraint along the lines of IDENT FEATURE _{α} ; since there are no features in the input or the output, this constraint cannot do any work.

I suggest that it is also necessary to consider the gestural configurations that underlie abstract phonological units, for example, the syllable. As it turns out, recent research has observed stable modes of coordination holding between the consonantal and vocalic gestures that pattern together as a syllable (see for example, Byrd 1996a,b, Krakow 1999, Browman and Goldstein 2000, Goldstein and Fowler 2003, Nam and Saltzman 2003, Nam 2004, Goldstein 2005, Goldstein *et al.* 2006 for discussion of timing relations between onset and nucleic gestures, among others). Thus, I propose that constraints referring to the syllabic unit must instead make reference to the intergestural relations that underlie the concept of the syllable. The same should be true of such units as the segment and the foot. In chapter 3, I show that favorable consequences arise from appropriately revising the syllable structure constraints ONSET and NOCODA to reflect their gestural underpinning. In particular, a unified analysis of the patterning of glottal stop becomes available with a gestural revision of the constraint ONSET.

This section has briefly discussed some of the innovations of research in the AP in OT framework, each of which will be adopted in this dissertation. To summarize, by incorporating the assumptions of all three frameworks (OT, AP and AP in OT) we arrive at the following assumptions:

- (21) a. Utterances are specified in terms of the gestures that comprise them
- b. Gestures are comprised of the abstract landmarks of ONSET, TARGET, RELEASE and OFFSET

- c. OT constraints can refer to the temporal coordination between gestures, via specifying alignment relations between landmarks
- d. All constraints refer to gestures (not features)
- e. All linguistic units (segment, syllable, foot) have gestural correlates
- f. OT constraint interaction continues to pick out the optimal output
- g. The form produced may differ from the output, but only in dynamically constrained ways¹²

1.2 Preview of the Analysis

In this chapter, I have presented data from a number of cross-linguistic patterns that each appear to distinguish glottal stop from the supralaryngeal consonants. For example, glottal stop alone is transparent to consonantly conditioned spreading of nasality in Sundanese and vowel lowering in St'át'imcets (Lillooet). While the transparency of glottal stop to spreading is a well-recognized phenomenon, this chapter has presented a number of other phenomena with the goal of ultimately providing a unified explanation that accounts for the unique patterning of glottal stop among the consonants. These patterns included *translaryngeal harmony*, in which the features of one vowel spreads onto another across a glottal stop, and the closely related pattern of *required identity-across-glottals* (e.g. in YM (4)), vowels flanking laryngeals are required to be identical. I also introduced the pattern of *hiatus resolution-across-glottals* (e.g. in YZ (5)), in which repair of vowel sequences separated by a glottal stop mimic hiatus resolution patterns (e.g. showing coalescence or diphthongization). This pattern is of interest because it suggests that intervocalic glottal stop, though putatively a consonant, fails to syllabify as an onset to a following vowel. This observation was further supported by the fact that many languages do not allow glottal stop in onset position, for example Chamicuro (Parker 1994, 2001), Standard Makassarese (Broselow 2001). Additionally, in some languages intervocalic glottal stop is treated as a coda, despite the general pattern of onset optimization. This was observed to occur in, for example, Balantak (Busenitz and Busenitz 1991, Broselow 2001, 2003), Palu'e and Tukang Besi (M. Donohue, p.c. 2006). Finally, this chapter discussed the general tendency of sequences with glottal stop to surface as non-sequential (for example, in vowel intrusion phenomena, and in C-? coalescence patterns (8) and (9)).

Based on the wide range of data from the patterning of glottal stop, I suggest that the placeless account of this consonant is unsatisfactory. In particular, the placeless approach

¹² This was originally suggested by Browman and Goldstein (1990), who make the proposal that deviations from the canonical output form associated with, for example, casual speech do not involve the deletion, addition or change of gestural specification. Instead, such deviations result from change in the degree of overlap between two adjacent segments, or change in such dynamical parameters as gestural stiffness or magnitude.

cannot easily account for the temporal patterning of glottal stop. Instead, I suggest that AP provides a better framework for understanding the patterning of glottal stop because this framework has the tools for dealing with temporal relations among phonological units (here, gestures).

The organization of this dissertation is as follows: Chapter 2 presents data from the cross-linguistic patterning of glottal stop in translaryngeal harmony and required identity across glottal stop, hiatus resolution across glottal stop, limitations on the syllabic positions in which glottal stop is found, vowel intrusion across glottal stop and the general failure of sequentiality for sequences with glottal stop.

Chapter 3 presents an AP in OT analysis of the patterns presented in Chapter 2. In this chapter, I argue that a unified analysis of the patterning of glottal stop is possible if we reject the autosegmental placeless account of laryngeal patterning in favor of a representational system in which gestures are the primary phonological units. In brief, the main insight of this proposal is that glottal stop is distinguished from other consonants, not in lacking a place-of-articulation specification, but rather in its failure to participate in the phasing relations required of sequences by constraints in the OT grammar (for example, as shown in (19)). In this chapter, I suggest that gestures may differ in terms of the abstract landmarks for which they are specified, and the choice of landmarks is determined by the acoustic cues provided by the articulation of the gesture. In this chapter, I argue that the acoustic cues provided by the production of a glottal stop do not provide the learner with enough evidence to posit a fully articulated landmark structure for this gesture (e.g. having all the landmarks in (15)). I refer to this proposal as the Landmark Underspecification proposal. In this discussion, I develop an account of the patterning of glottal stop in which the lack of certain abstract gestural landmarks precludes it from participating in the phasing relations that underlie syllabification and sequentiality. Thus, each of the patterns presented here can be explained as attempts to repair inputs with an unsyllabified and unphased glottal stop.

To give a complete picture of the patterning of glottal stop cross-linguistically, chapter 4 goes on to address two types of possible counterexamples to the analysis presented in Chapter 3, including challenges from languages in which glottal stop patterns with the supralaryngeal consonants, and in which glottal stop is putatively epenthesized pre-vocally in response to a violation of the constraint ONSET. Finally, chapter 5 provides a conclusion to the dissertation, discussing the findings of this study and the implications of the proposal within the field of phonology.

2.0 The cross-linguistic patterning of glottal stop

In this chapter, I present data demonstrating that glottal stop tends to be distinguished from other consonants in a wide range of languages. The data discussed here show that the laryngeal and supralaryngeal consonants pattern asymmetrically in a number of respects, including feature spreading and transparency, hiatus resolution, and consonant cluster simplification, among others. The goal of this dissertation will ultimately be to discover the unifying factor that accounts for why glottal stop so consistently behaves differently than other consonants.

Throughout this dissertation I present data from the patterning of [h] in parallel with that of glottal stop where possible in order to illustrate the fact that [h] and glottal stop are often treated as a class distinct from the supralaryngeal consonants. However, certain languages make distinctions even among the laryngeal consonants themselves, and thus no generalization holding of glottal stop necessarily holds of [h] as well.

This chapter is organized as follows: section 2.1 presents data from laryngeal transparency, showing that glottal stop tends to be transparent to spreading cross-linguistically, in contrast to the supralaryngeal consonants, which block spreading. Section 2.2 presents data from languages that require all vowels flanking laryngeals to be identical (*required identity-across-glottals* languages). This pattern bears a surface similarity to the translaryngeal harmony data discussed above, but differs in that feature spreading is not the only way that an offending $V_x\?V_y$ is repaired; languages exhibiting this requirement can also satisfy it through such means as deletion of the glottal stop. Section 2.3 goes on to discuss another pattern exhibited by languages with intervocalic glottal stop: a tendency for hiatus resolution-like processes to occur across glottal stop despite the presence of the intervening glottal stop. In this phenomenon, which I refer to henceforth as *hiatus resolution-across-glottals*, the same repair strategies employed in VV sequences are also employed in V?V sequences. This pattern presents a challenge to traditional OT approaches to hiatus resolution, which claim that the motivation for repair is the need for every syllable to have an onset.

Section 2.3 discusses the fact many languages avoid glottal stop in onset position, with some syllabifying intervocalic glottal stop as a coda. These data seem to support the position that glottal stop is a poor onset (which fits in with its failure to block hiatus), but a good coda. However, data presented in section 2.4 suggest that glottal stop is not a particularly good coda either: first, some languages avoid glottal codas (e.g. English, Arabic). Second, in many languages underlying sequences with glottal stop surface as non-sequential. Phenomena discussed in this section include vowel intrusion ($V_x\?C \rightarrow V_x\?V_xC$) and C? coalescence ($C? \rightarrow C'$). These patterns are analyzed as a reorganization of the gestures in the V? and C? sequence from sequentiality to simultaneity, a process that further supports the suggestion that sequential timing is not a possibility for glottal stop.

Languages discussed in this chapter include Sundanese (Malayo-Polynesian), St'at'imcets (Lillooet; Salish), Yucatec Maya (Mayan), Nez Perce (Penutian), Yatzachi

Zapotec (Otomanguean), Chemehuevi (Uto-Aztecan), Wichita (Caddoan), Yapese (Malayo-Polynesian), Makassarese (Malayo-Polynesian), Chamicuro (Arawakan), Kekchi (Mayan), Arbore (Cushitic), Tukang Besi (Malayo-Polynesian), Kashaya (Pomoan) and Yurok (Algic).

2.1 Transparency of glottal stop

One of the best known ways in which glottal stop tends to be distinguished from the supralaryngeal consonants cross-linguistically is in its transparency to spreading. Whereas oral consonants often block the spreading of vocalic features, glottal stop commonly allows vocalic features to propagate across it. Steriade (1987) gives a detailed discussion of translaryngeal harmony and presents data from a number of languages in which vocalic place features (e.g. height, backness) spread freely across an intervening laryngeal consonant, but do not spread across supralaryngeal consonants. Below I present data from two languages discussed in Steriade 1987 in order to illustrate the laryngeal transparency facts.

In Chemehuevi (Uto-Aztecan), phonotactic restrictions on vowel sequences result in the pattern that only a subset of possible underlying vowel sequences will surface into the output. Sequences that are realized faithfully are those that end in [a] or [i], and the sequences [aɛ], and [au].¹ When two vowels are input-adjacent due to morpheme concatenation, the result is rightwards spreading of the features of one vowel onto the other if the faithful sequence is ruled out by phonotactic restrictions:^{2,3}

- (1) Chemehuevi
- | | | | |
|----|-------------------------|-------------------------|----------------|
| a. | /kani-upaa/ | [kani- i pa] | ‘in the house’ |
| b. | /ma-upaa/ | [ma- u pa] | ‘in that’ |
| c. | /tɛka-vɛɛ- ɛ ka/ | [tika-vɛɛ- ɛ ka] | ‘ate it’ |

(Press 1979, Steriade 1987)

¹ The Chemehuevi inventory of allowed vowel sequences is apparently constrained by sonority; first, vowel sequences are allowed if they begin in the least sonorous vowel ([i]), or the most sonorous vowel ([a]), presumably because of the need for diphthongs to exhibit a steep sonority contour. The [i, u] final sequences also show a preference for diphthongs with falling sonority, a tendency that is common cross-linguistically (Rosenthal 1994, 1997).

² Examples (1a,b) also exhibit shortening of the final vowel of the underlying morpheme /upaa/ ‘in’. This is an instantiation of a general pattern in which all word final vocalic morae are deleted, resulting here in shortening of the underlying long vowel. When the word ends in a short vowel, the result is deletion of the entire vowel (e.g. /pacɛ/ → [pac] ‘daughter’; Press 1979, p. 26).

³ Press (1979) does not provide explicit evidence regarding the treatment of underlying V_xhV_y sequences; much of the data is presented in its surface form along. However, a survey of the forms she provides shows that the only VhV sequence that surface are those that conform to the pattern exhibited by V?V sequences.

Similar phonotactic restrictions hold of the vowels flanking laryngeal consonants in Chemehuevi; if a sequence of vowels is not possible when strictly adjacent, it is also not possible when a glottal stop intervenes. In the case of a disallowed $V_1\text{ʔ}V_2$ sequence, the result is progressive spreading of V_1 onto V_2 . The examples in (2) illustrate this pattern:

(2) Chemehuevi

- a. /nukwɨjɨʔumi/ → [nukwɨjɨʔɨmi] ‘run (pl.)’
 b. /ɨvɨjuni/ → [ɨvɨjuni] / * [ɨvɨjɨni] ‘ill/bad’
 c. /kacu-a-ra-ʔumɨ/ → [kacuaraʔumɨ] ‘aren’t they?’

(Press 1979, Steriade 1987)

Note that no spreading occurs if the vowels are separated by a supralaryngeal consonant, as in the [ɨju] sequence in *ɨvɨjuni* in (2b), even though the vowel sequence /ɨu/ is repaired in $V\text{ʔ}V$ (c.f. (2a)). Thus, in Chemehuevi, only glottal stop is transparent to vocalic spreading. Moreover, the fact that this process only applies to $V\text{ʔ}V$ sequences that correspond to the illegal VV sequences in Chemehuevi is shown in (2c); the [aʔu] sequence in *kacuaraʔumɨ* does not undergo coalescence (compare (2c) to (1b)).

Another example of a language in which there is productive spreading of vocalic features across an intervening glottal stop comes from Arbore (Cushitic). In Arbore, both [ʔ] and [h] are transparent to spreading. As in Chemehuevi, translaryngeal harmony is only exhibited for a subset of underlying $V(\text{ʔ}/h)V$ sequences; /e(ʔ/h)a/, /e(ʔ/h)o/, /e(ʔ/h)i/ and /a(ʔ/h)i/. In the case of Arbore, translaryngeal spreading is either progressive or regressive depending on the vocalic context, as shown in (3) below:⁴

(3) Arbore

- a. /eʔa/ → [eʔe], /eha/ → [ehe]
 /gereʔ-a/ → [gereʔe] ‘it is a belly’
 /yibeh-a/ → [yibeh-e] ‘it is a hippopotamus’
 b. /eʔo/ → [oʔo], /eho/ → [oho]
 /ma deʔ-o/ → [ma doʔ-o] ‘he is not throwing’
 /ma beh-o/ → [ma boh-o] ‘he is not going out’
 c. /eʔi/ → [iʔi], /ehi/ → [ihi]
 /ʔamma deʔ-i/ → [ʔamma diʔi] ‘I did not belch’
 /ma beh-i/ → [ma bih-i] ‘he did not go out’

⁴ One possible explanation for why regressive spreading occurs in all $V\text{ʔ}V$ sequences with the exception of /eʔ,ha/ is that under coalescence Arbore preserves the least sonorous vowel. This approach would force us to consider /o/ to be less sonorous than /e/ in order to account for its preservation in /eʔ,ho/.

- d. /aʔi/ → [iʔi], /ahi/ → [ihi]
 /ma zah-i/ → [ma zihi] ‘don’t die!’
 (Hayward 1984, Steriade 1987)

The data in (3) show that while laryngeal consonants allow spreading of vocalic features across them, supralaryngeal consonants do not (compare /ʔedi/ → [ʔedi] / *[ʔidi] ‘goats and sheep’ to /beh-i/ → [bihi], (3c)).

Other languages discussed by Steriade (1987) as exhibiting similar patterns of translaryngeal harmony include Acoma (Keres; Miller 1965), Nez Perce (Penutian; (Aoki 1970)), Yapese (Austronesian; Jensen 1977), Kekchi (Mayan; Campbell 1974), Tojolabal (Mayan; Furbee-Losee 1976) and Mohawk (Iroquoian; Postal 1969), among others. I will return to discuss the details of a number of these languages, in particular Acoma, Nez Perce, Kekchi and Mohawk, in sections 2.2-5 as we begin to classify types of translaryngeal harmony in an attempt to understand the motivations for spreading and glottal stop’s participation in it.

The data discussed in Steriade 1987 regarding translaryngeal harmony address only those cases of laryngeal transparency in which every feature of one vowel in the V?V sequence spreads onto the other vowel in the sequence. However, there are languages in which we can observe spreading of single features of consonants and vowels through the glottal stop. In the remainder of this sub-section, I present data from partial feature spread across an intervening laryngeal. I begin with the spreading of nasality to demonstrate the tendency for glottal stop to be transparent cross-linguistically.

Consider the nasal spreading data from Sundanese presented in (4) from Cohn (1993). In Sundanese, nasality spreads rightwards from a nasal consonant onto every following vowel until it is blocked by a supralaryngeal consonant, (4):

- (4) Sundanese
- | | | | | |
|----|----------|---|--------------------|---------------------|
| a. | /ɲatur/ | → | [ɲãtur] / *[ɲãtũr] | ‘arrange’ (active) |
| b. | /marios/ | → | [mãrios] | ‘exchange’ (active) |
| c. | /ɲawih/ | → | [ɲãwih] | ‘sing’ (active) |
| d. | /ɲayak/ | → | [ɲãyak] | ‘sift’ (active) |
| e. | /ɲiar/ | → | [ɲãiar] | ‘say’ (active) |
- (Cohn 1993)

In contrast to the supralaryngeal consonants, laryngeal consonants do not block spreading of nasality. The data in (5) show that nasality can spread from an initial nasal consonant on to each subsequent vowel across the laryngeals [ʔ,h]:

- (5) Sundanese
- | | | | | |
|----|---------|---|---------|----------------------------------|
| a. | /niʔis/ | → | [nĩʔis] | ‘relax in a cool place’ (active) |
| b. | /mihak/ | → | [mĩhāk] | ‘take sides’ (active) |
- (Cohn 1993)*

Taken together, the data in (4) and (5) demonstrate that the application of nasal spreading in Sundanese distinguishes between the laryngeal and supralaryngeal consonants in that only the former act as transparent to spreading. These data exemplify the pattern that laryngeal consonants show a tendency towards transparency, and that they are more likely than the supralaryngeal consonants to exhibit this tendency. In fact, surveys of the typology of nasal spreading (for example, Piggott 1992, Walker 1998, Walker 2003, Walker and Pullum 1999 among others) have found an implicational hierarchy in the likelihood of transparency to spreading. The full hierarchy, as presented in Walker and Pullum 1999, is given below in (8).

(7) Vowels >> Laryngeals >> Semivowels >> Liquids >> Fricatives >> Obstruent Stops

According to this hierarchy, if a language spreads nasality through a particular consonant, then nasality should also spread through all segments left of that consonant on the hierarchy. Thus, a language that allows nasality to spread through stop consonants will also allow it to spread through fricatives, liquids, glides and laryngeals.

A key characteristic underlying the hierarchy in (7) is that those consonants that are generally not contrastively specified for nasality will allow nasal spreading across them. Glottal stop shares this characteristic with many of the consonants of the hierarchy; like glides, liquids and fricatives it is generally not contrastively specified for nasality. Looking at the hierarchy, we can also observe that (with the exception of the laryngeal consonants) transparency of a less sonorous segment implies transparency of all more sonorous segments. For more detailed discussion of the factors that underlie the hierarchy in (7), including non-contrastiveness for nasality, sonorancy, and articulatory and acoustic independence see Cohn 1990, 1993, Piggott 1992, Walker 1995, 2003, Ní Chiosáin and Padgett 1997, and Walker and Pullum 1999, and references therein.

One question that arises here is whether glottal stop is really special in terms of its transparency to spreading since a number of supralaryngeal consonants also show transparency. In response, I suggest that the crucial observation is the *position* of laryngeals in the hierarchy. In fact, the position of laryngeal consonants in the hierarchy is inconsistent with the overall pattern exhibited in at least one way: while elements in the hierarchy pattern in terms of manner of articulation, the laryngeals instead pattern together with respect to place of articulation. The question then arises of why [h] doesn't pattern with the fricatives and [ʔ] with the stops, rather than patterning together. Furthermore, under at least some approaches (see Stevens and Keyser 1989, Bessell 1992, Zec 1995, and Lombardi 2002a for discussion), glottal stop is identified as a non-sonorant consonant. Under the glottal stop-as-obstruent approach, the position of the laryngeal consonants is again unexpected.

Before going on to discuss other phenomena that distinguish glottal stop from the supralaryngeal consonants, I present data from St'át'imcets (Lillooet; Salish) that show

another type of laryngeal transparency. In St'át'imcets, uvular and pharyngeal consonants condition local regressive faucal harmony with underlying /i, u, æ/ realized as [ɛ, ɔ, a]:

- (8) St'át'imcets
- | | | | | |
|----|----------------------|---|----------------------|----------------------------|
| a. | /suq ^w m/ | → | [ʃɔq ^w m] | ‘to skin an animal’ |
| b. | /liɣ ^w / | → | [lɛɣ ^w] | ‘to take apart, tear down’ |
- (Bessell 1998)*

The data in (9) show that regressive faucal harmony in St'át'imcets is blocked by any intervening consonant with the exception of glottal stop. (9a) shows that the presence of a glottal stop between the trigger of harmony and the target vowel does not block harmony in St'át'imcets; in other words, glottal stop is transparent to faucal harmony. (9b) shows that the presence of a supralaryngeal consonant intervening between the trigger and target of harmony does block the harmony process. Similar patterns also arise in Moses-Columbian Salish (Bessell (1998)).

- (9) St'át'imcets
- | | | | | |
|----|------------------------|---|------------------------|---------------------------------------------|
| a. | /ʔúʔq ^w aʔ/ | → | [ʔɔʔq ^w ɛʔ] | ‘to drink a little bit’ |
| b. | /súsq ^w əɱ/ | → | [šúšq ^w əɱ] | ‘to skin small animals’ <i>(c.f. (10a))</i> |
- (van Eijk 1997)*

This section has presented data to illustrate the fact that glottal stop patterns distinctly from the supralaryngeal consonants in a number of languages. The data presented here have shown that glottal stop is transparent to the spread of vocalic place features in translaryngeal harmony, and is also transparent to the spread of consonantal features, including nasality in languages like Sundanese and consonantly conditioned vowel retraction in St'át'imcets and Columbian Salish. In the following sections, we present additional data on the patterning of glottal stop, showing the laryngeal/supralaryngeal distinction is not limited to transparency.

2.2 Required Identity Across Glottals

In many languages, the transparency of glottal stop is exhibited in a requirement that the vowels flanking laryngeals surface as identical. This pattern is similar to the translaryngeal harmony pattern discussed in section 2.1 for Chemehuevi and Arbore, with the exception of the fact that these languages show across-the-board repair of offending

⁵ In St'át'imcets the retracted coronal consonants [z,z^ʷ] also condition faucal harmony, but only for /u, æ/, with [i] remaining unretracted (Bessell (1992),(1998))

$V_x?V_y$ sequences.⁶ The data shown below in (10) illustrate this pattern for Yucatec Maya (YM; Ola Orié and Bricker 2000). (10a,b) show that the requirement that the vowels flanking glottals be identical holds in monomorphemic words, while (10c) shows that this requirement does not hold of vowels flanking supralaryngeal consonants.⁷ (10d) shows that if a $V_x?V_y$ sequence is created through morpheme concatenation, this sequence is repaired through rightward spread of vocalic place features. (10e) shows that no such feature spreading occurs in response to a V_xCV_y sequence across a morpheme boundary with a supralaryngeal consonant, here exemplified by the preservation of an *učí* sequence (/y/ deletes due to a prohibition on consonant sequences).⁸

(10) Yucatec Maya

- | | | | |
|----|----------------------|------------------------|----------------|
| a. | wiʔit | | ‘loincloth’ |
| b. | tohol | | ‘price, value’ |
| c. | kitam | | ‘peccary’ |
| d. | héʔ im b’ineʔ | → híʔ im b’ineʔ | ‘I will go’ |
| e. | uy čič | → učič | ‘the hard one’ |

(Ola Orié and Bricker’s (2000) (1)-(4))

The data in (10) demonstrate that a language may satisfy the requirement that the vowels flanking laryngeals be identical either underlyingly in monomorphemic forms, or through spreading of the vocalic features across the glottal stop such that one of the vowels takes on the place features of the other. The data in (11) below demonstrate that Yucatec Maya also repairs ill-formed $V_x?V_y$ sequences through deletion of the intervening laryngeal, accompanied by hiatus resolution.

⁶ Recall that in both Chemehuevi and Arbore, the context for translaryngeal harmony were limited to only certain vowel sequences.

⁷ While all instances of $V?V$, and most of VhV , in Yucatec Maya obey the requirement that the vowels flanking laryngeals be identical, there are some exceptional cases of V_xhV_y . Ola Orié and Bricker (2000) suggest that this pattern may result because some tokens of [h] are diachronically related to the Classical Mayan voiceless velar fricative. Thus, it is possible that the exceptional V_xhV_y forms are listed in the lexicon as such, and do not pose true counterexamples to the generalization that YM exhibits a requirement that all vowels flanking laryngeals be identical.

⁸ Throughout the discussion of the YM data, we use the graphical conventions of Ola Orié and Bricker (2000). Thus, the acute and grave accents represent high and low tone, respectively, and *č* is a palato-alveolar affricate. One exception is the use of *ts* to replace their symbol for the alveolar affricate, and *ts’* for the alveolar affricated ejective. This substitution was made due to the difficulty of replicating the grapheme used by the authors, which overlaid *c* with /, using the available fonts.

- (11) Yucatec Maya
- | | | | | |
|----|---------------|---|----------------------|-------------------------|
| a. | le mèsesa-eʔ | → | le mèsesayeʔ | ‘that table’ |
| b. | le tyáa-oʔ | → | le tyáawoʔ | ‘that aunt over there’ |
| c. | čiʔ eh | → | čiyeh | ‘bite it!’ |
| d. | kin ts’ah ik | → | kin ts’ayik | ‘I give it’ |
| e. | maʔ ʔak-táan | → | mawak-táan | ‘it is not opposite me’ |
| f. | tiŋ wil ah eč | → | ...wil h eč / wil eč | ‘I saw you’ |
- (Ola Orié and Bricker’s (2000) (5)-(7))*

(11a,b) show that the usual repair strategy employed to resolve hiatus in YM is glide insertion. (11c-e) show that the same strategy is employed for some $V_xʔ/hV_y$ across a morpheme boundary, where the laryngeal is deleted and a glide is inserted instead. (11f) shows a third option for V_xhV_y , which is vowel deletion, and optional [h] deletion. The forms in (11c-f) satisfy the requirement that vowels flanking laryngeals be identical on the surface in that there are no instances of $V_xʔ/hV_y$ in the output, thus the relevance of this requirement is exhibited equally by the spreading data in (10d) as well as the deletion data in (11c-e).⁹

The data from YM in (10) and (11) illustrate one instantiation of what is a common pattern cross-linguistically. In order to further demonstrate the widespread nature of this requirement, I present data here from a number of unrelated languages that also prohibit non-identical vowels across a glottal stop. These languages include Nez Perce, Mazahua Otomi, and Tiv, as well as related patterns from Mohawk, Japanese, Kashaya and Yapese.

In Nez Perce (Penutian; Aoki 1970), vowels in $Vʔ/hV$ sequences are identical in monomorphemic words, as shown in (12a,b). When an illegal $V_xʔV_y$ cluster is created, the result is leftward spreading of vowel features across the glottal stop, as shown in (12c). (12d-e) show that the results for [h] vary; when the second vowel is unstressed, the result is either deletion of the [h] and coalescence of the two underlying vowels, or retention of the [h] and spreading, (12d). If the second vowel is stressed, the result for V_1hV_2 is always V_2hV_2 , (12e).

⁹ (11e) shows that the pattern of laryngeal deletion accompanied by glide insertion is not limited to cases where the vowels flanking the laryngeal are not identical. Apparently, the laryngeal is deleted for reasons independent of the prohibition of $V_xʔV_y$. Additionally, Ola Orié and Bricker (2000) note that with deletion of the laryngeal in (11e), there is a variant pronunciation in which the vowels have coalesced into a single long vowel, *máak-táan*. This may result from variability in choice of hiatus repair strategy between glide insertion and coalescence, possibly due to the unavailability of an agreeing glide for [a-a] sequences.

(12) Nez Perce

- | | | | | |
|----|-------------------|---|---------------------------|---------------------|
| a. | tuʔúnynu | | | ‘tail’ |
| b. | héhen | | | ‘stem, vine’ |
| c. | hiʔel’wíce | → | heʔel’wíce | ‘he spends winter’ |
| d. | hiheqtíse | → | heqtíse/ hiheqtíse | ‘he is getting old’ |
| e. | hihésce | → | hehésce | ‘he breaths’ |

(Aoki 1970)

Like Yucatec Maya, Nez Perce satisfies the requirement that all vowels flanking laryngeals be identical either through repair of the offending sequence, or through deletion of the laryngeal itself (cf. (12d)).

Additional languages that require the vowels flanking laryngeals to be identical include Mazahua Otomí (Otomanguean; Spotts 1953, Steriade 1995, Gafos and Lombardi 1999) and Tiv (Niger-Congo; Archangeli and Pulleyblank 1994, Gafos and Lombardi 1999). In Mazahua Otomí, there is a class of derivational suffixes of the form *Cə* that are added to root forms. If the vowel of the root is nonround, then the suffix vowel harmonizes with the root vowel, as shown in (13a,b). However, if the root vowel is round, the suffix vowel will not harmonize, and surfaces instead as schwa (13c). (13d) demonstrates the tendency towards translaryngeal harmony in Mazahua Otomí; here the suffix vowel harmonizes with the round root vowel across the glottal stop, despite the fact these suffixes do not otherwise harmonize with round vowels. In Tiv, adjacent vowels must be identical in all features except for tone (13e). The same holds true of vowels that are separated by [h] (13f). In contrast, vowels separated by a supralaryngeal consonant may differ (13g).

(13) Mazahua Otomi

- | | | |
|----|---------------|-------------------|
| a. | ji-ʔi | ‘head’ |
| b. | sÁ-tʔΛ | ‘arrive here’ |
| c. | tʔo-fə | ‘nest’ |
| d. | khù-ʔu | ‘sister of a man’ |

(Steriade 1995, (49), (51))

Tiv

- | | | |
|----|-------------|-------------------------|
| e. | tsèe | ‘mock’ |
| f. | gòho | ‘dart away’ |
| g. | áser | ‘wrench off, break off’ |

(Archangeli and Pulleyblank 1994, (15), (18), (24))

The languages discussed in this section are characterized by two general patterns; first, we do not find non-identical vowels flanking glottals in monomorphemic forms. These forms may have resulted from the faithful preservation of input $V_x\text{?}V_x$ sequences, and thus this pattern is not conclusive as to the requirement that all vowels flanking laryngeals be identical. However, a second key characteristic of these languages is that they exhibit repair of non-identical $V\text{?}hV$ when these are created through morpheme concatenation, and this does demonstrate that there is an active requirement that vowels be identical across glottals.

In addition to languages like Yucatec Maya, Nez Perce, Mazahua Otomí and Tiv, which exhibit an across-the-board requirement that vowels flanking laryngeals be identical, many other languages exhibit a tendency towards translaryngeal harmony even when it is not exhibited in every domain. For example, there is a strong tendency towards having only identical vowels flanking laryngeals in the Malayo-Polynesian languages of *Tukang Besi*, *Palu'e* and *Souw Amana Teru* (M. Donohue, p.c. 2006). Another common pattern is that the identity requirement may hold only of forms created through concatenation or epenthesis (e.g. forms in which the $V\text{?}V$ sequence is not underlying). This pattern is illustrated by the data in (14) from Mohawk and Japanese, in which this requirement holds of $V\text{?}V$ when it is created through epenthesis of a vowel.

In Mohawk, the default epenthetic vowel [e] is inserted to break up illegal $C\text{?}$ and $\text{?}C$ clusters when the glottal stop is peripheral in the word, as in (14a).¹⁰ If the glottal stop in a $\text{?}C$ or $C\text{?}$ cluster is adjacent to a vowel (e.g. it is non-peripheral), then the epenthetic vowel that breaks up the cluster is a copy of that vowel (14b,c). Similarly, in Japanese the default epenthetic vowel is [u], which is inserted in order to avoid clusters and word final consonants in loanword adaptation (14c). (14d) shows that the vowels flanking [h]-allophones may be non-identical if the VhV sequence is underlying. In contrast, if an epenthetic vowel follows an [h]-allophone, it must be identical to the underlying vowel (14e,f).¹¹

(14) Mohawk

- a. /yaknir Λ not ? / → [yagenir ? o:node ?] ‘we (dual.excl.) are singing’
- b. / Λ waoatunis ? auhak ? / → [...zu ? uhage ? ...] ‘it will have been ripening’
- c. / ? waatunis ? ashek ? / → [...za ? ashege ? ...] ‘it will be ripening repeatedly’

(Postal 1969, (2),(11))

¹⁰ (14a) also shows epenthesis of the default vowel [e] in order to break up the underlying /kn/ cluster ([gen] on the surface).

¹¹ We refer to the [h, ?] as allophones of /h/ following Kawahara (2003), from which the data in (17d-g) are taken. Another [h]-allophone not shown in (17) is [ç], found in adaptation of ‘Zurich’ /zuriç/ → [tsuriçi]. Presumably, at the point of vowel epenthesis each of these consonants can be considered as primarily laryngeal, with the labial and palatal components arising as a result of vowel-to-consonant coarticulation. Within a gestural approach, this coarticulation would result from overlap of the vocalic gesture over the [h], for example overlap of [i]’s palatal tongue tip gesture over [h] is responsible for the percept of [ç] in [tsuriçi].

Japanese

d.	/saks/	→ [sokk <u>us</u> u]	‘socks’
e.	to <u>φ</u> u		‘tofu’
f.	/bax/	→ [bahha]	‘Bach’
g.	/bux/	→ [bu <u>φ</u> u]	‘Buch’ (book, German)

(Kawahara 2003)

The data in (14) show the emergence of a pattern of translaryngeal harmony in epenthetic contexts in Mohawk and Japanese. This is an ‘Emergence of the Unmarked’ pattern, suggesting that all else being equal, the constraint hierarchy conspires to favor forms with identical vowels flanking laryngeals. In these languages, faithfulness constraints require faithful realization of underlying V ϕ /hV sequences, even if the vowels are non-identical. When the offending V ϕ /hV sequence is not underlying repair of the sequence is allowed. This results from the fact that Input-Output faithfulness constraints do not apply to segments that are not present in the input; the epenthetic vowel is free to harmonize with the underlying vowel because the former has no input correspondent. Conversely, for languages in which the constraint(s) that motivate translaryngeal harmony are lower ranked than the relevant faithfulness constraints, we expect no repair to occur at all. These languages may fail to show any evidence of translaryngeal harmony whatsoever, but there are interesting cases that hint that the identity requirement plays a role despite the dominance of the faithfulness constraints.

An example of the latter case is Kashaya (Pomoan; Buckley 1994), in which every instance of V(ϕ /h)V in the native lexicon satisfies the requirement that vowels flanking laryngeals be identical (15a,b). Exceptions to this pattern include loanwords adapted from Spanish (15c) and some multimorphemic forms (15d). For completeness, (15e) shows that the vowels flanking supralaryngeal consonants are not required to be identical.

(15) Kashaya

a.	ma <u>ʔ</u> a	‘food, eat’
b.	mi <u>h</u> ilá	‘west’
c.	[ka <u>h</u> ón] (from Sp. /kaxón/)	‘box’
d.	bi- <u>ʔ</u> ámhul	‘tomorrow’
e.	baco	‘boat’

(Buckley 1994)

The pattern exhibited by (15c,d) will result from a ranking of faithfulness constraints higher than the constraints that conspire to require identity of vowels across laryngeals. The pattern of V(ϕ /h)V in the native monomorphemic words suggests that this ranking may have been reversed at an earlier stage of Kashaya. At that stage, the identity requirement was active, forcing harmonization of the vowels flanking laryngeals. The

ranking of markedness >> faithfulness that resulted in harmony may have become reversed at a more recent stage, one that preceded the introduction of Spanish loans. As for the multimorphemic forms, we can conjecture that these are not listed in the lexicon, but rather created on the fly. Thus, they reflect the present stage of Kashaya's phonological grammar in which high ranked faithfulness constraints guarantee preservation of underlying $V_x\?V_y$.

This section has shown that a number of unrelated languages exhibit a requirement that the vowels flanking laryngeals be identical. Languages showing an across-the-board prohibition of non-identical vowels in $V\?V$ sequences included Yucatec Maya, Nez Perce, Mazahua Otomí and Tiv. Languages in which harmony is limited to certain contexts include Selayarese, Mohawk and Japanese for epenthetic consonants, and in Kashaya monomorphemic forms.¹²

In the following section I present data from additional languages in which there is interaction between the vowels flanking laryngeal consonants. These languages exhibit the familiar process of translaryngeal spreading, but also show patterns of diphthongization of the vowels flanking laryngeals, glide insertion and glottal deletion in $V\?V$, and full coalescence ($[a\?i] \rightarrow [a\?a]$) and feature preserving coalescence ($[a\?i] \rightarrow [e\?e]$), among others. Interestingly, in the languages discussed in the following section, the processes that are observed in $V\?V$ mimic the hiatus resolution patterns exhibited by strictly adjacent vowel sequences. This pattern is of interest because it challenges the traditional OT approach to hiatus resolution that attributes hiatus resolution to the lack of an intervocalic consonant in VV . The data presented in section 2.3 suggest that glottal stop fails to pattern as an onset to following vowels. This pattern is further supported by the fact that many languages have phonotactic prohibitions on onset glottal stops, as discussed in more detail in this section.

2.3 *Hiatus resolution across glottals*

In many languages, underlyingly adjacent vowels are not allowed to surface faithfully in the output. In response to underlying VV sequences, languages may employ a wide variety of hiatus resolution strategies, including vowel coalescence, vowel deletion,

¹² The reader may question the suggestion that cross-consonantal vowel assimilation is limited to $V\?V$; some languages do not limit the requirement that cross-consonantal vowel sequences be identical only to $V\?,hV$ sequences. In these languages, the laryngeal consonants pattern with a subset of the supralaryngeal consonants with respect to this identity requirement. Languages in which this requirement is active include Tiberian Hebrew, Iraqw, Hebrew, and Ge'ez for the class of gutturals, and Toba for the class of dorsals; in these languages the vowels flanking all gutturals (uvulars, pharyngeals and laryngeals) or all dorsals (velars, uvulars and laryngeals) must be identical (see McCarthy 1994, Rose 1996, and Gafos and Lombardi 1999 for in-depth discussion). For languages in which the laryngeal consonants pattern with the guttural or dorsal consonants with respect to transparency and other phenomena, I suggest that these patterns should be treated as distinct from the required identity-across-glottals patterns presented in this section. The reader is referred to section 4.1 for detailed discussion of the proposed approach to reconciling the two patterns.

diphthongization, consonantal insertion, or glide formation, among others. (16) gives examples of languages that employ a subset of the possible responses to underlying hiatus:

(16) Xhosa; Bantu: **V-V Coalescence**

- a. wa-inkosi → wenkosi ‘of the chiefs’
(Aoki 1974, Casali 1996)

Luganda; Bantu: **C-V Coalescence**

- b. li + ato → lʼa:to ‘boat’
(Rosenthal 1994)

Axininca Campa; Arawakan: **C Insertion**

- c. i-N-koma-i → iŋkomati ‘he will row again’
(McCarthy and Prince 1993)

English; Germanic: **Glide Formation**

- d. re + enter → [riyenter] ‘re-enter’

Spanish; Romance: **Faithful Realization**¹³

- e. dueto → du.éto ‘day’
(Hualde and Prieto 2002)

Attempts within OT to explain the cross-linguistic tendency for input hiatus to be repaired in the output have appealed to the unmarked nature of CV syllables in comparison to vowel initial syllables; while all languages have the former syllable type, some prohibit the latter. The fact that consonant initial syllables are relatively unmarked has been incorporated into the OT grammar in terms of a constraint requiring all syllables to have onsets, namely ONSET (Prince and Smolensky 1993). The presence of this constraint in the OT grammar will account for the fact that some languages require syllable onsets (if ONSET is undominated), and that all languages allow syllables with onsets (even if ONSET is low ranked, C will be syllabified as an onset rather than a coda in VCV, all else being equal). Most subsequent OT approaches to hiatus resolution have considered the motivation behind hiatus resolution to be the ONSET constraint (see Rosenthal 1994, 1997, Casali 1996 and Senturia 1997 for cross-linguistic surveys of hiatus resolution patterns employing this approach).

Consider the data in (17) for examples of languages that exhibit hiatus resolution-like repair of V?V:¹⁴

¹³ As Hualde and Prieto (2002) discuss, Spanish forms like the example in (16e) surfaces with hiatus between the input vowels. However, Spanish doesn’t syllabify all vowel sequences as heterosyllabic; some vowel sequences undergo diphthongization. For example, a near minimal pair of (16e) is *duelo* ‘sorrow’, pronounced [dwe.lo]. See Hualde and Prieto (2002) for more discussion.

¹⁴ A possibly similar pattern is exhibited by VhV in Gujarati (Indo-Aryan; Cardona 1965), in which hiatus at the boundary of a vowel final verb and the passive suffix [a] is resolved by insertion of a [w], (i). (ii)

(17) Yatzachi Zapotec

- a. /zetʃa + eʔ/ → [zetʃeʔ] ‘he stands’
/tʃʃagnaʔ + eʔ/ → [tʃʃagneʔe] ‘he marries’

(Butler-Haworth 1980, Borroff 2003, 2005)

Yucatec Maya

- b. /le meesa + eʔ/ → [le meesaye] ‘that table’
/maʔ + ʔak-taan/ → [mawak-taan] ‘it is not opposite to me’

(Ola Orié and Bricker 2000)

Chemehuevi¹⁵

- c. /tɛkavɛɛuka/ → [tɛkavɛɛɛk] ‘ate it’
/nukwijɛʔumi/ → [nukwijɛʔɛmi] ‘run (pl.)’

(Press 1979)

Wichita

- d. /ʔiri + a:has/ → [ʔira:has] ‘wet the bed’
/ti + ʔak + hisha/ → [taʔakhisha] ‘they went’

(Rood 1976)

Yapese¹⁶

- e. /fai + ng/ → [fe:ng] ‘to find something’
/ka+ʔa+i mi:l/ → [keʔe mi:l] ‘he ran first’

(Jensen 1977)

shows that [w] is inserted even when the verb ends in [h]. More research is required to determine whether this pattern is exhibited beyond the context shown in (i), (ii).

- (i) /ja + a/ → [jawa] ‘be eaten’
(ii) /nah + a/ → [nahwa] ‘be bathed’

¹⁵ The vowel [ɛɛɛ] in the Chemehuevi form ‘ate it’, (2c), represents a superlong vowel [ɛ::].

¹⁶ The Yapese data in (17e) show that the vowel sequence *a+i* will result in feature coalescence to *e* regardless of whether the vowels are strictly adjacent, or separated by a glottal stop. Another interesting form that shows this pattern is the word meaning ‘house foundation,’ which is pronounced by some speakers of Yapese as *dayif* and by some as *de:f*, leading Jensen (1977) to posit an underlying form for this word of *daif*. This pattern is quite interesting in terms of a variation in choice between glide formation or coalescence as a means of hiatus resolution. Intra-speaker variation in pronunciation possibly results from variation in the relative ranking of the constraints that attempt to rule out the application of these repair strategies (DEP_{L-O} (C) and UNIFORMITY; see, for example, Boersma and Hayes 2001 for an account of variation within OT).

Chickasaw

- f. /tof-to-a/ → [toftowa] ‘to spit more than once’
/chikoʔ-a/ → [chikoʔwa] ‘to be all sticking up’

(Ulrich 1993)

The data in (17) show that in each language there is a remarkable similarity in the modifications that occur in VV and VʔV sequences. For example, in Yatzachi Zapotec both VV and VʔV undergo coalescence, and in Yucatec Maya and Chickasaw, both VV and VʔV undergo glide insertion. Given the similarity in the repair strategies that are exhibited both in strictly adjacent vowel sequences and in vowel sequences separated by a glottal stop, it seems natural to attempt to subsume the two contexts under the same analysis. However, it is immediately clear that this attempt will challenge the validity of the ONSET approach to hiatus resolution; while the constraint ONSET predicts repair of VV sequences, it cannot predict repair of VʔV. In the VʔV sequences, the glottal stop should syllabify as an onset to the second vowel, thereby satisfying this constraint. Therefore, a main goal of this thesis is to explain why hiatus resolution-like processes are observed across glottal stop in a wide variety of languages, including YZ, YM, Chemehuevi, Wichita, and Yapese.

The organization of this sub-section is as follows: in section 2.3.1 I present additional data from the languages in (17) to illustrate the presence of hiatus resolution patterns in VʔV sequences. Here, I focus primarily on providing a detailed description of this pattern in Yatzachi Zapotec in section 2.3.1.1, with the data from the other languages presented in section 2.3.1.2. In section 2.3.2, I discuss the observation that VʔV in these languages pattern as though the intervocalic glottal stop fails to syllabify as an onset to the following vowel. This section presents data from a number of languages in which glottal stops are prohibited from prevocalic position, or fail to pattern as onsets even when intervocalic.

2.3.1 Yatzachi Zapotec

In this section, I introduce the patterns that obtain when vowels are input-adjacent in Yatzachi Zapotec (YZ). All of the data in this section are originally from Butler-Haworth 1980. The data discussed result from the affixation of a vowel initial suffix to a vowel final verb. Zapotec verbs may end in any of the five vowels of the language, [i], [o], [e], [a] and [ə].¹⁷ I will discuss data in which the vowel initial suffixes are affixed to both V-final and glottal stop-final verbal bases in parallel. For the purposes of this dissertation, only subject-marking suffixes will be considered.

¹⁷ Note that Yatzachi Zapotec lacks the vowel [u]. Butler-Haworth claims that Zapotec’s [o] is “un sonido entre o y u.”

These suffixes may affix to any Zapotec verbal base and must do so when the subject is not otherwise expressed in the clause.¹⁸ Thus, data relating to this issue are abundant. In (18) 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.

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

2.3.1.1 Coalescence

In YZ, sequences of identical vowels, sequences with schwa and input [a.e] sequences undergo coalescence. With identical vowels, the output segment is a faithful realization of both input vowels. 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]. These patterns are shown in (19).¹⁹

¹⁸ In my own fieldwork, I observed that speakers regularly use the subject marking suffix even when the subject is expressed in the sentence. Furthermore, when asked about the possibility of dropping the suffix in the appropriate contexts, my collaborators denied the grammaticality of doing so. Thus, the generalization from Butler-Haworth 1980 that speakers can drop the subject marking suffixes in overt-subject sentences may no longer reflect the grammar of Yatzachi Zapotec. An equally likely possibility is that the laboratory setting associated with data collection led my collaborators to apply a prescriptive rule of suffix attachment, and that natural speech might have exhibited more examples without the suffix.

¹⁹ I have analyzed the YZ hiatus resolution patterns in (19) to be instances of coalescence, rather than deletion, for a number of reasons. One of these is the fact that data from adaptation of Spanish loans lends support to the proposal that coalescence is a preferred alternative to vowel deletion. For example, Zapotec tends to delete final vowels in Spanish loans, as in (ii). However, where coalescence of the final vowel and immediately preceding consonant would result in a licit Zapotec consonant, then the vowel is retained as a secondary articulation rather than being deleted. Thus, [k], [g], [x] followed by [o] are adapted as [kw], [gw], [xw] as in (iii). This pattern suggests that deletion is last resort repair, only employed when coalescence is impossible.

ii.	a.	/bandera/	→	[bander]	‘flag’
	b.	/mozo/	→	[mos]	‘worker, servant’
	c.	/sobre/	→	[sobr]	‘envelope’
iii.	a.	/arko/	→	[ark ^w]	‘bridge (in the form of an arc)’
	b.	/domingo/	→	[ʒa domig ^w]	‘(day) Sunday’
	c.	/conexo/	→	[conex ^w]	‘rabbit’

(19)	a.	V_x	+	V_x	→	V_x
		zetʃa	+	-aʔ	→	ze.tʃaʔ
		stand		1 st Sg.		‘I stand’
		zo	+	-oʔ	→	zoʔ
		live		2 nd Sg.		‘You live’
	b.	ə	+	V_x	→	V_x
		V_x	+	ə	→	V_x
		tʃbeza	+	-aʔ	→	tʃbe.zaʔ
		wait		1 st Sg.		‘I wait’
		tʃxi	+	-əb	→	tʃxib
		clean		3 rd Animal		‘The animal cleans’
	c.	a	+	e	→	e
		zetʃa	+	-eʔ	→	ze.tʃeʔ
		stand		3 rd Resp.		‘He stands’

In the case of VʔV, feature spreading occurs in exactly the same environments as does coalescence in the VV cases; that is, with identical vowels, sequences with schwa and [aʔe] sequences. Moreover, when the input vowels are not identical, the choice of vowel features to survive into the input is also the same; schwa takes on the features of the non-schwa vowel, and [e] spreads onto a preceding [a]. One of the only differences between the realization of strictly adjacent input vowels and VʔV is that the result of coalescence in the latter case is a bimoraic vowel instead of a monomoraic one. Because of the similarity in the realization of underlying VV and VʔV in the ‘coalescence’ context (e.g., identical vowels, etc.), I propose that for the appropriate vowel sequences coalescence occurs regardless of whether the vowels in the sequence are strictly adjacent or separated by a glottal stop. Thus, in both environments the two underlying vowels have a single output correspondent, one that is monomoraic in VV and bimoraic in VʔV. In this case, the glottal stop articulation is overlain on the vowel, leading to the percept of two distinct vowels. For an explanation of the difference in moraicity of the surface realization of underlying VV vs. VʔV sequences, the reader is referred to Borroff 2003, section 3.2.

Another difference between the VV and VʔV forms is that the glottal stop often surfaces as laryngealization on all or part of the vowel, henceforth referred to as creakiness or creaky phonation. Reportedly, Zapotec speakers vary as to the amount of creakiness that occurs and whether it is realized on both moras of the vowel or solely the rightmost one (Rebecca Long, p.c.). My own fieldwork on YZ has shown

that glottal stop is sometimes also realized as a period of creaky or aperiodic vocal fold beats between two spans of modally phonated vowels. More discussion can be found in section 2.3.2. The data in (20) show examples of the V?V forms that undergo coalescence.

(20)	a.	V_x?	+	V_x?	→	V_x?V_x
		tʃʃagna?	+	-a?	→	tʃʃag.na?a
		marry		1 st Sg.		‘I marry’
		tʃbe?	+	-e?	→	tʃbe?e
		sit		3 rd Resp.		‘He sits’
	b.	ə?	+	V_x	→	V_x?V_x
		V_x?	+	ə	→	V_x?V_x
		tʃselə?	+	-a?	→	tʃse.la?a
		send		1 st Sg.		‘I send’
		tʃzi?	+	-əb	→	tʃzi?ib
		buy		3 rd Animal		‘The animal buys’
	c.	a?	+	e?	→	e?e
		tʃʃagna?	+	-e?	→	tʃʃag.ne?e
		marry		3 rd Resp.		‘He marries’

2.3.1.2 Diphthongization

Diphthongs are created in all YZ forms in which the first vowel is [i], [o] or [e], in both VV and V?V contexts. The proposal that diphthongization has, in fact, occurred in the V?V cases is supported by the fact that the initial vowels in these sequences undergo changes consistent with their forming part of a YZ diphthong; [e] raises to [i], and [o] is realized as [w]. As with vowel sequences that undergo coalescence, the V?V sequences differ from the VV sequences only in the glottal stop/creakiness in the former.

(21)	a.	i, e	+	V_x	→	yV_x
		tʃxi	+	-aʔ	→	tʃxjaʔ
		clean		1 st Sg.		‘You clean’
		tʃne	+	-oʔ	→	tʃnjoʔ
		speak		2 nd Sg.		‘You speak’
	b.	o	+	V_x	→	wV_x
		zo	+	-eʔ	→	zweʔ
		live		3 rd Resp.		‘He lives’
(22)	a.	iʔ, eʔ	+	V_x	→	jʔV_x
		tʃxiʔ	+	-aʔ	→	tʃxjʔa
		buy		1 st Sg.		‘I buy’
		tʃbeʔ	+	-oʔ	→	tʃbjʔo
		sit		2 nd Sg.		‘You sit’
	b.	oʔ	+	V_x	→	wʔV_x
		tʃʃoʔ	+	-eʔ	→	tʃʃwʔe
		rip		3 rd Sg. Resp.		‘He rips (something)’

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

(23)	a	+	o	→	ao
	zetʃa	+	-oʔ	→	ze.tʃaoʔ
	stop		2 nd Sg.		‘You stop’

Input [aʔ-oʔ] sequences result in diphthongization of the sequence, as shown below in (28).

(26) VʔV sequences

	iʔ	oʔ	eʔ	aʔ	əb, ən
iʔ	-	jʔo	jʔe	jʔa	iʔib, iʔin
oʔ	-	oʔo	wʔe	wʔe	oʔob, oʔon
eʔ	-	jʔe	eʔe	jʔa	eʔeb, eʔen
aʔ	-	aʔo	eʔe	aʔa	aʔab, aʔan
əʔ	-	oʔo	eʔe	aʔa	əʔəb, əʔən

This section has presented the patterns of hiatus resolution that occur in both VV and VʔV sequences in YZ when these are created through morpheme concatenation. The generality of the pattern exhibited by the YZ subject marking affixes is shown by the fact that these same patterns are found in other environments. For example, careful examination of the YZ lexicon shows that the vowel sequences present in monomorphemic forms are consistent with the patterns illustrated in (25) and (26). The adaptation of Spanish loans provides another context to examine the treatment of input vowel sequences; these undergo the same repairs as do the derived VV sequences at the root-affix boundary. For example, Spanish *[al.ko.ol]* and *[teatro]* become Zapotec *[al.kol]* and *[tja.tr]*, to be compared with the Zapotec verb forms *[zo-oʔ]* ‘you live’ and *[tʃne-aʔ]* ‘I speak’, which become *[zoʔ]* and *[tʃnjaʔ]*, respectively.

2.3.1.3 *On the Realization of Glottal Stop in Yatzachi Zapotec*

Before leaving the issue of hiatus resolution-across-glottals in Yatzachi Zapotec, I turn to the actual phonetic realization of glottal stop in this language below. This discussion addresses the issue of whether glottal stop should be characterized as present underlyingly in YZ, or whether it is present as underlyingly specified creaky phonation. This question is important in the light of the fact that YZ glottal stop is sometimes realized as creakiness on the surface (Rebecca Long, p.c.), and that other related languages have been described as having phonemic creakiness (for example, Jalapa Mazatec (Kirk *et al.* 1993, Silverman *et al.* 1996, Silverman 1997), Comaltepec

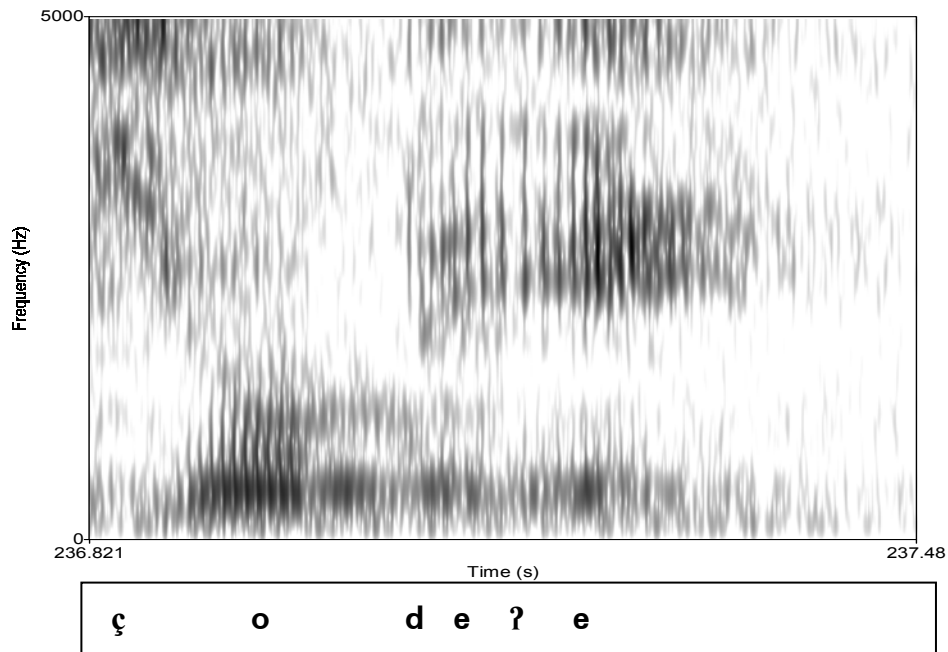
picture identification task. However, these speakers declined to be recorded and for this reason their data are not presented here.

The data were recorded using a SONY MZ-B100 mini-disk recorder, which was chosen for its portability and the capacity of the mini-disk for large recordings. These data were subsequently digitized using Praat 4.4.24, by Paul Boersma and David Weenink, and available at www.praat.org. Data collection sessions for the speakers who agreed to be recorded took place at the Centro de Investigaciones y Estudios Superiores en Antropología Social (Center for Research and Higher Studies in Social Anthropology) in the City of Oaxaca, an institute with which the author was affiliated as a visiting thesis-writer (Tesisista Visitante). These activities were conducted in the Center's seminar and presentation rooms, depending on availability. Unfortunately, due to the unavailability of sound-attenuated rooms, ambient noise has resulted in the recordings being somewhat degraded. Still, the data discussed below show that glottal stop in YZ is sometimes realized as a full stop, which suggests that it may be a consonant underlyingly. In the discussion below, forms are mentioned as having glottal stop in either the casual or careful productions if they were originally transcribed as such by the author. As for variations in the forms that lead to this we re identified as glottal stop, this is discussed on a case by case basis. We also consider cases in which forms identified by Butler-Haworth (1980), (1997) as having an intervocalic glottal stop were realized instead with creak; often these are variant tokens of a word that is sometimes pronounced with a full glottal stop.

To demonstrate the availability of hiatus resolution in V?V, consider the data below in (28) and (29). (28) gives a spectrogram of one token of the word *yode'e* 'he will mend.' The in put of this form is /çoda?-e?/ (the root 'mend' plus the 3rd person respectful subject marker). This form has undergone hiatus resolution via coalescence of an underlying /a?e/ sequence. The fact that hiatus resolution has occurred is supported by the fact that related forms retain the /a/ vowel; for example, /çoda?-o?/ → [çoda?o], 'you will mend,' and so on.

(28) Spectrogram for *yode'e* [çodeʔe] 'he will mend'

(ASE)

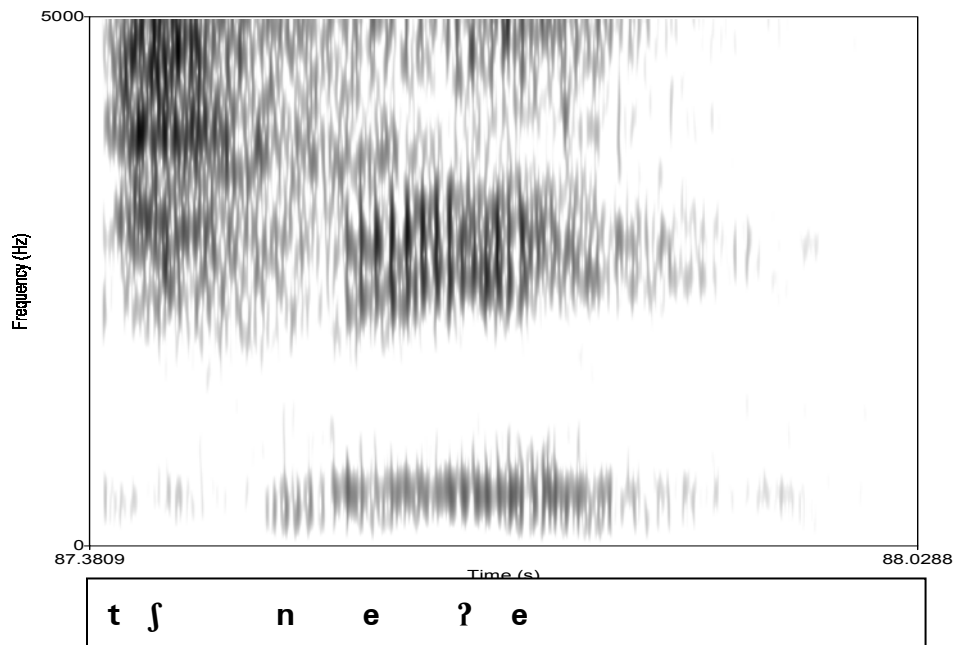


Considering the spectrogram in (28), we can easily see the presence of the glottal stop; it coincides with the increase in the periods of the vocal fold pulses. This is a common realization of glottal stop cross-linguistically, and is more often observed than full silence. In fact, Pierrehumbert and Talkin (1992) state that “a full glottal stop (with complete obstruction of the vocal folds) is quite unusual” (p. 93). Interestingly, one pattern that arises from the Yatzachi Zapotec data is that forms with intervocalic glottal stop may vary in the extent to which they exhibit glottalization.²² For example, consider the spectrogram in (29) of the phrase *chne'e* [tʃneʔe] 'he puts-his-hands'. Like the form in (28), the one in (29) has also undergone hiatus resolution despite the presence of the glottal stop; it is underlyingly /tʃnaʔ-ɛʔ/; to put ones hands-3rd Respectful. This form shows more evenly spaced (though still irregular) vocal fold pulses than the form in (28), which showed a lengthening of the pitch period corresponding temporally with the glottal stop.

²² In fact, many of the tokens with *yodaʔ-* did not show visually identifiable glottalization, and for this reason have not been included here. Furthermore, the other two tokens of *yode'e* were spoken softly enough so as not to provide clear spectrograms. In the discussion that follows, I present data to explain why some forms surface with glottalization and others do not.

(29) Spectrogram of *chne'e* [tʃneʔe] 'he puts his hands'

(ASE)



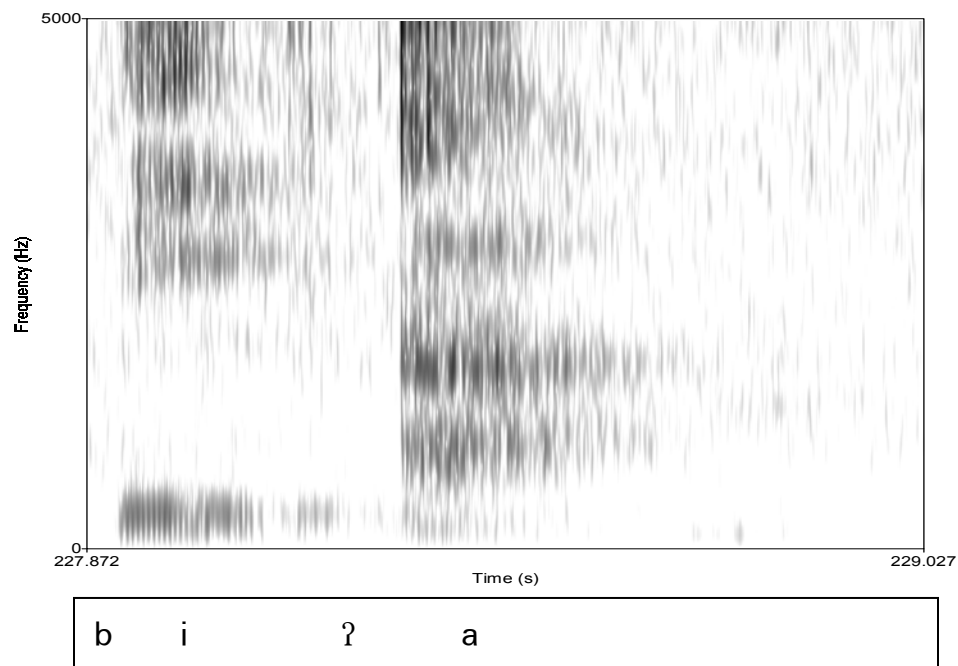
The forms in (28) and (29) show that underlyingly intervocalic glottal stop can sometimes be realized with a clear lengthening of the pitch period (as in (28)), or with more evenly spaced pulses (as in (29)). However, both retain the VʔV percept (to the author's ears). As for the source of this percept for (29), there are a number of possible sources of the glottal stop percept even in the absence of closure silence. For example, Hillenbrand and Houde (1996) note that a dip in F_0 or in amplitude can be sufficient to cue the presence of a glottal stop for English speakers. As for the spectrogram in (28), in measuring the periods of the vocal fold pulses, we see that they remain irregular in duration (a common characteristic of lenited glottal stop). This is exhibited in an increase in jitter (a measurement of period to period variability in length of the pitch period), followed by a fall in jitter. This was measured in a rough by-hand parsing of the pulses into overlapping four pulse chunks, and querying the Praat voice report for each chunk; p(ulses)1-4 show a local jitter of 6.757%; the value for p2-6 is 10.40%; for p4-8 it is 8.344%; for p.6-10 it is 4.274%; for p.8-12 it is 2.30%; and for p.10-14 it is 1.44%. The jitter measurement correlates well with the irregular vocal fold pulses often associated with glottal stops that do not achieve full closure (for example, Pierrehumbert and Talkin 1992 note that glottal stop is often "realized as period-to-period irregularities in the timing ... of the glottal excitation pulses" (p. 94)). The values here show that the variability of the duration of the pulse period first increases, then decreases. This pattern may be responsible for the percept of the intervocalic glottal stop in (29) (see section 3.1 for more discussion of the acoustic correlates of glottal stop). An important point to note in the context of the larger dissertation research is that hiatus resolution of the underlying

/aʔe/ sequence has occurred in both (28) and (29), despite variations in the degree of lenition for the intervocalic glottal stop.

Let us turn now to consider the factors that influence the realization of glottal stop in Yatzachi Zapotec.

One pattern that emerged from the data was that glottal stop in YZ is more likely to be realized as a full stop under emphasis, or in particularly careful speech. This pattern was first noted in transcriptions of the consultant’s speech during the translation task, and these transcriptions were based on the author’s auditory impression of the forms. Upon commencing data analysis, it was hypothesized that those forms that had originally been transcribed as having a full glottal stop would exhibit a period of silence during the glottal closure. The spectrogram in (30a) shows that this was the case. This form shows the YZ word *bi’a* [biʔa], ‘fly’, produced under emphasis in the context in (30b), in which the author attempted to pronounce the word and was being corrected by the consultant ASE.

(30) a. Spectrogram of emphatic *bi’a* /biʔa/ ‘fly’ (ASE)

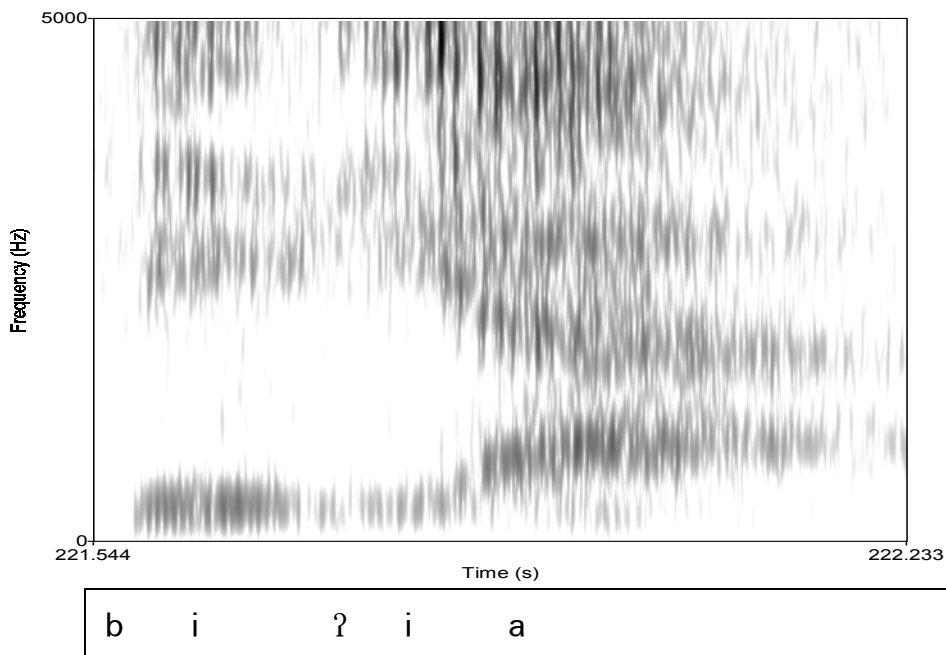


b. MLB “Ah, bi’ia...
 ASE ...bi’a ...**bi’a** ... mosca”
fly

The spectrogram in (30a) shows that there is closure silence associated with the achievement of glottal constriction for glottal stop in emphatic forms. This contrasts with other productions of the same word, which exhibit varying degrees of constriction. For

example, the spectrogram in (31) shows a careful, but less emphatic, form of *bi'a* (in the context of '*bi'a es nada más 'mosca' ... bi'a*' ('*bi'a, is nothing more than 'fly' ... bi'a*'; see (32) for the first *bi'a* in this utterance). In this spectrogram, the glottal constriction no longer coincides with obvious silence, but rather with a weakening of energy in comparison to the surrounding vowels. Note that the high front vowel is found on both sides of the glottal constriction (as evidenced by the relatively low F_1 and high F_2), resulting in the percept [bi'ia]. This suggests that Yatzachi Zapotec glottal stop can 'float' with respect to the surrounding vowels, a pattern we discuss in section 2.4 for other languages; in other words, the glottal stop in *bi'a* is not always found at the i-a boundary (compare (30a) to (31a)).

(31) a. Spectrogram of careful, non-emphatic *bi'a* [biʔia] *fly* (ASE)

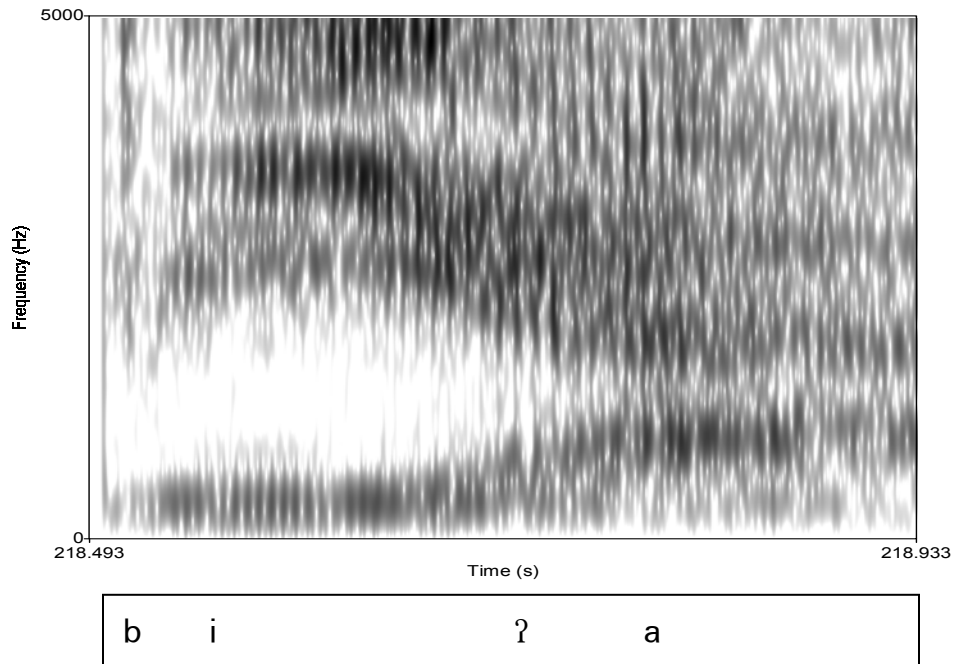


To complete the picture of the varying realizations of glottal stop, the spectrogram in (32a) shows a casual speech production of *bi'a* in the sentence '*bi'a es nada más 'mosca*' ('*bi'a is nothing more than 'fly*'). Here we see that there is neither silence, nor a clear weakening of formant structure for the glottal stop in *bi'a*. Note, however, that the voicing pulses were identified by Praat only during the first part of the vowel in (32), see (32b) for overlay of the spectrogram in (32a) with Praat-identified pulses. The visually apparent pulses in the remainder of the spectrogram failed to be identified by Praat, suggesting that pulses in the [a] portion of the utterance were weaker in comparison to the ambient noise than were those in the [i] portion. This weakness may be sufficient to indicate the presence of the glottal stop to the speaker.²³

²³ In fact, forms with glottal stop often exhibited such devoicing, as indicated by the inability of Praat to identify glottal pulses. Often, it is still possible to view pulses in the spectrogram, but analyses that might

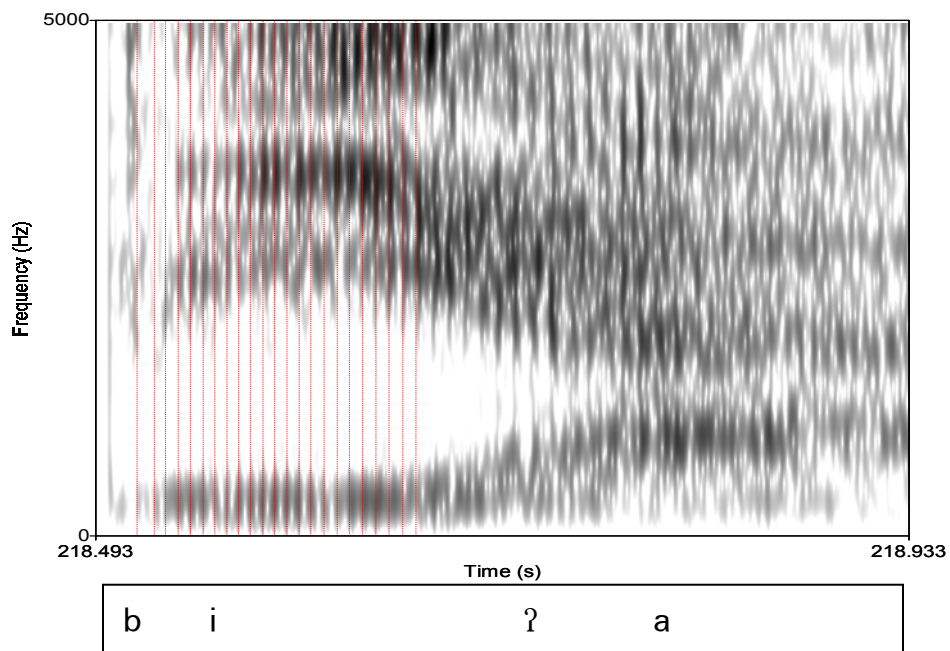
(32) a. Spectrogram of casual speech *bi'a fly*'

(ASE)



b. Spectrogram of casual speech *bi'a fly*, with pulses

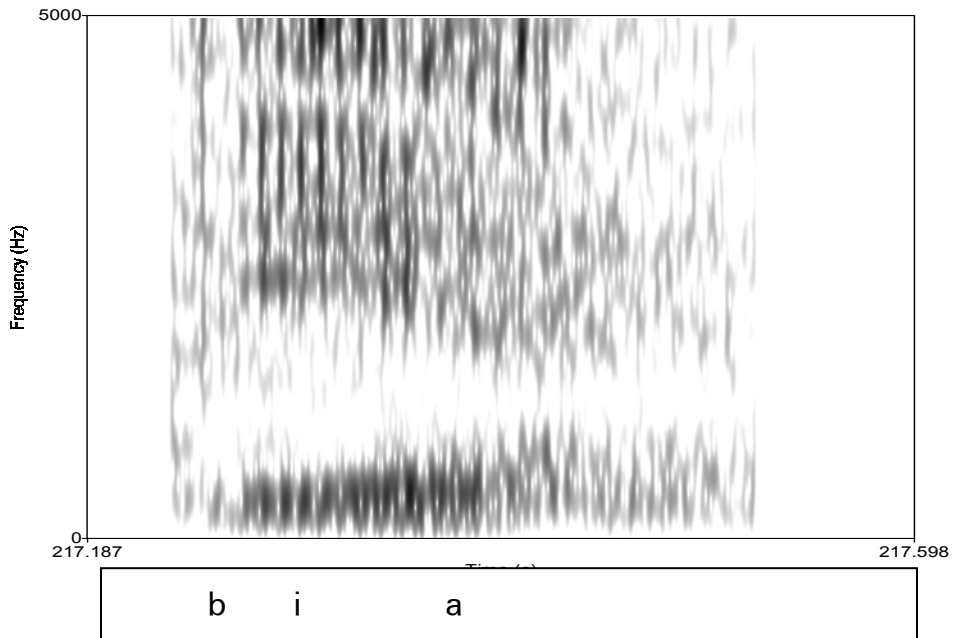
(ASE)



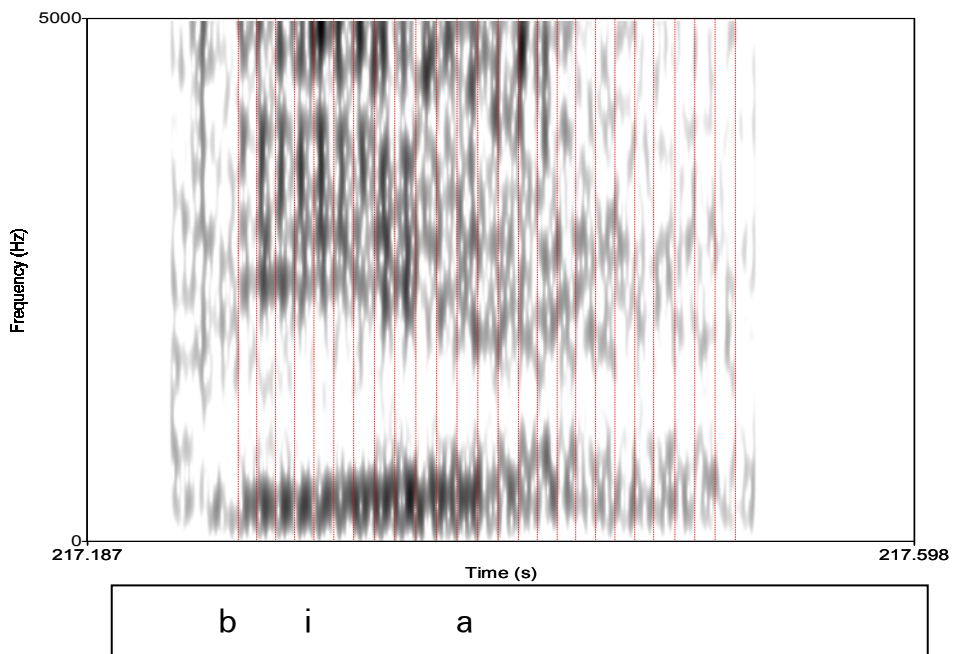
further indicate the presence of glottal stop (e.g. variation in the glottal period; jitter) are impossible without the presence of some pulses.

For comparison, consider the spectrogram in (33a), which shows the word *bia* [bia], ‘animal’. Note that glottal pulses continue throughout the word for *bia*, (33b).²⁴

(33) a. Spectrogram for *bia*, [bia] ‘animal’ (ASE)



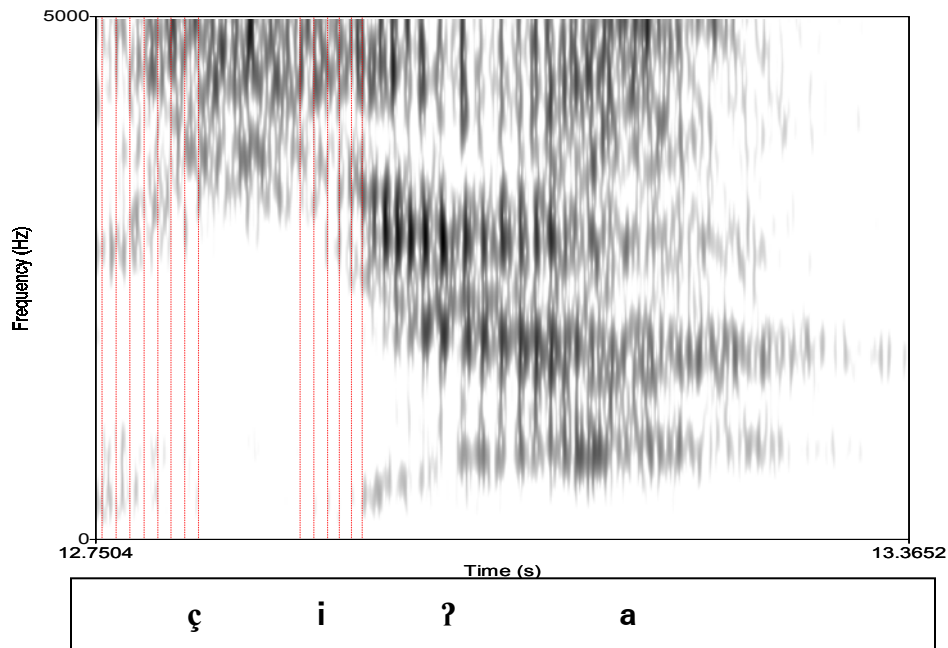
b. Spectrogram of *bia*, animal, with pulses (ASE)



²⁴ *bia* is also much shorter than *bi'a* in (31-33), but is also a casual speech production of this word- it is the second repetition confirming the author's comment: 'Ah, *porqué he visto 'bia'*' (Ah, because I've seen 'bia', which the speaker follows with '*bia...uh huh bia...*').

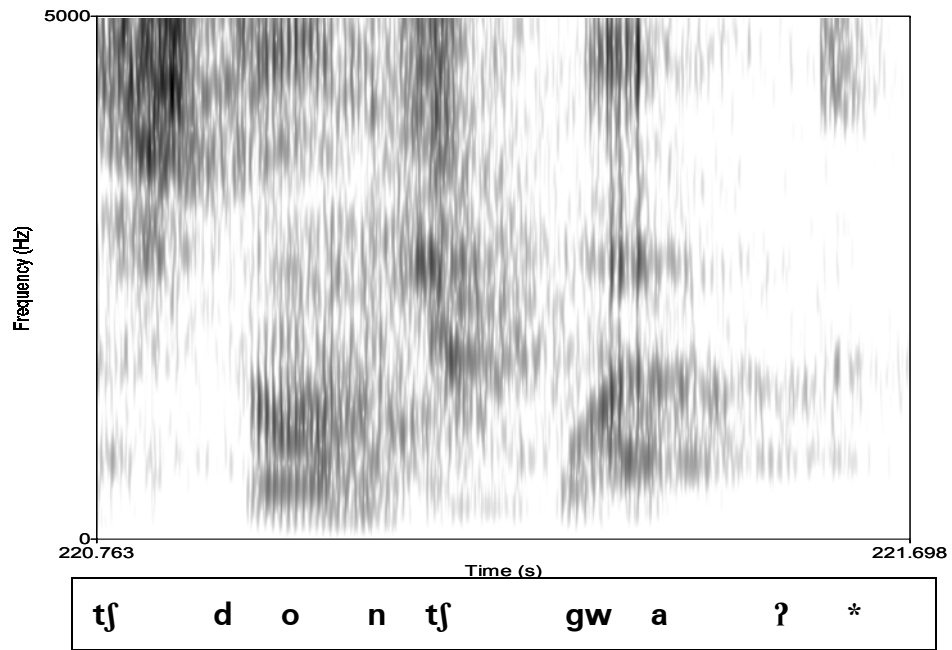
The spectrogram in (34) shows another instance of a casual speech production of a word with VʔV, *yi'a* [çiʔa] 'mercado', 'market.' Here, as for the spectrogram of casual speech *bi'a* in (33), the percept of glottal stop coincides with the end of voice pulses. Note that there also appears to be a visible widening of the glottal period in the spectrogram, but this is not confirmed by computer analysis because no pulses are identified for the latter half of the *bi'a* utterance.

(34) Spectrogram of casual speech *yi'a* [çiʔa] *mercado, market* (ASE)

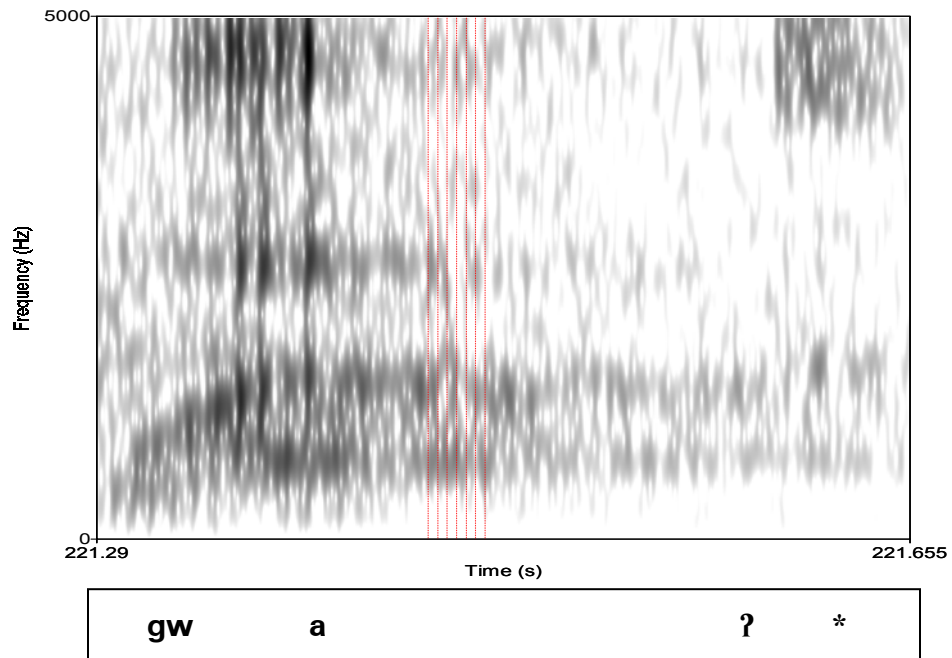


As for word final glottal stop, these are sometimes difficult to diagnose given the quality of the recording; often background noise masked vowel edges, particularly as the vowel itself got weaker. One quite clear example of a word final glottal stop is shown below in (35a). This is the word *chdonchgua* [tʃdontʃgwaʔ] 'I am very hungry'. In this form, there is clear weakening of the vowel energy coinciding with the position in which I have marked glottal stop to be present. The clearest indication of the glottal stop is a release burst, indicated with the asterisk in the transcription. This burst is identified both visually and auditorily. (36b) shows just the second syllable in this word *gua* [gwaʔ] to show the burst more clearly.

(35) a. Spectrogram of *chdonchgua*' [tʃdɔntʃgwaʔ] 'I am very hungry' (ASE)



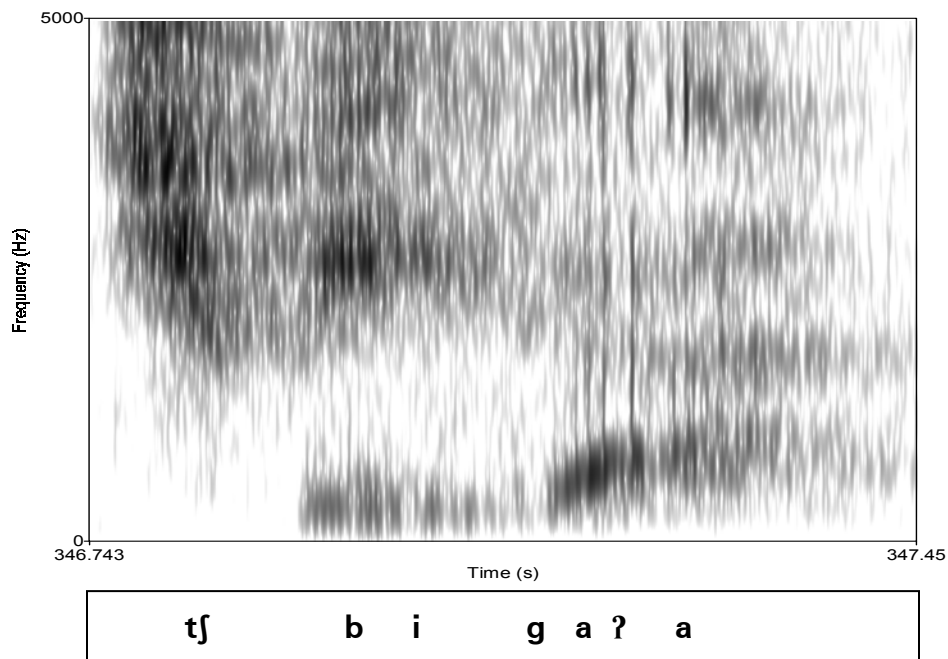
b. Spectrogram of *chdonchgua*', second syllable only -*gua*' [gwaʔ] (ASE)



To further demonstrate the possible acoustic correlates of the percept of glottal stop in YZ, the following spectrograms show additional V?V forms; in each case below, the percept of glottal stop is accompanied by a lengthening of the glottal period. (36) shows a spectrogram for the word *chbiga'a* [tʃbigaʔa] 'I approach' (/tʃbigaʔ + -aʔ/). (37) and (38) show additional examples of glottal stop from a different speaker, JLL, *yo'o* [joʔo] 'house' and *doa* [doaʔ] 'maguey', each of which also show lengthening of the glottal period coinciding with the glottal stop.

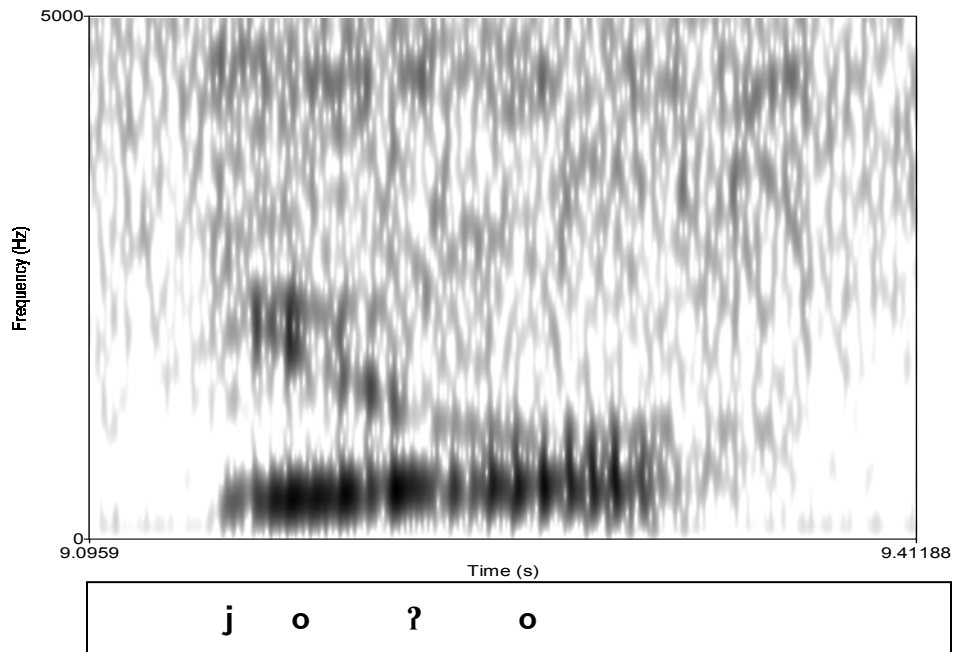
(36) Spectrogram for *chbiga'a* [tʃbigaʔa] 'I approach'

(ASE)



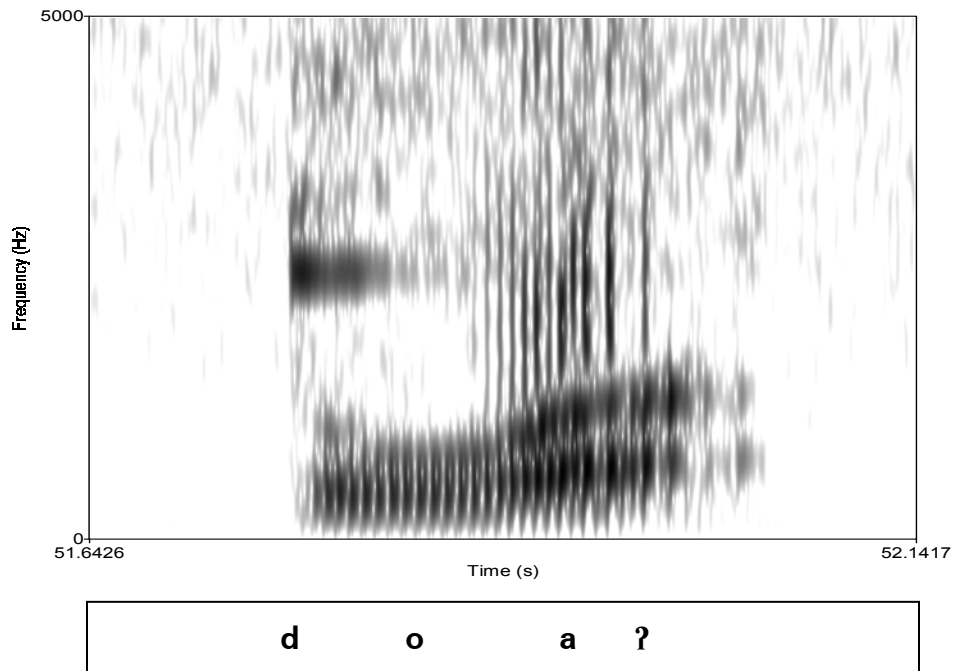
(37) Spectrogram *yo'o* [joʔo] 'house'

(JLL)



(38) Spectrogram of *doa?* [doaʔ] *maguey*

(JLL)



The data presented above show that glottal stop can have a number of realizations in YZ, from that of a full stop as in (30) (or a near full stop in (31)) to a weakening of energy or lengthening of the glottal period ((28), (29), (32), (34), (36)-(38)). (35) showed that final glottal stop can also be realized as a full stop, as evidenced by the release burst observed for the word *chdonchgua* 'I am very hungry'. However, glottal stop can sometimes be realized in such a way as its presence is not very clear from the spectrogram (as in (32)). Importantly, the realization of glottal stop does not affect the processes of hiatus resolution in V?V; hiatus resolution-like processes occur in V?V regardless of whether there is full glottal closure, as in (30) or just lengthening of the glottal period, as in (29).

The presence of a full glottal stop in careful speech provides some support for the conclusion that glottal stop exists as a discrete segment in YZ, following the hypothesis that careful speech forms represent the closest approximation of underlying forms, with casual speech representing a deviation from the target form (Johnson *et al.*'s (1993) "hyperspace effect"). Furthermore, additional study is necessary to determine the effect of YZ tone on the realization of glottal stop since it has distinct realizations depending on the tone (M. Ríos, p.c.). Because there is no systematic documentation of the tone system of Yatzachi Zapotec (tone is not marked in Butler-Haworth 1980, 1997) it is difficult to determine what the exact effects of tone are on the realization of glottal stop.²⁵ Furthermore, a number of studies have shown that prosodic position has an effect on the realization of glottal stop; for example it is stronger in prosodically prominent positions (e.g. domain initial position, accented position, stressed position; Pierrehumbert and Talkin 1992, Dillely *et al.* 1996). I leave the investigation of the tone system and its effects on glottal stop for future research.

Based on the findings of this study, I propose that that YZ glottal stop is a underlyingly a consonant, since it is sometimes realized as such (full closure), but that it has creak as a contextual allophone (e.g. under casual speech lenition and as an influence from low tone). Such a pattern accords with the findings of a number of studies on the realization of glottal stop; it is often realized as glottalization rather than a full glottal stop, particularly in casual speech (for further discussion, see sections 3.1 and 4.2, and references therein). Thus, orthographic *V'V* in YZ is equivalent to /V?V/, and the observed hiatus resolution-like repair does pose a challenge to the ONSET approach to hiatus resolution. The data in section 2.3.2 below show further examples of this pattern from a number of other languages, including Yucatec Maya, Chemehuevi, Wichita and Yapese.

²⁵ In discussion regarding Zoogocho Zapotec with Maestro Manuel Ríos Morales, it appeared that glottal stop in high toned forms were more likely to be realized as a full glottal stop, while low toned forms were more likely to be realized with creak.

2.3.2 Additional Examples of Hiatus Across Glottals

In addition to Yatzachi Zapotec, a number of other unrelated languages also exhibit apparently unmotivated hiatus resolution-like patterns across glottal stop. For some, the cross-glottal interaction of the vowels in VʔV is the sole indication of the transparency of glottal stop, while in other languages the transparency of glottal stop is exhibited in a number of ways. Consider, for example, the data from Yucatec Maya in (41). As discussed in section 2.2, in YM the vowels flanking laryngeals are required to be identical. All underlying Vʔ/hV obey this requirement, (41a-b), and regressive spreading across the glottal occurs in derived Vʔ/hV in order to ensure the satisfaction of this requirement, (41c-d).

- (41) Yucatec Maya
- | | | | | |
|----|---------------------|---|----------------------|----------------|
| a. | wiʔit' | | | 'loincloth' |
| b. | tohol | | | 'price, value' |
| c. | heʔ im b'ine | → | hiʔ im b'ineʔ | 'I will go |
| d. | heʔ a b'ineʔ | → | haʔ a b'ineʔ | 'You will go' |

(Ola Orié and Bricker 2000)

The data in (41) show that all VʔV sequences in the output satisfy the requirement that the vowels be identical. However, it is not the case that all underlying VʔV sequences in YM survive. Instead, in some forms the glottal stop is deleted, accompanied by glide insertion. Examples of this pattern are shown in (42a-c). Interestingly, glide insertion also occurs as a means of repairing underlying hiatus in YM, as shown in (42d-e). (42f) shows that consonantal deletion and associated glide insertion do not occur with supralaryngeal consonants.

- (42) Yucatec Maya
- | | | | | |
|----|------------------------------|---|--------------------|----------------------------|
| a. | maʔ ʔak-taan | → | mawak-taan | 'it is not opposite to me' |
| b. | p'oʔ eh | → | p'oyeh | 'wash it!' |
| c. | kin c'ah ik | → | kin c'ayik | 'I give it' |
| d. | le meesa eʔ | → | le messaye | 'that table' |
| e. | le tya oʔ | → | le tyaawo | 'that aunt' |
| f. | táan inw il ik h wàan | → | táan in ... | 'I am seeing John' |

(Ola Orié and Bricker 2000)

The question that the data in (42) pose is why glide insertion, YM's preferred method of hiatus resolution, might be employed in a V?V sequence. Particularly interesting is (42a), in which a glide is inserted into a V?V sequence in which both vowels are already identical. The repair of this form suggests that glide insertion occurs as a means of resolving hiatus, rather than strictly as a way of avoiding an ill-formed $V_x?V_y$ sequence.

Another example of hiatus resolution across glottal stop comes from Chemehuevi. Though Chemehuevi has been described as showing a pattern of translaryngeal harmony, this harmony pattern is in fact quite limited; only those vowel sequences that are illicit when strictly adjacent are repaired when separated by a glottal stop. To illustrate the similarity between the repairs that occur in VV and V?V, first consider the data from underlyingly adjacent vowels in (43). (43a,b) show that certain vowel sequences in the input are not realized faithfully in the output, and instead undergo coalescence. (43c,d) demonstrate that some vowel sequences are allowed to surface into the output faithfully, including sequences ending in [i] or [a], as well as [aɪ], and [au].²⁶

- (43) Chemehuevi
- | | | | | |
|----|-------------------------|---|------------|----------------|
| a. | /kani- u pa/ | → | [kani:pa] | 'in the house' |
| b. | /tɛka-vɛɛ- u ka/ | → | [tɛkavɛɛk] | 'ate it' |
| c. | /ma- u pa/ | → | [maupa] | 'in that' |
| d. | /na- ko a/ | → | [naɣoɑ] | 'cut oneself' |

(Press 1979)

Now compare the data from V?V shown in (44).

²⁶ Press (1979) does not discuss the syllabic affiliation of the sequences exemplified by the data in (43). Therefore, it is possible that these sequences are realized in the output either in hiatus or as diphthongs. While the ultimate constraint ranking accounting for the hiatus resolution-across-glottals patterns in Chemehuevi will crucially depend on this distinction, the present discussion still holds in either case; in both cases the repairs in V?V mimic the patterns in VV. I assume that it is possible that the Chemehuevi V?V data corresponding to legal sequences may be represented either as two distinct vowels or as a single diphthongized unit. In the latter case, the glottal stop would be superimposed upon the single unit. Note also that intervocalic glottal stop in Chemehuevi may delete in rapid speech (Press 1979, p. 32).

- (44) Chemehuevi
- | | | | | |
|----|---------------|---|-----------|-------------------|
| a. | nukwi-jɛ-ʔumɛ | → | nukwijɛʔm | ‘they ran’ |
| b. | asivoʔa | → | asivoʔa | ‘to peel, skin’ |
| c. | mamaʔu | → | mamaʔu | ‘woman’ |
| d. | na-hukwivi | → | nahukwivi | ‘to hurt oneself’ |
| e. | ɛvɛjuni | → | ɛvɛjuni | ‘ill/bad’ |

(Press 1979)

In (44a) the same vowel sequence, /ɛʔu/, which undergoes coalescence in VV also exhibits regressive spreading across the glottal stop. We may consider /ɛ/ and /u/ to also have undergone coalescence in (44a), in the sense that the two underlying vowels have a single surface correspondent which is overlain by a glottal stop. (44b-d) show that sequences of vowels that would be legal when strictly adjacent undergo no apparent hiatus resolution patterns when separated by a glottal stop, as expected if they interact equivalently to the VV forms. The forms in (44b-d) represent underlying VʔV sequences, which are all consistent with the prediction that only those sequences which would be allowed in VV are present in monomorphemic VʔV. This suggests that any other possible sequences have been ruled out by the language’s constraint ranking.²⁷ (44e) shows that no cross-consonantal interaction occurs between vowels separated by a supralaryngeal consonant, despite the fact that this sequence would not be allowed to surface faithfully in either VV or VʔV (see (43a)).

The pattern in Wichita is quite similar to the one exhibited by Chemehuevi, in that the cross-glottal vowel interaction is limited to those vocalic sequences that would be illegal if adjacent. (45a,b) illustrate that hiatus resolution in Wichita is accomplished through deletion of the second vowel in the sequence. (45c,d) show that [iʔa] and [aʔi] sequences are repaired through coalescence, with the former becoming [aʔa] and the latter [eʔe]. (45e) also illustrates repair of VhV in [ahi] to [ehe]. Another way in which underlying VʔV sequences are repaired in Wichita is through deletion of the laryngeal, as illustrated in (45e,f). Rood (1976) states that the deletion of intervocalic glottal stop occurs sporadically. (45g) demonstrates that no interaction between the vowels flanking a supralaryngeal consonant occurs, thus the [ari] sequence in this form is retained despite the fact that a-i and aʔi sequences are repaired.

²⁷ It should also be noted that there is little data available to show repair of offending sequences across glottal stop along the lines of (44a). This may be an artifact of the presentation of the data in Press 1979, as (44a) is the only form presented to exemplify a rule of regressive spreading across [ʔ]. As the remainder of Press 1979’s data is presented within the context of a syntactic description of the language, information concerning underlying representations is scarce. However, the lack of VʔV forms in the data that violate the overall pattern described here is suggestive of the presence of hiatus resolution across laryngeals beyond the form in (44a).

(45) Wichita

a.	ʔiri- a :has	→	ʔira:has	‘wet the bed’
b.	tata- i ya:s	→	tatiya:s	‘follow around’
c.	ti-ʔawir-ʔahi	→	taʔawirʔehe	‘he is holding it in his arms’
d.	na-ʔicaki-h	→	neʔecekih	‘sitting’
e.	iski ʔucʔ asirrirʔi	→	iski:cʔasinnʔI	‘make me some shoes’
f.	re::his	→	re::s	‘buy’
g.	raric	→	raric	‘hot’

(Rood 1976)

In Wichita, vowel sequences undergo hiatus resolution in VV, and also undergo repair in VʔV, as predicted. Since many forms undergo spreading in VʔV such that the underlying vowels surface as identical in the output, Wichita blurs the distinction between a harmony-across-glottals language and a hiatus resolution-across-glottals language. Note that Wichita is similar to Yucatec Maya and Nez Perce in that it apparently satisfies the requirement that the vowels flanking laryngeals be identical either through coalescence of the non-identical vowels or through deletion of the glottal stop, the former a harmony pattern and the latter more similar to the hiatus resolution patterns discussed in this section. Moreover, Rood (1976) states that the only allowed vowel sequence in Wichita is [a:i:] and that this is only found in two forms ka:hi:ra:i:c ‘old woman’ and ra:i:c ‘try’. Despite the fact that these sequences are so rare, it is interesting to note that non-identical vowel sequences are created in VʔV as a sort of repair; Rood (1976) states that underlying /uʔa/ sequences are realized as [iʔa] on the surface. This shows that the harmony-across-glottals patterning exhibited by Wichita is not complete, though it is difficult to determine the generality of this pattern.²⁸

In Yapese, hiatus resolution of certain vowel sequences occurs through coalescence, as shown in (46a,b). (46c) shows that for the input *daif*, the actual output chosen varies from speaker to speaker, having undergone either glide formation or coalescence, suggesting variability or lack of crucial ranking between the relevant OT constraints (perhaps DEP_{L-O} (C) and UNIFORMITY). (46d,e) illustrate that there is repair of VʔV sequences analogous to that which we find in VV sequences. Note that the process of hiatus resolution-across-glottals only applies to multimorphemic VʔV, as discussed previously in section 2.2. The forms in (46f,g) illustrate that non-identical vowel sequences are allowed in VʔV if they are within the same morpheme.

²⁸ Rood (1976, p. 2) states that “underlying uʔa is surface iʔa” but presents no data to exemplify this pattern. Note also that he describes the translaryngeal harmony patterns in (44) as occurring ‘often’, but does not identify the frequency of, or conditions on, their occurrence. For example, /hiriʔa/ ‘to rain’ retains its [iʔa] sequence in [ta:hiriʔas] ‘it is raining’.

- (46) Yapese
- | | | | | |
|----|---------------------|---|---------------------|----------------------|
| a. | fai-ng | → | fe:ng | ‘to find something’ |
| b. | ku-i marwe:l | → | ki: marwe:l | ‘he also worked’ |
| c. | daif | → | de:f ~ dayif | ‘house foundation’ |
| d. | ka-ʔa-i mi:l | → | keʔe mi:l | ‘he ran first’ |
| e. | pardeʔ-i | → | pardiʔiy | ‘to pound something’ |
| f. | luʔa:-g | → | luʔa:g | ‘my tears’ |
| g. | naʔun | → | naʔun | ‘house’ |
- (Jensen 1977)*

Finally, in Chickasaw when a vowel initial suffix is added to a glottal stop final root, an agreeing glide is epenthesized between the glottal stop and the second vowel as in (47a,b). (47c) shows that the same strategy is employed in repair of strictly adjacent vowels. A similar pattern occurs in the related language of Oklahoma Choctaw (Western Muskogean; Ulrich 1993). This is shown by the data in (47d,e), in which an [y] replaces an underlying glottal stop regardless of the vowels in the sequence (e.g. front or back).

- (47) Chickasaw
- | | | | | |
|----|-----------------|---|-----------------|--------------------------|
| a. | chikoʔ-a | → | chikoʔwa | ‘to be all sticking up’ |
| b. | boʔ-a | → | boʔwa | ‘to be beaten’ |
| c. | tof-to-a | → | toftowa | ‘to spit more than once’ |
- (Ulrich 1993)*
- Oklahoma Choktaw
- | | | | | |
|----|----------------------|---|-------------------|-----------------|
| d. | kowiʔ-a-n | → | kowiya | ‘mountain lion’ |
| e. | ish-ishko-ʔ-o | → | ishishkoyo | ‘do you drink?’ |
- (Ulrich 1993)*

While this dissertation primarily focuses on the patterning of glottal stop, it is important to note that in many languages [h] also tends to pattern similarly to glottal stop in terms of phenomena like identity- and hiatus- across glottals. For example, in both Yucatec Maya and Nez Perce [ʔ,h] pattern together with respect to the requirement that the vowels flanking glottals be identical. As for hiatus resolution across glottals, [h] patterns with glottal stop in Yucatec Maya and Chemehuevi.

This section has demonstrated that the pattern of hiatus resolution-across-glottals is exhibited by a number of unrelated languages. Moreover, languages may exhibit patterns of hiatus resolution in the context of VʔV in parallel with other phenomena that have traditionally been taken to indicate the transparency or ‘placelessness’ of glottal stop, for example the identity-across-glottals patterns. Descriptively, it appears that the glottal

stops in languages like Yatzachi Zapotec, Yucatec Maya, Chemehuevi, Wichita and Yapese fails to behave as an onset to the following vowel in that its presence does not block hiatus resolution. In fact, this pattern is reminiscent of facts from a number of other languages in which glottal stop is prohibited from onset position. Even more interesting in the light of the hiatus resolution-across-glottals data presented here are languages in which intervocalic glottal stop patterns as codas, contra the general principle that languages maximize onsets (VCV → V.CV, *VC.V). The following section introduces some of the relevant data to illustrate that glottal stop often fails to syllabify as an onset to a following vowel. In this section, I suggest that previous ‘placeless’ accounts of the prohibition of glottal stop onsets do not satisfactorily explain the patterning of intervocalic glottal stop in the languages described in sections 2.3.1, 2.3.2 and the following.

2.3.3 Prohibitions on Glottal Onsets

Many languages prohibit glottal stop from appearing prevocally, thus exhibiting a prohibition on glottal onsets. The data in (47) demonstrate that the Makassarese languages of Standard Makassarese, Selayarese and Konjo exhibit this prohibition. In these languages, root final glottal stop is realized as [k] when affixation of a vowel initial morpheme (suffix or clitic) would result in the glottal stop’s being prevocalic.²⁹

(47) Standard Makassarese

- | | | | | |
|------------|------------------|---|-----------------|-------------|
| a. | bájiʔ | | | ‘good’ |
| b. | bajiʔ-aŋ | → | bajíkaŋ | ‘better’ |
| c. | bajiʔ-a | → | bájika | ‘I am good’ |
| Selayarese | | | | |
| d. | bákkaʔ | | | ‘big’ |
| e. | bakkaʔ-aŋ | → | bakkákaŋ | ‘bigger’ |
| f. | bakkaʔ-a | → | bákkaʔa | ‘I am big’ |

²⁹ It should be noted that the treatment of word final glottal stop differs between standard Makassarese and that in Selayarese and Konjo; while the addition of a true suffix to a glottal stop final base results in /ʔ/ ~ /k/ alternation (as in (47b,e,h), only in Standard Makassarese is this alternation observed when the vowel initial ‘suffix’ is a clitic (e.g. (47c)). In Selayarese and Konjo, in contrast, the glottal stop remains even when a vowel follows, if that vowel forms part of a clitic (47f,i). Broselow 2001 suggests that this pattern is an indication that clitics are outside the prosodic domain of the word. This proposal is further supported by the fact that true suffixes, but not clitics, are counted in stress assignment (Basri *et al.* 2000, Broselow 2001).

Konjo				
g.	hájiʔ			‘good’
h.	hajiʔ-a	→	hajíka	‘better’
i.	hajiʔ-a	→	hájiʔa	‘I am good’
<i>(Broselow 2001)</i>				

The data in (48) below show additional examples of languages that avoid glottal onsets. For example, the data from Uma (Central Sulawesi; Broselow 2001) show that this language avoids glottal onsets by means of metathesizing root final glottal stop around a vowel initial suffix (c.f. (48a) vs. (48b)).³⁰ Zoque (Mixe-Zoque; Wonderly 1951, Blevins and Garrett 1998, Hume 2000) and Mandaic (Semitic) show similar patterns. In Zoque (48c) suffix initial glottal stop metathesizes with root final liquids and glides. Particularly interesting in the context of this dissertation is the tendency of $V_xʔV_y$ to surface with a postvocalic glottal stop (and with repair of the vowel sequence), (48d,e). Note that glottal stop still surfaces intervocalically between identical vowels. In Mandaic (Semitic; Macuch 1965, Malone 1971, 1985, Hume 2000, 2002), laryngeal consonants undergo metathesis with a preceding consonant. Each of the languages in (48) exhibit reordering of laryngeal and supralaryngeal consonants such that the underlyingly prevocalic laryngeal surfaces as post-vocalic.^{31,32}

³⁰ Broselow (2001) assumes, following Martens (1988) and Martens and Martens (1988), that the metathesized postvocalic glottal stops in Uma have been “reanalyzed as glottalization on a preceding vowel” (p. 3).

³¹ Blevins and Garrett (1998) discuss a number of additional instances of metathesis of laryngeal consonants with vowels, including from Cayuga and Cherokee (both Iroquoian) and Ntɛʔkepmxcín (Thompson River Salish; Salish). These do not all result in avoidance of prevocalic laryngeals but interesting patterns remain; for example, in Ntɛʔkepmxcín $V_1ʔV_2$, [ʔ] is realized prevocalically (as in $ʔV_2$, but V_1 is lost). Interestingly, Blevins and Garrett (1998) argue against an approach in which metathesis results under pressure from markedness constraints, suggesting that the Zoque data in (48d,e) is difficult to handle under such an account. Their reasoning is that “intervocalic position is arguably the most perceptually salient position for any non-syllabic segment, including glottal stop” (p. 522). Their position conflicts directly with the one taken here: I argue that intervocalic position is (1) not a perceptually salient position for glottal stop, because lack of formant transitions means that no additional information conveyed by intervocalic position; and (2) markedness of intervocalic glottal stop is results from high ranked syllable structure constraints, and the fact that glottal stop lacks the appropriate gestural landmarks to satisfy them.

³² Hume (2002, 2004) presents additional data on laryngeal metathesis with consonants, in which Pawnee (Caddoan) is shows similar reordering of prevocalic glottal stop to postvocalic by metathesis with [r]. Examples of laryngeal metathesis that result in prevocalic glottal stop include Balangao (Malayo-Polynesian) and Hungarian (Finno-Ugric) (Hume 2002, 2004). See Yoon 2003 for surveys of range of metathesis data of laryngeal consonants and contrasts with adjacent elements and Hume 2002, 2004 for metathesis generally with some discussion of laryngeal metathesis.

- (48) Uma
- | | | | | |
|----|--------------|---|------------|---------------------------------------|
| a. | ʔánaʔ | | | ‘child’ |
| b. | /mo-ʔanaʔ-i/ | → | [moʔanáíʔ] | ‘to have children’
(Broselow 2001) |
- Zoque
- | | | | | |
|----|-------------------------|---|-------------|---------------------------------------------------|
| c. | /lugar-ʔoyh/ | → | [lugaʔroyh] | ‘at the place’
(Hume 2000) |
| d. | /min _Λ -ʔaʔ/ | → | [minaʔ] | ‘come now’ |
| e. | kenu-ʔaʔa | → | [kenwaʔa] | ‘he already looked’
(Blevins and Garrett 1998) |
- Mandaic
- | | | | | |
|----|----------|---|----------|-------------------------|
| e. | /tirʔa:/ | → | [tiʔra:] | ‘door’ |
| f. | /yarha:/ | → | [yahra:] | ‘mouse’
(2000, 2002) |

As discussed in chapter 1, a common response within OT to languages that prohibit glottal onsets is to posit a constraint that requires onsets to be specified for place (see for example, Itô and Mester 1993, Padgett 1995, Lombardi 1995, Ola Orié and Bricker 2000, Broselow 2001, Parker 2001, among others.) One consequence of this approach is that we expect to see, in languages that rank an ONSETPLACE constraint low, that underlying prevocalic or intervocalic glottal stops will surface faithfully as onsets. However, even among languages that allow intervocalic glottal stop, we see evidence that it still does not pattern as though it were an onset. Consider for example, the data in (49) below:

- (49) Palu’e
- | | | | | |
|----|---------|--|--|---------------------------------------|
| a. | tu: | | | ‘knee’ |
| b. | lǒd.ʒǒn | | | ‘their porridge’ |
| c. | věʔi | | | ‘leg’
(Donohue, p.c. handout 2006) |

The Palu’e (Malayo-Polynesian) data in (49) illustrate that V_1 in $V_1ʔV_2$ exhibit closed syllable allophones despite the fact that the intervocalic glottal stop could putatively have

syllabified as an onset. A similar pattern is exhibited by the related language of *Tukang Besi* (Malayo-Polynesian).³³

Another language in which intervocalic glottal stop appears to syllabify as a coda is *Balantak* (Central Sulawesi) in which it is reported that speakers identify intervocalic glottal stop as a coda rather than as an onset (Busenitz and Busenitz 1991, see discussion in Broselow 2001, 2003) Likewise in *Chickasaw* and *Choctaw* (Western Muskogean), glottal stops syllabify as codas (Ulrich 1993), and coda glottal stops do not syllabify with following vowel initial suffixes (from Pam Munro, as quoted in a summary of responses to a recent *Linguist List* query by Mark Donohue (Vol-17-3292, posted Nov. 12, 2006).

The data in this section have shown that many languages avoid glottal onsets, even when the glottal consonant is intervocalic. The prevalence of this pattern suggests a possible analysis of hiatus resolution-across-glottals languages in which the glottal stop in a V?V sequence is a coda on the surface. Under this approach, hiatus resolution would occur because the resulting V?.V sequence still fails to provide an onset to the second vowel. However, there is one key drawback to this approach; some languages that show harmony and hiatus resolution in V?V do allow prevocalic glottal stop. For example, while a survey of the YZ lexicon shows no glottal stop initial forms and few vowel initial ones,³⁴ YM, Nez Perce and Chemehuevi each have forms with word initial glottal stop and [h].³⁵

(50) Yatzachi Zapotec

a. antzlə

‘badly’

b. iz

‘year’

(Butler-Haworth 1997)

³³ Interestingly, Burling (1992) and Duanmu (1994) discuss a pattern that is the inverse of the one found in *Palu’e*: *Garó* (Tibeto-Burman) shows the same vowel allophones in [V?] as in [V], as distinguished from the allophones found in closed syllables.

³⁴ Most vowel initial words in YZ are Spanish loans, or are particular conjugations or pronunciation variants of consonant initial verbs; for example, the potential aspect (future) of the verb ‘to say’, *chna*, is *əna*. Of the 65 vowel initial words listed in Butler-Haworth 1997, 36 are loans from Spanish, 13 are variants of consonant initial verbs, and 16 are from the native vocabulary. Note that the number of *ə*-initial verbal variants may be much higher than suggested by the forms listed in the lexicon; most conjugated forms are listed as sub-headings under the verb’s entry. Furthermore, verbs listed in the lexicon as taking the prefix [gw] in the completive or potential aspect were often pronounced as [əgw-] initial in this conjugation.

³⁵ Here, I present data only from word initial glottal stop due to the fact that it is difficult to determine whether word medial glottal stop syllabifies as an onset; as we have seen, appearing before a vowel is not a sufficient indicator of onsethood. Likewise, hypothetical VC?V sequences would not necessarily be unambiguous indicators of onsethood for glottal stop, because in some languages C? sequences are accurately represented as single segments.

Yucatec Maya³⁶

- | | | | | |
|----|-------|---|--------|--------|
| a. | arroz | → | ʔáaroz | ‘rice’ |
| b. | ojo | → | ʔòohoh | ‘eye’ |

(Ola Orié and Bricker 2000)

Nez Perce

- | | | |
|----|-----------|----------|
| c. | ʔiceyé:ye | ‘coyote’ |
| d. | ʔóykala | ‘all’ |
| e. | hímin | ‘wolf’ |

(Aoki 1979)

Chemehuevi

- | | | |
|----|------------|----------|
| f. | ʔaipats | ‘boy’ |
| g. | hɛpɛkitsɛ | ‘hole’ |
| h. | hokosoʔavi | ‘spider’ |

(Press 1979)

The data in (50) show that across-the-board prohibition of glottal onsets is not a necessary requirement for cross-glottal vowel interaction in VʔV. In each of the languages in (50), intervocalic glottal stops pattern as though it fails to syllabify as an onset to a following vowel (as diagnosed by translaryngeal harmony and hiatus resolution processes), despite the fact that prevocalic glottal stops surface in word initial position. This fact poses a challenge to the proposal that required identity- and hiatus resolution-across-glottals result from a prohibition on glottal onsets.

Another challenge to this approach is that it suggests that laryngeal consonants should be unmarked in coda position, a prediction that I will show is not empirically supported.³⁷ First, some languages prohibit glottal stop from appearing in coda position (e.g. English, some Arabic dialects). In the following section, I show that there is a cross-linguistic

³⁶ In the Yucatec Maya data glottal stop is epenthesized into word initial position in order to satisfy the requirement that all roots begin and end with a consonant. In (49b), the final [h] is also epenthetic, added to satisfy a final-C requirement. See section 4.2 for discussion of epenthetic glottal stop epenthesis in word initial position.

³⁷ In the literature, the unmarkedness of laryngeal codas has been attributed to a constraint prohibiting independent place features in coda position (the Coda Condition, Ito 1986:1988, 1989). This is supported by the fact that some languages show debuccalization of syllable final consonants to [ʔ,h] for example as in Slave (Athabaskan; Rice 1989) and Kelantan Malay (Teoh 1988). See Lombardi 1995 for further discussion of these patterns, including a proposal that [ʔ,h] are not placeless in coda, but rather have an unmarked PHARYNGEAL place. Rose (1996) also suggests that evidence of coda conditions favoring laryngeal codas supports the proposal that they are unmarked in coda. Note that Rose (1996) argues that laryngeal consonants are specified as PHARYNGEAL when other guttural consonants are present in the language, and may be represented as placeless otherwise.

tendency for underlying Xʔ sequences to fail to surface as sequential. Patterns that illustrate this tendency include vowel intrusion patterns ($V_xʔC \rightarrow V_xʔ^{V_x}C$), and Xʔ coalescence patterns, in which sequences with glottal stop are realized as simultaneous (e.g. $Vʔ \rightarrow V_{\text{̥}}$). I suggest that these patterns indicate a general failure of sequentiality in Vʔ sequences, a pattern that is unexpected if glottal stop is unmarked in coda position. This section also shows that the failure of sequentiality for sequences with glottal stop extends to Cʔ sequences; for example, Arbore exhibits glottal stop intrusion into the span of a preceding glide (Hayward 1984), and languages like Kashaya and Yurok exhibit reorganization of underlying Cʔ sequences to simultaneity, resulting in the percept of a glottalized consonant (Buckley 1994 and Blevins 2003, respectively).

2.4 Failure of Sequentiality for Vʔ and Cʔ; Glottal stop is not a good coda either.

The discussion in the preceding section raised the question of whether an analysis whereby intervocalic glottal stops syllabify as codas could explain patterns of cross-glottal vowel interaction (e.g. harmony and hiatus resolution). In this section, I present data to show that glottal stop is little more stable in coda position than in onset; underlying $V_xʔ$ sequences are realized on the surface instead as $V_xʔV_x$ in many languages. Consider, for example, the data in (51) below.³⁸

- (51) Kekchi
- | | | | | |
|----|-----------------|---|---------------|-----------------------|
| a. | kwaʔ + k | → | kwaʔak | ‘to eat (transitive)’ |
| b. | seʔ + k | → | seʔek | ‘to laugh’ |
- (Campbell 1974, Hall 2003)*
- San Juan Atzingo Popoloca
- | | | | | |
|----|---------------|---|--------------------------|---------------|
| c. | itʔa | → | it^aʔa | ‘your father’ |
| d. | itsʔen | → | its^eʔẽ | ‘wet’ |
- (Kalstrom-Dolson et al. 1995, Hall 2003)*
- Chamicuro
- | | | | | |
|----|----------------|---|-----------------|---------|
| e. | túʔlu | → | túʔulu | ‘chest’ |
| f. | maʔnáli | → | maʔanáli | ‘dog’ |
- (Parker 1994, Hall 2004)*

³⁸ The data in (51) and throughout retain the graphical conventions of the source, hence the representation of the intrusive vowel in SJA Popoloca as a superscript but in regular script in Kekchi and Chamicuro.

In each of the languages above, an underlying V?C sequence is realized on the surface with an intrusive vowel intervening between the glottal stop and the following consonant.³⁹ Following Hall (2003), I consider the vowel intrusion exhibited by the languages in (51) to have resulted from overlap of the underlying vowel gesture over the ?C sequence; that is, vowel intrusion is not equivalent to vowel epenthesis.⁴⁰ As Hall (2003) argues, the vowel overlap analysis of vowel intrusion is supported by the fact that the resulting V?V sequence continues to pattern as a single syllable. Furthermore, since the intrusive vowel is not epenthesized phonologically its presence can be influenced by prosodic factors such as speech rate, with these vowels often deleting in certain prosodic contexts. The data from Kekchi, Chamicuro, Choapan Zapotec and Arbore shown below in (52), (53) serve to further illustrate the particular characteristics of vowel intrusion for clusters with glottal stop, including the lack of syllabicity and the susceptibility to the influence of speech rate.

(52) Kekchi

- a. **tʃaʔ -aq** → **tʃaʔaq** ‘to say (future)’ *tʃapa ʔapaq / *tʃaʔa paq*
 b. **poʔt** → **poʔot** ‘blouse’ *popo ʔopot / poʔo pot*

(Campbell 1974, Hall 2003)

In Kekchi, V?V sequences may either be underlying or they may be created through vowel intrusion, as in (52a vs. b). Campbell (1974) showed, however, that while underlying V?V is treated by speakers as disyllabic, vowel intrusion V?V is treated as monosyllabic, as evidenced by variation in the application of the word-game *Jerigonza*. In *Jerigonza*, a reduplicative syllable of the form *pV* is added after each underlying syllable, with the quality of *V* determined by the vowel in the underlying syllable. Thus, by eliciting a *Jerigonza* version of V?V, Campbell (1974) was able to evaluate the syllabic status of V?V. The results show that the reduplicated form of underlying V?V has four syllables, as in *V pV ʔV pV*, (52a), while the reduplicated form of V?V resulting from vowel intrusion can be reduplicated as either four or as two syllables; *V?V pV*,

³⁹ Note that it appears to be a coincidence that each of the forms exhibiting vowel intrusion in Kalstrom-Dolson *et al.* 1995 has a similar form. In addition to those forms listed in (51c,d), the authors present only *it'i* [it'i] ‘steam,’ and *it'o* [it'o] as examples of this process. However, their description of the process is quite general and should apply beyond this context; “*después de un consonante ... se oye una brevísima vocal de la misma calidad que la vocal que sigue al saltillo* [after a consonant ... one hears a brief vowel of the same quality of the vowel that follows the glottal stop- MLB]” (Kalstrom-Dolson *et al.* 1995, p. 292). Their discussion suggests that vowel intrusion occurs in a wider range of forms than those in which it is presented.

⁴⁰ As noted in Hall 2003, this proposal has precedents in previous research, for example in Steriade 1990, among others.

(52b). This means that while all speakers treat underlying VʔV as disyllabic, vowel intrusion VʔV is treated by some speakers as monosyllabic.

In Chamicuro, the presence of vowel intrusion is dependent on speech rate, with vowel intrusion only occurring in emphatic speech, as in (53a,b), where the casual speech form is in the left-hand column and the emphatic form is on the right. The opposite pattern is found in Choapan Zapotec (Lyman and Lyman 1977) in which vowel intrusion is more likely to occur in fast speech; formal speech non-final Vʔ is sometimes realized as VʔV in rapid speech (the left and right column of (53c), respectively). The Arbore data in (53d,e) are examples of another pattern in which there is variability of vowel intrusion with glottal stop; in these examples, the position of glottal stop varies in temporal position with respect to a preceding long vowel.⁴¹

(53) Chamicuro

a. ułáʔlo ułáʔalo ‘my wife’

b. yapléʔti yapléʔeti ‘lightning’

(Parker 1994, Hall 2003)

Choapan Zapotec

c. beʔgídiʔ → beʔegídiʔ ‘bat’

(Lyman and Lyman 1977)

Arbore

d. be:k-t-aw → be:ʔtaw / beʔetaw ‘my wound’

e. ʔína gá:d-ne → ga:ʔne / gaʔane ‘we buried’

(Hayward 1984)

The data in (51)-(53) show that sequences of VʔC are often realized such that the underlying sequentiality between the vowel and the glottal consonant is not strictly realized in the output. Moreover, because the glottal stop appears within the span of a

⁴¹ Note that the /V:ʔC/ sequences in Arbore shown in (53d,e) have two possible variants but Hayward (1984) does not mention whether the choice of variant is determined by speech rate or register. Hayward (1984) states that vowel intrusion does not occur if the vowel preceding glottal stop is short, or if the glottal stop is not immediately preceded by a vowel. These possibilities are shown in (iv). Note however that Hayward (1984), pg. 72, describes a pattern of echo-epenthesis between the members of a ʔC sequence when the preceding vowel is short that is optionally, but commonly, applied. This is essentially a case of vowel intrusion, and thus, the form in (iv-a) may in fact exhibit vowel intrusion in some instances.

(iv) a. ġéd-lo → ġeʔlo / *ġéʔélo ‘this scorpion’

b. bónb-lo → bómʔlo / *bóm^óʔlo ‘this pond’

(Hayward 1984, pg. 64-5)

single vowel (rather than between two vowels) it is questionable if it is playing the expected role of a coda in these examples.

Interestingly, echo-epenthesis and vowel intrusion patterns can also occur in sequences without glottal stop (for example across s, r, and l in Selayarese (Makassarese; Mithun and Basri 1986, Kitto and de Lacy 2000), in Glide-C and Liquid-C sequences Kolami (Dravidian; Zou 1991, Kawahara 2003), and in Cl and Cr clusters in Mono (Niger-Congo; Olson 2003, Hall 2003)). However, Hall (2003)'s survey of languages that exhibit vowel intrusion shows that an implicational hierarchy with respect to the availability of vowel intrusion cross-linguistically. Specifically, if a language allows vowel intrusion into consonant clusters, and this language has clusters with laryngeal consonants in the appropriate context, then there will also be vowel intrusion into those laryngeal clusters.⁴² The implicational hierarchy that Hall (2003) establishes is shown below in (54).⁴³

(54) Gutturals >> r, ʁ >> l >> r >> Glides, Nasals

There are unfortunately no data available to make finer distinctions among the guttural consonants; according to Hall (2003) there is no language that distinguishes between the laryngeals and the other guttural consonants in the availability of vowel intrusion. This may simply be an artifact of the data set; languages with non-laryngeal gutturals that allow vowel intrusion are apparently few. Examples provided by Hall (2003) include Tiberian Hebrew and some dialects of Bedouin Arabic, including Negev Bedouin Arabic. For now, we must assume that there is no implicational relationship between the laryngeals and the non-laryngeal gutturals with respect to vowel intrusion. However, at the very least this hierarchy does demonstrate a higher degree of availability of vowel intrusion for the laryngeals as members of the class of gutturals.

Hall's (2003) survey of vowel intrusion patterns reveals some interesting characteristics that are proposed to hold of all contexts in which vowel intrusion is possible, both in underlying sequences with glottal stop and without. One such pattern is that vowel intrusion appears to be constrained by syllable affiliation; in vowel intrusion, the vocalic gesture overlaps the elements in its onset and coda. Hall (2003) accounts for this observation by positing an OT constraint that requires the nucleic vowel gesture to be aligned to the left and right edges of syllabically affiliated consonants.⁴⁴ This approach

⁴² By 'in the appropriate context', I mean that the language must allow clusters with laryngeal consonants in the context that it would otherwise allow vowel intrusion. For example, Dutch allows vowel intrusion into coda sonorant-C clusters. And while this language does have [h], it does not allow it in coda (Hall 2003, pg. 26), so there are no [h-C] clusters in the appropriate context.

⁴³ The formulation of the hierarchy in (54) differs minimally from the one presented in Hall's (2003) (45), pg 28.. While she presents the contexts for vowel intrusion in increasing order of availability of VI, I have presented the context in descending order of availability of VI. (54) gives the format of an implicational hierarchy whereby the presence of VI for a context α implies the presence of VI for all contexts leftwards on the scale from α .

⁴⁴ Hall's (2003) constraint is shown in (iv):

(v)a. ALIGN (V ONSET, SYLL ONSET): Align the onset of the vowel with the onset of the first

leads to some interesting predictions regarding the direction of overlap; in $V_x C_1 . C_2 V_y$, we expect overlap of C_1 by V_x ($V_x C_1 V_x . C_2 V_y$), but overlap of C_2 by V_y ($V_x C_1 . V_y C_2 V_y$). Crucially, vowels should not overlap the coda of a preceding syllable or the onset of a following one. This prediction is supported by Hall's (2003) survey, and additional examples cross-linguistically, as shown by the Yurok data in (55):

- (55) Yurok
- | | | | | |
|----|---------|---|-----------------------|----------------------------------|
| a. | haʔpóh | → | haʔ ^a poh | ‘pitch’ |
| b. | ʔeʔgurʔ | → | ʔeʔ ^e gurʔ | ‘basket used in the jump dance.’ |
- (Robins 1958)*

The examples in (55) illustrate a pattern from Yurok in which coda glottal stops are realized on the surface with an echoic release of the preceding vowel, a pattern which “is most notable before a pause.” (Robins 1958, p.5).⁴⁵ This discussion suggests that, like many instances of vowel intrusion into clusters, the Yurok vowel overlap in (55) is also affected by prosodic factors.

The data presented by Hall (2003) on vowel intrusions at all places of articulation support an analysis of vowel overlap as constrained by syllable affiliation. However, data from the patterning of glottal stop suggest that vowel overlap is more widely available for glottal stop than is reflected by the vowel intrusion data. First, echoic vowels are observed in cases of vowel overlap over glottal stop even when the glottal stop is not a member of a cluster. Thus, Hall's (2003) survey may even have understated the susceptibility of glottal stop to echoic vowel overlap. This is telling, for even when only considering vowel intrusion into clusters (and not vowel overlap over single consonants) glottal stop is still most likely to exhibit overlap across it.

The data in (56) illustrate the availability of vowel overlap of glottal stop outside the traditional contexts for vowel intrusion. For example, the Yurok form in (56a) show that echoic releases occur for coda glottal stop even word finally. As (56b,c) show, in *Tukang Besi* input sequences of $V_1ʔV_2$ in which V_2 is a high vowel are realized on the surface with a glide agreeing in frontness with V_2 preceding the glottal stop. This form results from glottal stop intrusion into the underlying expanse of the following vowel leading to the percept of an off-glide where the V_1 and V_2 meet.⁴⁶

-
- consonantal gesture of the syllable
- b. ALIGN (V OFFSET, SYLL OFFSET): Align the offset of the vowel with the offset of the last consonantal gesture in the syllable.

⁴⁵ Robins (1958) notes the presence of echoic release in $Vʔ$, but he does not transcribe them throughout the grammar perhaps due to the predictability of the pattern. In order to illustrate the pattern exhibited by Yurok, the data in (55a,b) has been altered from the original source to reflect this release.

⁴⁶ According to Donohue (1999) this pattern is found in the *Tukang Besi* variants spoken in the island areas of Tomea and Binongko, and “to a lesser extent on Wanci” (Donohue 1999, p.24). For this reason, the process is shown in the examples as a variation in outputs between the faithful form and the one exhibiting glottal stop intrusion into the following vowel.

- (56) Yurok
- a. **wiʔ** → **wiʔⁱ** ‘it’
(Robins 1958)
- Tukang Besi
- b. /goraʔu/ → [goraʔu] ~ [gora^wʔu] ‘egg’
- c. /moʔini/ → [moʔini] ~ [moⁱʔini] ‘shy, embarrassed’
(Donohue 1999, p. 24)

Interestingly, the direction of overlap exhibited by the Tukang Besi examples in (56b,c) is predicted by a syllable affiliation analysis only if the glottal stop is assumed to be an onset to the following vowel (in $V_1ʔV_2$, V_2 overlaps [ʔ]). At the same time, this syllabification does not reflect the general avoidance of glottal onsets, nor the more specific facts about the treatment of intervocalic glottal stop as a coda in Tukang Besi (see discussion in section 2.3.3). In fact, a second way in which vowel overlap over glottal stop may be more widely available than predicted by examining just the vowel intrusion data is that vowels in many languages overlap glottal stops they aren’t traditionally assumed to be syllabically affiliated with. This is unexpected under an analysis along the lines of Hall 2003, in which syllable affiliation determines direction of overlap. Examples of this pattern are shown below in (57).

- (57) Chemehuevi
- a. **jaʔiji** → **jaʔ^aij** ‘dead’
- b. **jaʔiji** → ***jaⁱʔij**
(Press 1979)
- Acoma
- c. /siʔukatʃa/ → [siʔiukatʃa] ‘I see them (dual)’
- d. /siʔumʔayanikuya/ → [siʔiumʔa...] ‘I made fun of them (dual)’
(Miller 1965)
- Tariana
- e. /pi-ha/ → **pihā** **pihyā** ‘you (sg.)’
- f. /du-héni/ → **du-heni** **du-h^héni** ‘her ear’
(Aikhenvald 2003)

In Chemehuevi, the initial vowel in an [aʔi] sequence overlaps the glottal stop, resulting in the percept of a post-consonantal diphthong, [ai] (57a). Under the assumption that intervocalic consonants syllabify as onsets to the following vowel, we expect overlap in an input [aʔi] to result in overlap of the glottal stop by [i] instead,

(57b).⁴⁷ In the Acoma data in (57c,d), the underlying pre-glottal vowel also overlaps the glottal stop on the surface, resulting in a post-sonantal diphthong.⁴⁸ The Tariana (Tucanoan) data in (57e,f) show that similar patterns are observed for intervocalic [h]. In Tariana, casual speech V_1hV_2 sequences where a prefix-root boundary immediately precedes the [h] exhibit overlap of the [h] by the first vowel.⁴⁹ For these data, the underlying form is in the left-hand column, with the careful and casual speech forms to its right in order.

The data in (57) can either be taken as evidence that vowel overlap is not constrained by syllable affiliation, or as further supporting the proposal that intervocalic glottal stops are codas in many languages. But recall that Chemehuevi does allow laryngeal onsets in word initial position (see (50)). Likewise, Yurok exhibits laryngeal onsets in this position as well (e.g. *hohkum* ‘tobacco’, *?ekah* ‘hat’). Furthermore, even if the glottal stops in (57a-d) are syllabically affiliated with the preceding vowel, we must question why strict sequentiality is not observed for $V?$, while other consonants that exhibit vowel intrusion in clusters are stably post-vocalic as single codas.

Even more suggestive of a pattern of far ranging temporal variability for sequences with glottal stop is data showing that glottal stop fails to surface as sequential even with respect to adjacent consonant clusters. For example, in Arbore glottal stop varies in

⁴⁷ Interestingly, Press’ (1979) discussion of the Chemehuevi data suggests that this pattern is also observed for [ahi] and [aqi] sequences, as shown in (vi).

(vi)	a.	pahiju	→	pahe^hi	‘three’
	b.	jaaqivii	→	jaaq^hivi	‘brought’
<i>(Press 1979)</i>					

However, note that only in the [aʔi] sequence is the initial element in the post-sonantal diphthong an exact echo of the preceding [a]. This fact suggests that the post-glottal diphthongs in (v) may result from coarticulation between the underlying [a] and [i] across [h,q], but not through overlap of the initial vowel gesture over the intervening consonant.

⁴⁸ Note that the Acoma pattern of vowel overlap exhibited by the data in (57c,d) is not limited to [iʔu] sequences, as the data presented might suggest. However, this phenomena feeds an identity-across-glottals pattern whereby initial [e] coalesces with post-glottal [a] (*seʔainazi* → *seʔé inazi* ‘I ran over them (dual)’). Miller (1965) does not address the output of other $V?V$ sequences whose vowels do not undergo coalescence when strictly adjacent, for example, [aʔu], [uʔi]; these are expected to behave like the [iʔu] forms. One exception is the sequence [aʔi], in which overlap is not exhibited (*/saʔuyaam’i/* → */saʔuyaam’i/* ‘my paint brush’). Additionally, vowel overlap is also blocked by the boundary of certain morphemes (e.g. the possessive prefix *-qa-*), and certain phonological properties, for example if V_1 and V_2 is short and V_1 accented). Data on more $V?V$ sequences, and further study of all relevant factors will be necessary to get a complete picture of this process.

⁴⁹The data in (57) reflect Aikhenvald’s transcriptions, and it is unclear if the choice between representing the overlapped portion of the vowel as a full vowel in (57a-c) vs. as a superscript in (57d) represents an actual difference in their realization. Additionally, an interesting fact to note regarding the Tariana data is that rapid speech form (not shown here) undergoes metathesis of [h] with V_1 such that (57e) is realized as *phiã*, (57f) as *dhueni*.

temporal position with respect to adjacent glides, appearing within the expanse of the glide, (58a-c).⁵⁰ See (53d,e) for data from vowel overlap over glottal stop in Arbore.

(58) Arbore

- | | | | | |
|----|------------|---|------------|-----------------------|
| a. | ʔíy dayʔ-e | → | ʔíy dajʔje | ‘he guarded’ |
| b. | ɲáwʔ-a | → | ɲáwʔwa | ‘(it) is a crocodile’ |
- (Hayward 1984)*

The data in (58) show that underlying Gʔ sequences are realized as GʔG sequences in Arbore, with the glottal stop appearing within the span of a glide that overlaps it. Another example of the failure of strict sequentiality for Cʔ sequences comes from languages like Kashaya (Buckley 1994), Yurok (Blevins 2003) and Garo (Burling 1992, Duanmu 1994). In these languages, the gestures in underlying Cʔ sequences surface as simultaneous in the output. Relevant examples are shown below in (59).

In Kashaya, glottalized consonants are formed through diachronic and synchronic processes of coalescence between the members of underlying Cʔ sequences. The data in (59a-c) show coalescence of Cʔ sequences in Kashaya, resulting in the creation of ejectives and glottalized sonorants. In Yurok, ejectives and glottalized sonorants may result from coalescence of a sonorant and glottal stop at a morpheme boundary. This is exhibited by the data in (59d-f).^{51,52} In Garo, glottal stops coalesce with adjacent nasals and liquids. Interestingly, glottalized nasals and liquids often alternate with a form in which the glottal stop and sonorant are separate, but the preceding vowel overlaps the glottal stop (59g).

⁵⁰ Hayward (1984) considers the process shown in (56a-c) to be an instance of copy-epenthesis of the underlying glide into the position immediately following the glottal stop. This is analogous to his approach to vowel intrusion, which he calls epenthesis of an echo vowel. Following Hall 2003, this section has considered vowel intrusion to result from gestural overlap of the cluster by the vocalic gesture. Accordingly, we consider the glide ‘epenthesis’ data in (58a-c) to result from overlap of the glottal stop by the consonantal gesture associated with the glide.

⁵¹ See Buckley 1994 and Blevins 2003, for citation of the sources of their data (both from fieldwork of the author, and from previously published sources). In order to preserve unity in the representation of glottalized consonants across languages, I differ from Blevins (2003) in transcribing glottalized sonorants as [Rʔ] rather than as [ʔR]. Note that Blevins’s (2003) is an accurate indication of the fact that the Yurok glottalized sonorants are pre-glottalized. However, they should arguably have the same phonological representation as the post-glottalized sonorants in Kashaya, though a different phonetic realization.

⁵² In discussing the examples in (59e-f), Blevins (2003) proposes these exhibit a floating [+constricted glottis] feature rather than a glottal stop. However, under an AP approach the gestural specification of glottal stop is as a gesture of glottal constriction, and thus glottal stop and the traditional [+cg] feature should not be distinguished. Moreover, I will argue that the fact that the glottalization appears to ‘float’ results from an overall temporal its cross-linguistic failure to be realized as sequential; this failure results in glottal stop’s being unstable as a discrete segment in Yurok.

- (59) Kashaya
- | | | | | | | |
|----|-----------------------------------------|---|-----------------------------------------------------|-------------|-------------------------------------|-----------------------|
| a. | s'uwac-ʔk ^h e | → | s'uwac ^h k ^h e | ‘will dry’ | | |
| b. | p ^h ak'u:m-ʔk ^h e | → | p ^h ak'u:m ^h k ^h e | ‘will kill’ | | |
| c. | p ^h a-nem-n'o | → | p ^h anemʔdo | → | p ^h anem ^h do | ‘they say he punched’ |
- (Buckley 1994)*
- Yurok
- | | | | | |
|----|-------------|---|------------------------|-----------------|
| d. | kesomewep-ʔ | → | kesomewep ^h | ‘be lonely’ |
| e. | holim-ʔ | → | holim ^h | ‘weave baskets’ |
| f. | ten-ʔahsp | → | ten ^h asp | ‘to be drunk’ |
- (Blevins 2003)*
- Garó
- | | | | | |
|----|--------|---|--------|--------------------------------|
| g. | jo'l-a | ~ | joʔola | ‘rise, of water’ ⁵³ |
|----|--------|---|--------|--------------------------------|
- (Burling 1992, Duanmu 1994)*

Similar patterns to those shown in (59) have been observed in other languages, including synchronically in Klamath (Penutian; Blevins 1993) and Yokuts (Penutian; Newman 1944, Archangeli 1983, 1988) and diachronically via coalescence in *ʔN from Proto-Tibeto-Burman into Proto-Burmese (Botma 2004). Furthermore, Ch sequences pattern with Cʔ sequences in exhibiting reorganization of the gestures from sequentiality to simultaneity. This is shown in (60) for Yavapai (Yuman; Shaterian 1976, 1983, Buckley 1994) and Tariana (Aikhenvald 2003).^{54,55} Other examples of languages that exhibit such Ch coalescence include Kashaya, and Havasupai (variably) (Yuman; Hinton 1984, Buckley 1994).

⁵³ Duanmu (1994) transcribes the glottalized liquid as [ʔl], but since he describes the liquid and glottal as being realized simultaneously, I transcribe it here as [l̥] to emphasize its status as a single segment.

⁵⁴ My transcription of the Tariana data differs from that in Aikhenvald 2003 in representing the aspirated consonants that are the output of Ch coalescence with a superscript [h] (e.g. C^h) rather than a sequence (e.g. Ch). This serves to highlight the fact that the output of Ch is a single aspirated consonant (as described in Aikhenvald's (2003) formulation of the structural description of this phenomenon (p. 46)) rather than as a cluster or sequence.

⁵⁵ Note that this phenomenon occurs when a vowel final prefix or root precedes an [h] initial root, and that the aspiration occurs on the prefix/root consonant immediately preceding the pre-[h] vowel if it is a stop, a nasal or [w]. (metathesis also occurs in #VhV, see Aikhenvald 2003, p. 46-47 for further discussion). Moreover as support for this phenomenon as a hiatus resolution-across-glottals pattern, note that this pattern is not limited to V_xhV_x, and that coalescence or diphthongization will result; pá:-hipa → p^hepa ‘one (human)’, i-hemát^ha → hiemat^ha ‘you shout.’

- (60) Yavapai
- | | | | | |
|----|-----------|---|----------------------|--------------|
| a. | /hla/ | → | [lá] | ‘moon’ |
| b. | /ʔəhna:l/ | → | [ʔaŋá:l] | ‘gourd’ |
| c. | /ʔ-hta/ | → | [ʔat ^h a] | ‘reed, cane’ |
- (Shaterian 1976, 1983, Buckley 1994)*
- Tariana
- | | | | | |
|----|-----------------------------|---|--------------------------|------------|
| d. | /di-híma/ | → | [d ^h íma] | ‘he hears’ |
| e. | /yaw ^h i-hípani/ | → | [yaw ^h ipani] | ‘lauaretê’ |
- (Aikhenvald 2003)*

The examples in (59), (60) illustrate a general tendency for sequences with glottal stop to be realized as simultaneous rather than sequential. This pattern is reminiscent of the patterns of vowel and consonant overlap of glottal stop shown in this section, in which sequences with glottal stop were realized with the glottal stop internal to the other member of the sequence.

Further evidence for a resistance to sequentiality for sequences with glottal stop comes from diachronic instances of Vʔ coalescence. For example, analyses of tonogenesis in some tonal Athabaskan variants (for example, Sarcee, Navaho, Kutchin, Chipewyan and Hare) have suggested that the emergence of tone was preceded by a stage at which the glottal stop conditioned creakiness throughout the vowel. The creakiness of the vowel conditioned an allophonic change in its fundamental frequency, which was subsequently reanalyzed as phonemic; tone. See Krauss 1979:2005, Leer 1979, 1999, Kingston 2005 for more discussion of this pattern. A similar pattern is suggested by Egerod (1971) for tonogenesis in Ancient Chinese; he suggests that “the origin of tone in pre-Ancient Chinese may be interpreted as phonation types” (Thongkum 1990, p. 20). Vʔ coalescence is also claimed to have been a precursor to phonemic register in, for example, Hmong-Mien. In Hmong-Mien, loss of [ʔ] and [h] was accompanied by the emergence of creaky and breathy voice on the vowel, phonation distinctions that were subsequently phonologized (Martha Ratliff, p.c. 2006).⁵⁶ These data suggest that Cʔ and Vʔ sequences are not only likely to be realized with echoic overlap (e.g. C_xʔ → C_xʔC_x,

⁵⁶ The present-day register system in Hmong-Mien is more complicated, as loss of voicing contrasts in initial position contributed to registers with phonation contours (e.g. breathy-modal, modal-creaky, breathy-creaky, etc.). Interestingly, loss of laryngeal contrasts on stops has been correlated with emergence of both tone and register in a number of languages; proto-voiceless consonants often lead to high tone and creaky voice, while proto-voiced consonants give rise to low tone and breathy voice (though not necessarily in the same language). Further research may find support for claiming that these patterns result from coalescence of the vowel with just the glottal gestures associated with the stop consonant, leaving the oral gestures of the consonant as independent. For more discussion of the relation of glottal stop and laryngeal contrasts to tone and register see Haudricourt 1954a,b, Phu *et al.* 1992, Edmondson and Gregerson 1993, Ross 1993, Sagart 1993, Thurgood 1993, Bhaskararao 1999, Haacke 1999, Matisoff 1999, Svantesson 2001, Wayland and Jongman 2002, among many others.

$V_x? \rightarrow V_x?V_x$), but also with total simultaneity of the gestures in the sequence ($C? \rightarrow C'$, $V? \rightarrow V$). This latter pattern is not easily subsumed under a syllable-constrained vowel overlap analysis, because the glottal stop patently fails to be realized as a coda; it is not even realized as a discrete element here. Furthermore, these patterns highlight the fact that sequences with glottal stop are unstable, and that coda glottal stops appear just as marked as onset glottal stops in that they fail to exhibit the sequential relation expected between a nucleus and its coda.⁵⁷

It should be noted that there are possible counterexamples to the proposal that glottal stop is marked in coda from languages like Balantak, Choctaw and Chickasaw, in which speakers identify intervocalic glottal stops as codas rather than as onsets (see section 1.2 for discussion). I suggest that this pattern does not necessarily indicate that the intervocalic glottal stops actually syllabify as codas. Instead, the identification of intervocalic glottal stops as codas may result from the forced choice between coda and onset; extrasyllabicity was not an option. Furthermore, speakers may be influenced in their decisions by the fact that glottal stop is not an onset anywhere else in these languages.

An interesting pattern to address is the fact that in some languages, codas are (mostly) limited to the laryngeal consonants. An example is Chamicuro, in which glottal stop is overwhelmingly preferred in coda position (94% of codas in Parker's (2001) data are laryngeal). One might take this as support for the proposal that glottal stop is the best coda; I take it as support for its being the worst. I propose that because glottal stop is marked in coda position, post-vocalic glottal stop surfaces as extrasyllabic in Palu'e. Because of its extrasyllabicity, the high-ranked NOCODA constraint fails to rule out post-vocalic glottal stop; for all intents and purposes glottal stop is invisible to NOCODA. Supralaryngeal consonants, on the other hand, incur fatal violations of NOCODA because they do syllabify as codas when post-vocalic.⁵⁸ Thus, the pattern arises that all forms with supralaryngeal codas are ruled out, but postvocalic laryngeals are preserved.⁵⁹ More

⁵⁷ Another pattern of $V?$ coalescence is observed in Colloquial Tehrani Farsi, in which loss of coda glottals leads to compensatory lengthening (CL) of a preceding vowel (Darzi 1991, Sumner 1999, Kavitskaya 2002). Kavitskaya (2002) proposes that CL in Colloquial Tehrani Farsi result from absorption of glottal stop's phonetic length by the vowel. She suggests that this result obtains because glottal stop in this language is very vowel like; even careful speech glottal stop does not achieve full closure, and thus there is some light formant structure present during its production. In the case of glottal stop triggered CL, the glottal stop adds to the overall vowel duration because the learner treats the expanse of the glottal stop as a vowel itself. This type of coalescence does not follow directly from the proposal that glottal stop cannot be phased sequentially to flanking gestures, but is interesting nonetheless. In the end, any analysis must account for the fact that glottal stop is susceptible to reanalysis as a vowel. In the discussion in chapter 3, I suggest that the same factors that lead to failure of sequentiality for glottal stop also alert the learner to its not being canonically consonantal, and thus its reanalysis as a vowel.

⁵⁸ A similar pattern might be present in Chamicuro (Parker 1994, 2001) in which 94% of the coda consonants are laryngeal (the remaining 6% could be analyzed as listed exceptions). Lombardi (1995) also mentions Burmese as allowing only glottal stop in coda position (Okell 1969).

⁵⁹ A number of languages limit codas to the laryngeal consonants, and a subset of the supralaryngeal ones, often geminates and nasals homorganic with a following onset. In fact, it was patterns of this type that led to the positing of coda condition and prohibitions on codas with singly linked place features. If we analyze postvocalic laryngeals as extrasyllabic, this would explain their appearance postvocally without

difficult to handle is the fact that languages like Palu'e and *Tukang Besi*, which exhibit closed syllable allophones before intervocalic glottal stop. These data do suggest that glottal stop actually is a coda in these languages. I leave this issue to future research.

The data that have been presented in this section, particularly in (56)-(60), show that while many consonants exhibit the availability of vowel intrusion into clusters, glottal stop is distinguished from the supralaryngeal consonants in that the latter are more likely to deviate from underlying temporal relations (underlying sequentiality is not preserved). Moreover, this deviation is exhibited outside the contexts that delimit vowel intrusion for consonants, namely clusters and syllabically affiliated consonants. For example, forms with glottal stop exhibit overlap of the glottal stop by adjacent vocalic gestures even when the glottal stop is not in a cluster, and also that the direction of overlap does not always coincide with syllable affiliation. This suggests that variability in temporal realization is a property of glottal stop itself, independent of syllable structure. Furthermore, the increased likelihood that clusters with glottal stop will undergo vowel intrusion may result at least in part from the characteristic lack of sequentiality in underlying sequences with [ʔ].

Based on this observation, I henceforth consider the availability of vowel overlap with glottal stop as indicative of an overall inability for this gesture to participate in sequential temporal relations; vowel intrusion in clusters with glottal stop is only a *symptom* of this general tendency. Thus, in accounting for these patterns, my goal is to answer the question of why glottal stop is not anchored in temporal position with respect to adjacent segments. The approach taken to answering this question will ultimately inform our explanation of other patterns, including identity- and hiatus resolution-across-glottals. Most importantly, these patterns illustrate the importance of a phonological approach that can incorporate insights from temporal patterning. Specifically, I propose that the AP in OT approach sketched in chapter 1 provides us with just the right tools to appropriately explain the temporal characteristics of glottal stop.

2.5 Summary and Conclusion

This chapter discussed the tendency for the glottal stop to be distinguished in its patterning from the supralaryngeal consonants cross-linguistically. A well-known example of this distinction is the fact that glottal stop, but not the supralaryngeal consonants, is often transparent to spreading. Furthermore, I discussed one prevailing approach to explaining this pattern: namely, that glottal stop is transparent to spreading because it lacks a specification for oral place. However, data beyond laryngeal transparency call into question this account of the patterning of glottal stop. Specifically, data presented in this chapter showed that glottal stop has unique temporal characteristics that cannot be accounted for in any autosegmental approach. For example, vowel intrusion into clusters with glottal stop was shown to be susceptible to prosodic factors

recourse to laryngeal placelessness. However, it appears that a coda condition constraint will still be necessary to account for the limitation of the remaining codas to geminates and homorganic nasals.

like speech rate and register (as in the Chamicuro and Choapan Zapotec data in (52)). These data suggest that a satisfactory analysis of the patterning of glottal stop must incorporate timing in a way that is unavailable for an autosegmental approach. Additionally, it was suggested that a placeless account is not explanatorily adequate because it simply restates the laryngeal/supralaryngeal distinction without shedding any light on the factors that underlie it.

The data presented in this chapter included patterns of translaryngeal harmony, required identity-across-glottals, and hiatus resolution-across-glottals. The phenomenon of hiatus resolution in V?V poses a challenge to traditional OT analyses of hiatus resolution, which claim that repair of VV occurs because of the lack of an intervening consonant to syllabify as an onset to the following vowel. Descriptively, glottal stop in these languages appeared to pattern as though it weren't an onset; it could not block hiatus between the vowels that flank it. Interestingly, many languages prohibit glottal stop from appearing in onset position, even when it is intervocalic. These data suggested that a possible explanation of the required identity- and hiatus resolution-across-glottals languages might be that the glottal stop in V?V might actually be a coda rather than an onset. However, this analysis hinges on the proposal that coda glottal stop is unmarked. Nevertheless, V? sequences regularly fail to be realized with a strict precedence relation holding between the vowel and the glottal stop; often the glottal stop appears within the span of the vowel. This is unexpected if glottal stop is unmarked in coda position; codas are expected to be realized in a strictly sequential temporal relation with the nucleus.

And while vowel intrusion is also exhibited for supralaryngeal consonant clusters, the data presented in this section demonstrated that failure of sequentiality for glottal stop is observed in a remarkably wide range of phenomena. These included vowel overlap over single glottal stops (not in clusters), vowel overlap over non-sequentially affiliated glottal stop,⁶⁰ consonant overlap over glottal stop, and C? and V? coalescence. These data were taken as support for the proposal that strictly sequential phasing is unavailable for the glottal gesture, and that coda glottal stop, like glottal stop in onset, is marked.

In Chapter 3, I go on to propose an Articulatory Phonology inspired Optimality Theoretic approach to the data introduced in this chapter. This analysis must account for several patterns exhibited by the glottal stop data:

⁶⁰ Recall most notably the data from *Tukang Besi* in (54) in which a vowel overlapped a preceding intervocalic glottal stop. This pattern presented us with a paradox; if we analyze the glottal stop in $V_1?V_2$ as a coda, then overlap of V_2 over [?] is unexpected given Hall's (2003) analysis of vowel intrusion. On the other hand, if we analyze glottal stop as an onset in this form, the directionality of overlap is explained at the cost of positing glottal onsets for *Tukang Besi* (contra its patterning, see discussion in section 2.3.3).

- (61)
- a. Glottal stop tends to allow unexpected interaction of the vowels that flank it (e.g. assimilation, hiatus resolution, etc.).
 - b. Glottal stop is prohibited from onset position in some languages, and from coda position in others.
 - c. Sequences with glottal stop fail to be realized as sequential on the surface (e.g. they show patterns of overlap and coalescence of the gestures in the sequence).

In brief, the main insight of this proposal is that glottal stop is distinguished from other consonants, not in lacking a place-of-articulation specification, but rather in its failure to participate in the phasing relations required of sequences by the OT grammar. This approach has a number of favorable consequences, including that glottal stop will not be parseable into syllable or sequential structure, thus explaining the various patterns discussed in this section.

3.0 A Landmark Underspecification Account of the Patterning of Glottal Stop

This chapter presents an account of the patterning of glottal stop within the AP in OT framework. In chapter 1, I suggested that the prevailing feature geometric approach to the patterning of glottal stop (namely, a placeless account of glottal stop) failed to provide a satisfactory analysis of a range of other patterns observed.¹ In particular, it was suggested that this approach could not readily incorporate information from the temporal patterning of glottal stop. For example, it could not readily explain glottal stop's participation in patterns of vowel and consonant overlap, and the tendency for underlying sequences with glottal stop to be realized non-sequentially. In order to begin the process of arriving at a satisfactory gestural representation for glottal stop, the following section describes its physical properties, including its articulatory and acoustic characteristics. We then continue on to discuss the implications of these facts for the construction of a gestural representation for glottal stop within an Articulatory Phonology framework.

3.1 The Representation of Glottal Stop; The Articulatory and Acoustic Characteristics of Glottal Stop

3.1.1 Articulation

To begin, it is helpful to step back and consider what is the core of glottal stop that is shared by all instantiations of the consonant cross-linguistically. We may begin by considering the articulatory gestures that occur during the articulation of a glottal stop.

¹ It should be noted that there have been alternative feature geometric approaches to glottal stop that did not rely on its placelessness to account for its patterning. For example, in order to account for the fact that glottal stop patterns with the guttural consonants in some languages, it has been proposed that it is specified for [PHARYNGEAL] place. There is a wealth of literature that has proposed pharyngeality for glottal stop. To name only a few, see for example, Hess 1990, McCarthy 1991a,b, 1994, and Bessell 1992 for discussion (and additional references mentioned in chapter 4 of this dissertation). For proposals that the placeless and pharyngeal accounts can be reconciled by allowing languages to choose between the two types of glottal stop at the point of inventory construction, see McCarthy 1991a,b, 1994, Bessell 1992, and Bessell and Czakowska-Higgins 1992 (though Rose 1996 provides an alternate account in which the choice is not free, but rather is constrained by the inventory of gutturals in the language). Other pharyngeal glottal stop analyses include Lombardi 1995, 2002a, in which it is suggested that even some of the classic signs of placelessness (here, debuccalization to glottal stop, and glottal stop's being a preferred epenthetic consonant) can be accounted for under a pharyngeal-? analysis if we assume a place markedness hierarchy in which [PHARYNGEAL] is least marked. Note that under an AP approach to the representation of sound, identical articulatory gestures must have the same underlying representation. Variation of representation between 'segments' having the same percept is possible, but will result from distinct patterns of overlap among the gestures that comprise them. See section 4.1 for an account of 'pharyngeal-?' languages that reconciles them with the account of 'placeless-?' languages presented in this chapter.

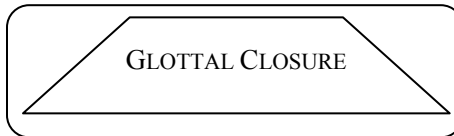
Let us start with the assumption that the physical gesture that is present in all instances of glottal stop is the gesture of glottal constriction.²

In an AP in OT approach, then, the specified gesture associated with glottal stop would be a gesture on the glottal tier with a constriction degree of closure (Glottis Constriction Degree (GCD) = {closed}). The proposed gestural specification for glottal stop is shown below in (1a). (1b) provides an example of a gestural score for the gesture of glottal constriction, as it would unfold in time and space.

(1) Proposed Gestural Representation of Glottal Stop:

a. GLOTTIS CD = {CLOSED}

b. GLOTTIS



The diagram in (1) represents glottal stop as being comprised of a single glottal closure gesture. However, cross-linguistic investigation of the articulation of glottal stop from laryngeoscopic studies shows that it is not necessarily produced solely at the glottis. Esling and colleagues (Esling, 2002; Esling and Edmondson, 2002; Esling and Harris, 2003; Edmondson *et al.* 2005, Esling, Fraser and Harris 2005; Carlson, Esling, and Harris 2003) have conducted research on the production of the laryngeal consonants as well as consonants produced with secondary laryngealization or glottalization. The languages of study include Arabic, Tigrinya, Somali, Amis, Thai, Cantonese, Yi, Bai, Tibetan, Korean, Sui, Pame, Nlaka’pamux, and Nuuchahnulth. Interestingly, the findings indicate that “the most common realization of glottal stops ... includes an adduction of the arytenoid cartilage, complete adduction of the vocal folds, a partial adduction of the ventricular folds, and moderate narrowing of the laryngeal vestibule through its epilaryngeal sphincter mechanism” (Esling *et al.* 2005, p. 386).

Interestingly, Esling *et al.* 2005 suggest that “a glottal stop typically requires supraglottic reinforcement to arrest the vibration of the vocal folds” (p. 402). Thus, in the context of voicing, the achievement of the glottal constriction is facilitated by an accompanying constriction of the epilaryngeal tube, or their ‘laryngeal vestibule’ (p. 386-7). Presumably, the difficulty in stopping the vibration of the vocal folds without some supralaryngeal constriction results from the fact that airflow will continue through the glottis as long as there is a pressure differential between the subglottal air and the supraglottal air. This airflow will actually facilitate the continuation of voicing until full stop constriction is achieved. By constricting the epilaryngeal tube and closing the ventricular folds we reduce the pressure differential between the sub- and supra-glottal air, thus reducing the airflow through the glottis and facilitating achievement of the required degree of glottal constriction.

² See below for discussion of the articulatory and acoustic correlates of glottal stop, as well as discussion of the articulatory, aerodynamic and acoustic correlates of glottal stop in Pennington (2005) and references therein.

As for the representational status of the supralaryngeal articulations, we can either consider them to be phonologically present as separate gestures, or present as secondary articulators of the glottal constriction gesture. The latter possibility is supported under the suggestion that constriction of the laryngeal vestibule facilitates achievement of glottal closure. Under this approach, each articulator contributes to the achievement of a single glottal gesture like the one specified in (1) above; the epiglottis and pharynx form part of the Model Articulator specification for the glottal gesture. Moreover, this possibility is completely in line with analogous patterns in the articulation of supralaryngeal gestures in which multiple structures work together to articulate a single gesture.³

An alternative to the model articulator analysis sketched above is one in which the supralaryngeal articulations are represented as phonologically specified gestures produced simultaneously with the glottal gesture. In this case, the supralaryngeal gesture and the glottal constriction gesture are independent, but may be coordinated such that they overlap in time. Descriptively, they would form a single ‘segment’ with the supralaryngeal gesture playing the role of a secondary articulation on the glottal stop. An inverse example comes from the production of the Nuuchahnulth pharyngeal [ʕ], which is produced with both glottal and supralaryngeal constriction, but perceptually is pharyngeal. Esling *et al.* (2005) presented laryngeoscopic data on the production of the pharyngeal stop, showing that it is a complex segment involving general tightening of the epilarynx, as well as stop-like constriction at the glottis, the ventricular folds, and the aryepiglottal folds, in addition to tongue root retraction. In fact, based on these observations, Esling *et al.* (2005) reconsider the Nuuchahnulth pharyngeal stop as “a voiceless epiglottal stop [ʔ] with a voiced pharyngeal offglide [ʕ̥]” (p. 396).

In the case of the Nuuchahnulth epiglottal or pharyngeal stop, the epiglottal constriction is primary with the glottal constriction being a secondary, and even necessary, consequence of the constriction of the epilaryngeal tube. However, the possibility arises that in other languages we might see a gesture of glottal constriction as primary within the segment, and the accompanying gesture as secondary. Presumably, the accompanying gesture must either be of lesser constriction degree than the glottal gesture, or of lower magnitude (failing to reach its target constriction), in order for the glottal constriction gesture to be perceived as dominant (and thus to have been transcribed as laryngeal instead of supralaryngeal).

Under this approach, the core gesture associated with a glottal stop is the gesture of glottal constriction, as diagrammed in (1), and repeated here in (2a,b). (2c,d) show the representation of a complex ‘segment’ created through the coordination of a gesture of glottal constriction with a gesture of pharyngeal constriction (a gesture on the tongue root tier). Here, the glottal gesture is phased in relation to the pharyngeal gesture such that their targets are synchronous.

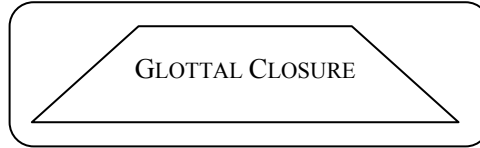
³ To review, the model articulator for a gesture includes the active and supporting articulators that help to achieve the target constriction. For example, the primary articulators of a gesture of labial closure are the upper and lower lips. However, the jaw is also specified as part of the model articulator because raising of the jaw is often necessary to facilitate the achievement of closure by the lips. The reader is directed to the chart in section 1.2.2, (12) and (13), which identify the vocal tract variables, including gestural tiers, constriction location and degree, and model articulator.

(2) Proposed Gestural Representations:

a. [ʔ]:

GLOTTIS: CD = {CLOSED}

b. GLOTTIS:



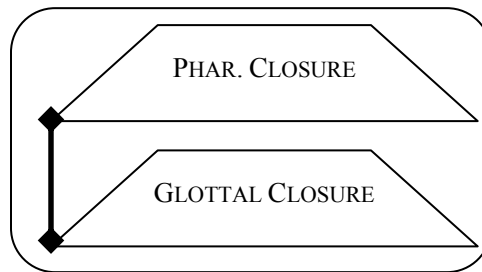
c. [ʔ] with secondary pharyngeal constriction:

TONGUE ROOT: CL = {PHARYNGEAL}, CD = {CLOSED}

GLOTTIS: CD = {CLOSED}

d. TONGUE ROOT:

GLOTTIS:



The gestural representation of glottal stop shown in (2c,d) might very well be an accurate underlying specification for the glottal stop segment in languages in which glottal stop patterns as pharyngeal, such as many of the Semitic and Cushitic languages (for more discussion of these patterns, see section 4.1). Additionally, this approach will be compatible with any refinements in our understanding of the articulation of post-velar consonants; for example, as we see from Esling's *et al.* (2005) Nuuchahnulth data, pharyngeals aren't necessarily primarily tongue root gestures. However, the picture remains the same even if we replace the pharyngeal gesture in (2c,d) with an epiglottal one to better reflect the laryngeoscopic data.⁴

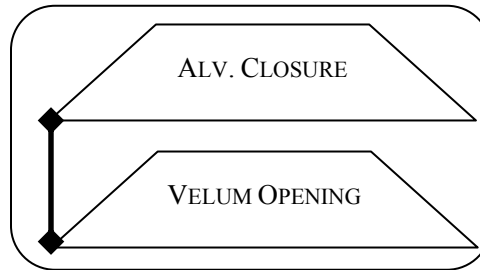
One important thing to note about the gestural scores in (2) is that the proposed coordination for the pharyngealized glottal stop is entirely equivalent to the coordination we might expect between any two other simultaneously coordinated gestures (as evidenced by comparison to the diagram in (3) of a nasal stop, where VCD stands for velic constriction degree).

⁴ Theoretically, any two gestures could be coordinated along the lines in (2c,d), so it would not be surprising to find glottal stops exhibiting contribution of any supralaryngeal articulator. In fact, this possibility might allow accounts of languages in which glottal stop patterns as a natural class with any set of supralaryngeal articulators, not just the guttural/pharyngeal consonants. For example, in Toba (Guaykuruan), glottal stop patterns with the dorsal consonants (velar and uvular stops). Thus, we might propose that this patterning gives support for the presence of an overlapping tongue dorsum gesture for each member of the class, including for glottal stop. See section 4.1 for an approach to reconciling the so-called placeless-ʔ and pharyngeal-ʔ language along these lines.

(3) [n]:

- a. TONGUE TIP: TTCL = {ALVEOLAR}, TTCD = CLOSURE
VELIC: VCD = {WIDE}

- d. TONGUE TIP:
VELIC:



Having discussed the articulatory properties of glottal stop, we turn in the next section to discuss its acoustic characteristics, which differ in important ways from those available during the production of supralaryngeal stops.

3.1.2 Acoustics

The articulation of a gesture of full closure at a particular place of articulation (e.g. a ‘stop’ consonant) has certain regular effects on the acoustic signal as the gesture unfolds in time. For example, an intervocalic oral stop will be characterized by (1) formant transitions on the preceding vowel; (2) total or partial silence during the closure;⁵ (3) a burst upon release of the constriction; and (4) formant transitions on the following vowel. The acoustic characteristics described here play a significant role in the identification of the consonant produced. In particular, studies have shown that information provided in the release burst of a pre-vocalic consonant, and in its formant transitions onto flanking vowels, is used by speakers to identify the place of articulation of the consonant.⁶ Restated in AP terms, information from release bursts and formant transitions helps the speaker identify the gesture produced in terms of its tier (Lips, Tongue Tip, Tongue Body, etc.) and in terms of its Constriction Location (Labial, Alveolar, Palatal, etc.)

Let us now compare the acoustic effects of the articulation of the gesture of glottal constriction associated with a glottal stop. Interestingly, the acoustic cues provided during the production of a glottal stop are quite different from those provided by an oral stop. For example, in contrast to the supralaryngeal stops, the production of this glottal gesture does not cause formant transitions on flanking vowels (Kent and Read 1992, as

⁵ While voiceless stops are accompanied by a period of silence during closure, voiced stops may also have acoustic energy at the fundamental frequency during at least some part of the closure period.

⁶ For example, Blumstein and Stevens 1980 considered the contribution of burst frequency and formant transitions to stop place of articulation identification. Their results showed that listeners could accurately identify synthetic stimuli based on the presence of only release burst or formant transitions, though performance was better when both cues were present.

cited in Shank and Wilson 2000b). In fact, a number of studies have confirmed that there are no formant transitions for glottal stop. This even holds of glottal stop in varieties of Arabic, despite the fact that it patterns with the pharyngeal and uvular consonants. Alwan (1986) showed that speakers identified synthetic [ʔV] sequences as glottal stop initial even when no formant transitions were provided. This contrasts with her findings for the pharyngeal and uvular initial sequences, which crucially relied on the presence of formant transitions. Natural language data also confirm that Arabic glottal stop doesn't condition transitional coarticulation on the formants of flanking vowels, as production data collected by Klatt and Stevens (1969) and Butcher and Ahmad (1987) for Lebanese and Iraqi Arabic, respectively, showed no formant transitions.⁷

As for the period of closure for glottal stop, while an idealized glottal stop may result in a period of silence in the speech stream, Hillenbrand and Houde (1996) note that in English "glottal stops ... are often not realized as stops at all, but rather show voicing that is continuous throughout the glottal constriction gesture" (p. 1182). This fact is also observed by Pierrehumbert and Talkin (1992) who state that "a full glottal stop (with complete obstruction of the vocal folds) is quite unusual" (p. 93). Often, glottal stop is characterized by pitch periods that are both longer and more variable in length than that of modal voicing. Consequently, glottal stop will also often lack the burst generally associated with release of constriction at other places of articulation. This lack of a release burst and formant transitions for glottal stop is interesting, particularly in the light of the important role these cues play in stop identification at other places of articulation. Studies have shown that in the absence of these cues, learners identify glottal stop based on other information. For example, Hillenbrand and Houde (1996) showed that subjects reliably identified the presence of glottal stop based on a lowering of F_0 , even in the presence of continued voicing. A dip in amplitude was also shown to contribute to the percept of glottal stop, though this effect was weaker than for the F_0 results. For further discussion of the acoustic characteristics of glottal stop, including its tendency to be realized as irregular vocal fold pulses and its characteristic drop in amplitude, see among others Priestly 1976, Fischer-Jorgensen 1989, Pierrehumbert and Talkin 1992, Pierrehumbert and Frisch 1996, Dille *et al.* 1996, Redi and Shattuck-Hufnagel 2001, Huffman 2005 (and references therein).

In the light of the fact that learners make use of different types of acoustic information in the perception of glottal vs. supralaryngeal consonants, one issue to

⁷ A number of studies have also explored the possibility that glottal stop conditions global effects on flanking vowels, for example Al Ani 1981 for Iraqi Arabic, Bessell 1992 for Salish languages, and Shank and Wilson 2000b for Nuuchahnulth. For our present purposes, we ignore the possibility of global effects from laryngeal consonants because of the difficulty in interpreting these data. For example, Shank and Wilson (2000b) noted that for both [ʔ] and [ʕ], there was raising of F_1 (more so for the former consonant) in comparison to a control of averaged formant heights for non-guttural stops. Still, Shank and Wilson (2000b) concede that the control consonants also condition co-articulatory effects, so it's difficult to determine what is the actual contribution of any single consonant. Moreover, the results vary from language to language; Bessell (1992) states that there is no coarticulatory effect caused by laryngeals in the Salish languages, and Colarusso (1988) makes the same statement implicitly for the Caucasian languages; he indicates that it is possible "to determine the independent articulatory positions of /ə/ and /a/ [by] eliciting them ... in the environment of a laryngeal" (Colarusso (1988) p. 299, Bessell 1992, p. 89).

consider is what implications this difference has for the gestural representations that learners posit for these sounds. Section 3.2 advances the following hypothesis: in positing a gestural representation for an utterance, learners will only posit those gestures to be present whose articulation has recoverable acoustic reflexes. Furthermore, on the level of single gestures, learners rely on the acoustic cues present in order to determine the internal structure of the gesture (e.g. what gestural landmarks comprise it among the set in (15), section 1.2.3).

The remainder of this chapter is organized as follows: section 3.2 presents a proposal regarding the nature of the perceptual/gestural relationship in the AP in OT framework. In this section, I propose that gestures may differ in terms of their internal structure (their landmarks); by hypothesis, differences in internal structure result from differences in the acoustic cues each gesture provides. Ultimately, the distinct patterning of the laryngeal vs. supralaryngeal consonants will be argued to result from this representational difference (in section 3.3). Section 3.4 concludes the chapter with a summary of the findings of this chapter, and also discusses some of the questions that remain for future research.

3.2 Gestural Perception and the Development of Gestural Representations

3.2.1 Gestural Perception and the Construction of Utterance Level Representations

One question that has been addressed in the AP literature is the problem of how learners construct gestural representations of utterances, considering the fact that the medium of transmission of speech is acoustic, not gestural.⁸ I propose that learners accomplish the task of determining the gestural make-up of utterances by extrapolating back from a given acoustic signal to determine the gestures whose production resulted in that signal. Throughout this section, I refer to the linguistic competence that allows learners to interpret the gestural sources of a particular acoustic signal as the Speech Perception Module (SPM).⁹

⁸ Two prevalent approaches to answering this question include Direct Realism (Fowler 1986, 1996, Fowler and Dekle 1991, Fowler *et al.* 2003, Goldstein and Fowler 2003) and Motor Theory (Liberman *et al.* 1967, Liberman and Mattingly 1985, 1989). In the former approach, hearers can directly perceive gestures through the medium of the acoustic signal, while in the latter, hearers interpret the acoustic signal using a speech perception module (which happens to be at least partially co-extensive with the speech production module). Additionally, it should be noted that recovery of linguistically significant elements from the speech signal is a problem for any phonological approach. For example, one approach to recovering features in the speech signal is developed by Stevens 1995, Liu 1996, Stevens 2002, Slifka *et al.* 2004, Slifka 2005, among others. This approach proposes that listener's identify features by examining spectral properties of the speech stream in the vicinity of certain salient acoustic landmarks (e.g. discontinuities associated with formation and release of consonantal constriction, amplitude minima for glides and maxima for vowels).

⁹ However, I make no proposals regarding the form or make-up of the SPM, leaving this to future research. One possibility is that it is a production/perception module along the lines of that which has been proposed

One consequence of the proposal that learners use acoustic information to recover the phonological gestures of an utterance is that they can only posit gestures to be present if the acoustic signal provides sufficient cues. On the other hand, if the production of a particular gesture in a particular context does not result in sufficient acoustic cues, the SPM will fail to recognize the presence of that gesture. This possibility is also suggested by Fowler (1996), who noted that “if a gesture does not structure the air in noticeable ways, it is likely to go unnoticed” (p. 1737).

Let us consider a hypothetical example of how the learner constructs gestural representations based on the acoustic signal, using data from Browman and Goldstein 1990. (4) presents data from the casual speech processes of deletion of word final /t/ in the context of preceding /k/ and following /m/. Here, the careful speech form is given on the left, followed by the casual speech form to its right:

(4) /pəˈfɛkt məmri/ → [pəˈfɛkʰ məmri] ‘perfect memory’
(Browman and Goldstein 1990)

Browman and Goldstein (1990) hypothesize that while casual speech processes like those shown in (4) are illusory in the sense that while they appear to involve the change or loss of gestures, they actually involve a change in the temporal relations between gestures such that they overlap. For example, overlap of the underlying /t/ gesture by the flanking velar and labial gestures is hypothesized to be the source of the percept of /t/ deletion in the casual speech form of ‘perfect memory.’ In fact, Browman and Goldstein (1990) show that in X-ray tracings of productions of ‘perfect memory,’ the tongue tip gesture associated with /t/ is present in both the careful and casual versions of the sentence. Crucially, in the latter version, the velar gesture associated with the /k/ and the bilabial gesture associated with the /m/ overlap the tongue tip gesture, thus resulting in the percept of its deletion.

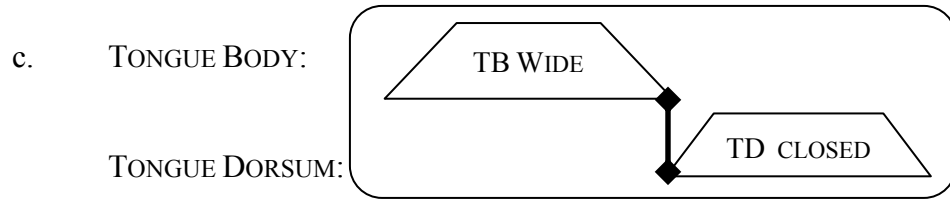
One of Browman and Goldstein’s (1990) main conclusions is that gestures are not deleted, added or altered in casual speech. Still, one question to ask is how a learner handles casual speech forms of the sort shown in (4), in which the speaker’s production contains gestures that are not recoverable in the speech stream (e.g. /t/ in ‘perfect memory’ (4c)). Consider, for example, a learner who first hears the word ‘perfect’ in the context of a casual speech production of ‘perfect memory.’¹⁰ Under an account of speech perception in which learners only posit those gestures to be present that have recoverable effects on the speech signal, the learner will be unable to construct adult-like representations of the word ‘perfect’ in this context. Instead, the learner will posit a gestural representation that differs from that of the adult speaker in lacking the /t/ closure.

by Motor Theorists. Note that by positing that speakers apply interpretive cognitive processes to the incoming speech stream, I necessarily reject a main proposal Direct Realism: namely, that hearers directly perceive gestures of speech without the necessity of an intermediary interpretive process.

¹⁰ We may also assume for the sake of this hypothetical learner that his lexicon already includes the word ‘memory’, so that we can ignore the possibility that he will posit the word ‘perfekmemory’ given [pəˈfɛkʰmɛməi].

The hypothetical gestural score that results is shown below in (5a-d), for reasons of space looking only at the final syllable's rhyme. For comparison, (6a) shows the gestures specified in the adult output, and (6b) and (6c) show the implemented phasing relations in the careful and casual speech forms, respectively.¹¹

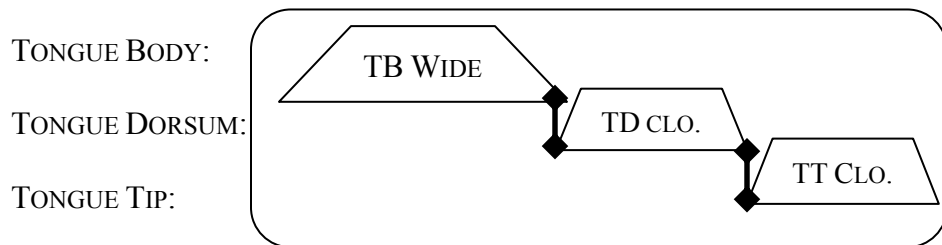
- (5) a. Learner hears casual speech [pəˈfɛkʰ məmɔːi]:
 b. Learner Posits: 'perfect' = /pəˈfɛk/
 TONGUE BODY: TBCD = {WIDE}, TBCL = {PALATAL}
 TONGUE DORSUM: TDCD = {CLOSED}, TDCL = {VELAR}



- d. Learner's phasing relations: TB OFFSET = TD ONSET

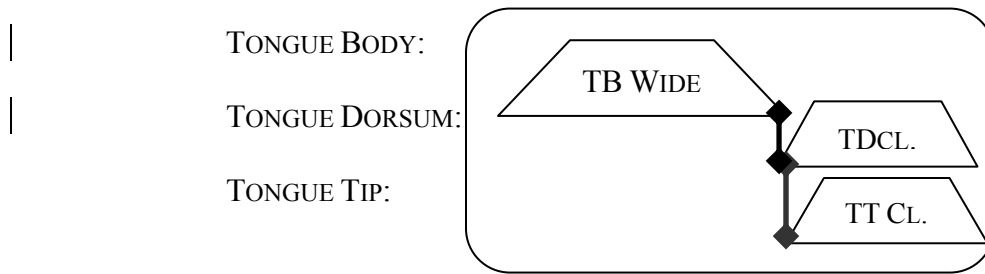
- (6) a. Adult specified phasing relations: 'perfect'
 TONGUE BODY: TBCD = {WIDE}, TBCL = {PALATAL}
 TONGUE DORSUM: TDCD = {CLOSED}, TDCL = {VELAR}
 TONGUE TIP: TTCD = {CLOSED}, TTCL = {ALVEOLAR}

- b. Adult Careful Speech: 'perfect' [pəˈfɛkt] ((6a) is input)



¹¹ Note that for both (6b) and (6c), the underlyingly specified phasing relations are as shown in (6a). (6b) represents a faithful realization of the underlying phasing relations, an outcome that would be consistent with the careful speech pronunciation of 'perfect memory.' (6c) shows a casual speech production of 'perfect memory,' in which the implemented phasing relations differ from those specified underlyingly and exhibited by the careful speech form; it exhibits overlap of the alveolar closure gesture by the adjacent velar and labial gestures.

c. Adult casual speech: [pəˈfɛkʰ] ((6a) is input)



As is illustrated in the schematic diagrams in (5) and (6), the learner's first approximation of the gestural representation for the word 'perfect' will differ from that of the adult native speaker's (cf. (5) vs. (6a)). If the learner never hears the careful speech form of the word, then he will retain the representation lacking the /t/ gesture. This might be the source of a sound change.¹² However, it is more likely that at some later point the learner will revise the initial hypothesis based on having heard the careful speech form. This speaker will use the audible presence of the /t/ release in the careful speech form as evidence for the presence of a tongue tip closure gesture. By analogy with the careful speech form, the learner will posit that the casual speech form also contains a tongue tip closure gesture (even though it is not audible) and will subsequently produce it as such.¹³

In the next section, I extend this analysis to consider what effects particular acoustic events have on the development of representations of the internal structure of gestures. I present a proposal that the SPM relies on the presence of acoustical events in the speech stream to posit the internal structure of gestures in terms of the landmarks that comprise them. Importantly, this discussion suggests that gestural landmarks are only indirectly

¹² It has been proposed previously in the literature that misperception of the speaker's output by the listener, and consequent failure to recover the form intended by the speaker, may lead to sound change. This results from the listener forming "a different ... lexical underlying form ... from that of the speaker," though such misperceptions are often corrected on a day to day basis (Ohala 1992, p.322). Notably, Ohala and colleagues (among others) have argued that many observed sound changes have their source in listener misparses or misperception of acoustic cues in the speech stream. (Hombert *et al.* 1979, Ohala 1981, 1987, 1989, 1992, 1993, 2005, Ohala and Busà 1995, Ohala and Lorentz 1977, among many others). Many of the examples of diachronic changes in this body of work result from the hearer inaccurately misinterpreting the status of an acoustic cue that is actually present in the speech stream (e.g. an allophonic effect is deemed phonetic, and so on). The situation described in the body of this text differs slightly, in that misperception of the gestures intended (and produced) by the speaker is suggested to result from cue absence rather than misinterpretation of the source of an extant cue.

¹³ Thus, influence from morphological paradigms will affect the creation of gestural representations; importantly the hypothetical learner will arrive at an adult like representation of 'perfect' because he or she assumes that the casual and careful speech forms have the same gestural specifications. Interestingly, this brings us back to Browman and Goldstein's (1990) proposal that casual speech processes never involve change in underlying gestures, but only changes in overlap and dynamical parameters. An interesting topic for future study would be to explore the possibility of this proposal forming part of the Language Acquisition Device as an acquisition bias.

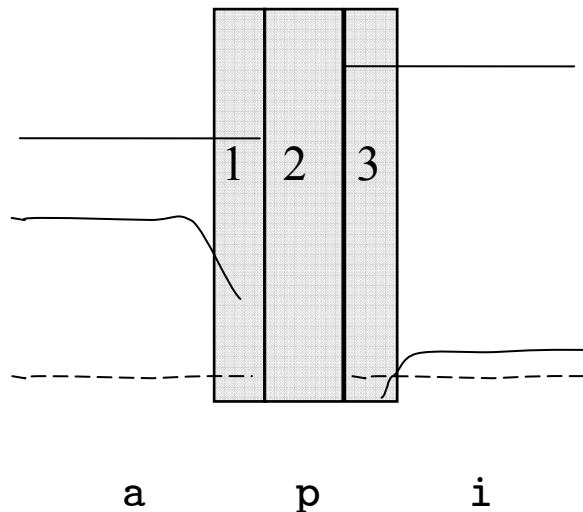
related to the associated physical events (e.g. ONSET to onset of movement), and that this relationship is mediated by the acoustic signal and the SPM.

3.2.2 *Internal Gestural Representations, with focus on [p] vs. [ʔ]*

Let us now consider a concrete example of how the perceptual system might rely on acoustic cues to construct abstract representations of the internal structure of a gesture in terms of its gestural landmarks. I focus here on how the acoustic cues of a stop consonant might be interpreted by the perceptual system as revealing the internal structure of one particular gesture associated with that consonant; namely, closure at a particular point of articulation.¹⁴ I begin by examining the internal gestural make-up and acoustic consequences of labial closure during the production of the consonant /p/. In AP terms, /p/ is specified for a gesture on the labial tier with a Constriction Location of the lips and Constriction Degree of closure (in shorthand, LCL = {lips}, LCD = {Closure}). The implementation of this gestural target for the lips has certain regular effects on the acoustic signal. Consider the schematic diagram of the formant frequencies of an [api] sequence shown in (7):

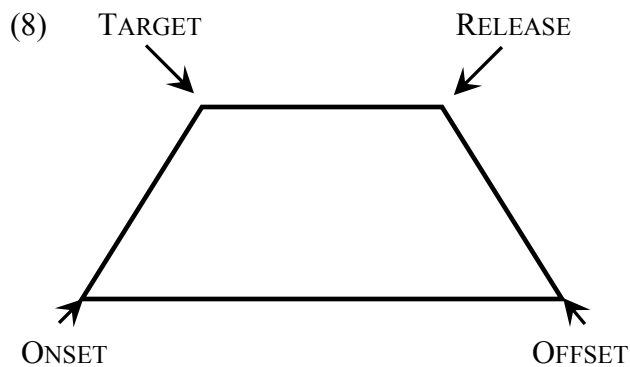
(7) Schematic diagram of the acoustic signature of /p/ in /api/:

LCL={lips}, LCD={closure},



¹⁴ For the time-being, I consider this approach to apply only to gestures of full closure. One question for future research, as discussed in section 3.4 how the SPM deals with the acoustical cues provided by non-plosive gestures.

In the schematic diagram in (7), there are three main recoverable acoustic consequences of the labial closure associated with /p/, each of which is marked within a numbered box on the diagram. These are: (1) the fall of the F_1 of the immediately preceding [a], (2) total silence during the alveolar closure, and (3) the fall of the F_1 of the immediately following [i]¹⁵. From these acoustic cues, the learner must recover the gesture that resulted in this particular speech signal, namely LCL = {labial}, LCD = {closure}. I propose that the SPM uses the evidence provided by each of the acoustic events in the speech stream (beginning of preceding formant transitions, beginning of silence, end of silence and beginning of following formant transitions) to develop a representation of the internal make-up of the labial closure gesture in terms of the particular gestural landmarks that comprise it. To see how such a proposal plays out, first consider the schematic diagram of the time course of a gesture and the hypothesized gestural landmarks in (8), repeated from section 1.2.3 (15). This visualization of the time course of a gesture is from Gafos 2002, as are the descriptions of the gestural landmarks.



Definition of Gestural Landmarks: (Gafos 2002)

- ONSET: The onset of movement towards the target gesture
- TARGET: The point in time at which the gesture achieves its target
- RELEASE: The onset of movement away from the target of the gesture
- OFFSET: The end of all movement associated with the gesture

Now consider what the expected acoustic effects of the articulation of a labial closing gesture with the particular landmarks shown in (8) might be. First, at the onset of the gesture, the upper and lower lips begins to move toward a point of contact, which results in changes in the shape of the vocal tract from its beginning state at [a]. Because the mouth is still open for the production of [a] during the period between the onset of movement for the labial closure gesture and the actual achievement of labial closure, this

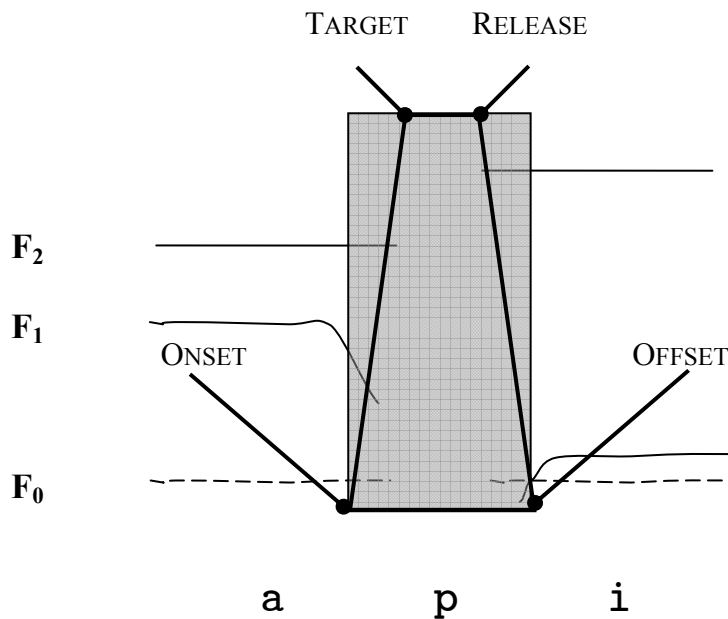
¹⁵ For stop consonants, there may also be a release burst at the point of the release of the constriction. Though a number of researchers have shown that the burst frequency is a cue to place of articulation in stops (for example, see discussion of Blumstein and Stevens 1980, in footnote 6), I do not include it in my discussion for the sake of simplicity. We may consider both the burst and the end of silence to coincide with the release of consonantal constriction, and either is a possible cue to the presence of the RELEASE landmark (see discussion below).

perturbation of the shape of the vocal tract has an acoustically recoverable effect on the speech signal; that of a fall of the F_1 of the [a] vowel. Thus the point at which we begin to see formant transitions on the vowel immediately preceding tongue tip closure should coincide temporally with the ONSET landmark of the gesture. Upon achievement of the full closure of the lips the acoustic result is silence, which holds throughout the closure until its release. This provides evidence for the landmarks of TARGET and RELEASE. Finally, following release of the labial constriction the upper and lower lips move away from the target closure. During this period, the articulation of the following vowel has begun and the movement away from the target towards a neutral state is also acoustically recoverable; it results in formant transitions on the immediately following vowel.

Thus, the acoustic cues of a gesture of closure associated with a given stop consonant (as sketched in (7) and (9)) provide the perceptual system not only with enough evidence to posit the presence of the gesture itself, but also provide all the evidence needed to posit the gestural landmarks of ONSET, TARGET, RELEASE and OFFSET for that gesture. In fact, I propose that the presence of acoustic events corresponding to the relevant physical events (e.g. onset of movement, achievement of target, etc.) is a necessary condition for positing of an articulated landmark structure for a given gesture.

Before continuing on to consider the consequences of this proposal for glottal stop, (9) shows the temporal correspondence of the proposed landmark structure in (8) with the schematic speech signal in (7):

(9) Schematic Diagram of /api/: Acoustic Cue Correspondence with Gestural Landmarks



This section and the preceding one have made several key proposals regarding the development of abstract gestural representations of utterances. For review, these are listed below in (10):

- (10) a. A Speech Perception Module (SPM) interprets the acoustic signal of utterances to determine the gestures that comprise them.
- b. Gestures are posited to be present only if their articulation is accompanied by recoverable acoustic cues.
- c. Gestural Landmarks are posited to be present only if acoustic events in the speech stream give evidence for their presence.

The proposals developed here are reminiscent of other accounts of speech perception in which the learner uses the presence of acoustic landmarks or discontinuities in the speech stream to identify the presence and featural make-up of a segment. This approach is reminiscent of that developed in what I will refer to as “A Landmark-Based Model of Speech Perception” (henceforth, LBA) (Stevens 1995, Liu 1996, Stevens 2002, Slifka *et al.* 2004, Slifka 2005, among others).¹⁶ In this approach, the listener identifies acoustic landmarks in the speech stream that “provide initial information about the manner of articulation and the order of intended segments.” For the LBA, the available landmarks are the acoustic discontinuities associated with achievement and release of consonant closure, the point of minimum low frequency amplitude for a glide, and the point of maximum low frequency amplitude for vowels. Identification of the presence of a landmark gives evidence of the presence of a particular segment. Other features of the segment are identified by examining the spectral properties of the speech stream at or around the landmark; for example, spectral properties of the release burst give evidence for place-of-articulation of a consonant (Stevens 2002; see also studies on the importance of release burst and formant transition for stop identification, for example Blumstein and Stevens 1980, among others).

Interestingly, the recoverability of a landmark can be degraded in connected speech, for example by overlap of one landmark by another. An example discussed in much of the literature mentioned here is overlap of adjacent stops, for example in an alveolar-velar sequence (‘cat game,’ Slifka *et al.* 2004). In a casual speech pronunciation of this phrase, the closure landmark for the velar consonant tends to overlap the release landmark for the alveolar stop. Thus, any cues to features of ‘t’ that might have been found in the vicinity of its release landmark are lost. In this case, learners may rely on supplementary information to identify the features of the segment, for example, formant transitions. However, Slifka *et al.* 2004 suggest that discontinuities beyond those identified (consonant constriction achievement and release, glide minima and vowel maxima) “do not have the same privileged relationship to underlying ... segments” (p. C-86). For them, this would also be the case with any discontinuity associated with formant transitions (we return to this issue in the discussion of the gestural representation of glottal stop).

¹⁶ This name is taken from the title of Slifka *et al.* 2004, “A Landmark-Based Model of Speech Perception: History and Recent Developments.” However, it is unclear whether this was intended to be used as the name for the overall theory, since Slifka 2005 instead refers to it as “the Lexical Access from Features (LAFF) model” (p. 29).

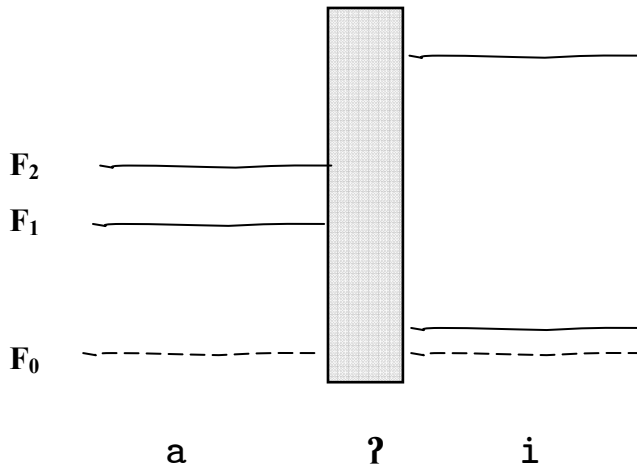
The LBA shares with the present account the fact that absence of a particular landmark will hinder identification of the intended linguistic units, whether they be gestures or segments. Landmark absence can come about through overlap of adjacent gestures, as discussed above and in the ‘*perfect memory*’ example from (4) based on discussion in Browman and Goldstein 1990. In both approaches, total absence of recoverable cues for a gesture/segment will result in failure of the listener to perceive its presence, even if it was produced by the speaker. However, the two approaches differ in the weight given to the acoustic discontinuity associated with formant transition; in the LBA formant transitions can supplement information on features when cues at landmarks are obscured, but this discontinuity/landmark is not primary. In contrast, the proposal I am developing here argues that all acoustic events associated with physical landmarks in gestural production must be present in order for the listener to develop a fully articulated internal gestural representation for a sound. Importantly, the required acoustic events include formant transitions on flanking vowels.¹⁷

Returning to the proposals outlined in (10), particularly (10c), the question that arises is what are the implications of this account for the representation of the internal structure of the glottal constriction gesture in terms of its landmarks. Recall that, as discussed in section 3.1.2, the articulation of a gesture of glottal constriction fails to cause formant transitions on flanking vowels. In other words, the acoustic signal of the glottal constriction gesture lacks two acoustic events usually associated with stop consonants: the beginning of formant transitions on a preceding vowel, and the end of formant transitions on a following vowel. Following proposal (10c), which I will refer to as the Landmark Underspecification proposal, the lack of these acoustic events will have a direct effect on what representation of its internal structure the learner posits for the glottal gesture. Specifically, a comparatively deficient acoustic signal will result in a comparatively deficient internal structure. For example, consider the diagram below, a schematic diagram of the acoustic cues associated with an [aʔi] sequence.¹⁸

¹⁷ This is not to say, however, that we need cues for all landmarks to be present in order for the listener to perceive the presence of the gesture itself. My claim is only that a gesture lacking cues for a particular landmark will have a comparatively deficient landmark structure. Ultimately, I will show that differences in landmark structure will result in differences in phonological patterning, and that these differences underlie the laryngeal/supralaryngeal distinction.

¹⁸ This diagram characterizes [ʔ]’s glottal constriction gesture as resulting in a period of silence in the speech stream between the two vowels. This is an idealized version of the actual acoustic results of the articulation of a glottal stop, as discussed above. A more accurate characterization would be a series of vocal fold pulses with periods of varying length, rather than silence. For the purposes of this example, I believe we lose nothing by abstracting away from this particular difference between [ʔ] and other stops.

- (11) Schematic Diagram of the Acoustic Signature of /ʔ/:
 GL.TD={closure}, GL.CL={glottis}



The reader will immediately note a significant difference in the acoustic signal represented in the diagram in (11) from the one for /p/ in (7); for glottal stop there are no acoustically recoverable formant transitions on the vowels that flank it (Kent and Read 1992, as cited in Shank and Wilson 2000b). As proposed above, the acoustic events associated with the left edge of preceding formant transitions and the right edge of following formant transition are exactly those events that allow the learner to posit the presence of the gestural landmarks of ONSET and OFFSET for the /p/'s labial closure gesture. Thus, the absence of these same acoustic events for glottal stop means that the gesture of glottal constriction likewise lacks the abstract gestural landmarks of ONSET and OFFSET; it is underspecified for these gestures. In fact, the only gestural landmarks for which the perceptual system will have sufficient evidence will be the achievement of the target and its release (TARGET and RELEASE), these coinciding with the left and right edges of the closure silence (here in an idealized glottal stop).

The proposed gestural representation for glottal stop is shown in (12), which is a variant of the normal trapezoidal schematic gestural representation, except that the lack of the ONSET and OFFSET landmarks results in a flat trajectory for /ʔ/.

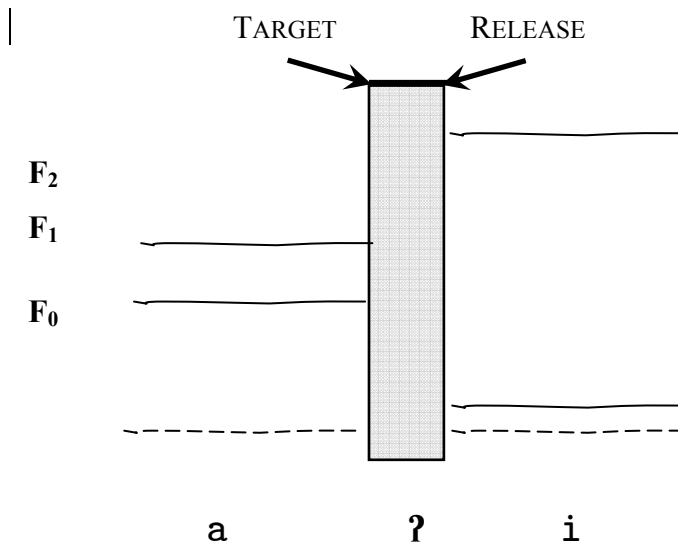
- (12) A Schematic Gestural Representation of [ʔ]:



In the diagram in (12), glottal stop is represented as lacking the abstract gestural landmarks of ONSET and OFFSET.¹⁹

The schematic diagram in (13) shows the proposed gestural representation for glottal stop as it coincides with the acoustic signal associated with the articulation of the gesture of glottal constriction between vowels.

(13) Schematic Diagram of /aʔi/: Acoustic Cue Correspondence with Gestural Landmarks:



In this section, I have proposed that abstract phonological gestures may differ in their internal structure, and that these differences are rooted in differences in the acoustics of each particular gesture. In particular, I have suggested that the acoustic cues resulting from the articulation of a gesture of glottal constriction are such that the speaker is unable to posit the gestural landmarks of ONSET and OFFSET.²⁰ In the next subsection, I consider

¹⁹ Note that some approaches to speech perception (for example, the Direct Realism –for further discussion see footnote 7, and Fowler 1986, 1996 and references therein) would be incompatible with the Landmark Underspecification proposal. The incompatibility of DR with Landmark Underspecification lies in the fact that the former posits that listener’s perceive gestures directly through the medium of the speech signal, while the latter posits that learners must interpret evidence provided in the speech stream to create a gestural representation of the utterance. It is important to note, however, that proponents of DR do not posit the presence of abstract gestural landmarks, and thus are concerned only with the perception of the gesture itself. If we do assume the presence of gestural landmarks (as AP in OT does), however, we must address how the learner posits their presence for each gesture. Importantly, the Landmark Underspecification proposal presented is compatible only with an indirect approach to speech perception.

²⁰ Note that only across-the-board absence of a particular acoustic event, for example as is the case for glottal stop, will result in failure of the learner to posit the presence of the corresponding landmark. Importantly, the absence of a landmark that might result from overlap of two adjacent gestures on a token-

the implications of this reconsideration of the internal gestural representation of glottal stop for its phonological patterning, proposing that the particular representation of this gesture precludes it from participating in both the syllabic and temporal structure of the utterance.

3.3 Consequences of the Landmark Underspecification Analysis for the Cross-Linguistic Patterning of Glottal Stop

Now we must consider what effects the lack of the landmarks of ONSET and OFFSET have on glottal stop's linguistic patterning. Recall that previous approaches to incorporating AP gestures into OT have proposed that the OT grammar constrains intergestural temporal relations via specifying the alignment between their gestural landmarks. This approach was first presented in Gafos 2002 and was subsequently employed in Davidson 2003 and Hall 2003 (see section 1.2.3 for more discussion.)²¹ Satisfaction of constraints on landmark alignment (e.g. ALIGN C₁ OFFSET, C₂ ONSET) requires certain gestural landmarks of a set of gestures (here the OFFSET of C₁ and ONSET of C₂) to be synchronous. But what if a particular constraint in the grammar makes reference to the ONSET or OFFSET landmark of a consonantal gesture? It is clear that the glottal gesture will fail to satisfy this particular constraint, since it lacks the necessary landmarks.

In this section, I develop an analysis of the effect of landmark underspecification on glottal stop's patterning along these lines; because it lacks the ONSET landmark, glottal stop will not satisfy constraints governing the formation of syllabic structure. Thus, even when glottal stop is present in the utterance, it fails to syllabify with adjacent segments. This accounts for the repair of V?V sequences in identity- and hiatus resolution-like processes across [ʔ] (§2.2, §2.3); glottal stop is extrasyllabic in V?V, and these patterns are *exactly* hiatus resolution phenomena, rather than merely hiatus resolution-like. Furthermore, the fact that glottal stop's presence fails to satisfy syllable structure constraints helps to account for the fact that many languages avoid prevocalic glottal stop (§2.3).

to-token basis (e.g. in the casual speech production of 'perfect memory' (4) or 'cat game') will be more problematic for identifying the presence of the gesture (and also for lexical access). However, this absence should not preclude the gesture from participating in the full range of phasing relations because the learner will have stored a landmark scheme for that gesture based on experience with many tokens of the gesture for which all acoustic events were audible. Importantly, the learner will never have experience with a glottal constriction gesture for which formant transitions were present, and thus will store a landmark scheme as in (12).

²¹ The idea that articulatory landmarks play a role in determining the relative temporal expression of phonological features has precedent in Huffman 1989, in which it is observed that targets of nasality and orality are aligned with such landmarks as stop release (for oral stops), stop closure and release (for nasal stops), and vowel midpoint (for oral and nasal vowels). Huffman (1989) develops an analysis of this pattern in which presence of articulatory landmarks determine the edges of the implementation of targets for a particular feature.

Additionally, I propose that because sequentiality of gestures results from phasing relations that hold of ONSET and OFFSET landmarks (i.e. G_1 precedes G_2 if G_1 OFFSET = G_2 ONSET), glottal stop will also fail to be parsed into the sequential structure of the utterance. The failure to parse glottal stop into the sequential structure will result in its failure to be anchored sequentially with respect to other gestures. It is for this reason that the observed phenomena of vowel intrusion in V?V occur. Likewise, related patterns in which underlyingly sequential V? and C? are realized with overlap of the glottal stop by the adjacent gesture have the same source. The failure of sequentiality also accounts for the reorganization of C? and V? sequences to simultaneity; for example as in the formation of glottalized consonants in Kashaya and Yurok (§ 2.4). Reorganization occurs as a result of constraints requiring exhaustive parses of input gestures (ASSOCIATE CC/CV). Because glottal stop fails to participate in sequential or syllabic phasing relations with flanking gestures, its presence violates the ASSOCIATE CC/CV constraints. In languages that rank ASSOCIATE CC/CV high, the output may exhibit reorganization of the input gestures such that glottal stop does get parsed. This is the case in the languages in section 2.4, in which the gestures in sequences reorganize to a variety of non-sequential alignments using the TARGET and RELEASE landmarks of glottal stop.

As a background for the remaining discussion, the next subsection addresses the issue of syllable structure within the framework of Articulatory Phonology. I show that there is evidence to suggest that the relationship between an onset and its nucleus is instantiated by particular stable phasing relations that hold between them (Browman and Goldstein 2000, Nam and Saltzman 2003, Nam 2004, Goldstein *et al.* 2006). I suggest that this forces us to reconsider the formulation of the constraint ONSET – not only must this constraint make reference to gestures (rather than consonants and vowels), it must also make reference to the particular phasing relations that underlie syllable structure. This section also discusses the phasing relations that result in sequentiality among segments (for example, among members of consonant clusters).

3.3.1 *Gestural Accounts of Syllabic Relations*

A long-standing issue in Articulatory Phonology is the extent to which sound constituents that are key to traditional approaches to phonology (e.g. the segment, the syllable, the foot) carry over into a gestural approach to phonology. The approaches that researchers have taken to this issue vary with the constituent; for example, the segment is generally considered an unnecessary notion within Articulatory Phonology since the percept of a segment results from the overlap of independent gestures. At the same time, previous frameworks posited the existence of structure within the phonology based on recurring support for the existence of said structure; it would therefore be short-sighted to reject the notion of constituents like the syllable wholesale. If we are to incorporate the notion of the syllable into Articulatory Phonology, however, then we must show that the syllable has grounding in the relations among gestures in an utterance. Browman and

Goldstein (2000) accounted for one particular pattern that supports the existence of syllable structure: that there are stable phasing relationships between the gestures of members of syllable onsets, and between syllable onsets and following vowels (their C-CENTER effect). In other words, they addressed the observation that pre-vocalic consonants appear to act as a unit, a syllabic onset, without claiming syllable structure independent of the gestures of an utterance and the phasing relations that hold between them. In their paper, Browman and Goldstein (2000) proposed that the fact that onset consonants act as a unit falls out from the competing gestural phasing relationships in which those consonants participate; each consonant in the onset is phased to the following vowel, and all members are phased to each other. The C-C relation holding among onset members works to force a sequential articulation of those gestures, while the C-V relation works to force all onset members to be articulated synchronously (e.g. with the same phasing relation with respect to the vowel). Thus, the observed tight coordination both within onsets and between onsets and following vowels falls out from the need to satisfy both specified phasing relations maximally.

Discussion of the temporal relations that hold within syllables can be found in Byrd 1995, Byrd 1996, Krakow 1999, Browman and Goldstein 2000, Nam and Saltzman 2003, Nam 2004, Goldstein *et al.* 2006, among others. In this literature, it has been proposed that consonants that have traditionally been considered to be members of the syllable onset have a particular phasing relation with the following vowel. Specifically, onset consonants are phased such that the onset of the consonantal gesture is synchronous with the onset of the vocalic gesture; within the field of task dynamics, this is an inphase mode of coordination.²² This coordination is accomplished in the AP literature by coupling the dynamical equations for two gestures with either inphase (onset –to– nucleus) or antiphase (gesture₂ begins when gesture₁ ends; nucleus –to– coda) coordination modes.²³ See the abovementioned sources and references therein for further discussion of dynamical coupling, and its implications for explaining syllabic patterning.

Sequentiality of gestures in an utterance also results from particular phasing relations that hold between utterances. For example, the in-phase relationship between onsets and nuclei results in an illusory precedence relation between the consonantal gesture and the vocalic one.²⁴ Likewise, the observed precedence relation between codas and preceding

²² Note that within the Articulatory Phonology framework, the term ‘onset of a gesture’ refers to the physical event of the beginning of movement of the articulators toward the gestural target. Thus, it is a concrete physical landmark in the time course of the gesture. In contrast, the ONSET landmark in the AP in OT framework is an abstract representation of that physical event.

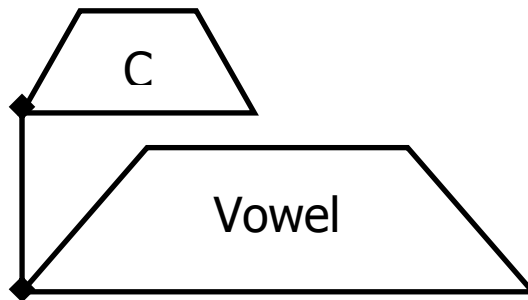
²³ ‘Coupling’ of gestures involves a mathematical coupling of the dynamical equations for each gesture, which is treated for the purpose of the equation as an ‘oscillator’. Within the field of task dynamics this sort of coupling has been shown successful in accounting mathematically for the relative cohesiveness of the inphase and antiphase coupling modes (inphase coupling is more cohesive than antiphase coupling), as well as the entrainment of coupled oscillators on an in-phase relation as frequency increases. Readers are directed to the works mentioned in section 1.2.2 and above, as well as references therein, for more discussion of task dynamics and the properties of coupled oscillators.

²⁴ This precedence relation is illusory because the vowel and consonant actually overlap, the latter being contained within the former. The percept of precedence comes about because a) the vowel articulation is obscured by the simultaneous consonantal constriction, and b) vowels are longer than consonants, so even

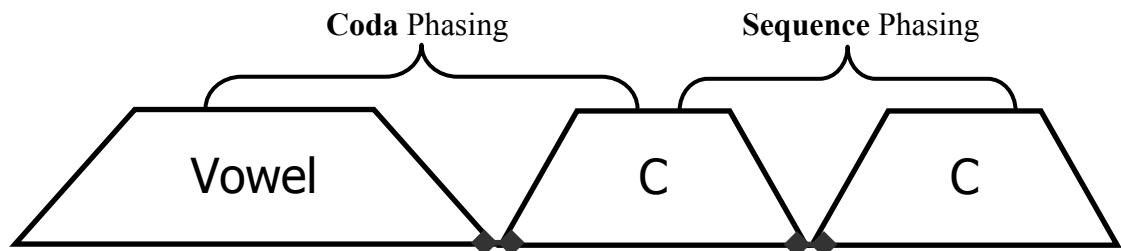
vowels result from the antiphase coordination between the coda and the nucleus. Additionally, precedence relations among members of onsets and codas result from their being coordinated antiphase to each other. In AP in OT terms, the ONSET of C2 coincides with the OFFSET of V. For example, Browman and Goldstein 2000 proposed that the antiphase coordination in sequences contributes to the C-CENTER effect; the specified sequential phasing for the consonants in onset competes with the specified inphase coordination holding between each consonant and the vowel (see section 3.4 for discussion). The AP literature has also argued that there is an antiphase relationship between members of codas (see for example, Browman and Goldstein 2000, Nam 2004), a coordination that is incorporated here as the C1 OFFSET –to– C2 ONSET alignment.

Based on the observation that onset consonants are stably phased to nuclei in this way, I propose that consonants will be treated as syllabic onsets just in case the associated gestures begin at the same point in time as the vocalic gesture. Thus, for onset consonants and following vowels, the specified phasing relationship that is observed to hold is one in which the ONSET landmark of the consonantal gesture is aligned to the ONSET landmark of the vocalic gesture. A schematic representation of the onset-nucleus phasing relation is sketched in (14a). (14b) shows the anti-phase relation holding between codas and their nuclei, and between members of codas. Note that members of multiple onsets will have the same underlying phasing relations as exhibited by the CC sequence in (14b), but will surface as overlapped due to pressure from the C-V relation (see discussion above, and in Browman and Goldstein 2000).

(14) a. Onset –to– Nucleus Phasing: C ONSET = V ONSET



b. Nucleus –to– Coda Phasing: V OFFSET = C ONSET
 Sequence Phasing: C₁ OFFSET = C₂ ONSET



though an onset consonant has the same starting point as an vowel, the vowel will continue after the consonant is no longer being produced.

Having discussed the particular phasing relations that have been observed to hold between syllable members, we can return to the question of whether abstract units of phonological organization like the syllable, the segment and the foot, have validity within the Articulatory Phonology framework. The research discussed above suggests that, at least for the syllable, abstract units of organization correspond to concrete modes of coordination between gestures. One implication of this research is that the traditional notion of what it means to be a syllabic onset is incorrect or incomplete; onsets are not merely consonants that precede vowels, they are consonants that stand in a particular phasing relationship to the vowel. That relationship is shown in AP in OT terms (e.g. with reference to gestural landmarks) in (15):

- (15) Onset Phasing: In a CV sequence, the ONSET landmark of the consonantal gesture is synchronous with the ONSET landmark of the vocalic gesture. (See diagram in (14a))

Given this elaborated understanding of the gestural grounding for the onset relationship, we can now reconsider the formulation of the OT constraint ONSET, as in (16). (16a) gives the standard OT definition of the ONSET constraint, and (16b) gives the revised definition of this same constraint, incorporating insights regarding the gestural relationship between syllabic onsets and syllabic nuclei. Note that the redefinition of the ONSET constraint is not substantially different from its standard formulation in its application, and instead essentially differs only in being phrased in gestural terms. However, as discussed in section 1.1.3, one result of incorporating the representational conventions of AP into OT is that every OT constraint will have to be redefined in gestural terms; constraints requiring, for example, faithfulness to input features will be incompatible with a framework in which features have been replaced by gestures.

- (16) a. Standard ONSET: All syllables should have onsets.
b. Revised ONSET: For every vocalic gesture, the ONSET landmark of some consonantal gesture should be synchronous with the ONSET landmark of that vocalic gesture.

The revised ONSET constraint will continue to apply to candidate outputs of the phonology in the standard way; outputs in which there exist vocalic gestures that are not phased ONSET-to-ONSET with a consonantal gesture will violate this constraint. If ONSET is high ranked in a given language, such a violation will be fatal. If it is not, the candidate will survive to either surface or be ruled out by other constraints. In fact, the revised ONSET constraint continues to account for all of the same phenomena that the standard ONSET constraint did – that is, with the exception of cases in which [ʔ] is the putative onset consonant. Recall that the main claim of section 3.2.2 was that the acoustic signature of the gesture of glottal constriction does not provide the perceptual

system with enough evidence to posit the gestural landmarks of ONSET and OFFSET. If [ʔ] lacks the gestural landmark of ONSET, then it is clear that [ʔ] will never be able to be phased to a following vowel in the manner required by the ONSET constraint, for it is exactly this missing landmark that would be necessary for it to satisfy the constraint.

I propose, therefore, that the fact that [ʔ] behaves differently from other consonants with respect to hiatus resolution-across-glottals and harmony-across-glottals falls out from the fact that it cannot be an onset to the following vowel in these configurations. Furthermore, the failure of glottal stop to participate in syllabic relations is a subcase of its inability to participate in *any* phasing relations that require coordination of the ONSET or OFFSET landmarks. Thus, the fact that underlying sequences with glottal stop are realized on the surface in various non-sequential configurations (e.g. in vowel intrusion patterns, and Cʔ coalescence) results because glottal stop fails to participate in sequential phasing relations. In the subsequent sections, I illustrate how the Landmark Underspecification analysis, when taken together with our renewed understanding of the phasing relations that underlie syllabic and sequential relations, can explain the patterning of glottal stop first presented in chapter 2.

3.3.2 *The Patterning of Glottal Stop in Onset and in Coda*

Let us start by briefly considering how the Landmark Underspecification account of glottal stop allows us to explain its patterning in onset and coda. Recall that sections 1.1 and 2.3 provided evidence that many languages avoid glottal stop onsets. Previous analyses of this pattern have claimed that it results from the presence of a constraint in the grammar that requires all onsets to be specified for PLACE (see for example, Ola Orié and Bricker 2000, Broselow 2001, Parker 2001, among others. This approach is also taken by, for example, Itô and Mester 1993, Lombardi 1995, and Padgett 1995 but is not limited to onset consonants).

In the Landmark Underspecification account, glottal stop is proposed to be a poor onset, not because it is placeless, but because it lacks the gestural landmarks that would allow it to satisfy the revised ONSET constraint in (16). Thus, even in languages that allow prevocalic glottal stops, glottal stops do not participate in phasing relations with adjacent gestures. In addition to incurring a violation of a high ranked ONSET (REVISED) constraint, an unparsed gesture will also incur a violation of the constraints in (17) (following Davidson (2003)):

- (17) a. ASSOCIATE CV: A consonantal gesture must have a coordination relationship with an adjacent vocalic gesture.
- b. ASSOCIATE CC: A consonantal gesture must have a coordination relationship with adjacent consonantal gestures.

The constraints in (17) require all gestures to be parsed into the global phasing relations of the utterance. Thus, they penalize forms with glottal stop because it is not parsed.²⁵ Positing the presence of both the revised ONSET constraint and the ASSOCIATE constraints in the grammar has some consequences for the patterning of pre-vocalic glottal stop. First, some languages will allow pre-vocalic glottal stop because the constraints in (16) and (17) are too low ranked to force repair (e.g. deletion of underlying [ʔ]), but regardless, glottal stop should never pattern as an onset. This appears to be the case for many of the languages discussed in chapter 2, in which the glottal stop is often retained in configurations in which there is harmony or hiatus resolution across it. Additionally, we must reconsider the motivation behind the common pattern of glottal stop epenthesis into prevocalic position; while most analyses of this process claim it results under pressure from ONSET, this cannot be the case under the Landmark Underspecification account. Instead, glottal stop epenthesis must have a non-syllabic motivation. As it turns out, the data on epenthesis of glottal stop suggest that this may be the case; languages that insert glottal stop prevocalically tend to do so in very limited environments (e.g. limited by prosody; phrase initial not phrase medial, before a stressed vowel not before an unstressed vowel, etc.). I return to the question of explaining languages that insert glottal stop prevocalically in section 4.2.

As for postvocalic glottal stop, by analogy with the discussion above I propose that postvocalic glottal stop is also never a coda. This proposal may be controversial in the light of patterns suggesting that intervocalic glottal stop is syllabified as a coda in many languages. For example, in Balantak, Chickasaw and Choctaw /VʔV/ is reportedly syllabified as [Vʔ.V] (Busenitz and Busenitz 1991, Broselow 2001, 2003, Ulrich 1993, Pam Munro (as quoted in *Linguist List* Vol-17-3292). In Palu'e and *Tukang Besi*, postvocalic glottal stop is never an onset. Finally, Chamicuro avoids glottal stop onsets, and the vast majority of codas are laryngeal (94%), suggesting a preference for glottal stop in coda position.

To reconcile these patterns with Landmark Underspecification, I suggest that native speaker judgments are not necessarily accurate representations of the presence or absence of syllabic phasing relations, since these correspond to fine grained distinctions in temporal relations. Instead, speakers may have subtle intuitions that intervocalic glottal stop is not cohesively phased to the following vowel and therefore they resist identifying it as an onset. Thus, in a forced choice between onset and coda, speakers will identify glottal stop as a coda. That is not to say that this gesture is actually phased with respect to the preceding vowel as a coda, only that speakers recognize that the glottal stop patterns more like a coda than like an onset. Recall that coda consonants are phased anti-phase to a preceding vowel, a coordination mode that is more weakly cohesive than the onset-to-nucleus in-phase coordination. Thus, speakers may have come to tacitly accept a greater degree of variability in phasing for coda consonants than for onset consonants, and they identify glottal stop as a coda because it is also variable.

Turning to the fact that languages like Chamicuro overwhelmingly prefer laryngeal consonants in coda position, this is not necessarily an indication that glottal stop

²⁵ This is not to say that glottal stop can never participate in phasing relations with other gestures in the utterance. However, any phasing relation in which it does participate must refer to its TARGET and RELEASE landmarks alone.

syllabifies as a coda either. Instead, it is possible that the extrasyllabicity of glottal stop allows it to escape the power of the NOCODA constraint, which rules out all supralaryngeal codas. First, consider the formulation of the NOCODA constraint in its standard instantiation, (18a), and gesturally defined in (18b):

- (18) a. Standard NOCODA: Syllables should not have codas
b. Revised NOCODA: the OFFSET of a vocalic gesture should not be synchronous with the ONSET of a consonantal gesture.

When undominated, the Revised NOCODA constraint will rule out all supralaryngeal codas, because supralaryngeal consonants can syllabify with the preceding vowel. In contrast, because glottal stop lacks the ONSET landmark referred to in (18b), it never syllabifies as a coda and its presence postvocally will be ignored. Thus, glottal stop survives in postvocalic position where other gestures do not, and interestingly, it *appears* to be preferred as a coda exactly because it can never *actually* be one.^{26,27} This proposal is additionally supported by data showing that V? sequences are often not realized as strictly sequential (as would be expected for elements in nucleus and coda), but instead exhibit various nonsequential alignments (e.g. V? → V?V). We return to this issue in section 3.3.5.

3.3.3 Translaryngeal Harmony Patterns and Required Identity Across Glottals

Turning to the phenomena of translaryngeal harmony and required identity-across-glottals, the data presented below in (19) repeat some examples of languages in which the vowels flanking glottal stops must be identical. This requirement may hold across intervocalic laryngeals in mono-morphemic words and also holds across morpheme boundaries when the underlying vowels are not identical. For example, the Yucatec Maya data in (19a,b) show that vowels flanking [ʔ] are identical in both monomorphemic and bimorphemic V?V. The same is true for Nez Perce (19c,d).

²⁶ This proposal remains difficult to reconcile with data from languages like Palu'e and Tukang Besi, in which V₁ in V₁?V₂ shows closed syllable allophones. This is unexpected if glottal stop is not a coda in this configuration. I leave this issue for future research.

²⁷ It was pointed out to me at my dissertation defense by members of my committee that the crucial test of coda-hood for glottal stop, or lack thereof, would be to investigate the patterning of glottal stop in quantity sensitive languages; are glottal stops treated as though they add weight to the syllable? The Landmark Underspecification proposal leads me to predict that they would not, but I do not have enough information to answer this question at the moment.

- (19) Yucatec Maya
- | | | | |
|----|----------------------|------------------------|-------------|
| a. | wiʔit | | ‘loincloth’ |
| b. | héʔ im b’ineʔ | → hiʔ im b’ine’ | ‘I will go’ |
- (Ola Orié and Bricker 2000)*
- Nez Perce
- | | | | |
|----|-------------------|---------------------|--------------------|
| c. | tuʔúnynu | | ‘tail’ |
| d. | hiʔel’wice | → heʔel’wice | ‘he spends winter’ |
- (Aoki 1970)*

While the languages presented in (19) exhibit the requirement that the vowels in a VʔV sequence be identical across-the-board, some languages show translaryngeal harmony in certain regular environments. For example, in Kashaya (20a-c) only the vowels in native monomorphemic VʔV forms are required to be identical, while VhV and VʔV sequences in loans and multi-morphemic forms need not obey this requirement.²⁸ In contrast, for Yapese VʔV, identity is only required of the vowels in the sequence if the sequence crosses a morpheme boundary (20d,e); monomorphemic VʔV may surface with non-identical vowels (20f).

- (20) Kashaya
- | | | | |
|----|------------------|--------------------|-------------|
| a. | maʔa | | ‘food, eat’ |
| b. | [kahón] | (from Sp. /kaxón/) | ‘box’ |
| c. | bi-ʔámhul | | ‘tomorrow’ |
- (Buckley 1994)*
- Yapese
- | | | | |
|----|------------------------|-----------------------|----------------------|
| d. | pardeʔ + i | → pardiʔiy | ‘to pound something’ |
| e. | ka-ʔu-i marwele | → kiʔi marwe:l | ‘he used to work’ |
| f. | luʔaag | | ‘my tears’ |
- (Jensen 1977)*

²⁸ The data in (20b) show that vowels flanking the laryngeal [h] in a Spanish loan are not required to be identical. We do not present an instance of loanword adaptation of a form with [ʔ] because no such loan exists (the Spanish consonant inventory does not include [ʔ]). Still, I suggest that the lack of translaryngeal harmony in loaned VhV suggest the same might have occurred with loaned VʔV but for this gap. This suggestion is supported by the fact that there are instances in which V_xʔV_y is allowed to surface in Kashaya, namely in multi-morphemic forms (20c).

Previous approaches to data of the sort shown in (19) and (20) have suggested that the placelessness of glottal stop contributes to its transparency to the spreading processes that occur in these languages. For example, Ola Orié and Bricker (2000) propose that the translaryngeal harmony processes occurring in Yucatec Maya result from the fact that onset consonants must be specified for oral place. They suggest that the assimilation of the vowels in a V_1V_2 sequence is a type of hiatus resolution process. The Landmark Underspecification account of the patterning of glottal stop takes a similar approach, one that also considers translaryngeal harmony processes to be instances of hiatus resolution. These harmony processes take place because the vowels in a V_1V_2 sequence are in hiatus as a result of glottal stop's failure to syllabify as an onset to V_2 , and crucially its failure to satisfy the revised ONSET constraint. The remainder of this subsection explains how and why this outcome arises.

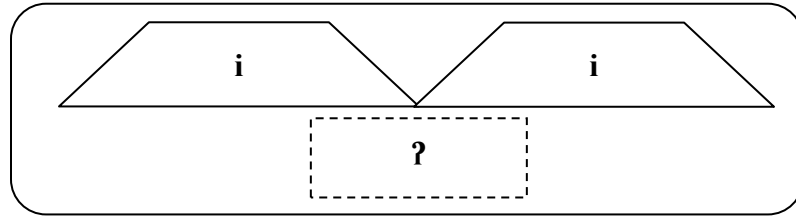
The Landmark Underspecification account of the internal gestural representation of glottal stop can straightforwardly handle the patterns exhibited by harmony-across-glottals languages like those shown in (19) and (20). In this approach, repair of the offending non-identical vowels in an underlying V_1V_2 sequence is a result of a constraint hierarchy in which the revised ONSET constraint is high ranked. Because the gesture of glottal constriction associated with the glottal stop fails to syllabify as an onset to the second vowel in a V_1V_2 sequence, the fully faithful output candidate will incur a fatal violation of ONSET (REVISED) ($\text{ONSET}_{(\text{REV})}$). Thus, the winning output candidate will diverge from the input in having undergone repair of the onsetless syllable. In the case of required identity-across-glottals languages, repair takes the form of coalescence of the two underlying vowels into a single output correspondent, which retains the gestural representation of one of the input vowels.

In fact, coalescence of the two vowels is what gives rise to the percept of assimilation; rather than one vowel taking on the features of another, the two vowels have become one long vowel. Note that a competing analysis of translaryngeal harmony patterns in which identity of the vowels in V_1V_2 results from an output form that contains a sequence of two distinct tokens of the same vowel is untenable. Under the assumption that feature spreading is motivated by the need to avoid an onset violation, the coalescence account is the only viable one; simply changing the feature specification of the initial vowel in a V_xV_y sequence would not avoid the ONSET violation at the $V_x - V_y$ juncture. Consider the schematic diagram of the two possible representations of the form in (19b), *hi?im b'ine* 'I will go', assimilation in (21a) and coalescence in (21b).²⁹

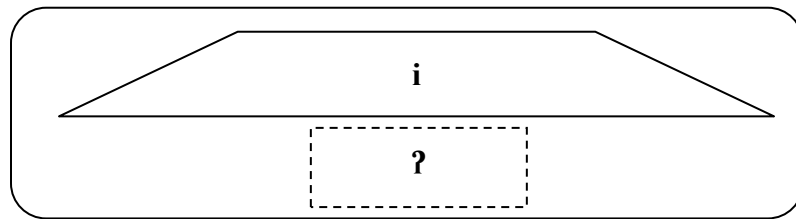
²⁹ In these diagrams, the glottal stop's activation interval is represented as a rectangle to capture graphically the proposal that glottal stop lacks the gestural landmarks of ONSET and OFFSET. Additionally, while I do not identify any phasing relations as holding between glottal stop and the overlapping vowel, it is possible that one obtains. In this case, glottal stop can be phased to the vowel in any configuration so long as it only makes reference to its TARGET and OFFSET landmarks. Because the exact nature of the phasing relations that hold between glottal stop and the vowel (if any) are not crucial to the discussion of required identity, I do not include them here.

(21) Yucatec Maya: /heʔ im b'ine'/ → [hiʔ im b'ine'] 'I will go'

a. Translaryngeal Harmony via Assimilation



b. Translaryngeal Harmony via Coalescence



The diagrams in (21a,b) show that there are two possible ways for identical vowels to arise from an underlying $V_xʔV_y$ sequence; through assimilation or through coalescence. However, only the latter output will satisfy the $ONSET_{(REV)}$ constraint; assimilation does not help the problem that V_2 in a $V_1ʔV_2$ sequence heads an onsetless syllable. In either case, the glottal stop remains unparsed into the syllable structure of the utterance (as indicated by its dashed border). Furthermore, while the coalesced example in (21b) contains a single vowel on the surface, the percept of two vowels is an illusion of the fact that the output vowel spans the glottal constriction. Additional data that suggest that offending $V_xʔV_y$ sequences are repaired in this way comes from the treatment of the underlying form *maʔ ʔak-táan* in Yucatec Maya; the output of this form undergoes hiatus resolution through glide insertion, becoming *mawak-táan* 'it is not opposite me.' If it were sufficient that each of the vowels flanking glottal stop be identical, then there should be no repair of *maʔ ʔak-táan*. Instead, the vowels flanking laryngeals must be identical *and* each must have an onset. This requirement is accomplished for *maʔ ʔak-táan* through glide insertion.

Let us turn now to see how the constraint ranking of a language like Yucatec Maya will conspire to force hiatus resolution through coalescence in the case of forms like /heʔ im b'ine'/. In the case of required identity-across-glottals languages, the actual output candidate avoids the $ONSET_{(REV.)}$ violation at the cost of violating the constraint

UNIFORMITY.³⁰ The result is an optimal candidate in which the two underlying vowels have coalesced into one. Additionally, the fact that other repair strategies, for example consonant deletion and epenthesis, are not employed in Yucatec Maya suggests that the corresponding OT constraints (DEP_{I-O} (C) and MAX_{I-O} (C)) are at least as high ranked as the ONSET_(REV.) constraint. The fact that the constraint ranking of ONSET_(REV.) over UNIFORMITY results in the observed identity of the vowels in an underlying V_x?V_y sequence is illustrated by the tableau in (22).^{31,32}

(22) Yucatec Maya; /he ?im b'ine?/ → [hi ?im b'ine?] 'I will go'

Input: he ?im	DEP	MAX	ONSET (REVISED)	UNIFORMITY
...				
1. he <?>im...			*!	
2. he im...		*!	*	
3. he t<?>im	*!			
4. he tim	*!	*		
5. hi _x <?>i _y m			*!	
6. hi _x <?>i _x m				*

³⁰ UNIFORMITY: Output segments (gestures) should have at most one input correspondent. (McCarthy and Prince 1995, Lamontagne and Rice 1995, de Lacy 2000).

³¹ In this tableau, and the following, the fact that an underlying [ʔ] is not parsed into the surface syllable structure is indicated by the surrounding brackets. Note also that one possible candidate would be one in which the glottal stop has been parsed into the syllable as an onset. However, since onsets are defined as consonants that are phased ONSET-to-ONSET with a following vowel, the gesture of glottal constriction is precluded from being syllabified as an onset; GEN could not create such a candidate. We return to the issue of apparent glottal stop onsets in chapter 4, in which I suggest that putative cases of [ʔ] onsets are illusory; either [ʔ] is present but is not an onset, or glottal stop is a multi-gestural segment in which one of its non-glottal gestures syllabifies as an onset to the vowel.

³² The fact that the [i] vowels in candidate 5 of Tableau 14 have undergone coalescence is indicated by their sharing the same subscript.

In the tableau in (22), we see that the faithful candidate in (1) is ruled out because it incurs a fatal violation of the constraint $\text{ONSET}_{(\text{REV.})}$.³³ Candidate (2) likewise fatally violates $\text{ONSET}_{(\text{REV.})}$, but has also deleted the extrasyllabic [ʔ], violating $\text{MAX}_{\text{I-O}}(\text{C})$. The candidate in (3) avoids a violation of the $\text{ONSET}_{(\text{REV.})}$ constraint by inserting a /t/ to provide an onset to V_2 , but in so doing incurs a fatal violation of $\text{DEP}_{\text{I-O}}(\text{C})$. Candidate (4) incurs no violation of $\text{ONSET}_{(\text{REV.})}$, and no longer contains the extrasyllabic glottal stop.³⁴ However, this candidate instead fatally violates both $\text{MAX}_{\text{I-O}}(\text{C})$ and $\text{DEP}_{\text{I-O}}(\text{C})$. The fate of candidate (5) further demonstrates that coalescence, rather than assimilation, must occur in the winning output. Here, the vowels assimilate but remain distinct, and thus this candidate incurs a fatal violation of $\text{ONSET}_{(\text{REV.})}$. The only remaining candidate is the one in (6), which has undergone coalescence of the two underlying vowels /e₁/ and /i₂/ and which violates only the low ranked constraint UNIFORMITY .

This discussion has shown that the Landmark Underspecification analysis, and the consequent failure of glottal stop to participate in syllabic and other phasing relations, allows us to easily explain why some languages require the vowels flanking glottal stop to be identical. The conclusion we draw is that translaryngeal harmony processes are actually hiatus resolution processes. The fact that these patterns appear to involve feature spreading is a consequence of the fact that the constraint ranking of translaryngeal harmony languages conspires to allow only coalescence as a means of repairing an $\text{ONSET}_{(\text{REV.})}$ violation.

Turning now to the case of hiatus resolution-like patterns occurring in V?V , I suggest that a similar account is available for this phenomenon. Essentially, required identity-across-glottal stop and hiatus resolution-across-glottal stop patterns are subcases of the same phenomenon; the apparent divergence between the two patterns results from the language-specific ranking of the ONSET constraint with respect to constraints ruling out repair (e.g. UNIFORMITY , DEP , NODIPHTHONG , etc.).

3.3.4 *Hiatus Resolution Across Glottals*

The data in (23) give representative examples from languages in which hiatus resolution-like patterns occur in V?V despite the presence of a glottal stop. As discussed in section 2.3, these patterns present a problem for standard OT approaches to hiatus

³³ Note that in the case of the form [hiʔ im b'ineʔ], the coalesced vowel [i] should take the initial [h] as its onset. However, this brings up the question of whether [h] itself can be an onset to the vowel. Though we return to this question in more detail in section 3.4, one possibility is that like [ʔ] the [h] is not an onset to the syllable headed by [i]. Thus, winning output in (22:6) will incur a single violation of the constraint $\text{ONSET}(\text{REVISED})$, whereas the faithful candidate will be ruled out by two violations of this constraint. It is also possible that other constraints in the grammar conspire to make it impossible to repair initial $\text{ONSET}(\text{REVISED})$ violations in Yucatec Maya (e.g. McCarthy and Prince's (1995) $\text{ALIGN LEFT}(\text{ROOT}, \text{PRWD})$ constraint).

³⁴ Deletion of an extrasyllabic or unparsed gesture might also result from a constraint hierarchy that highly ranks the ASSOCIATE constraints (17).

resolution, which attribute it to the action of the constraint ONSET; presumably, glottal stop should provide an onset to the following vowel and block hiatus resolution. However, given the gesturally grounded redefinition of the ONSET constraint proposed here, the fact that [ʔ] doesn't block hiatus in the languages in (23) is easily explained.

(23) Yatzachi Zapotec

- a. /zetʃa + eʔ/ → [zetʃeʔ] 'he stands'
 /tʃʃagnaʔ + eʔ/ → [tʃʃagneʔe] 'he marries'

(Butler-Haworth 1980, Borroff 2003, 2005)

Yucatec Maya

- b. /le meesa + eʔ/ → [le meesaye] 'that table'
 /maʔ + ʔak-taan/ → [mawak-taan] 'it is not opposite to me'

(Ola Orié and Bricker (2000))

Chemehuevi

- c. /tɛkavɛɛuka/ → [tɛkavɛɛɛk] 'ate it'
 /nukwɛɛʔumi/ → [nukwɛɛʔɛmi] 'run (pl.)'

(Press 1979)

Wichita

- d. /ʔiri + a:has/ → [ʔira:has] 'wet the bed'
 /ti + ʔak + hisha/ → [taʔakhisha] 'they went'

(Rood 1976)

Yapese

- e. /fai + ng/ → [fe:ng] 'to find something'
 /ka+ʔa+i mi:l/ → [keʔe mi:l] 'he ran first'

(Jensen 1977)

Chickasaw

- f. /tof-to-a/ → [toftowa] 'to spit more than once'
 /chikoʔ-a/ → [chikoʔwa] 'to be all sticking up'

(Ulrich 1993)

Like languages that require the vowels flanking glottal stop to be identical, languages that repair hiatus in VʔV sequences rank the constraint ONSET_(REV.) high, as exhibited by the fact that hiatus does not survive into the output in VV sequences (cf. the first examples in (23a-f)). Thus, under the proposal that [ʔ] does not satisfy the ONSET_(REV.) constraint due to its underspecification for the gestural landmarks of ONSET and

OFFSET, V?V sequences will fatally violate $\text{ONSET}_{(\text{REV.})}$. The type of repair strategy (e.g. coalescence, epenthesis, diphthongization) that a form will undergo is determined by the language specific ranking of constraints in the grammar. For example, a constraint ranking of $\text{ONSET}_{(\text{REV.})} \gg \text{MAX}_{\text{I-O}}(\text{C}), \text{DEP}_{\text{I-O}}(\text{C}), \text{UNIFORMITY}, \text{NODIPHTHONG}$ might distinguish a language exhibiting hiatus resolution-across-glottals from one exhibiting required identity-across-glottals. A concrete example of the local constraint hierarchy in a hiatus resolution-across-glottals language is provided in (24) for Yatzachi Zapotec:

(24) $\text{DEP}_{\text{I-O}}\text{C}, \text{MAX}_{\text{I-O}}\text{V}, \text{ONSET}(\text{REVISED}) \gg \text{UNIFORMITY}, \text{NODIPHTHONG}$

The relative ranking among the anti-repair constraints can be determined by considering the various repair strategies employed in each distinct context. Because consonant insertion and vowel deletion are not employed as repair strategies for hiatus in Yatzachi Zapotec at all, we can conclude that $\text{ONSET}_{(\text{REV.})}$ dominates neither $\text{DEP}_{\text{I-O}}(\text{C})$ nor $\text{MAX}_{\text{I-O}}(\text{C})$, though the relative ranking between the three constraints is indeterminate. The observed coalescence and diphthongization employed in Yatzachi Zapotec (cf. the coalescence in (23a)) results from the fact that ONSET dominates both UNIFORMITY and NODIPHTHONG .³⁵ The fact that the proposed constraint ranking can handle both the VV and V?V hiatus resolution patterns in YZ is illustrated in the tableaux in (25) and (26). These tableaux deal only with the relative ranking of $\text{DEP}_{\text{I-O}}(\text{C}), \text{MAX}_{\text{I-O}}(\text{C}), \text{ONSET}_{(\text{REV.})}$ and NODIPHTHONG , ignoring for the moment the ranking of UNIFORMITY .³⁶

³⁵ An important question that remains with respect to the YZ constraint ranking is how to account for the fact that coalescence occurs in some forms (including in identical vowel sequences, sequences with schwa, and [ae, a?e] sequences,) while diphthongization occurs elsewhere. This issue is dealt with in detail in Borroff 2003, in which the author proposes that the choice between coalescence and diphthongization is made largely on the basis of sonority concerns. In brief, diphthongization is the default repair strategy, but is ruled out if the resulting diphthong would be rising in sonority or exhibit a shallow sonority contour. Directional variation in coalescence ([ae → e], but [ea → ia]) results from an interaction of sonority and morpheme recoverability constraints (e.g. preserve the more sonorous vowel if it is the sole element in a morpheme). The result is a constraint ranking of $\text{UNIFORMITY} \gg \text{NODIPHTHONG}$, interleaved with constraints on diphthong sonority and morpheme recoverability.

³⁶ In Tableaux (25), (26), the subscript ‘x’s on the vowels in a sequence (eg. candidate (25:4) and (26:5)) indicate that both vowels from a unit together, namely, a diphthong.

(25) Yatzachi Zapotec; /tʃne + oʔ/ → [tʃnjoʔ] ‘You speak’

Input ...e+oʔ	DEP _{I-O} (C)	MAX _{I-O} (C),	ONSET (R)	NODIPHTHONG
1. e.oʔ			*!	
2. etoʔ	*!			
3. eʔ		*!		
☞ 4. j _x o _x ʔ				*

In the tableau in (25), the high ranking of the constraints DEP_{I-O}(C), MAX_{I-O}(C), and ONSET_(REV.) is established by the fact that the candidates that violate these constraints, (1)-(3), do not survive into the output; thus violation of each of these constraints is shown to be fatal. The winning candidate (4), on the other hand, violates only NODIPHTHONG. The fact that this candidate can surface as the optimal candidate despite violating NODIPHTHONG supports the proposal that this constraint is relatively low ranked.

(26) Yatzachi Zapotec; /tʃbeʔ + oʔ/ → [tʃbjʔo]

Input ...e+oʔ	DEP	MAX	ONSET	NODIPHTHONG
1. e<ʔ>oʔ			*!	
2. etoʔ	*!	*		
3. et<ʔ>o	*!			
4. eʔ		*!		
☞ 5. j _x <ʔ>o _x				*

In this tableau, the fully faithful form is candidate (1), in which the extrasyllabic glottal stop is present, but the /o/ vowel lacks an onset. Thus, this candidate fatally violates the ONSET_(REV.) constraint. The candidates in (2) – (4) fare better than candidate (1) with respect to this constraint, but each avoids the ONSET violation by fatally violating at least one other constraint in the hierarchy. The result is that the only remaining

candidate is the one in which the two underlying vowels form a diphthong on the surface, thereby avoiding the $\text{ONSET}_{(\text{REV.})}$ violation.³⁷

In the next section, I turn to explaining the observation that underlying sequences with glottal stop often fail to be realized on the surface as strictly sequential. In this discussion, I address two patterns in particular; these are patterns in which vocalic gestures overlap an adjacent glottal stop ($V\? \rightarrow V\?V$) and patterns in which underlying $C\?$ sequences surface as single units ($C\? \rightarrow C'$).

3.3.5 Temporal Variability of Glottal Stop

In this section, I present an analysis of patterns that show a cross-linguistic tendency for sequences with glottal stop to fail to surface as sequential in such patterns as vowel intrusion (e.g. $V_1\?C \rightarrow V_1\?V_1C$), and related patterns of overlap of glottal stop by adjacent vocalic and consonantal gestures. Additionally, I address the pattern of $C\?$ and $V\?$ coalescence in which the underlying gestures surface in non-sequential configurations approximating simultaneity.³⁸

³⁷ In truth, it is likely that diphthongs are not appropriately represented as single units within AP; were it the case that a diphthong were a single unit, that unit would have to be represented as a single vocalic gesture with multiple conflicting targets. For example, the diphthong [ar] would have a single Tongue Body target that is specified with a palatal TBCD of both {WIDE} and {NARROW}. Such an approach was presented in Borroff 2003, in which I suggested that diphthongs result from the articulatory system's attempt to reconcile the conflicting target specification. Here, I propose instead that diphthongs are not single units gesturally, but rather are comprised of two vocalic gestures. The cohesion among members of diphthongs results from the fact that in a diphthong both vocalic gestures take the same consonant as its onset (e.g. the consonant that precedes V_1). In these forms, each vowel is specified to hold an ONSET-to-ONSET configuration with the preceding consonant, but they are also specified to hold an ONSET-to-OFFSET configuration between them (V_1 -to- V_2). The C-V and V-V phasing relations are in conflict such that no one relation can be faithfully implemented without violating all others. The result is an output in which the two vocalic gestures overlap in order to deviate only minimally from each specified phasing relation, resulting in the percept of a diphthong. The observed fact that diphthongs pattern as a unit results from the strength of the in-phase relationship between C and V_1 , and C and V_2 . Thus, diphthongs come about from a V-CENTER effect that is exactly analogous to Browman and Goldstein's (2000) C-CENTER effect, and for the same reasons (competition among conflicting phasing relations). A similar analysis was presented in Marin 2004 for Rumanian diphthongs, which were proposed to result from simultaneity of vocalic gestures.

³⁸ For the purposes of this section, I ignore cases of true echo-epenthesis. These are patterns in which epenthetic copy vowels can be shown to have been inserted into the utterance, for example because they add to the syllable count of the form into which they are epenthesized. Recall that vowel intrusion and overlap patterns result in outputs that tend not to be treated as disyllabic, and that are susceptible to prosodically conditioned variation. See Hall 2003 and section 2.4 for more discussion. Within the context of echo-epenthesis across glottal stop, a Landmark Underspecification account is also possible; in this approach, the echoic nature of the epenthetic vowel results under pressure from the high-ranked ONSET (R) constraint. Thus, echo-epenthesis in $V\?V$ is the result of a translaryngeal harmony process, and can be explained in the same way (e.g. two underlying vowels coalesce but may retain both moras).

I propose that the Landmark Underspecification account provides an explanation of the fact that glottal stop is more likely than the supralaryngeal segments to intrude upon the span of an adjacent consonant or vowel, and that underlying sequences are reorganized to non-sequential phasing. In brief, the lack of the gestural landmarks of ONSET and OFFSET results in the failure of the gesture of glottal constriction to participate in the phasing relations that would result in strict sequentiality with an adjacent gesture. Consequently, the output undergoes reorganization of the sequence to a configuration in which glottal stop is phased to the other gesture via its TARGET or RELEASE landmarks.

The data in (27) show some representative examples of vowel intrusion into clusters with glottal stop:

(27) Kekchi

a. $kwaʔ + k \rightarrow kwaʔak$ ‘to eat (transitive)’

b. $seʔ + k \rightarrow seʔek$ ‘to laugh’

(Campbell (1974), Hall (2003))

Chamicuro

c. $túʔlu \rightarrow túʔulu$ ‘chest’

d. $maʔnáli \rightarrow maʔanáli$ ‘dog’

(Parker (1994), Hall (2004))

Choapan Zapotec

e. $bɛʔgídiʔ \rightarrow bɛʔɛgídiʔ$ ‘bat’

(Lyman and Lyman (1977), p. 145)

These vowel intrusion patterns share certain regular characteristics discussed in Hall 2003. For example, vowel intrusion does not add to the syllable count of the word (Kekchi (27a,b)), and is often subject to influence from speech rate (e.g. occurring in emphatic speech in Chamicuro (27c,d), but in fast speech in Choapan Zapotec (27e)). Following Hall (2003), I propose that vowel intrusion results from overlap of the vocalic gesture over the consonantal cluster. For her, this overlap is forced by gestural alignment constraints requiring nucleic vocalic gestures to span the consonantal gestures in its onset and coda. However, though much of the vowel intrusion data support an account whereby overlap is constrained by syllable affiliation, additional data suggest that gestural overlap of glottal stop is more widely available than Hall’s (2003) analysis would predict. For example, the *Tukang Besi* data in (28a,b) show overlap of a vowel over a preceding glottal stop. The direction of overlap in these examples is only predicted by Hall’s (2003) analysis if intervocalic glottal stop is an onset in *Tukang Besi*, but recall that *Tukang Besi* glottal stop patterns as a coda in VʔV (see discussion in sections 2.3 and 2.4). Moreover, Hall’s (2003) account of overlap via gestural alignment constraints that require vocalic nuclei to overlap gestures in its coda and onset fails to explain variation of glottal stop in non-vocalic contexts. For example, (28c,d) show that a consonantal gesture ([j], [w]) may also overlap an underlying glottal stop.

(28) Tukang Besi

- a. /goraʔu/ → [goraʔu] ~ [gora^wʔu] ‘egg’
b. /moʔini/ → [moʔini] ~ [mo^jʔini] ‘shy, embarrassed’
(Donohue 1999, p. 24)

Arbore

- c. ʔiy dayʔ-e → ʔiy dajʔje ‘he guarded’
d. ɲáwʔ-a → ɲáwʔwa ‘(it) is a crocodile’
(Hayward (1984) p. 77-78)

The examples in (28) suggest that overlap of glottal stop by an adjacent vocalic segment occurs independently of the normal constraints on vowel intrusion; it does not accord with syllable affiliation, and neither is it limited to vocalic contexts. I suggest that the wide range of data on vowel and consonant overlap over underlyingly adjacent glottal stop indicate a failure of glottal stop to participate in the phasing relations that would anchor it sequentially. That this is the case is supported by data showing that glottal stop resists sequentiality even outside the contexts of the types of gestural overlap shown in (27) and (28) (e.g. other than overlap that results in the percept of two instances of the overlapping element; Vʔ or ʔV → VʔV in (27) and (28a,b) or Gʔ → GʔG in (28c,d)). Additional patterns in which underlying sequences with glottal stop are realized with overlap of the elements in the sequence come from languages that exhibit coalescence of Cʔ sequences. This pattern is exhibited by the data in (29) from Kashaya and Yurok, (29a-c) and (29d-e) respectively.

(29) Kashaya

- a. s^huwac-ʔk^he → s^huwac^hk^he ‘will dry’
b. p^hak^hu:m-ʔk^he → p^hak^hu:m^hk^he ‘will kill’
c. p^ha-nem-n^ho → p^hanemʔdo → p^hanem^hdo ‘they say he punched’
(Buckley 1994)

Yurok

- d. kesomewep-ʔ → kesomewep^h ‘be lonely’
e. holim-ʔ → holim^h ‘weave baskets’
f. ten-ʔahsp → ten^hasp ‘to be drunk’
(Blevins 2003)

The data in (27)-(29) demonstrate that glottal stop fails to participate in the phasing relations that would result in sequentiality. These phasing relations are V ONSET –to– ʔ

ONSET for prevocalic glottal stop, ? ONSET –to– C OFFSET for glottal stop initial consonant sequences, and C/V OFFSET –to– ? ONSET for glottal stop final sequences. Glottal stop fails to participate in these phasing relations because it is underspecified for the required gestural landmarks, namely ONSET and OFFSET. The general unavailability of sequentiality for glottal stop may be the source of Hall’s (2003) observation that clusters with glottal stop are more likely to exhibit vowel intrusion than clusters with other consonants; Hall’s (2003) vowel intrusion constraints are confounded with glottal stop’s greater general tendency to show rephasing from sequentiality.

Turning to the details of the analysis, reorganization of sequences with glottal stop results in languages that rank the constraints in (18), repeated here in (30), high. These constraints require that adjacent gestures be phased to one another, and have the effect of ruling out unparsed gestures.

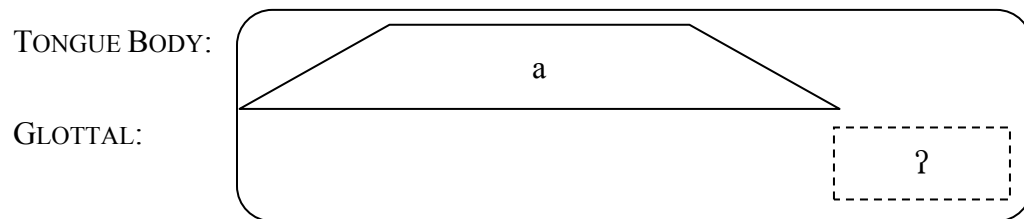
- (30) a. ASSOCIATE CV: Consonantal gestures must have coordination relationships with adjacent vocalic gestures.
- b. ASSOCIATE CC: Consonantal gestures must have coordination relationships with adjacent consonantal gestures.

That high-ranked ASSOCIATE constraints rule out sequences with glottal stop is shown in the tableaux in (31a) and (32a) for Kekchi vowel intrusion and Yurok C? coalescence, respectively. In these tableaux and each of the following, an unparsed glottal stop is surrounded by brackets. Here, we identify the phasing relations holding between the relevant gestures in each candidate (e.g. the glottal and adjacent vocalic or consonantal gestures) beneath the IPA transcription of that candidate (*Phasing* $\mathcal{R} = X$). Note that the actual phasing relations that obtain in the optimal candidate may vary from language to language, and the ones presented in the tableaux are hypothetical. They serve only to indicate that the glottal stop has been reorganized to a non-sequential alignment. I return to the issue of what might be the particular phasing relations that hold between the glottal and non-glottal gestures below. Finally, in the (31b,c) and (32b,c) we give a hypothetical gestural score for the winning and losing candidates for each tableau.

(31) a. Kekchi [V?C]; $kwa_x? + k \rightarrow kwa_x?a_xk$ ‘to eat (transitive)’

Input: / kwa? <i>?</i> -k / <i>Phase Relations:</i> \emptyset	ASSOCIATE CV	VC PHASING ³⁹
1. a< <i>?</i> > <i>Phase R:</i> \emptyset	*!	*
2. a? <i>a</i> <i>{? RELEASE=</i> <i>/a/ RELEASE}</i> :		*

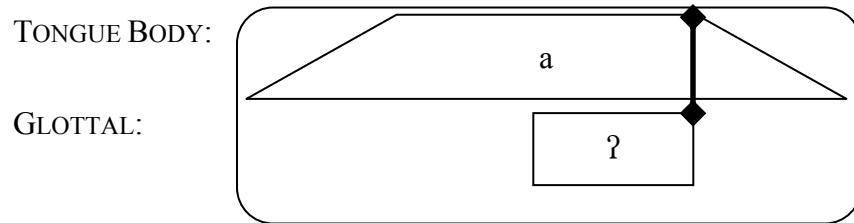
b. Hypothetical gestural score for Candidate 1: a<*?*>



✗ *Fatally violates ASSOCIATE CV*

³⁹ The VC phasing and CC phasing constraints in (31) and (32) are stand-ins for constraints that mediate the preferred phasing relations between VC and CC sequences. Here, these are V OFFSET –to– C ONSET and C₁ OFFSET –to– C₂ ONSET.

c. Hypothetical gestural score for V? Candidate 2: $a?a^{40}$



✓ *Does not violate ASSOCIATE CV*

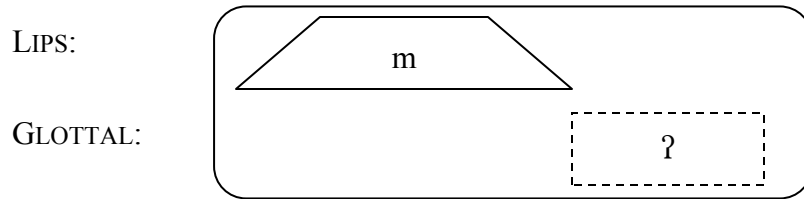
The tableau in (31) demonstrates that a high-ranked ASSOCIATE CV constraint will rule out forms with unparsed glottal stop (as in Candidate 1), in favor of forms in which the glottal stop has been rephased via its TARGET or RELEASE landmarks (Candidate 2). The tableau in (32) turns to the case of C? Coalescence in Yurok.

(32) a. Yurok C? → C'; holim-? → holim' 'weave baskets'

Input: /m?/ <i>Phase Relations:</i> ∅	ASSOCIATE CC	CC PHASING
1. m<?> <i>Phase ℛ:</i> ∅	*!	
2. 'm <i>Phase ℛ:</i> {?} <i>TARGET = C</i> <i>ONSET</i> }:		*

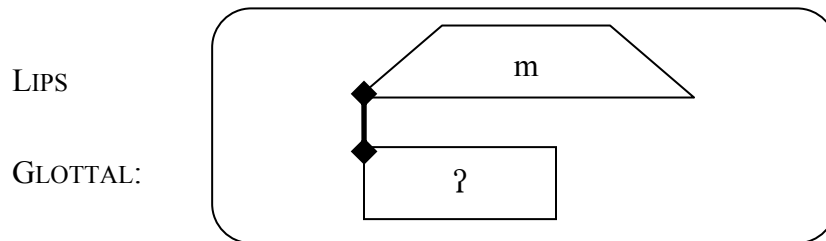
⁴⁰ Further study is required to determine what are the actual temporal relations that hold between V and ? in the context of vowel intrusion. The open possibilities depend on the landmark structure of vowels. For example, as will be discussed in section 3.4, I argue that we cannot uphold the C-CENTER landmark for closure gestures. Thus, an approach whereby the glottal stop is rephased such that its TARGET or RELEASE landmark is aligned to a hypothetical V-CENTER landmark may be unavailable.

b. Gestural score for C? candidate 1: $m<?>$



✗ *Fatally violates ASSOCIATE CC*

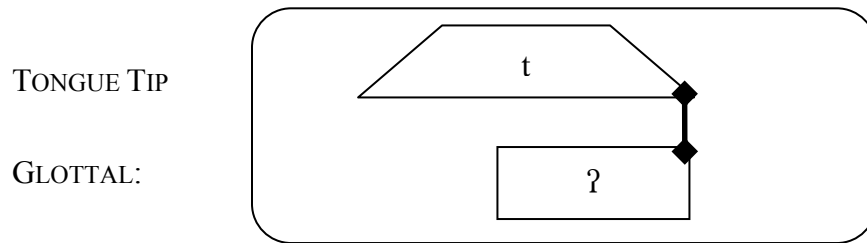
c. Gestural score for C?: winning candidate



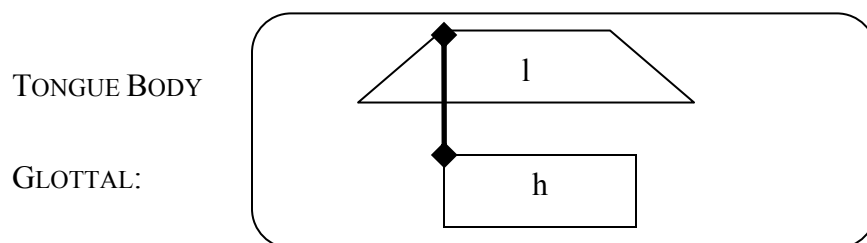
✓ *Does not violate ASSOCIATE CC*

The tableau in (32) illustrates that a constraint ranking of ASSOCIATE CC >> CC PHASING will result in repair of an unparsed glottal gesture. While the ultimate phasing relations that obtain as a means of satisfying ASSOCIATE CC will be language specific, and are not strictly of interest here, I note that differences in the phasing relations implemented may be a source of divergence cross-linguistically. For example, the hypothetical phasing relation between C and ? diagrammed in (32c) may be the correct one to account for preglottalization in Yurok (see Blevins (2003) for discussion of preglottalization in Yurok). Furthermore, Kashaya's postglottalized sonorants may result from a hypothetical phasing relation along the lines of that sketched in (33a). Note that one additional possible phasing relation, in which the TARGET of the laryngeal gesture is synchronous with the TARGET of the consonantal gesture, may underlie forms that have the percept of glottalization throughout the entire length of the consonant. This is shown in (33b) for a Yavapai example from (60) in chapter 2; (/hla/ → [lá] 'moon').

- (33) a. Post-glottalization in Kashaya ($\text{ʃeʔet-ʔ} \rightarrow \text{ʃeʔet}$ ‘it is a basket’)



- b. Voiceless R in Yavapai ($/\text{hla}/ \rightarrow [\text{ɰá}]$ ‘moon’)



To summarize the findings of this section, patterns in which underlying sequences with glottal stop are realized on the surface with non-sequential coordination between the members of the sequence can be accounted for by positing high ranked ASSOCIATE CC/CV constraints. Glottal stop fails to satisfy these constraints without reorganization because the glottal gesture is underspecified for the landmarks that would allow it to be realized as sequential.⁴¹ Glottal stop is distinguished from the supralaryngeal consonants in exhibiting reorganization, because supralaryngeal consonants can participate in strictly sequential phasing relations, thus satisfying both ASSOCIATE CC/CV and VC/CC PHASING. Importantly, rephasing of sequences with supralaryngeal consonants will be unmotivated, and will incur gratuitous violations of these constraints. Additionally, supralaryngeal consonants will generally not surface as extrasyllabic because such a form would violate both ASSOCIATE CC/CV and VC/CC PHASING (prevocalic supralaryngeal consonants will also violate ONSET_(REV.)). Glottal stop, on the other hand, cannot fail to surface so.

The account sketched here holds of vowel intrusion phenomena (31), and Cʔ coalescence phenomena (32). Additionally, such an analysis can be extended to handle some patterns of Vʔ coalescence, in particular those in which the constriction associated

⁴¹ Note that another possible response to a fatal violation of ASSOCIATE CC/CV might be to delete the glottal gesture altogether. In fact, this form would fare better than the actual winning candidates in languages like Kekchi and Yurok, which continue to violate constraints on the preferred VC and CV phasing relations. For this reason, another constraint must work to preclude glottal stop deletion in these languages (for example, MAX_{I-O}(C)).

with the glottal gesture is realized as simultaneous with the vowel. Such a process was briefly mentioned in section 2.4 as a precursor to tonogenesis in some modern tonal Athabaskan variants (Krauss 1979:2005, Leer 1979, 1999, Kingston 2005) and in Ancient Chinese (Egerod 1971), and is implicated in tonogenesis in (at least) Hmong-Mien (M. Ratliff, p.c. 2006).⁴²

A final question to address in this section is what happens in languages that rank both the ASSOCIATE and the PHASING constraints low. One possibility is that we will observe unconstrained variation in the position of glottal stop with respect to adjacent gestures. This is perhaps the case in a language like Arbore (53d,e) section 2.4, repeated here in (34), in which there is token-to-token variation in the position of glottal stop with respect to an adjacent long vowel (V:ʔ alternates with VʔV):

- (34) Arbore
- | | | | | |
|----|--------------|---|-------------------|-------------|
| a. | be:k-t-aw | → | be:ʔtaw / beʔetaw | ‘my wound’ |
| b. | ʔina gá:d-ne | → | ga:ʔne / gaʔane | ‘we buried’ |
- (Hayward 1984)*

One question that arises here is what factors do constrain the variation of glottal stop: if glottal stop is unparsed in Arbore, why does it appear that it only varies with respect to the immediately preceding gesture, rather than the whole utterance?⁴³ One possible response is that wider variation is dispreferred by constraints other than those mediating phasing relations (e.g. a contiguity constraint, assuming contiguity can be calculated for an unparsed element). On the other hand, the Uma data from (48) of chapter 2 might present a case in which glottal stop is mobile beyond the immediately adjacent gestures; Martens and Martens (1988) state that glottal stop metathesizes with derivational

⁴² Note that an analysis whereby Vʔ sequences rephase to simultaneity will not account for patterns of Vʔ coalescence that result in compensatory lengthening (e.g. in Colloquial Tehrani Farsi (Darzi 1991, Sumner 1991, Kavitskaya 2002, see Kavitskaya 2002 for detailed discussion of this phenomenon). Crucially, a simultaneous sequence should have the timing of a single element, rather than of two. Thus, there must be a different explanation for Vʔ coalescence in compensatory lengthening. One that is offered by Kavitskaya (2002) is that languages may have glottal stops that are either consonant like or vowel like, and that loss of the latter causes mora preserving compensatory lengthening (though following Sumner 1999, I propose that this is coalescence). Kavitskaya supports her proposal with evidence that shows that Colloquial Tehrani Farsi glottal stop never reaches the full consonantal constriction expected from a stop consonant. The approach I would suggest is similar, but does not claim that glottal stop may be underlyingly vocalic, contra Kavitskaya (2002). Instead, I suggest that vocalic status for glottal stop is not underlying, but rather arises from a failure of the learner to recognize the consonantal status of glottal stop at the point of perception. This failure results from glottal stop’s lack of certain specific cues to consonantality that the SPM is designed to expect for stop consonants; that is, the formant transitions on flanking vowels. Thus, even if the adult output is comprised of Vʔ, the learner perceives the input to be comprised of two adjacent vowels. Consequently, upon reproducing the form, the learner produces a form in which the two vowels have been simplified into one (a form of hiatus resolution through coalescence).

⁴³ A form of this question was first brought up by Ana Lubowicz at the 2005 WWCFL presentation of an earlier version of this paper.

suffixes. This description suggests that glottal stop will metathesize with multiple derivational suffixes, thus showing a wider range of temporal variation, though confirmation is needed that such metathesis is indeed possible.⁴⁴ More study is required to determine the extent to which the variation of glottal stop is limited.

3.4 Summary and Questions for Future Research

3.4.1 Summary of the Analysis

The goal of this chapter has been to present a unified analysis of four apparently disparate patterns involving glottal stop: the avoidance of glottal onsets and apparent preference for glottal codas, translaryngeal harmony, hiatus resolution in V?V, and the unavailability of sequentiality for glottal stop, as exhibited by patterns of vowel intrusion and C? coalescence.

In this chapter, I have proposed that learners develop gestural representations of utterances based on the availability of acoustic evidence for each gesture posited. Furthermore, I proposed that the acoustic cues provided by the articulation of a gesture influence the creation of abstract representations of the internal structure of gestures in terms of their gestural landmarks; a learner will posit the presence only of those landmarks for which there are recoverable acoustic cues in the speech stream. This proposal has important consequences for the construction of an internal gestural representation for glottal stop, whose acoustic signal is deficient in comparison to the typical stop consonant in that it does not condition formant transitions on flanking vowels. I propose that because the articulatory events of onset and offset of movement for the glottal gesture are not associated with recoverable acoustic cues, the learner will fail to posit the presence of the associated gestural landmarks. Specifically, the SPM posits a gestural representation of glottal stop that lacks the gestural landmarks of ONSET and OFFSET (each of which would otherwise correspond to the flanking formant transitions). I have referred to this proposal as Landmark Underspecification, because it argues that gestures may be underspecified for certain gestural landmarks. A summary of the proposals presented in this chapter is given below in (35):

- (35)
- a. A Speech Perception Module (SPM) interprets the acoustic signal of utterances to determine the gestures that comprise them.
 - c. Gestures are posited to be present only if their articulation is accompanied by recoverable acoustic cues.
 - d. Gestural Landmarks are posited to be present only if acoustic events in the speech stream give evidence for their presence.

⁴⁴ Thanks to Professor Ellen Broselow for pointing the Uma case out, and its bearing on the question of the extent to which glottal stop can vary temporally within an utterance.

Section 3.3 considered how the Landmark Underspecification proposal might help us to develop a unified analysis of the patterning of glottal stop cross-linguistically. This section first considered the status of the articulatory events associated with ONSET and OFFSET within the AP literature. Recent research has shown that the physical correspondents of these landmarks (the beginning and end of movement associated with a gesture) play an important role in the gestural phasing relations that underlie syllable structure and the sequentiality of gestures. For example, onset consonants exhibit a stable phasing with the nucleus such that the onset of movement for both are simultaneous. Likewise, coda status and sequentiality arise from certain regular phasing relations holding between the nucleus and coda, and members of a sequence; in a syllable, the end of movement for the vowel is phased to the beginning of movement for its coda, and within clusters sequentiality results from the same relation holding between C_1 and C_2 .

An important aspect of this proposal is that the limitations of the SPM constrain the learner's construction of underlying representations (i.e. input forms); the learner creates a gestural representation of an adult speaker's utterance believing that he or she has accurately represented it. In other words, the learner is unaware that his representation of the utterance differs from the adult representation because he fails to perceive the difference. Importantly, this proposal contrasts with accounts in which concerns of perceptual recoverability constrain *output* forms. Examples of such an approach are Steriade 1997, 2001 in which it is proposed that the OT grammar incorporates metaperceptual knowledge on the positions in which particular cues are most salient.⁴⁵ For example, Steriade (1997) proposes that harmonically ranked constraints on cue salience be included in the grammar; these constraints prohibit contrasts from being realized in non-salient position.

The account of gestural perception presented in this chapter suggests that there is a different source for the fact that contrasts are most stable in positions where the cues to the contrast are most salient. Specifically, if cues for a certain contrast are degraded in a particular position, then it is likely that a certain percentage of the time language learners

⁴⁵ Perceptual recoverability also plays a role in a number of other approaches to gestural coordination, including Silverman 1995:1997, 1997 and Chitoran, Goldstein and Byrd 2002. Silverman 1995:1997, 1997 give accounts of gestural coordination in which issues of recoverability influence the coordination relations that are observed to hold between two gestures; the preferred coordination will be the one that allows both gestures to be recovered. Another account of the effects of recoverability on gestural coordination is given in Chitoran *et al.* 2002, where the authors show that the need to recover acoustic cues for release of consonants determines the degree of overlap allowed in clusters; more gestural overlap is allowed in environments where the acoustic cues of release for both consonants are recoverable in spite of the overlap, and less overlap is found when the acoustic cues of the consonants would be obscured by overlap. Specifically, they found that in Georgian, word-internal sequences and front-to-back sequences (e.g. /pk/) showed more overlap than syllable initial and back-to-front sequences (e.g. /kp/). Chitoran *et al.* 2002 show that more cues to consonant identity are available in the former contexts than the latter. They also show that this pattern can help explain the distribution of consonant clusters cross-linguistically, with sequences of low recoverability (e.g. back-to-front) being less common, and are described in the literature as marked. Their account is consistent with an approach in which variation in overlap arises as an artifact of the perception of these sequences extragrammatically, rather than from a component of the grammar that obliges low recoverability sequences to have minimal overlap. Under this approach, the observation that we settle upon gestural configurations that maximize recoverability falls out from the fact that no other configurations will be recognized by the perceptual system.

will fail to acquire the contrast even when the adult speaker produces it faithfully in that position. This may result, not from a constraint ranking that forces an unfaithful realization of the adult's output as Steriade has proposed, but rather from the failure of the learner to have perceived the contrast in the first place. In this case, the learner takes the neutralized form as the input to the phonology because he or she has no notion of its not being identical to the adult's intended output. Thus, in this approach there is no need for meta-perceptual knowledge on the part of the speaker or, more precisely, the grammar. Instead, the fact that contrasts are most robust where they are most recoverable is an emergent fact of the perceptual system; the SPM proposed above. Kochetov (2003) presents a similar approach; he shows that apparent positional markedness patterns can be accounted for as an emergent fact of the acquisition process if we assume "inherent limitations on speech production and speech perception" (p. 3). A similar point is made by Ohala (1993) regarding the source of listener driven sound change: "universal and timeless physical constraints on speech production and perception leads listeners to misapprehend the speech signal. Any such misapprehension ... is potentially the beginning of a sound change" (p. 155). The position that extant sound patterns in language, as well as sound change, can be accounted for by consideration of universal phonetic facts is further developed, for example, in Blevins 2004, 2006a,b in the program of Evolutionary Phonology.

This discussion has shown that the Landmark Underspecification account of glottal stop allows us to explain each of the patterns identified in Chapter 2 that distinguish glottal stop from the supralaryngeal consonants. Furthermore, I propose that this analysis provides a unified explanation of the patterning of glottal stop that was unavailable under previous approaches that attributed the laryngeal/supralaryngeal distinction in patterning to the placelessness of laryngeal consonants. I suggest that this is the case because each context receives an explanation that follows directly from Landmark Underspecification, and a few independently supported proposals. For example, in an OT framework that employs the representational conventions of AP, it is independently necessary that OT constraints like ONSET be redefined to make reference to gestures rather than to features. Moreover, research in AP has provided confirmation of the actual temporal relations that hold between syllabically and sequentially affiliated gestures; the proposed analysis simply incorporates these insights into OT (for example, in the ONSET_(REV.) constraint). Assuming Landmark Underspecification for the glottal gesture in a framework in which the gestural landmarks of ONSET and OFFSET are required for syllabic and sequential affiliation has the consequence of providing an immediate account of three main patterns discussed in Chapter 2; the patterning of pre- and postvocalic glottal stop, translaryngeal harmony and required identity-across-glottals, and hiatus resolution in V?V. A further proposal that the OT grammar conspires to require output gestures to be parsed into the global phasing relations of the utterance is necessary to extend the analysis to, for example, vowel intrusion and C? coalescence. However, the constraint posited (ASSOCIATE CC/CV) is an independently proposed constraint type (Davidson 2003), thus it is not unwarranted to suggest that gestural reorganization results from these constraints.

3.4.2 *The Landmark Underspecification Account: Questions for Future Research*

3.4.2.1 *The landmark structure of [h], and the SPM's treatment of non-closure gestures*

In the preceding sections I proposed that glottal stop is not specified for the gestural landmarks of ONSET and OFFSET. The question that arises here is whether the same landmark underspecification holds of the laryngeal fricative [h], which tends to pattern similarly to glottal stop with respect to transparency phenomena (as was shown to be the case for a number of languages in Chapter 2).^{46,47} Thus, I propose that [h], like glottal stop, is underspecified for the gestural landmarks of ONSET and OFFSET cross-linguistically. This proposal is supported by the fact that [h], like glottal stop, does not condition formant transitions on flanking vowels, which I argued were necessary for the SPM to posit the ONSET and OFFSET landmarks.

However, discussion of [h] brings up the question of how the SPM deals with gestures other than the closure gesture associated with the laryngeal and supralaryngeal stops. In other words, what acoustic cues does the SPM use to construct the internal gestural representations of fricatives, glides, liquids and vowels? For consonantal gestures, we can continue to maintain the proposal that formant transitions are required for the SPM to posit the gestural landmarks of ONSET and OFFSET; for example, Stevens (1998) discusses the fact that fricatives show formant transitions consistent with stop consonants at the same place of articulation, but ones that are less extreme. Other research indicating the presence of formant transitions for non-stop consonants includes Recasens 1983, which showed that formant transitions from nasal consonants were used by speakers to identify nasal place of articulation in Catalan, and Espy-Wilson 1987, which showed that formant transitions can be used to distinguish among the members of the set /w, y, r, l/.

⁴⁶ Most cases in which [h] appears to pattern differently from glottal stop are not indicative of a general lack of transparency (and other related patterns) for [h]. For example, in Nez Perce different repair strategies are employed for $V_x h V_y$ sequences than for sequences with glottal stop (for example deletion and translaryngeal harmony for [h], but only translaryngeal harmony for glottal stop). In Yucatec Maya some instances of [h] do not pattern as transparent, but these are all diachronically related to Classical Mayan velar fricatives. Conversely, in Toba (Guaykuran) [h] patterns as transparent but glottal stop does not. Instead, glottal stop patterns with the dorsal (velar/uvular consonants). The Toba data are discussed in section 5.1, where I suggest that one possible approach is that Toba [ʔ] is articulated simultaneously with a low-magnitude dorsal gesture. It is the presence of this gesture that accounts for the fact that Toba [ʔ] patterns with the dorsal consonants.

⁴⁷ An additional challenging distinction in the patterning of glottal stop and [h] comes from English, in which distinct allomorphs of the definite and indefinite articles appear prevocally vs. pre-consonantly ([ðɪ], [æŋ] vs. [ðə], [ə]). As expected, glottal stop initial forms pattern identically to vowel initial forms ([æŋ æpəʃ], [æŋ ʔæpəʃ]). However, [h] unexpectedly patterns as a consonant in many dialects of English ([ə mɪstəɪ], [ə hɪstəɪ]). This suggests that English [h] does not pattern as transparent, though it should be noted that some dialects treat it as such ([ə hɪstəɪ] ~ [æŋ hɪstəɪ]).

As for the gestural landmarks of TARGET and RELEASE, the proposal presented in section 3.2 suggested that the SPM posits these for stop consonants based on the acoustic events of the left and right edges of silence, respectively. It is clear that this proposal must be adapted in order to account for the presence of these landmarks for consonantal gestures with less than full closure, for these gestures are not characterized by silence upon the achievement of the gestural target. Instead, during the achievement of the specified degree of constriction, fricatives are characterized by frication noise, liquids and nasals by weak formant structure, and glides by near vowel-like formant structure. Thus, I suggest that the SPM uses these identifiable acoustic cues as evidence (the edges of frication noise, the edges of formant structure for liquids and nasals) to posit the TARGET and RELEASE landmarks for fricative, liquid, and nasal gestures. Thus, along the lines of the LBA, the SPM uses acoustic discontinuities (boundaries) for identifying the presence of gestural landmarks, rather than any specific type of acoustic cue (e.g. silence vs. frication) (e.g. Stevens 1995, Liu 1996, Stevens 2002, Slifka *et al.* 2004, Slifka 2005, among others).⁴⁸

As for glides, the acoustic cue associated with these gestures is proposed by the LBA to be “a minimum in low-frequency amplitude, *without discontinuities* [emphasis mine-MLB]” (Stevens 2002, p. 1973). The fact that the main acoustic correlate of a glide lacks any discontinuities suggests that acoustic discontinuities may not be the only type of information that the SPM can use to posit the presence of a landmark. Furthermore, discussion in Liu 1996 and Stevens 2002 suggests that the minimum in low-frequency amplitude on the glide corresponds to the point at which the constriction is narrowest. Thus, I suggest that the SPM uses the dip in low-frequency amplitude to posit the presence of the TARGET landmark for the glide, since it is at this point that the glide gesture has reached its target constriction. However, since the relevant acoustic cue is necessarily a single point (i.e. the lowest amplitude), it is possible that the SPM identifies landmarks for TARGET and RELEASE that are simultaneous or near simultaneous. Another possibility is that the ‘lowest amplitude’ measurement is more coarse grained and the SPM admits a range on either side of the minimum. Certainly, more study is necessary to see which approach most closely reflects the empirical data; ideally, data on

⁴⁸ However, in Kingston’s (1985) discussion of the patterns of alignment of glottal gestures to stop, fricative and sonorant segments, it is argued that release of constriction for fricatives and sonorants is not acoustically salient, and thus not an appropriate point of anchoring for the glottal gesture. Kingston (1985) bases his conclusions on the fact that laryngeal contrasts for consonants with full closure (stops, ejectives and implosives) are consistently anchored to release of constriction, while the realization of laryngeal contrasts with respect to continuants is more variable. Kingston’s (1985) proposal appears to lend support to the position that release of fricative and sonorant constriction does not provide sufficient evidence for the learner to posit the RELEASE landmark for these gestures. However, if we look at Kingston’s (1984) data, we see that another approach is available; one from the maximization of recoverability for laryngeal contrasts. For example, release of the glottal closure for an ejective before the release of oral closure will result in a difficulty in recovering the laryngeal contrast. Laryngeal contrasts for continuants, on the other hand, will be recoverable throughout the oral constriction because acoustic evidence regarding the state of the glottis remains available throughout. Thus, the fact that stop consonants realize laryngeal contrasts at or after oral release falls out from the fact that all other configurations will fail to be recovered. Greater variability in realization of laryngeal contrasts with continuants is observed because each distinct configuration will be recoverable. See Silverman 1995:1997 for an in-depth discussion of the effects of recoverability on observed gestural configurations, with particular focus on the realization of laryngeal contrasts.

the phonological patterning of glides might be brought to bear on this issue in the same way that the patterning of glottal stop helped to elaborate its landmark structure.⁴⁹

An even more difficult question to answer is how the SPM posits abstract gestural landmarks for the vocalic gestures. This is a challenging problem, because unlike for most consonantal gestures, the acoustic patterns of vocalic gestures are not characterized by discontinuities of the sort that the SPM might use to determine their internal landmark structures. Still, in order for C-to-V phasing to be possible in an AP in OT framework, both consonantal and vocalic gestures must be phonologically specified for abstract gestural landmarks. This suggests that the SPM uses a different set of criteria to posit gestural landmarks for vocalic gestures. One acoustic cue for vowels that has been proposed in the LBA literature is a peak in low-frequency amplitude, which corresponds to the point in time in which the vocal tract is most open for the vowel. Analogously to our discussion of glides, we can propose that the SPM uses this cue to identify the vowels' TARGET landmark (though we face the same problems that we did with the glides). As for the ONSET and OFFSET landmarks, it remains to be seen what acoustic cues are provided that would give evidence for these landmarks on a vowel.

Note that the proposal that perception of vowels is treated differently from the perception of consonants by the SPM may be supported by research in categorical perception. This research has shown that while categorical perception exists for consonants, perception of vowels is more continuous (for example, Fry *et al.* 1962). Furthermore, research has generally shown a right-ear (left-hemisphere) advantage for speech, but not for vowels (Shankweiler and Studdert-Kennedy 1967).

Furthermore, research has shown that processing of vowels is slower than consonants, for example as exhibited in higher reaction times in phoneme identification tasks for vowel targets (and higher error rates for vowel targets) (Cutler and Otake 1994, van Ooijen 1994, Cutler *et al.* 1996, van Ooijen *et al.* 2000). Additionally, in tasks in which speakers were asked to replace a single phoneme to change a non-word into a real word (e.g. *kebra* → *cobra* or *zebra*; Cutler *et al.* 2000), speakers were more likely to replace vowels than consonants when given choice of phoneme to insert. Interestingly, when speakers were asked to make a real-word by replacing only consonants or only vowels, speakers were more likely to make vowel insertion errors in the consonant only task than vice versa (van Ooijen 1994, 1996, Cutler *et al.* 2000). Cutler *et al.* (1996) attribute these patterns to an awareness on the part of the speaker of “intrinsic variability of vowels;” the “apparent readiness of listeners ... to treat vowels as inherently more mutable objects than consonants, we would argue, is further evidence that listener’s have adjusted their speech-processing procedures to take explicit account of the intrinsic variability of vowels” (p. 818).

An alternative approach is that perception and processing of vowels is itself inherently distinct from that of consonants, and it requires no “adjustment of ... speech processing procedures” (Ibid) on the part of the listener. Importantly, it seems realistic to suggest that the SPM uses different evidence for positing the gestural landmarks of vocalic gestures than for consonants, since vocalic perception is distinguished from

⁴⁹ Note that the problem of the status of the TARGET and RELEASE landmarks arises for [h], which is identified as a glide by Stevens (2002) based on its sharing the property of a dip in low frequency amplitude but no discontinuities in the speech stream. Still, [h] continues to pattern with glottal stop with respect to lack of the ONSET and OFFSET landmarks.

consonantal perception in a variety of ways. Further research will be necessary to determine what cues are available in the acoustic signal of vowels for the positing of landmarks.

3.4.2.2 *On the status of the C-CENTER landmark*

The proposal that the SPM can only posit the presence of a gestural landmark if that landmark is associated with a recoverable acoustic event leads us to reconsider the validity of the five landmarks defined above in (8). Specifically, the validity of the C-CENTER landmark should be questioned under this approach. This is because, while the edges of the silence associated with closure for a stop consonant give evidence for the gestural landmarks of TARGET and RELEASE, there does not appear to be any acoustically recoverable evidence for C-CENTER. In fact, I suggest that there is no appropriate acoustic evidence that would allow the SPM to posit the C-CENTER landmark: the ‘midpoint of the gestural plateau,’ as C-CENTER has been defined, is merely the midpoint of a period of silence (at least for stops; other types of gestures have more acoustic information during constriction), and for this reason is not associated with any distinguishable acoustic cue. Thus, I propose that the gestural representation of closure does not contain the landmark of C-CENTER. Consequently, for every phenomenon that has been taken to demonstrate the existence of the C-CENTER landmark, I predict that this non-landmark is not a necessary participant in that phenomenon. Instead, these phenomena will ultimately be shown to arise from a confluence of other factors.

One such pattern is Browman and Goldstein’s (2000) C-CENTER effect. They observe that the mid-point of a single onset consonant maintains a stable relationship with the following vowel. One approach to explaining this pattern would be to propose that the phasing relationships that hold between onset consonants and following vowels involve alignment of the onset’s C-CENTER landmark with the vowel. However, data on multi-consonant onsets show that the same relationship holds of the mid-point of the combined consonant cluster, rather than of one or both of the centers of the individual consonantal gestures. Browman and Goldstein (2000) demonstrate that this effect falls out because of competition between the phasing relationships that hold between the two consonants and between each consonant and the following vowel. Specifically, the onset of movement for each consonantal gesture is phased to be synchronous with the onset movement of the following vowel (in AP in OT terms, $C_1 \text{ ONSET} = V \text{ ONSET}$ & $C_2 \text{ ONSET} = V \text{ ONSET}$).⁵⁰ At the same time, the consonantal gestures are phased to be

⁵⁰ Note that Browman and Goldstein (2000) do not discuss the phasing relations holding between onset consonants and following vowels in exactly these terms. For example, for them simultaneity results from a coupling relation holding between C_1 and C_2 such that the two gestures are specified to be ‘in-phase’ (i.e. they begin at the same point in time) with each other. Adopted into the AP in OT approach, such a relationship is specified using phasing relations holding between gestural landmarks, namely, $\{C_1 \text{ ONSET} = C_2 \text{ ONSET}\}$.

sequential; the offset of movement for the first gesture is synchronous with the onset of movement for the second (AP in OT's C_1 OFFSET = C_2 ONSET).

Browman and Goldstein (2000) show that these phasing relations are in conflict because faithful realization of the C_1 -V and C_2 -V relationships would lead to total overlap of C_1 by C_2 and failure to recover one or the other of the consonants. Now consider an alternate possibility; that is, the possibility of faithfully realizing the $C_1 - C_2$ relation at the expense of the $C_1 - V$ or $C_2 - V$ relation. In this case, we avoid the pitfall of simultaneity for C_1 and C_2 by faithfully realizing the $C_1 - C_2$ phasing relation but must abandon the $C_2 - V$ relation. Thus, the phasing relations holding within onsets and between onsets and nuclei are incompatible; neither can be realized faithfully without causing the other to fail to be realized. Browman and Goldstein (2000) propose that the competition between these two types of phasing relations is what results in the C-CENTER effect; instead of realizing any one relation faithfully at the expense of all others, the result is minimal deviation from each. Thus, the observation that onset consonants pattern as a unit falls out from the fact that the members of onsets are essentially competing for the same position. Interestingly, the lack of a C-CENTER effect for codas lends support to the proposal that, in a sequence of coda consonants, only the first consonant is phased to the vowel. Subsequent consonants are phased ONSET – to– OFFSET with the preceding consonant, as sketched above in (14b).

Crucially, since the midpoint of a single onset consonant holds a stable relation to the vowel does not constitute evidence for C-CENTER as a landmark, since the midpoint of combined consonant sequences hold the same stable temporal relation to the vowel. Thus, the C-CENTER effect is epiphenomenal, in that it does not involve the putative C-CENTER landmark at all. For this reason, I propose to abandon the C-CENTER landmark on the basis that we lack both acoustic and empirical evidence for its presence. More study is required to see whether or not this prediction will hold of gestures beyond full closure, however.⁵¹

3.4.2.3 *Reconciling the Landmark Underspecification Account with Pharyngeal-? and Glottal Stop Epenthesis*

Perhaps the best test of the Landmark Underspecification analysis is whether it can reconcile the placeless/pharyngeal accounts of glottal stop; the placeless account of glottal stop can be extended to handle the data discussed herein, but fares poorly in explaining languages in which glottal stop patterns as a natural class with some set of

⁵¹ Huffman (1989) proposes that the target for implementation of the feature [\pm NASAL] is associated with the midpoint of an oral or nasal vowel. One possibility is that this constitutes another pattern in which the center of a gesture is salient, but Huffman (1989) states that the midpoint of the vowel corresponds to the articulatory landmark of “the peak of the vowel gesture” (p. 73). Thus, it is likely that this landmark corresponds to the TARGET landmark of AP in OT, rather than a V-CENTER. Interestingly, one result of this approach is that the types of landmarks to which features associate are identical for stops and vowels; they are the TARGET and RELEASE for stops (Huffman’s (1989) ‘onset and release of closure’ (p. 69)) and the TARGET of the vowel.

supralaryngeal consonants, notably the guttural consonants. Furthermore, in these languages glottal stop does not pattern as transparent and does not fail to be realized as sequential with respect to adjacent segments (or at least, if the glottal stop patterns in this way, it shares this property with some set of supralaryngeal consonants). Chapter 4 addresses the issue of the pharyngeal-? languages, suggesting that an analysis of these languages that maintains Landmark Underspecification is possible. Specifically, I propose that the glottal gesture is underspecified for the ONSET and OFFSET landmarks in every language. However, glottal stop patterns with other consonants because it forms part of a complex segment with an overlapping supralaryngeal gesture. Furthermore, it appears to be stably phased with respect to adjacent gestures because of the transitivity of phasing relations that anchor the glottal and the pharyngeal gesture, and the pharyngeal gesture and the vowel.

Chapter 4 also addresses the fact that some languages appear to epenthesize glottal stop prevocally, putatively under pressure from the ONSET constraint (e.g. in English ‘apple’ → [ʔæpəɫ]). This pattern challenges the Landmark Underspecification account of glottal stop because glottal stop epenthesis is proposed not to satisfy the ONSET_(REV.) constraint, and thus this constraint could never motivate glottal stop insertion. Instead, I suggest that the glottal stop is inserted prevocally in these languages for reasons other than the need to provide an onset to a vowel initial syllable. This discussion draws on the fact that insertion of glottal stop into prevocalic position is overwhelmingly limited to prosodically prominent environments, for example utterance, phrase or word initial position, under emphasis, or before a stressed vowel. Based on this observation, I propose that the constraints that motivate glottal stop insertion must make reference to prosodic structure, and may have different requirements on the configurations that satisfy them (e.g. no reference to the ONSET or OFFSET landmarks).

4.0 Challenges to Landmark Underspecification from ‘Guttural’ Languages and Glottal Stop Epenthesis

The analysis of the patterning of glottal stop presented in this dissertation claims that the gestural representation of glottal constriction lacks the gestural landmarks of ONSET and OFFSET, and therefore glottal stop cannot syllabify as either an onset or as a coda. This falls out from the proposal that the OT constraint ONSET is more specific in its requirements than has been traditionally assumed; though traditional approaches consider ONSET to require a syllable to have a consonantal onset, I have suggested that this requirement does not reflect how syllables are actually formed. Rather, syllables are formed through the instantiation of particular gestural coordination relations holding between syllabic nuclei and the consonantal gestures that precede or follow them. Only when those particular phasing relations hold will an acceptable syllable be formed. Following work in Goldstein 2005, Nam and Saltzman 2003, Nam 2004, Goldstein *et al.* 2006, the preceding chapter proposed that the crucial phasing relation necessary for a consonantal gesture to syllabify as an onset is a relation in which the ONSET of the consonantal gesture and the onset of the nucleic vocalic gesture are phased to be simultaneous (e.g. ONSET {C} = ONSET {V}).

In the preceding chapter, I also argued that the landmarks that comprise a gesture’s internal structure are not *a priori* present for all gestures, but rather must be posited by the learner based on the availability of acoustic evidence for their presence. For the gestural landmark of ONSET, then, the acoustic cues provided by formant transitions on a preceding vowel will provide evidence for this landmark. However, as the gesture of glottal constriction associated with a glottal stop is not accompanied by formant transitions on flanking vowels, the evidence that would provide the learner with sufficient support to posit the ONSET landmark is absent. Thus, the gesture of glottal constriction lacks the gestural landmarks of ONSET and OFFSET. Taken together with the revised understanding of the onset/nucleus relation, the fact that glottal stop’s gestural representation lacks an ONSET landmark will preclude it from syllabifying as an onset to a following vocalic nucleus.

One obvious challenge to this analysis comes from languages in which glottal stop does appear to syllabify as an onset and/or coda. In this section I discuss how the present analysis might be extended to handle these languages. I claim that languages with glottal onsets can be divided into two groups; (1) languages in which [ʔ] appears in all syllabic positions and is not obviously ‘transparent,’ (2) languages in which the distribution of [ʔ] as an onset is limited either to word initial position, or to other prosodically prominent environments. I claim that of the two subgroups only the first presents a real problem for this analysis, which include the languages in which glottal stop has traditionally been analyzed as pharyngeal. In section 4.1, I suggest a possible extension of the Landmark Underspecification proposal to handle Type (1) languages.¹ In this discussion, it is

¹ Type (1) languages often show a patterning in which glottal stop patterns with the guttural or pharyngeal consonants, and have therefore been analyzed as having glottal stops that are underlyingly specified with the feature [+PHARYNGEAL]. The discussion of type (1) languages, then, will answer the question of whether the Landmark Underspecification approach to glottal stop can subsume those patterns that have

proposed that the lack of transparency for glottal stop results from the presence of another consonantal gesture that is phased to the glottal constriction, and which itself syllabifies with the vowel and blocks transparency. Section 4.2 discusses the type-(2) languages, in which it is proposed that glottal stop does not syllabify as an onset in these languages. Instead, glottal stop epenthesis in type-(2) languages does not result under pressure from $\text{ONSET}_{(\text{REV.})}$, but rather under pressure from constraints on the optimal configuration of edges of prosodic domains.

4.1 Glottal stop in onset; Type (1) languages: Non-transparent glottal stop and Pharyngeal-ʔ

Most challenging for the present analysis are languages in which glottal stop appears to syllabify as an onset and/or coda and does not appear to participate in phenomena like the ones discussed in this thesis; for example, transparency to spreading or hiatus resolution across it. The Landmark Underspecification approach to glottal stop predicts that it acts as an onset in no environment cross-linguistically, and pre- and postvocalic glottal stops should only survive if extrasyllabic. Thus, languages in which glottal stop is present in both pre- and post-vocalic position with no concrete indication of extrasyllabicity pose a challenge to the Landmark Underspecification account.²

In this section, I suggest an analysis to the patterning of glottal stop in Type (1) languages that is compatible with the account of the gestural representation of glottal stop presented in Chapter 3. Crucially, this discussion maintains that there is a single gestural representation for the gesture of glottal constriction in all languages, regardless of whether transparency patterns are observed. Thus, I propose that even in the Type (1) languages glottal stop fails to syllabify as an onset to a following vowel. I further suggest that the apparent stable phasing between glottal stops and flanking vowels in Type (1) languages results from the presence of a consonantal gesture associated with a secondary articulation on the glottal stop. It is this gesture that is actually phased as a syllabic onset to the vowel; the apparent tight cohesion in ʔV sequences is an illusion of the transitivity of a phasing relationship that holds between the three elements (C-to-V, and ʔ-to-C).

In section 4.1.1 I present the relevant data from Type (1) languages, and in section 4.1.2 I sketch an analysis that can handle the challenge posed for the present approach by the Type (1) languages.

been attributed both to the placeless-ʔ analysis and to the pharyngeal-ʔ analysis. Ultimately, I suggest that it can, and this is further support for the Landmark Underspecification as preferable to either previous approach for explaining the patterning of glottal stop.

² In theory, we might propose that languages in which glottal stop does not pattern as transparent simply arise from the fact that constraints like $\text{ONSET}_{(\text{REV.})}$ are too low ranked to force repair of ʔV sequences. While this may indeed be the preferred analysis of some languages, it is still interesting to discuss those type (1) languages in which glottal stop not only acts as non-transparent, but also patterns with the pharyngeal consonants.

4.1.1 Data from Type (1) Languages

Type (1) languages are characterized primarily by the fact that glottal stop may appear pre- and post-vocally at all or most constituent levels (syllable, word, phrase). Other patterns that are exhibited by these languages are that glottal stops may be found between non-identical vowels, and no interaction between the vowels flanking a glottal stop is observed. This section presents data from a number of such languages to illustrate the patterning of glottal stop in Type (1) languages. The data presented here are meant to represent some of the phenomena observed cross-linguistically that show that glottal stop does not universally pattern as has been demonstrated throughout this dissertation. This discussion can by no means be exhaustive, but rather gives representative examples of linguistic phenomena that would seem problematic for the Landmark Underspecification approach to the patterning of glottal stop.

The data in (2) demonstrate that word initial glottal stop is preserved in Arabic when it appears word medially due to morpheme concatenation. This pattern may be compared to the English and Selayarese data shown in (2c-f), in which phrase initial glottal stop is lost when it becomes phrase medial in connected speech (we return to these patterns in section 4.2). This suggests that, while the presence of glottal stop in initial position in both Selayarese and English is prosodically determined, it is not in Arabic.

- (2) Arabic
- | | | |
|----|-----------------------|-------------------------------------------|
| a. | ʔibra | ‘a needle’ |
| b. | qaa.lat. ʔibra | ‘she said ‘a needle’’
(Lombardi 2002a) |
- Selayarese
- | | | |
|----|--------------------|------------------------------------|
| c. | [ʔinn] | ‘this’ |
| d. | [ʔaapa inn] | ‘what is this’
(Lombardi 2002a) |
- English
- | | | |
|----|--------------------------------|-------------|
| e. | [ʔæpət] | ‘apple’ |
| f. | [ði ʔæpəl] ~ [ði jæpəl] | ‘the apple’ |

Another pattern is shown below in (3a-c); these data show that in Hebrew glottal stop cannot be found in coda position. If the morpheme template would result in a glottal stop appearing as a coda, it is resyllabified as an onset through echo epenthesis (3b).³ (3c) shows the prohibition on final glottal stop extends to [h]. However, the prohibition of

³ The epenthetic vowel in (3b,c) is identified by McCarthy 1994 as a schwa, but takes on the features of the preceding vowel. The use of the superscript font for the epenthetic vowel follows conventions in that paper.

laryngeal codas cannot be analyzed as resulting from Landmark Underspecification; the data in (3d,e) show that the same phonotactic restrictions that hold of glottal stop also hold of the pharyngeal consonants.

- (3) Hebrew
- | | | |
|----|-----------------------|-----------------------|
| a. | yiktob | ‘he will write’ |
| b. | yeʔ ^e sop | ‘he will gather’ |
| c. | yah ^a mo:d | ‘he will turn’ |
| d. | yof ^o mad | ‘he is made to stand’ |
| e. | yeh ^e zaq | ‘he is strong’ |

(McCarthy 1994)

The data in (3) exhibit a common pattern in Type (1) languages; that is, glottal stop often patterns with other consonants as an apparent natural class. Often, this class is comprised of uvulars, pharyngeals and laryngeals, referred to as the ‘guttural’ consonants. Other languages that exhibit general prohibitions on guttural codas include Negev Bedouin Arabic (NBA) and Bedouin Hijazi Arabic (BHA). In NBA and BHA, there is a prohibition against guttural codas after low vowels, which holds of the laryngeal [h] (but data from [ʔ] are unavailable) (see Blanc 1970, Abboud 1979, and McCarthy 1994 for discussion of these data).

McCarthy 1991a,b, 1994 presents data on root consonant co-occurrence restrictions that support the idea that uvulars, pharyngeals and laryngeals pattern as a group (the gutturals). In Arabic, roots must not contain adjacent consonants from any single place of articulation, unless they are geminates. This restriction holds of the gutturals as well, inclusive of the laryngeals; a root may contain only one adjacent guttural. McCarthy argues that this pattern supports the proposal that the guttural consonants share the specification of [+PHARYNGEAL], as determined by their being articulated in the same region of the vocal tract, offering a place-based, rather than articulator-based feature geometry. Similar restrictions also hold in a number of other languages, including the Semitic languages of Amharic and Hebrew. Hayward and Hayward (1989) discuss such a restriction in the Cushitic language Qafar, in which there is a general restriction on homorganic consonants within the same root unless they are geminates. Here, the pharyngeal [ʕ] and laryngeals [ʔ,h], pattern as though they are homorganic.⁴

Other phenomena that demonstrate the patterning of laryngeals with the uvulars and pharyngeals include the pattern that in some languages, the guttural consonants are each associated with vowel lowering or low vowels. For example, recall that the gutturals in NBA and BHA are prohibited from syllable codas only following low vowels. The data

⁴ Interestingly, Tukang Besi, a language that has transparent glottal stops, also has a root co-occurrence constraint on laryngeals; two laryngeals cannot be in the same root (Donohue, p.c., 2006). Additionally, laryngeals are not allowed in adjacent syllables (even when these are not in the same root). This may result from an OCP constraint in which two extrasyllabic glottal stops in a form like *ʔVʔV would be considered adjacent because of their tendency to float.

in (4) illustrate that the presence of a guttural has the effect of lowering an adjacent vowel in Tigrinya (Ethiopian Semitic) and Anaiza Bedouin Arabic:

- (4) Tigrinya
- | | | |
|----|--------------------------|------------------------|
| a. | s ä bär- ä | ‘he broke (something)’ |
| b. | f ä n ä wä | ‘it decayed’ |
| c. | ʔ a xälä | ‘it was enough’ |
| d. | bä a ʔk ä | ‘you have eaten’ |

(Hayward and Hayward 1989)

Anaiza Bedouin Arabic

- | | | | | |
|----|------------------|---|------------------|----------------------|
| e. | /k a tab/ | → | [k i tab] | ‘he wrote’ |
| f. | /j a mal/ | → | [j i mal] | ‘camel’ |
| g. | /ʔ a kal/ | → | [ʔ a kal] | ‘he ate’ |
| h. | /h a bit/ | → | [h a bit] | ‘became flat (hair)’ |
| i. | /ʕ a zam/ | → | [ʕ a zam] | ‘he invited’ |

(Johnstone 1967, McCarthy 1994)

In Tigrinya, the vowels *ä* ([ə]) and *a* ([a]) are in complementary distribution, appearing as [ə] in the context of the non-guttural consonants (4a,b), but as [a] when preceded or followed by a laryngeal or pharyngeal in the same syllable (4c,d). The data in (4e) show that Anaiza Bedouin Arabic (ABA) exhibits [a] to [i] raising in open syllables. (4e-i) shows that raising of [a] is blocked if the vowel is preceded by a guttural, including uvulars, pharyngeals and laryngeals. The pattern exemplified by the ABA data in (5e-i) is common in the Semitic languages, where the presence of guttural consonants often influences the realization of morphological templates. The data in (5) give an additional example in which guttural consonants in a root result in the appearance of a low vowel on the surface where a higher vowel would otherwise be expected.

In Maltese, the first and second person prefix are ‘ni-’ and ‘ti-’, respectively, (5a,b). In the context of a guttural consonant, however, these prefixes are realized instead as ‘na-’ and ‘ta-’, as shown in (5c,d). (6e,f) show that guttural stems in Palestinian Arabic have [a] as the stem vowel in both the present progressive and imperfective conjugation, column 1 and 2, respectively, despite the fact that non-guttural roots use [a] only in the imperfective (cf. (5g))

- (5) Maltese
- | | | | |
|----|----------------|--|-------------|
| a. | ni-kteb | | ‘I write’ |
| b. | ti-kteb | | ‘you write’ |
| c. | na-ʔsam | | ‘I divide’ |
| d. | ta-ħrab | | ‘you flee’ |
- (Brame 1972, Bessell 1992)*

Palestinian Arabic

- | | | | |
|----|-----------|------------|-----------|
| e. | [yi-sʔal] | [yi-saʔal] | ‘copy’ |
| f. | [yi-blaʕ] | [yi-balaʕ] | ‘swallow’ |
| g. | [yi-mlis] | [yi-malas] | ‘level’ |
- (Herzallah 1990, Bessell 1992)*

The data in (6) show an additional context in which a guttural consonant is associated with low vowels. (6a,b) show that in Hebrew a noun with an underlying consonant cluster exhibits echo epenthesis of the default vowel [e] to split the cluster. (6c,d) show that the epenthetic vowel inserted after a guttural is always [a].

- (6) Hebrew
- | | | | | |
|----|--------|---|------------------|------------------|
| a. | /malk/ | → | [me le k] | ‘king, my king’ |
| b. | /qudʃ/ | → | [qō de ʃ] | ‘holiness’ |
| c. | /tuʔr/ | → | [toʔ a r] | ‘form, his form’ |
| d. | /baʕl/ | → | [baʕ a l] | ‘master’ |
- (McCarthy 1994)*

Another example of the low vowel~laryngeal/guttural association comes from the Cushitic language D’Opassunte, in which the distribution of the vowels [a] and [e] are predictable in every position, with the exception of word finally. Non-finally, if the local context of the vowel is non-guttural, the vowel will surface as a variant of [e], [ɛ], whereas if the context is guttural the vowel will surface as a variant of [a], [a, æ]. These data are shown in (7) below:⁵

⁵ The forms in (7) follow the orthographical conventions in Hayward and Hayward (1989), where the phoneme that may alternately be realized as [ɛ,a,æ] is written as ‘A’. Bracketed vowels are the surface instantiations of this underlying vowel.

- (7) D'opaasunte
- | | | | | | |
|----|------------|--------|---|-------------|----------------------|
| a. | χáar[ɛ] | + -tte | → | χáar[ɛ]tte | ‘fish (gen.pl.)’ |
| b. | t'Arɣ[ɛ] | + -tte | → | t'Arɣ[æ]tté | ‘tapeworm (gen.pl.)’ |
| c. | ʔan kód[a] | + y | → | ʔan kód[ɛ]y | ‘I am working’ |
| d. | ʔan fÁʔ[a] | + y | → | ʔan fÁʔ[a]y | ‘I am loading’ |
- (Hayward and Hayward 1989)*

The fact that the guttural consonants tend to be associated with low vowels or with vowel lowering in their immediate environment has often been attributed to a shared feature among the guttural consonants and low vowels. This feature is usually labeled as [PHARYNGEAL], which is both a C-Place specification and V-Place specification (but see Hayward and Hayward 1989 for an account whereby the shared feature among guttural Cs is [GUTTURAL]). Note that, within the AP in OT framework adopted here, we must reanalyze the feature [PHARYNGEAL] gesturally, perhaps as shared constriction of the tongue root or pharynx walls.

Interestingly, the guttural-low vowel association appears to hold in some languages in which the laryngeal consonants are the only members of the guttural class present. Data from Tamil (Dravidian) in Christdas 1988 show that the preferred method of hiatus resolution in a sequence where the initial vowel is mid or high is epenthesis of a glide, as in (8a,b). When the initial vowel is low [a], glottal stop is epenthesized (8c). This pattern is conceivably an instantiation of the influence that [+PHARYNGEAL] consonants have on adjacent vowels, but may also result from the absence of an agreeing glide for low vowels. A similar pattern is exhibited by Ilokano (Austronesian), in which input vowel sequences with initial high or mid vowels become glides when followed by the suffixes *-an*, *-en*, while sequences with initial [a] exhibit epenthesis of a glottal stop and retention of the vowel. This pattern is illustrated by the data in (8d,e) vs. (8f).⁶

⁶ Lombardi (2002a) notes that in the adaptation of loanwords, the picture of Ilokano hiatus resolution is a little different; for underlying forms with initial mid vowels, there is variation with respect to whether the output form exhibits glide or glottal stop epenthesis, whereas these sequences would only exhibit glide epenthesis in the native language forms:

(iii)	pag-yoyo-en	→	pagyoyowen	‘to cause to play with a yoyo’
			pagyoyoʔen	

(Lombardi (2002a))

- (8) Tamil
- | | | | | |
|----|---------|---|------------|---------------------|
| a. | /irutt/ | → | [yirutʈʈu] | ‘darkness’ |
| b. | /uuciy/ | → | [wuusi] | ‘needle’ |
| c. | /aacay/ | → | [ʔaase] | ‘hope’ ⁷ |
- (Christdas 1988 and Lombardi 2002a)*
- Ilokano
- | | | | | |
|----|--------------|---|--------------|-----------------------------|
| d. | /babáwi –en/ | → | [babawyén] | ‘regret-goal focus’ |
| e. | /sáŋo/ | → | [pag-saŋwén] | ‘to cause to face forwards’ |
| f. | /bása/ | → | [basaʔén] | ‘read-goal focus’ |
- (Hayes and Abad 1989)*

Prunet (1990) cites an additional example in which the presence of a low vowel conditions epenthesis of a laryngeal from Carrier (Na-Dene). In Carrier, vowel initial words often surface as glide initial, as shown in (9a,b). However, when the word begins with either [ʌ] or [a], the epenthetic consonant of choice is [h], (9c-e). Prunet (1990) also notes a similar pattern in Axininca Campa (Arawakan) from Payne 1981 and Yip 1983, and an inverse pattern from Nupe (Niger-Congo) adaptation of Hausa (Chadic) loans, in which [a] is epenthesized between CC if C₂ is [h], [u] if C₂ is labial and [i] elsewhere.

- (9) Carrier
- | | | | | |
|----|-----------------------|---|------------------------|------------------------|
| a. | /int ^s o/ | → | [yint ^s o] | ‘you (sg.) are crying’ |
| b. | /uzʌ/ | → | [wuzʌ] | ‘his soul’ |
| c. | /ʌt ^s o/ | → | [husso] | ‘he is crying’ |
| d. | /a/ | → | [ha] | ‘yes’ |
| e. | /ait ^s oh/ | → | [hait ^s oh] | ‘it cannot’ |
- (Prunet 1990)*

An interesting fact about laryngeal consonants in Type (1) languages is that they sometimes participate in transparency phenomena very similar to the ones discussed in Chapters 2 and 3. One example comes from faucal harmony in the Salish languages, in particular the data from the Interior Salish languages Nxaʔamxcin (Nx; Moses-

⁷ It should be noted that the glottal stop epenthesized into word initial position in Tamil does not appear when the word is no longer strictly initial, as the data in (iv) show.

(iv) /peer-aacay/ → [peeraase] ‘greed’

The data in (iv) suggests that Tamil is Type (2) language rather than a Type (1) language, despite the low vowel~laryngeal association exhibited. It is perhaps the case that the Tamil constraint hierarchy conspires to rule out the presence of a glide correspondent of [a]. A similar analysis may also be available for the Ilokano data in 8-f). See Rosenthal 1997 for discussion of the general availability of glide forms of non-high vowels.

Columbian Salish) and Snychitsuʔumshtsn (Sn; Coeur D’Alene Salish) presented in Bessell 1997. In Nx and Sn, the uvulars and pharyngeals pattern as a class of faucal consonants, and condition regressive lowering or backing on both adjacent and non-adjacent vowels. Consider the data in (10):

- (10) Snychitsuʔumshtsn
- | | | |
|----|-------------------------------|--------------------|
| a. | u-tseɛq ^w | ‘it’s bright red’ |
| b. | táq-nt ^s | ‘he touched it’ |
| c. | sétt-nt ^s | ‘he twisted it’ |
| d. | nεʔ-sátt ^ʃ -εʔqs-n | ‘crank (on a car)’ |
- (Bessell 1997)*

In Sn, vowels immediately adjacent to a faucal consonant are limited to [ε,α,ɔ], (10a,b). Faucal consonants also condition regressive vowel lowering on more distant vowels, as shown in (10c,d). Here, glottal stop is transparent to the faucal harmony, as are all other consonants. Similar patterns are exhibited by Tiberian Hebrew, Iraqw, Hebrew, and Ge’ez for the class of gutturals; in these languages the vowels flanking gutturals must be identical (see McCarthy 1991b, 1994, Rose 1996, and Gafos and Lombardi 1999 for in-depth discussion). (11a-d) illustrates that this is the case for Tiberian Hebrew, as does (11e-h) for roots in Ge’ez (Classical Ethiopic; gloss not provided in source). Note that in both the Tiberian Hebrew and Ge’ez data, the vowels flanking gutturals must be identical but need not be low.

- (11) Tiberian Hebrew
- | | | |
|----|------------|-------------------|
| a. | ye.ʔe.soop | ‘he will gather’ |
| b. | he.he.ziiq | ‘he strengthened’ |
| c. | ya.ʃa.mood | ‘he made stand’ |
| d. | ya.ha.lom | ‘he dreams’ |
- (Gafos and Lombardi 1999)*

Ge’ez

- | | |
|----|----------------------|
| e. | yaʔammin |
| f. | yil ^h hik |
| g. | yaʃaqqib |
| h. | yis ^h hit |

(McCarthy 1989b)

A defining characteristic of transparent laryngeals in Type (1) languages, in comparison to the languages discussed in Chapters 2 and 3, is that in the former languages other consonants act as transparent as well (here, the gutturals), while in the latter, glottal stop patterns distinctly from all other consonants. Were this not the case, an analysis of laryngeal transparency in Type (1) languages would be identical to that

presented in Chapter 3 (e.g. failure of [ʔ] to syllabify as an onset in [ʔV]). In fact, the observed patterning of the laryngeal consonants with at least some supralaryngeal consonants is important for distinguishing these languages from the ones in Chapters 2 and 3; for example, the phonotactic prohibition on laryngeals in syllable codas exhibited by Hebrew (cf. (3)) would otherwise be evidence of a laryngeal/supralaryngeal distinction but for the fact that the supralaryngeal guttural consonants pattern identically.

This section has presented evidence on the patterning of glottal stop in a number of languages to illustrate the fact that the patterns discussed in Chapters 2 and 3 regarding the transparency of glottal stop and related phenomena are not universal. In the light of the existence of languages that do not treat glottal stop as transparent, and allow it to surface in all positions within the word or phrase, it appears on the surface that the analysis presented in Chapter 3 likewise cannot be universally true. In the next section, I present an analysis of the patterning of glottal stop in Type (1) languages that allows us to maintain the proposed gestural representation for glottal stop and its consequent failure to participate in the phasing relations required for syllabification. Under the approach to be sketched in section 4.1.2, the Landmark Underspecification account of the gesture of glottal constriction *is* proposed to be universal, even of Type 1 languages.

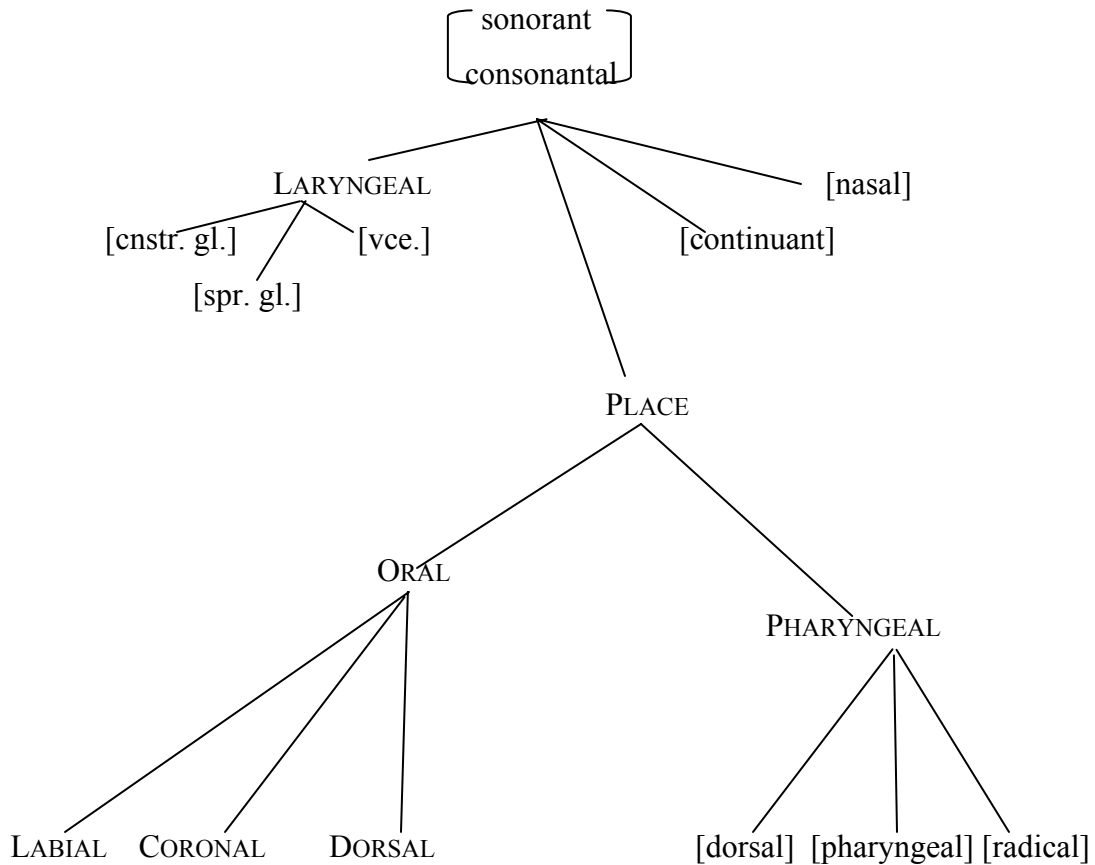
4.1.2 *An Analysis of the patterning of glottal stop in Type (1) languages*

4.1.2.1 *Previous approaches and challenges to these approaches*

Analyses of the patterning of glottal stop in Type (1) languages, particularly in those languages in which there is consistent evidence of the laryngeals forming a natural class with the guttural consonants, have often proposed that laryngeals share the place feature of [+PHARYNGEAL] with the uvular and pharyngeal consonants. One possible implementation of this approach is shown in the feature geometric tree in (12) below, which represents a simplified version of the one presented in Bessell 1992 following McCarthy 1991a.⁸

⁸ There have been many noteworthy treatments of the features that characterize the uvulars, pharyngeals and laryngeals both previous to, and within, the feature geometric approach (Clements 1985, Sagey 1987.) These include Chomsky and Halle 1968, Lindqvist 1969, 1972, Cole 1987, Czaykowska-Higgins 1987, Ladefoged and Maddieson 1988, Goreka 1989, Hayward and Hayward 1989, Halle 1989, 1992, Ladefoged 1989, Ladefoged and Halle 1989, and Herzallah 1990, among many others. Interested readers should see Hess 1990 and Bessell 1992 for in-depth discussions of the treatment of the guttural consonants within the feature geometric framework, as well of the status of related secondary articulation on vowels and consonants (including ATR, RTR harmony on vowels, and emphatics). As this thesis will ultimately reject the feature geometric approach in favor of the Articulatory Phonology approach sketched in Chapters 1 and 3, I do not focus on evaluating the relative advantages and disadvantages of competing approaches to guttural feature specifications within feature geometry. Thus, the feature tree from McCarthy 1991 in (13) is presented here simply as representative of how we might formalize the proposal that laryngeal consonants are [+PHARYNGEAL].

(12)



Under McCarthy's (1991) analysis, laryngeals, dorsals and pharyngeals pattern together because they all share a specification of [pharyngeal] under the PHARYNGEAL node. For him, the pharyngeal consonants are specified as both [pharyngeal] and [radical], while the laryngeals are specified only as [pharyngeal]. His analysis further distinguishes the class of uvulars in order to account for the fact that sometimes [q] does not pattern as guttural. For example, Arabic root consonant cooccurrence constraints treat [q] as dorsal rather than guttural; [q] may appear with [ʔ,ħ,χ,ʕ,h], etc., in the same root, but not with [k,g]. Furthermore, while the Ge'ez patterns in (11) demonstrate that vowels flanking gutturals must be identical in this language, this is not the case for vowels flanking [q] (c.f. *yaʕaqqib*). The proposal presented in McCarthy 1991 is that guttural uvulars are specified as both [dorsal] and [pharyngeal] under the PHARYNGEAL node, but in addition to these features, [q] is also specified as [dorsal] under the ORAL node. This is an attractive account in the light of the fact that the uvulars sometimes pattern with the velars cross-linguistically. An example comes from Moroccan Arabic, where the dorsal consonants (velars and uvulars) pattern together exclusively of the pharyngeal consonants:

(13) Moroccan Arabic

- | | | |
|----|--------------------|--------------|
| a. | dχ ^w əl | ‘come in!’ |
| b. | nq ^w əl | ‘copy down!’ |
| c. | rg ^w əd | ‘sleep’ |
| d. | nʃəs | ‘sleep!’ |

(McCarthy 1994)

The data in (13), from McCarthy 1994 (from his personal communication with Ahmed Alaoui and from Heath 1987), show that labialization may appear on a velar or uvular consonant in Moroccan Arabic (13a-c). Laryngeal and pharyngeal consonants never undergo labialization (13d).

At the same time, however, this account of the featural specifications of uvulars, pharyngeals and laryngeals is also problematic, and cannot handle all patterns observed. For example, it leads us to expect that there is no language that will treat the uvulars and pharyngeals as a natural class but exclude the laryngeals from this class.⁹ McCarthy 1994 presents data from Tigre (Ethiopian Semitic) that suggests that the pharyngeal and pharyngealized (emphatic) consonants pattern together with respect to conditioning the presence of the low vowel [a] (14a-c), but laryngeals do not (14d).¹⁰

(14) Tigre

- | | | |
|----|-----------------|-------------|
| a. | ʃəna <u>ɬ</u> | ‘haversack’ |
| b. | wa <u>r</u> əq | ‘gold’ |
| c. | fa <u>r</u> aʃ | ‘clan’ |
| d. | dʒə <u>h</u> ət | ‘direction’ |

(Palmer 1956, Lowenstamm and Prunet 1989, McCarthy 1994)

In fact, there are a number of languages in which glottal stop patterns with a set of oral consonants, and it is sometimes difficult to determine the features that define this class. An example from a non-Semitic language is Toba (Guaykuran). In Toba, echo vowels are inserted following velars, uvulars and [ʔ] to break up an illegal cluster:

⁹ That is, unless a distinct feature is posited for uvulars and pharyngeals that they do not share with the laryngeals. At least for the approach diagrammed in (13), it is not clear what this feature might be.

¹⁰ In the data in (15) the emphatic consonants, which McCarthy 1991 considers to have a primary coronal specification with a secondary pharyngeal one, are shown as underlined.

- (15) Toba
- | | | | | |
|----|----------------------|---|---------------------|----------------------|
| a. | la-rona q -wa | → | larona G awa | ‘his brother-in-law’ |
| b. | ɲa-so Gok -ji | → | ɲaso Gog oǰi | ‘my patios’ |
| c. | hi- qaʔ -ji | → | hi qaʔ aji | ‘my chins’ |

(Klein 2001, Borroff and Klein 2004)

This pattern presents a challenge to analyses in which the laryngeal consonants are always either placeless or pharyngeal, as the Toba data show they may also pattern as dorsal. In contrast, recall that Moroccan Arabic treats the dorsals (velars, uvulars) as a class exclusive of the pharyngeals, as shown in (13) above. These data suggest that there is more to the problem of the representation of glottal stop than just the placeless/pharyngeal distinction.

Another problematic case is illustrated by the Salish faucal harmony data from Bessell 1997, which presents a case in which the pharyngeals and uvulars pattern together, but the laryngeals do not. Bessell (1997) notes vowel lowering and backing in the environment of the faucal consonants, which she specifies as the uvulars and pharyngeals only. A subset of the relevant data was presented above in chapter 2, which showed that glottal stop is transparent to faucal harmony. For completeness, the data in (16) demonstrate that [ʔ] does not condition faucal harmony, as seen in comparing (16a) to (16b). In (16b) the presence of [q] within the word causes long distance faucal harmony (lowering) on the underlying [e], which surfaces faithfully when the [q] is not present but glottal stop is, (16a). (16c) shows that the pharyngeal [ʕ] also conditions regressive vowel lowering.¹¹

- (16) Sn. (Flathead Variety)
- | | | |
|----|------------------|-------------|
| a. | q'eʔʃin | ‘shoe’ |
| b. | q'aʔʃin-sqá(χeʔ) | ‘horseshoe’ |

(Bessell 1997)

Sn. (unspecified variety)

- | | | | | |
|----|-------------------|---|-----------------|------------|
| c. | /cɛn-ʕɛc-ipleʔ-n/ | → | [cɛnʕɛcipleʔɛn] | ‘fishline’ |
|----|-------------------|---|-----------------|------------|

(Bessell 1992)

¹¹ Bessell (1997) identifies the data in (16a,b) as being from the Flathead variant of Snychitsuʔumshtsn (Coeur D’Alene). The data in (16c) from Bessell 1992 is identified primarily as Coeur D’Alene, but the exact variant is not given, so this form may not be from Flathead Snychitsuʔumshtsn. However, as Bessell (1997) states that the pharyngeals and uvulars pattern together with respect to faucal harmony, I assume that forms similar to (16c), in which the pharyngeal conditions vowel lowering are found across Snychitsuʔumshtsn variants.

The data in (16) show that laryngeals in Sn. Flathead are transparent, and do not condition harmony, in contrast to the uvular and pharyngeal consonants. Bessell (1992) notes that discussion of Ubykh (Caucasian) co-articulatory effects found in Colarusso 1988 shows a similar pattern; all consonants condition coarticulatory effects on flanking vowels, with pharyngeals conditioning low vowels. Laryngeals, on the other hand, do not appear to condition any co-articulatory effects on an adjacent vowel. This is evidenced by the fact that Colarusso (1988) indicates it is possible “to determine the independent articulatory positions of /ə/ and /a/ [by] eliciting them ... in the environment of a laryngeal.” (Colarusso 1988 p. 299, Bessell 1992, p. 89).

The data from Tigre, Toba and the Salish faucal harmonies are difficult to handle under an analysis in which patterning amongst the guttural consonants is the result of a shared [PHARYNGEAL] feature. If we assume the feature make-up for velars, uvulars, pharyngeals and glottals discussed above, and sketched in (17), the phonological phenomena exemplified in (14)-(16) above are puzzling; the participating segments do not form a natural class.¹²

(17)	Velars [+DORSAL]	Uvulars [+DORSAL] [+PHARYNGEAL]	Pharyngeals [+PHARYNGEAL] [+RADICAL]	Laryngeals [+PHARYNGEAL]
------	---------------------	---------------------------------------	--------------------------------------------	-----------------------------

The diagrams in (18) illustrate that the guttural patterning in languages like Tiberian Hebrew and Moroccan Arabic follow along the lines expected in terms of the formation of a natural class (18a,b), but the patterns in Tigre, Toba and Sn. Flathead do not, (18c-e). In (18c-e), the actual consonants which are treated as a group for the purposes of the relevant rules are circled with a solid line, and the expected group is circled with a dotted line.

¹² One possible response to the problem posed by the Tigre data is to posit a pharyngealization feature for Tigre (and possibly Arabic) emphatics that is distinct from the feature [PHARYNGEAL] and is not shared by the laryngeal consonant. For example, the approach in Anderson 1974 analyzes pharyngeals and pharyngealized segments as [+RTR] (retracted tongue root, identifying them as a natural class separate from the [+PHARYNGEAL] segments. Hess (1990) suggests that the articulatory correlate of pharyngealization or [+RTR] may be epiglottal retraction. The key specification within McCarthy’s framework in (12) could be [RADICAL]. McCarthy (1994) himself identifies the Tigre data in (14) as problematic for the pharyngeal-? account, and also notes the problematic case that Tigre [ʔ] and [ʕ] are in complementary distribution with the latter appearing only in the context of a pharyngeal or emphatic consonant. However, if we consider the latter case to be caused by [RADICAL] spread from the pharyngeal(ized) segment onto a [+PHARYNGEAL] [ʔ], we could presumably retain the originally proposed feature representation.

- (18) a. Tiberian Hebrew Vowel Spreading ($V_x C_{\text{gtrl}} V_x, *V_x C_{\text{gtrl}} V_y$)
- | | | | |
|-----------|---------------|---------------|---------------|
| Velars | Uvulars | Pharyngeals | Laryngeals |
| [+DORSAL] | [+DORSAL] | | |
| | [+PHARYNGEAL] | [+PHARYNGEAL] | [+PHARYNGEAL] |
| | | [+RADICAL] | |
- b. Moroccan Arabic Labialization
- | | | | |
|-----------|---------------|---------------|---------------|
| Velars | Uvulars | Pharyngeals | Laryngeals |
| [+DORSAL] | [+DORSAL] | | |
| | [+PHARYNGEAL] | [+PHARYNGEAL] | [+PHARYNGEAL] |
| | | [+RADICAL] | |
- c. Tigre Vowel Lowering
- | | | | |
|-----------|---------------|---------------|---------------|
| Velars | Uvulars | Pharyngeals | Laryngeals |
| [+DORSAL] | [+DORSAL] | | |
| | [+PHARYNGEAL] | [+PHARYNGEAL] | [+PHARYNGEAL] |
| | | [+RADICAL] | |
- d. Toba Echo Epenthesis
- | | | | |
|-----------|---------------|---------------|---------------|
| Velars | Uvulars | Pharyngeals | Laryngeals |
| [+DORSAL] | [+DORSAL] | | [??] |
| | [+PHARYNGEAL] | [+PHARYNGEAL] | [+PHARYNGEAL] |
| | | [+RADICAL] | |
- e. Flathead Snchitsuʔumshtsn Faucal Harmony
- | | | | |
|-----------|---------------|---------------|---------------|
| Velars | Uvulars | Pharyngeals | Laryngeals |
| [+DORSAL] | [+DORSAL] | | |
| | [+PHARYNGEAL] | [+PHARYNGEAL] | [+PHARYNGEAL] |
| | | [+RADICAL] | |

The data from Tigre, Toba and Sn. Flathead are particularly difficult to incorporate into the analysis of the featural specifications of the guttural consonants if we wish to uphold the assumption that the feature make-up of a consonant must be identical in all languages. Indeed, this issue has been a problem for the laryngeals-as-placeless approach as well; both the placeless-ʔ and the pharyngeal-ʔ approaches can handle the data from the phenomena that each was initially proposed to handle, but neither can be extended to successfully account for the other's data. In order to handle this and similar data, McCarthy (1994) raises the possibility that glottal stop may be phonologically different in different languages. He notes the possibility that glottal stop in Arabic is not a true glottal stop, but rather is aryepiglottal, following discussion in Hess 1990.

This section has briefly discussed previous analyses to the patterning of glottal stop in Type (1) languages. One common characteristic of these analyses has been to propose

that the featural specification of glottal stop includes specification for place of articulation. For example, researchers dealing with languages in which the laryngeal consonants pattern with the gutturals have claimed a [+PHARYNGEAL] feature to define the natural class of guttural consonants. However, there are a number of problems for the claim that laryngeal consonants are [+PHARYNGEAL] across the board. First, in some languages the laryngeal consonants pattern as a natural class with a set of consonants that do not share the [+PHARYNGEAL] specification. An example given in this section was Toba, in which glottal stop patterned with the velar and uvular, or dorsal, consonants. It is unclear what features define this natural class, unless we propose that glottal stop is also specified as [+DORSAL], perhaps in this language alone. Another problematic case is presented by the Salish faucal harmony data presented in Bessell 1992, 1997, 1998, in which the gutturals pattern together exclusive of glottal stop. However, if the only feature shared among the gutturals is [PHARYNGEAL] we expect that every process that acts on elements with this feature must act on all elements with the feature. Thus, faucal harmony in Salish should be conditioned by glottal stop, and not just by the uvulars and pharyngeals, if laryngeals are universally specified as [PHARYNGEAL].¹³

Even more striking are the within-language instances of variation in the patterning of the laryngeal consonants. These are problematic for the proposal that the laryngeals have the same featural specification in every language, for it appears that perceptually identical segments even within the same language may pattern distinctly. One source of evidence for within-language variation in the patterning of glottal stop comes from glottal stop epenthesis. In Arabic, Kisar and Selayarese, epenthetic glottal stop is treated distinctly from underlying glottal stop, with the distribution of the former being more similar to that of the Type (2) languages (for example, deleting when word internal). For example, (19a,b) show that some word initial glottal stops in Arabic fail to surface when they would no longer be in word initial position. This contrasts with the data from Arabic presented in (2), in which word initial glottal stop survives when no longer word initial. Data from Kisar that show that [ʔ] is treated differently based on whether it is epenthetic or not are given in (19e-g); when a verb begins with a consonant or underlying glottal stop, the first person pronoun is *yaʔu*. (19g) shows that other instances of word initial epenthetic glottal stop take a truncated first person pronoun *yV*, in which *V* echoes the post glottal vowel.¹⁴

¹³ If we accept that laryngeals have variant representations from language to language, this may not be a problem. For example, in Tiberian Hebrew (12), (18a) glottal stop is specified as [+PHARYNGEAL], while Tigre (18c) and Sncitsuʔumshtsn (18e) exhibit a non-pharyngeal (possibly placeless) glottal stop. However, such a proposal will have to be further extended to handle data of the sort shown in (18d) from Toba, in which glottal stop is apparently neither pharyngeal nor placeless but rather is phonologically dorsal.

¹⁴ Section 4.2.1 presents further data from epenthetic glottal stop in Kisar, showing that it is lost when made word medial following reduplication (a pattern similar to the Arabic data in (20a,b)).

- (19) Arabic
- | | | |
|----|-------------------------|---------------------|
| a. | ʔis .maq | ‘listen’ |
| b. | qaa.la. tis .maʔ | ‘she said ‘listen!’ |
| c. | ʔibra | ‘a needle’ |
| d. | qaa.lat. ʔibra | ‘he said ‘a needle’ |
- (Lombardi 2002)*

Kisar

- | | | |
|----|--------------------|-----------|
| e. | ya ʔu karu | ‘I bury’ |
| f. | ya ʔu ʔelek | ‘I close’ |
| g. | ya ʔu hiʔi | ‘I do’ |
| h. | ye ʔesne | ‘I kill’ |

(Christensen and Christensen 1988, Lombardi 2002a)

Another example of [ʔ] being treated distinctly depending on whether it is epenthetic or not comes from Selayarese, in which [ʔ] is epenthetic phrase initially and between identical vowels. Despite the restriction of epenthetic glottal stop to flanking identical vowels, it may appear between non-identical vowels if underlying (e.g. *baʔo* ‘corn dish’ (Lombardi (2002a)).

Such data pose a challenge to the Landmark Underspecification proposal, in which it was claimed that the gesture of glottal constriction lacks the landmarks of ONSET and OFFSET universally. Thus, the strongest prediction is that every language’s glottal stop will show evidence of the lack of these landmarks (e.g. transparency, hiatus repair in VʔV, temporal variability), evidence that is not forthcoming in the Type (1) languages. The picture is complicated even further by the fact that even in Type (1) languages, glottal stop fails to condition formant transitions on flanking vowels (see discussion in 3.1.2, and in Klatt and Stevens 1969, Alwan 1986, Butcher and Ahmad 1987, Kent and Read 1992, Shank and Wilson 2000b). Thus, the question arises as to whether the Landmark Underspecification proposal can ultimately handle the observed variation in patterning of laryngeals cross-linguistically, and even within the same language. In the next section, I present an analysis of glottal stop that maintains Landmark Underspecification for the glottal gesture in all languages. This section argues that divergence in patterning does not result from multiple distinct representations for the glottal gesture itself, but rather from distinct representations for the glottal stop as a multi-gestural segment; in placeless-ʔ languages, the glottal stop segment is comprised of a single glottal gesture, while in Type (1) languages it is comprised of at least two gestures, one glottal and one supralaryngeal.

4.1.2.2 *Glottal stop as a complex segment in Type (1) Languages*

I propose that we can explain the patterning of glottal stop in Type (1) languages within a Landmark Underspecification frame by focusing on the distinction between what we might call a ‘glottal stop’ and what we refer to as a ‘gesture of glottal constriction.’ The former term picks out a sound or segment, and as such is neutral regarding the gestures that comprise it. The ‘gesture of glottal constriction’ is one of the gestures produced in the articulation of the ‘glottal stop’ segment, but crucially it is not necessarily the only one. In theory, there is no reason why what we call a ‘glottal stop’ could not be comprised of more than just a glottal gesture. Compare, for example, our understanding of the gestural make-up of the supralaryngeal consonants. For these consonants, it is the standard assumption that the supralaryngeal consonants involve gestures on multiple tiers; ‘p’ for example, results from the synchronous achievement of gestural targets at the lips, the velum and the glottis. I propose that the same situation is also the case for glottal stop; while the ‘segment’ of glottal stop is always associated with the gesture of glottal constriction, it may also be accompanied by other gestures. Thus, the percept of the glottal stop observed cross-linguistically may at times be a complex segment comprised of a gesture of glottal constriction as well as other secondary gestures.

The proposal that glottal stop in some languages (e.g. the Type (1) languages) involves the articulation of multiple distinct gestural targets is consistent with the fact that laryngeoscopic examination of the articulation of glottal stop cross-linguistically has shown contribution of the immediately supralaryngeal articulators (see discussion above and the aforementioned references). Recall that in section 3.2 we suggested that this fact might have two ultimate sources. A first possibility is that the supralaryngeal articulators (e.g. the pharynx and epiglottis) work together to implement the single glottal constriction gesture. Such a form would still consist only of the gesture of glottal constriction, and would be the simple glottal stop found in language in which glottal stop patterns as transparent or placeless.

A second possibility is that the observed constriction of supralaryngeal articulators that accompanies glottal constriction is indicative of the presence of multiple gestures in the single glottal stop utterance or ‘segment.’ These possibilities were diagrammed in (4), section 3.2.1, and are repeated in (20).^{15,16} (20a,b) shows the gestural score for a simple

¹⁵ Here, the phasing relation exhibited between the pharyngeal gesture and the glottal one is specified as [ʔ]-TARGET-to-[ʔ] TARGET. This is not the only possible coordination relation between these gestures, but it is necessary that the coordinated landmark of the glottal gesture be either TARGET or RELEASE (the pharyngeal landmark could be ONSET, TARGET, RELEASE, and OFFSET). Additionally, the secondary gesture need not be pharyngeal at all (see the subsequent paragraphs for discussion).

¹⁶ Note that the coordination relation proposed to hold in the glottal stop ‘segment’ in (20c,d) is identical to the one proposed to result from gestural reorganization of underlying ?C/C? clusters in the languages discussed in section 3.3.4. Thus, this brings up the possibility that simultaneity of gestural targets is what results in the percept of the segment. Furthermore, the fact that the gestures that comprise segments often vary in their temporal extent will fall out from the fact that the TARGET-to-TARGET phasing is not particularly strong (at least in comparison to the in- and anti-phase coordination modes associated with syllabic and sequential affiliation).

segment glottal stop, while (20c,d) show the complex segment glottal stop. Note that in the diagram in (20c,d) the glottal and pharyngeal gestures are assumed to phase TARGET-to-TARGET. Because the intergestural relations specified to hold among the gestures of a complex glottal segment are phased in this way (rather than say, ONSET-to-ONSET), glottal stop does become temporally anchored to the pharyngeal gesture (I return to this point shortly). The schematic diagram of a nasal stop in (20e,f) highlights the fact that the percept of a single segment may arise from the coordination of gestures on multiple tiers. Crucially, the intergestural relations holding in (20e,f) are quite similar to the ones holding among the gesture proposed to constitute the complex glottal stop, as illustrated in (20c,d).

(20) Proposed Gestural Representations:

a. [ʔ]:

GLOTTIS: CD = {CLOSED}

b. GLOTTIS:

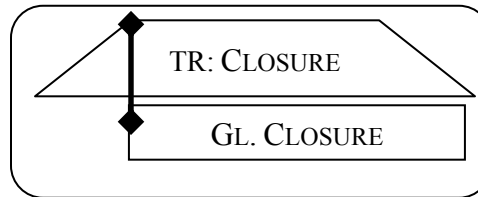


c. [ʔ] with secondary pharyngeal constriction:

TONGUE ROOT: CL = {PHARYNGEAL}, CD = {CLOSED}

GLOTTIS: CD = {CLOSED}

d. TONGUE ROOT:



(TARGET TR = TARGET G)

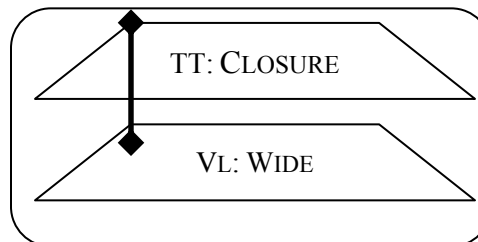
GLOTTIS:

e. [n]:

TONGUE TIP: CL = {ALVEOLAR}, CD = {WIDE}

VELUM: CD = {WIDE}

f. TONGUE TIP:



(TARGET TT = TARGET VL)

GLOTTIS:

The fact that the overlapping coordination of two gestures is generally available for the supralaryngeal gestures (as illustrated in (21e,f) suggests that it may also be generally

available for laryngeal gestures. In fact, it is commonly assumed that laryngeal gestures may be coordinated with supralaryngeal gestures, resulting in such percepts as voicelessness, glottalization, and aspiration. In each of these examples, the main percept is a supralaryngeal segment exhibiting a certain laryngeal contrast. The analysis of Type (1) presented here proposes the presence of gestural configurations in which the percept is primarily glottal, and the contribution of the supralaryngeal gesture is secondary.

The claim, then, is that in languages in which glottal stop patterns with other consonants, for example the pharyngeal consonants or the dorsal consonants, the glottal stop is a complex segment comprised of the glottal gesture and a gesture at some other location.¹⁷ Henceforth, I will call this the ‘Complex Segment’ account. For example, in languages in which glottal stop patterns as guttural (for example, the Semitic and Cushitic languages) there may be secondary constriction in the pharynx that will account for its patterning with other consonants that also involve constriction in the pharynx; the pharyngeals, and, by hypothesis, the other guttural consonants. One advantage of such an approach, in comparison to a feature geometric account, is that we are allowed more freedom in the types of patterns in which glottal stop may participate; there is nothing to preclude the gesture of glottal constriction from being articulated with, for example, a secondary tongue dorsum gesture. The consistent presence of a tongue dorsum gesture during the articulation of a glottal constriction gesture might account for the fact that glottal stop patterns as dorsal in some languages, for example in Toba, and to a lesser extent in Yucatec Maya (see footnote 44, section 3.4).

This analysis has important consequences for how we can reconcile the fact that glottal stop appears to pattern distinctly in a language like Yatzachi Zapotec in comparison to languages like Arabic and other Type (1) languages. Recall that in the former language glottal stop fails to block hiatus resolution processes, whereas in the latter glottal stop is not transparent. As was proposed in the preceding chapter, the YZ pattern results from the failure of the glottal gesture to satisfy the requirements of the OT constraint $\text{ONSET}_{(\text{REV.})}$, for reasons discussed more fully above in section 3.3.2. Thus, it falls out that a language ranking $\text{ONSET}_{(\text{REV.})}$ high will also exhibit repair of $V_x?V_y$ sequences, whether it be coalescence to $V_x?V_x$ or some other repair such as vowel deletion, consonant insertion, or diphthongization across the intervening glottal stop. This is the expected pattern if a particular language’s glottal stop is comprised of the gesture of glottal constriction and this gesture only (c.f. (20a,b)); since this gesture cannot be phased to the vowel as required by the $\text{ONSET}_{(\text{REV.})}$ constraint, repair is necessary.¹⁸

In contrast, in languages in which glottal stop is a complex segment, as in (20c,d), this is not the expected outcome. Instead, we expect that the winning candidate will be one in which the *secondary* consonantal gesture has syllabified as an onset to the

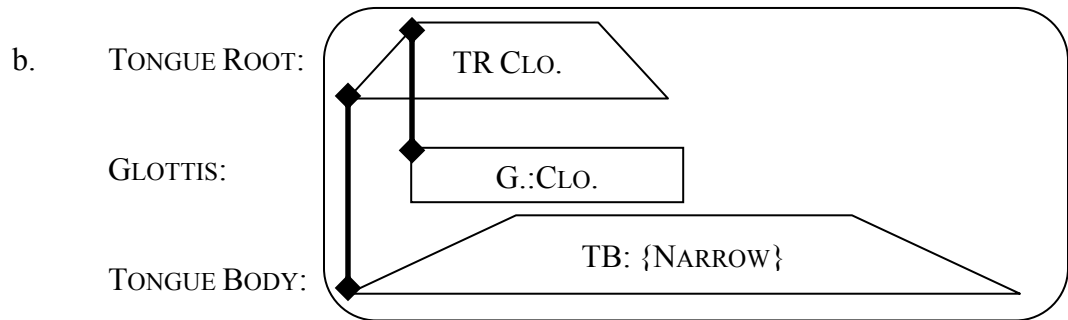
¹⁷ Such a possibility was suggested for the non-laryngeal gutturals in Goldstein (1994) in which it was proposed that the pharyngeals are characterized by a tongue root gesture, and this gesture was also shared by the uvular gutturals, which could be specified as a tongue body/dorsum gesture accompanied by a tongue root gesture. This discussion suggests that the laryngeal consonants lack the tongue root gesture, but evidence from laryngeoscopic analysis shows that it is possible that laryngeal segments can contain both glottal and tongue root gestures.

¹⁸ To review, the constraint $\text{ONSET}_{(\text{REV.})}$ is defined as follows: For every vocalic gesture, the ONSET landmark of a consonantal gesture should be synchronous with the ONSET of that vocalic gesture.

following vowel in the place of the primary gesture of glottal constriction. In such a form, the requirements of the revised ONSET constraint are satisfied, and no repair of the VʔV sequence is necessary in the winning candidate. The diagram in (21) shows the surface coordination relations expected to hold between the glottal stop segment and the following vowel in languages in which a secondary tongue root gesture is present:¹⁹

(21) [ʔi] in a language where ʔ is a complex segment

- a. TONGUE ROOT: CL = {PHARYNGEAL}, CD = {CLOSED}
 GLOTTIS: CD = {CLOSED}
 TONGUE BODY: CL = {PALATAL}, CD = {NARROW}



- c. {TR ONSET = TB ONSET} & {GL. TARGET = TR TARGET}

In the gestural configuration sketched in (22), the tongue root gesture associated with the secondary articulation is coordinated with the tongue body gesture of the following vowel ONSET-to-ONSET. That is, it is phased to the vowel as a syllabic onset. For this reason, the configuration will not incur a violation of the ONSET_(REV.) constraint. This particular phasing relation is the source of the lack of repair in VʔV for the glottal stop segment in Type (1) languages.

The fact that the proposed configuration will result in a winning candidate that has not undergone any repair is shown by the tableau in (22). This tableau applies the YZ constraint ranking to an input with the form in (21). In this tableau, the crucial phasing relations holding in each candidate are identified immediately below the candidate.²⁰

¹⁹ In the interest of providing a clear gestural score for the Type (1) [ʔi] sequence in (21), we specify the gestural coordination relations that hold between the gestures in this sequence in (21c), rather than next to the gestural score in (22b), as has been the pattern in previous such diagrams.

²⁰ Note that in the input and output forms, we use the symbol [ʔ] to represent a glottal stop with secondary pharyngeal constriction; this symbol represents two underlying gestures. Thus, in the specification of the phasing relations below the candidate, we give the phasing relations of the gestures comprising the three ‘segments’: [e, ʔ, ʔ, a], for the sake of simplicity specifying these gestures of [E, G, P, A], respectively.

(22) Hypothetical [eʔi]: $TARGET: \{G\} = TARGET \{P\}$, $ONSET \{P\} = ONSET \{A\}$

Input ...eʔi	DEP _{I-O} (C)	MAX _{I-O} (C)	ONSET (R)	NODIPHTHONG
<i>TARGET: \{G\} = TARGET: \{P\}</i> <i>ONSET: \{P\} = ONSET: \{V\}</i>				
1. eʔti <i>ONSET: \{T\} = ONSET: \{A\}</i> <i>TARGET: \{G\} = TARGET: \{P\}</i> <i>OFFSET: \{V\} = ONSET: \{P\}</i>	*!			
2. eʔ <i>OFFSET: \{E\} = ONSET: \{P\}</i> , <i>TARGET: \{G\} = TARGET: \{P\}</i>		*!		
3. jʔi <i>TARGET: \{G\} = TARGET: \{P\}</i>				*
4. eʔi <i>TARGET: \{G\} = TARGET: \{P\}</i>			*!	
↻ 5. eʔi <i>TARGET: \{G\} = TARGET: \{P\}</i> <i>ONSET: \{P\} = ONSET: \{A\}</i>				

In this tableau, we see that the constraint ranking works to rule out all candidates except the faithfully realized candidate 5. Candidate 1 violates the DEP_{I-O}(C) constraint because it exhibits the insertion of the consonant [t] in the output. In candidate 2, the form has undergone deletion of the final vowel. This candidate therefore violates MAX_{I-O}(C), and has also re-phased the pharyngeal gesture as a coda to the preceding vowel though still preserving the glottal-to-pharyngeal phasing. Thus, candidate 2 also violates the constraint CV PHASING (see discussion in section 3.3.4).

Candidate 3 has undergone diphthongization, thus violating NODIPHTHONG and exhibiting repair when none was necessary. Here, no output phasing relations are assumed to hold between the pharyngeal gesture and the vowel because this gesture no longer plays the role of an onset. Instead, I assume that diphthongs arise through a situation in which two vocalic gestures take the same consonant as an onset (also discussed in section 3.3.3, footnote 37; see Marin 2004 for a similar account). Thus, in CV₁V₂ the crucial phasing relations that hold are $ONSET: \{C\} = ONSET: \{V_1\}$ and $ONSET: \{C\} = ONSET: \{V_2\}$. I propose that the observed contour from V₁ to V₂, and the fact that

diphthongs pattern as single segments, results from the competing phasing relation that holds between V_1 and V_2 , namely $OFFSET: \{V_1\} = ONSET: \{V_2\}$. In essence, this approach treats diphthongization as being exactly equivalent to the C-CENTER effect observed for onset consonants. Thus, sequentiality in diphthongs results from the fact that a sequential phasing relation also holds between the two vowels, and competition between the C- V_1 , C- V_2 and V_1 - V_2 phasing relation results in the diphthongs patterning as though a single unit. See Browman and Goldstein 2000 and section 3.4 above for more discussion of the C-CENTER effect. In candidate 4, the glottal constriction gesture and the pharyngeal gesture are phased to each other as specified in the input, but the coordination of the pharyngeal and vocalic gestures required by the $ONSET_{(REV.)}$ constraint is not present. In this candidate, the second vowel lacks an onset and incurs a violation of $ONSET_{(REV.)}$.

The winning candidate, the one in 5, is the one that has undergone no repair whatsoever and also has preserved all input phasing relations. Here, while the glottal constriction gesture is extrasyllabic, the pharyngeal constriction is not. Crucially, the constraint $Onset_{(REV.)}$ is satisfied by the phasing relation holding between the pharyngeal constriction and the vowel. Furthermore, glottal stop will appear to be stably anchored to the vocalic gesture because of the transitivity of the phasing relation holding between it and the pharyngeal gesture, and between the pharyngeal gesture and the vowel. This candidate violates no constraints, and thus any repair would have been unnecessary and therefore impossible by OT standards.²¹ This form represents the hypothesized winning candidate for languages like Arabic, in which glottal stop is apparently stably phased to surrounding gestures, and does not show transparency or hiatus resolution across it. Furthermore, the relative temporal stability of the glottal stop in Type (1) languages will result from the transitivity of the phasing relation holding between the glottal gesture and the tongue root gesture, and between the tongue root gesture and the tongue body gesture. This is shown graphically in the gestural score in (21b) and in words in (21c). The fact that we observe lack of temporal variability of glottal stop in Type (1) languages results from the fact that the glottal gesture is anchored to the pharyngeal gesture, which is itself anchored to the vocalic gesture.

One benefit of the complex segment account of glottal stop in Type (1) languages is that it allows us to maintain the universality of the Landmark Underspecification account of glottal stop's internal gestural structure. Most importantly, the Complex Segment and Landmark Underspecification proposals allow us to handle its patterning in Type (1) languages without losing the ability to explain the patterning of so-called 'placeless'-? languages, as described throughout Chapters 2 and 3. This analysis also provides an explanation of inter- and intra-language variation in the patterning of glottal stop, and suggests that a single language may have both the simple segment glottal stop in (21a,b) and the complex segment glottal stop in (21c,d).²² Moreover, this analysis can also

²¹ Candidate 5 in the tableau in (23) does violate ASSOCIATE CV, because the glottal gesture is not phased to the following vowel. However, I suggest that this constraint is low-ranked in our hypothetical language.

²² This may account for the patterns from Arabic, Kisar and Selayarese discussed above, in which epenthetic glottal stop is treated distinctly from underlying glottal stop. In these languages, the epenthetic glottal stop patterns with glottal stop in the Type (1) languages, in that they are found with limited distributions. In section 4.2, I will suggest that glottal stop epenthesis in Type (2) languages results from constraints on optimal prosodic configurations that impose different requirements on the gestures that satisfy them (i.e. they do not require an $ONSET (R)$ -like gestural coordination, and can be satisfied by the

account for the patterning of glottal stop with non-pharyngeal segments; the glottal gesture could theoretically be phased as in (21c,d) with any supralaryngeal gesture.²³

The flexibility of the Landmark Underspecification analysis in terms of handling cross- and inter-linguistic variation makes it better equipped to explain the patterning of glottal stop than either the placeless-? or pharyngeal-? accounts, while building on the main insights of each (with the positing of simple vs. complex glottal segments). From the placeless-? approach we retain the distinction between laryngeal and supralaryngeal consonants, but we root the distinction in the articulatory gestures of glottal stop, the acoustic consequences of the production of this gesture, and the implication that this has for the SPM's construction of an abstract representation of this gesture. From the pharyngeal-? approach, we retain the insight that glottal stop should share place of articulation with other consonants in order to explain its patterning, but we link shared place features here obligatorily to a common secondary articulatory gesture (rather than to a distinct specification for the glottal element itself). Ultimately, the present analysis of the patterning of glottal stop is similar to previous accounts that have attributed cross-linguistic distinctions in patterning to language inventories including either placeless or pharyngeal glottal stop (for example, McCarthy 1991a, 1994, Bessell 1992, Bessell and Czaykowska-Higgins 1992, Rose 1996).

Before going on to discuss an account of the apparent ONSET motivated glottal stop epenthesis in Type (2) languages, the next section discusses one question that arises in the context of the Complex Segment proposal. Following the reasoning of Chapter 3 (section 3.3 in particular), the SPM needs acoustic evidence in order to posit the presence of a gesture. This brings up the question of whether recoverable acoustic cues result from the articulation of the complex glottal segment that would provide the SPM with enough evidence to posit the presence of the secondary gesture. In other words, is there sufficient acoustic evidence to posit a distinction in the gestures that comprise a simple vs. complex glottal stop? We address this issue in section 4.1.2.3, which discusses the acoustic patterns of glottal stop in comparison to the pharyngeal consonants with which it patterns in a variety of Type (1) languages. This section concludes that distinctions in the acoustic signals of putative simple and complex glottal stops are not immediately

glottal gesture). Further study should be conducted to determine what factors influence the choice of the simple glottal segment in contrast to the complex glottal segment in languages like Arabic (perhaps due to pressure from a high ranked DEP_{L,O} {GESTURE}). Additionally, it would be interesting to determine if laryngeoscopic examination of the articulation of epenthetic glottal stop in comparison to the underlying glottal stop reveals any divergence between the two.

²³ Consider, for example, the debuccalization of consonants in which oral constriction is lost but glottal constriction remains. One example comes from English, in which failure to release the supralaryngeal constriction associated voiceless stops [p, t, k] results in the percept of glottal stop as primary: For example, [ʃip, ʃit, ʃik] alternate with [ʃiʔp^ʔ, ʃiʔt^ʔ, ʃiʔk^ʔ] ('sheep', 'sheet', 'chic'). However, since the oral constriction continues to be produced, the vowels in the debuccalized forms are realized with coarticulatory effects consistent with supralaryngeal constriction. The complex segment approach to Type (1) glottal stop suggests that it may exhibit similar intergestural phasing relations to debuccalized consonants (e.g. a coordinated glottal and oral gesture in which the percept is primarily glottal), but that this is a stable fact about glottal stop in Type (1) languages (rather than arising out of casual speech debuccalization, as is the case in English).

apparent, though further investigation may discover reliable acoustic differences between these segments. Thus, we must consider the possibility that there is no such evidence available. Section 4.1.2.3 develops a proposal that explains the construction of complex representations of glottal stop despite this lack of acoustic evidence. I propose here that the SPM may posit the presence of a gesture even without acoustic evidence in certain limited contexts. These contexts are those in which the SPM is ‘tricked’ into believing a gesture to be present even when there is no evidence for its presence; this occurs in contexts where top-down clues from allophonic paradigms, coarticulatory patterns and utterance context are available that suggest the presence of the gesture.

4.1.3 The Construction of Gestural Representations of the Complex Glottal Stop

A challenging problem for the proposal that languages exhibit either simple or complex glottal stops is whether learners will find support in the speech stream for positing such a distinction. Recall that the discussion of the perceptual consequences of stop formant transitions in Chapter 3 made the proposal that learners posit only those gestures for which they have acoustically recoverable evidence in the speech stream. Thus, in order for a learner to posit the presence of a complex glottal stop, it will be necessary that not only the glottal stop, but also the associated secondary gesture have recoverable acoustic cues. This is especially true for languages in which there are multiple instantiations of a single sound, here [ʔ,h], that pattern differently. There must be enough evidence in the speech stream for the learner to posit a distinction in representation for the two sounds.

In section 4.1.2.1, I discuss cross-linguistic studies of the acoustics of the laryngeal consonants, in particular the glottal stop. Here we focus on languages in which the behavior of glottal stop suggests that it patterns with a set of non-laryngeal consonants, comparing the acoustic cues provided by the non-laryngeal gestures and those provided by glottal stop. For example, assuming that natural classes are defined by sharing a common gesture, we hope to see identifiable acoustic similarities that may lead the SPM to posit the presence of that gesture for all members of the class. In order to examine this question, I discuss previous research on the acoustic cues of pharyngeal and laryngeal gestures in languages in which these gestures pattern together. Section 4.1.2.2, then goes on to present an analysis of how the complex glottal stop might arise even without recoverable acoustic cues.

4.1.2.1 The Acoustics of Complex Glottal Stop in Type (1) Languages

Section 4.1.1.2 proposed that we can explain the fact that glottal stop appears to syllabify with the vowel in Type (1) languages by attributing it to the presence of a low-magnitude secondary gesture. For languages in which glottal stop patterns as guttural,

this gesture may be pharyngeal.²⁴ Thus, in order to determine whether there is acoustic evidence for the secondary pharyngeal gesture in the complex glottal stop, we begin with a discussion of the acoustic characteristics of the pharyngeal consonants and their coarticulatory effects. This may be considered a basis for judging the pharyngeality of the laryngeal consonants.

In considering the acoustics of the Iraqi Arabic pharyngeal [ʕ] Al-Ani (1981) notes the presence of stop-like silence accompanied by a release burst. As for the effect of [ʕ] on the formant values of flanking vowels, it conditions lowering of F_2 . Lowering of F_2 in the context of the pharyngeal will have the percept of vowel retraction, whether categorical or not, as there is an inverse correlation between F_2 value and perceived vowel backness. Note that this pattern has been phonologized in Arabic and many other languages, in which the pharyngeal and guttural consonants condition vowel lowering and the presence of low vowels in their immediate environment (see section 4.1.1 for discussion). Additionally, Al-Ani (1970) notes some variation in the stricture of [ʕ] depending on context and register, appearing as a stop or a glide (see Al-Ani (1981) p.90 for discussion). Lowering of F_2 in the context of [ʕ] has also been found in other studies of Arabic dealing with a variety of dialects, including Ghazeli (1977), Alwan (1986) and Butcher and Ahmad (1987). However, Al-Ani (1981) discusses the fact that F_2 lowers following Arabic pharyngeals only for [i] and [a], whereas it raises for [u]. This pattern may be the result of [u]'s canonical F_2 value being the lowest of the three to begin with. Ghazeli (1977), Alwan (1986) and Butcher and Ahmad (1987) also note raising of F_1 in the context of a pharyngeal. Alwan (1986) specifically notes raising of F_1 in the context of formant transitions from a pharyngeal, as she mentions a fall of F_1 from the raised initial position to the steady state of the vowel. Pharyngeally conditioned raising of F_1 should result in the percept of vowel lowering; thus, vowels next to pharyngeals may appear as both lower and backer than vowels in non-guttural contexts.

The coarticulatory effects of pharyngeal consonants on flanking vowels found for the Arabic varieties are very similar to the results from studies of pharyngeals in the Wakashan languages in Rose 1981, Shank and Wilson 2000b and Wilson, in press. Rose (1981) notes patterns of vowel retraction for vowels of all heights in Kyoquot, a pattern also apparent in research on Nuuchahnulth (Ahousaht dialect) in Shank and Wilson (2000b). Acoustically, this is reflected in general patterns of coarticulatory effects for pharyngeals including raising of F_1 and lowering of F_2 , as would be expected in light of the phonological patterns of lowering and retraction in Kyoquot and Ahousaht. Shank and Wilson (2000b) found that the exact effect of the pharyngeal on the vowel varied with the vowel context tested, [i], [a] or [u], in comparison to vowels in the context of a non-guttural consonant. For example, raising of F_1 was more pronounced for [a,i] than for [u]. As for their F_2 data, Shank and Wilson (2000b) demonstrated that there is consistent formant lowering for all vowels tested, though the pattern indicated the amount of lowering was less for [u], perhaps a correlate of the F_2 lowering data for Arabic [u].²⁵

²⁴ But see discussion in Esling 2003 that suggests that the Arabic and Tigre pharyngeals may actually be epiglottal.

²⁵ Though the Shank and Wilson (2000b) data presented in their Figure 2 (p. 6) appear to indicate a drop for F_2 on [a], and one that is in fact larger than the drop for [i] or [u], Wilson (to appear) indicates that his results show “only one type where /a/ is realized as [a], confirming the results of Shank and Wilson

In addition to showing that [ʕ] conditions coarticulatory effects on F₁ and F₂, Shank and Wilson (2000b) note a lowering effect for F₃ on all vowels. Ahousaht Nuuchahnulth [ʕ] also conditions creakiness on an adjacent vowel (Shank and Wilson (2000a,b)), which accords with the articulatory description in Esling *et al.* (2005) in which Nuuchahnulth [ʕ] (actually an epiglottal stop) is obligatorily preceded by a glottal stop. In terms of manner of articulation, Shank and Wilson (2000a) argue that [ʕ] has the status of a glide, based on the fact that it patterns with the glottalized resonants; for example, it exhibits the pre-glottalization characteristic of glottalized resonants, instead of the post-glottalization characteristic of glottalized stops (ejectives). Another piece of evidence they present in favor of the analysis of [ʕ] as a pharyngeal glide is that the duration of its formant transitions is similar to a glide's, but longer than a stop's.

Bessell (1992) gives a detailed discussion of the coarticulatory effects between consonants and vowels in the Interior Salish languages, giving the most in-depth analysis of these effects in Moses-Columbian (Nxa'amxcin) Salish. Her findings show phonological lowering of all vowels conditioned by pharyngeals, a pattern shared with the uvulars, the two of which pattern together in terms of faucal harmony. Bessell (1992)'s formant plots in her table 5.26 (p. 128) show F₁ as higher for vowels next to pharyngeals than for the coronal, retracted coronal, and velar contexts. Furthermore, the rise in F₁ is consistent across the steady state of the vowel; Bessell (1992) gives vowel nuclei and offset data that show that F₁ in vowels within pharyngeal contexts remains high, whereas F₁ in other contexts is lower in the offset than the nucleus (with the exception of F₁ for [ə] in the context of a bilabial).²⁶ As for F₂, vowels in pharyngeal contexts exhibit varying coarticulatory patterns depending on the vowel. For example, for her subject MM, in a comparison between pharyngeal contexts and coronals, retracted coronals and velars, show that pharyngeal [i] as 266-191 Hz lower than the pre-velar environments, but F₂ for [ə] was actually higher for the pharyngeals by 84-104 Hz. Bessell (1992)'s data from [a] in a pharyngeal context showed F₂ as lower only in the pharyngeal to coronal and pharyngeal to bilabial comparison (71 Hz. and 121 Hz, respectively). The F₂ for [a] was higher in the pharyngeal context than in both the velar (+6 Hz) and retracted coronal (+229 Hz) conditions. The same pattern was observed for [ə] in the bilabial condition. Thus, it appears that the expected phonetic effect of pharyngealization varies significantly with the vowel in Nxa'amxcin, possibly due to differences in the canonical position of the vowel's formants. A similar pattern was noted by Al-Ani (1981) for [u], but data from Nxa'amxcin is not available for [u] in pharyngeal contexts. Similar patterns are observed for the uvular consonants, but F₁ is not as high for uvulars as for the pharyngeals. For F₂, uvulars condition raising like the

(2000b), who found no significant change in F₂ of [a]” (p. 20) Note that Shank and Wilson (2000b) found a lack of phonological retraction of [a] in Ahousaht Nuuchahnulth in contrast to Rose (1981)'s Kyoquot data which did show [a] to [ɑ] retraction. However, the lack of observable phonological retraction apparently does not necessarily indicate lack of F₂ lowering, as Shank and Wilson (2000b) did show significant F₂ lowering (contrary to what discussion in Wilson (in press) indicates).

²⁶ Data presented in table 5.26 of Bessell (1992) show the formant frequencies of vowels in various consonantal contexts for two speakers, one recorded by Bessell herself, MM, and the other recorded by M. Dale Kincaid, JM. Bilabial data are only available for JM.

pharyngeals, with the values for F₂ on [a] and [ə] being within 8 Hz of the F₂ of the same vowel in the environment of a pharyngeal, while F₂ is 109 Hz higher for the uvular context than for the pharyngeal context.

The Nxa'amxcin data suggests that the most consistent effect of pharyngealization is raising of F₁, and this is consistent with the regular phonological patterns of vowel lowering in the context of faucal consonants in this language. Pharyngeal influence on F₂ value was far less consistent, but Bessell (1992) attributes some of this pattern to the fact that formant values for vowels in pharyngeal contexts were collapsed across the four pharyngeal consonants, [ʕ,ʕ^w, ħ,ħ^w]. In her table 5.27 (p. 139), Bessell (1992) distinguishes the coarticulatory effects of each of the pharyngeal consonants, but shows that F₂ for [ə], the only vowel present in each of the contexts, still remained high. Thus, it appears that while F₁ raising and consequent perceived vowel lowering is a consistent identifier of pharyngealization in Nxa'amxcin, the perceived vowel retraction exhibited by Arabic and Nuuchahnulth (as conditioned by F₂ lowering) is not. This is despite the fact that the pharyngealization coarticulation patterns have been phonologized in terms of the faucal harmony phenomena, in which vowels in pharyngeal and uvular contexts exhibit both lowering and retraction.

Bessell (1992) also notes some creakiness conditioned by the presence of a pharyngeal, but states that “the descriptive literature does not report glottal effects on non-glottalized pharyngeals in Interior Salish” (p. 188). More regular patterns of creak are exhibited on the glottalized pharyngeals, which Carlson *et al.* (2003) found to be articulated as an epiglottal stop for which the increased degree of creakiness can be attributed to the glottal constriction necessarily accompanying full epiglottal closure. Thus, the Interior Salish glottalized pharyngeal [ʕ'] articulatorily closely resembles the [ʕ] found in Nuuchahnulth (Esling *et al.* (2005)), and Arabic and Tigrinya (Esling *et al.* (2003)), which are each realized as epiglottal stops as well. The fact that the Salish glottalized pharyngeal corresponds articulatorily to the so-called plain pharyngeals in Arabic and Nuuchahnulth is interesting considering the fact that in the latter two languages creak has been identified as a more consistent effect of pharyngeal articulation on the vowel (Shank and Wilson 2000a,b, Wilson (to appear)). The plain pharyngeal in Nlaka'pamux exhibits a lesser degree of constriction at the epiglottis, for which strong glottal constriction is not necessarily present (Carlson *et al.* (2003)); this would explain the absence of consistent creak associated with the plain pharyngeals in Nxa'amxcin, assuming the plain pharyngeals are realized in the two Salish varieties identically.

In comparing the data from the varieties of Arabic, Wakashan and Salish discussed above, it is apparent that one consistent effect of a pharyngeal on an adjacent vowel is raising of F₁ either over the whole vowel, or only during formant transitions. This coarticulatory effect should lead to the percept of vowel lowering, whether categorical or not. This prediction is upheld by the various vowel lowering patterns observed cross-linguistically in the context of a pharyngeal consonants. As for the effects of pharyngealization on the value of F₂, this is less consistent in general, with both lowering and raising of F₂ observed in the context of a pharyngeal cross-linguistically. Thus, this may result in some vowels being perceived as fronter in the context of a pharyngeal, while others may have the percept of increased backness. For example, the vowel [a] is realized as [æ] in the context of a pharyngeal in Egyptian Arabic, rather than as a

retracted form, [ɑ] (from Harrell (1957), as cited in Bessell (1992)). While the coarticulatory effect of a pharyngeal consonant on the acoustics of adjacent vowels is strongest for F₁ and F₂, a lowering effect on F₃ has been noted by Catford, as cited in Ladefoged and Maddieson (1996), and Shank and Wilson (2000b). This was subsequently confirmed for Nuuchahnulth by Shank and Wilson (2000b). Another common characteristic of the coarticulatory effects on vowels in pharyngeal environments is creakiness.

In languages in which pharyngeal consonants are present, it is presumably these coarticulatory effects that provide the learner with evidence for positing the presence of the pharyngeal/epiglottal consonantal gesture, and for specifying the constriction location of that gesture. If a language consistently treats the laryngeal consonants as though they share a place of articulation with the pharyngeals (in traditional terms), we might expect that this pattern arises because of a perceived similarity in the coarticulatory effects of laryngeals on vowels. Thus, we predict that laryngeals in Type (1) languages will cause patterns consistent with pharyngealization on flanking vowels (or consistent with the coarticulatory effects of whatever secondary gesture is present, i.e. dorsal for Toba). Most importantly, we expect raising of F₁ on the complex glottal stop, which appears to be the most regular indicator of pharyngeality. Let's now turn to see whether this prediction holds of Type (1) glottal stop.

As was mentioned in Chapter 3, the articulation of a glottal stop does not cause formant transitions on flanking vowels, as discussed by Kent and Read 1992, cited in Shank and Wilson (2000b), and supported by research discussed above. One question that arises is whether the lack of formant transitions caused by the articulation of glottal constriction is universal. If some languages exhibit a complex glottal stop with a secondary articulation, it is possible that in languages with these complex glottal stops these do condition formant transitions. One test case is Arabic, in which the patterning of glottal stop points to its being a complex segment according to the reasoning presented in section 4.1.2.1. However, a number of studies have confirmed that there are no formant transitions for [ʔ] even in varieties of Arabic. For example, Alwan (1986) showed that speakers identified synthetic [ʔV] sequences as glottal stop initial even when no formant transitions were provided, but identification of pharyngeal and uvular initial sequences crucially relied on the presence of formant transitions. Natural language data also confirm that Arabic glottal stop doesn't condition transitional coarticulation on the formants of flanking vowels, as production data collected by Klatt and Stevens (1969) and Butcher and Ahmad (1987) for Lebanese and Iraqi Arabic, respectively, showed no transitions. The observed lack of formant transitions for [ʔ] in Arabic leads us to the conclusion that any pharyngeal-like coarticulatory effects conditioned by glottal stop must be realized globally, if they are present at all. Therefore, we should consider whether the laryngeal is associated with overall lowering or raising effects on a vowel's formant structure. The following discussion presents data from the various languages of study (Arabic, Nuuchahnulth, Nxa'amxcin) together.

Al-Ani (1981) presents data that directly compares the acoustic consequences of [ʕ] and [ʔ] in Iraqi Arabic. First, he notes that glottal stop is both shorter and weaker in comparison to [ʕ], exhibiting a weaker burst in word initial position (p. 89). As for the coarticulatory effects of glottal stop on adjacent vowels, he notes that while the

pharyngeal conditions lowering of F_2 , F_2 in the context of the laryngeal is higher. It is unclear from Al-Ani (1981)'s discussion how the formant frequencies for both pharyngeal and laryngeal F_2 compare to the values for these formants in non-guttural environments. Thus, it is possible that the laryngeal conditions F_2 lowering in comparison to the non-guttural consonants but not in comparison to the pharyngeals. Al-Ani's data showed lowering and retraction for [i] and [a] in the context of a pharyngeal; neither of these patterns was exhibited by vowels in the context of glottal stop. Most importantly, Al-Ani states that for vowels, "there is no lowering of F_2 when they are next to /ʔ/..." (p. 91). Al-Ani (1981) makes no mention of the effect of F_1 conditioned by either the pharyngeals or the laryngeals.

Shank and Wilson (2000b) also provide data regarding the presence of coarticulatory effects on vowels caused by the pharyngeals and laryngeals, the first set of which was presented above. Recall that raising of F_1 for vowels adjacent to [ʔ] was a cross-linguistically common pattern, and one that Shank and Wilson (2000b) also found for the Ahousaht Nuuchahnulth data. The data presented in their Figure 1 (p.6) show that F_1 in pharyngeal contexts is higher than in both the context of a pre-velar consonant and in the context of a laryngeal. However, glottal stop did condition higher F_1 for all vowels than in the consonantal control, though it was not as high as F_1 for vowels next to pharyngeals. Moreover, there was variation in terms of how much F_1 was raised in comparison to the control, for example for [i] F_1 had raised by 41 Hz., for [a] 54 Hz., but for [u] only 8 Hz. Thus we can draw the conclusion that raising of F_1 may be a consistent global affect of laryngeal coarticulation. However, since the rise in F_1 conditioned by the laryngeal consonants is considerably smaller than that conditioned by pharyngeals, we cannot be sure that this would provide enough acoustic evidence for the speaker to posit the presence of a pharyngeal gesture on glottal stop. Pending further research on this issue, a conservative approach is to assume that it does not, and account for the presence of the pharyngeal gesture by other means (as in the account developed in section 4.1.3

As for the effects of laryngeal coarticulation on the F_2 of a flanking vowel, we see that its effects are more variable than those for F_1 . But interestingly, where the coarticulatory patterns in the glottal stop context vary from vowel to vowel, they do not necessarily vary in the same direction as the pharyngeal contexts (which exhibited lowering of varying degrees for all vowels). So, while pharyngeals condition F_2 lowering for [i] in comparison to the control, glottal stop conditions slight raising (70 Hz.). Likewise, while pharyngeals lower the F_2 for [a] by 222 Hz., lowering for the glottal stop is less extreme (39 Hz.). The pattern changes, however, for [u]; here F_2 lowers more for [ʔ] than for [ʕ] (316 Hz. vs. 241 Hz.). Note that while lowering of F_2 seems to be a common cross-linguistic reflex of pharyngeality, Nuuchahnulth differs from both Nxa'amxcin and Arabic in exhibiting F_2 lowering for [u] also, as the former languages show F_2 raising in this context. Additionally, while pharyngeal contexts in Nuuchahnulth condition across-the-board lowering of F_3 , glottal stop conditions lowering of F_3 in comparison to the control only for [i] and no lowering whatsoever in comparison to the pharyngeal contexts. Finally, glottal stop in Nuuchahnulth does cause creakiness on adjacent vowels, like the pharyngeals. This similarity is a consequence of the fact that the epiglottal stop exhibited by Nuuchahnulth is preceded by glottal stop-like glottal constriction. Turning now to the data from Salish, Bessell (1992) notes that there is little coarticulatory effect caused by laryngeals on flanking vowels, unless those effects are

conditioned by other consonants across the glottal stop. Most importantly, she states that there is no lowering in the environment of a laryngeal, indicating that it doesn't pattern with the faucal consonants. The glottal stop in Nxa'amxcin follows the pattern of Arabic and Nuuchahnulth in conditioning creakiness on the vowel, a characteristic it shares with some tokens of the plain pharyngeals and with all tokens of the glottalized pharyngeals.

One conclusion that we can draw from this survey of the acoustic consequences of the coarticulatory effects of glottal constriction is that it does not always exhibit the same patterns as the pharyngeal (epiglottal) stop. Also, when the same acoustic patterns are exhibited for glottal stop as the pharyngeal, they are almost always less pronounced for the laryngeal than for the pharyngeal. Thus, it has been claimed by some researchers that there is no coarticulatory effect conditioned by glottal stop whatsoever (Arabic, (Al-Ani 1970)), (Salish, Bessell (1992)). Shank and Wilson (2000b)'s data showed a different pattern for Nuuchahnulth in which glottal stop conditioned a coarticulatory pattern similar to the cross-linguistically most stable indicator of pharyngeality: raising of F_1 . These patterns were consistent across all vowels studied, but were much more slight than the effects conditioned by the pharyngeals. As for the lowering of F_2 noted for pharyngeals consistently in Nuuchahnulth, and less so in Arabic and Nxa'amxcin, glottal stop showed this pattern for a subset of the Nuuchahnulth vowels ([a],[u]), but to a much lower extent than did the pharyngeals. A third coarticulatory effect of pharyngeal articulation, lowering of F_3 , was not exhibited at all by the Nuuchahnulth glottal stop.

Considering the data from Arabic, Nuuchahnulth and Nxa'amxcin, the main finding is that the articulation of glottal constriction does not consistently condition pharyngeal-like coarticulatory effects. For those effects in which glottal stop patterns with the pharyngeal (F_1 raising in Nuuchahnulth), it is an open question whether the slight degree of raising conditioned by glottal constriction is sufficient evidence for a learner to posit the presence of a pharyngeal gesture for this segment. This is an open question. In the interest of constructing the most constrained theory, we will for the moment assume the answer is "no" and will consider a possible explanation of why a learner might posit a pharyngeal gesture for glottal stop in the absence of any significant acoustic evidence for its presence.

4.1.2.2 *Top-Down Influence on the Representation of the Complex Glottal Stop*

In this section, I propose that learners find support for the presence of secondary gestures on glottal stop in certain stable allophonic patterns, even in the absence of direct acoustic evidence for the presence of these gestures. Under this proposal, information from allophonic patterning leads the learner to posit the presence of the gesture, and this prevails over the usual process of forming gestural representations of utterances. Instead of extrapolating back from the acoustics of the speech stream to determine its gestural make-up, the SPM is influenced into positing the gesture.

An example of how this might work in a language in which glottal stop consistently patterns as pharyngeal is shown below. Here we use data from Palestinian Arabic to

illustrate how allophonic patterns can influence the construction of the gestural representation of glottal stop:

(23) Palestinian

a.	Non-pharyngeal environments		
	yi- ktib	katab	‘write’
	yi- mlis	malas	‘level’
b.	Pharyngeal environments		
	yi- blaʕ	balaʕ	‘swallow’
	yi- shal	saʕal	‘slid’
c.	Laryngeal environments		
	yi- sʔal	saʔal	‘asks’
	yi- sfah	safah	‘rude’

(Herzallah 1990, Bessel 1992)

The data in (23a) show the present progressive and imperfective conjugation of verbs in Palestinian Arabic, column 1 and 2, respectively. These data show that for non-guttural roots, [i] is the thematic vowel for the present progressive, while [a] is used for the imperfective. (23b,c) show that when there is a guttural consonant in the root, the thematic vowel is [a] in both conjugations.

Now consider a learner presented with the data in (23a,b). The learner will recognize the consistent pattern that the pharyngeal consonants [ʕ,ħ] are associated with the vowel [a], while non-pharyngeal roots are sometimes associated with [i] and sometimes with [a]. The learner may posit that it is the presence of the pharyngeal gesture in the (23b)-type roots that accounts for the fact that [a] is the only thematic vowel employed in these conjugations. This would be a reasonable assumption, considering that [a] and the pharyngeal consonants share a low, back articulation. Moreover, since pharyngealization has as its effects raising of F₁ and lowering of F₂, the learner may attribute the relatively high F₁ and low F₂ for this vowel to the effect of the flanking pharyngeal. Now consider what will happen when the learner is presented with the data in (23c). Given that he has posited a concrete connection between the presence of [a] as a thematic vowel and the presence of a pharyngeal gesture, data like that shown in (23c) may be interpreted by the learner as sufficient evidence that the laryngeals also have a pharyngeal component. Thus, if there is strong evidence that connects the presence of a particular gesture to a particular allophonic pattern, the SPM may posit the presence of that gesture for any segment that also participates in the same allophonic pattern. Consequently, learners will develop underlying representations of glottal stop in which it is a complex segment with coordinated pharyngeal and glottal gestures. Importantly, this speaker will subsequently produce glottal stop with both gestures.

The reasoning presented here can be applied to any stable allophonic pattern, and need not be limited to languages in which glottal stop patterns with the pharyngeal consonants. Let’s consider the data from Toba glottal stop as an example. The Toba data

from (16) is repeated here as (24). (24a,b) shows that the velar and uvular consonants condition echo epenthesis when input-adjacent to a consonant. (24c) shows that echo epenthesis occurs for glottal stop too.

- (24) Toba
- | | | | | |
|----|----------------------|---|---------------------|----------------------|
| a. | la-ron aq -wa | → | larona G awa | ‘his brother-in-law’ |
| b. | ɲa-so Gok -ǰi | → | ɲaso Gog ǰi | ‘my patios’ |
| c. | hi-qa ʔ -ji | → | hiqa ʔ aji | ‘my chins’ |

(Klein 2001, Borroff and Klein 2004)

It is reasonable to assume that, based on the data in (24a,b), learners will draw the conclusion that the tongue dorsum gesture shared by velars and uvulars is what accounts for these consonants forming a natural class. Thus, when presented with the data from (24c), where glottal stop also forms a member of this class, the learner will come to the further conclusion that glottal stop also is specified as having a tongue dorsum gesture.

The allophonic patterns in (23) and (24) will cause the SPM to posit the presence of the pharyngeal and dorsal gestures for glottal stop, and the learner will ultimately produce the glottal stop with both laryngeal and pharyngeal/dorsal constriction. However, the presence of a complex glottal stop in a language must be somewhat precarious, in that it depends on the presence of stable allophonic patterns like the ones shown in (23), (24). For example, if Palestinian Arabic were somehow to lose all verbs with pharyngeal consonants, there would no longer be any evidence that the presence of [a] as a thematic vowel is in any way related to the presence of a pharyngeal gesture. Likewise, loss of echo-epenthesis for the Toba dorsals would destroy the evidence for dorsality as a prerequisite for this process, and the echo-epenthesis after glottal stop would not be treated as evidence that it is partially comprised of a tongue dorsum gesture. In such a situation, the learner would again be forced to rely solely on acoustic cues to determine the gestural make-up of the utterance containing the glottal stop. In this case, we expect that glottal stop would be posited as a simple glottal stop, and patterns of transparency and ‘placelessness’ should arise over time.²⁷

The proposal that allophonic patterns may lead speakers to posit underlying representations for which there is no direct acoustic evidence has precedent in work by Walker and Pullum (1999). In this paper, the authors examine cross-linguistic patterns of nasal spreading to determine the status of nasalized laryngeals and their placement in a hierarchy of compatibility with nasalization. They show that in languages that allow nasality to spread through vowels and semivowels, nasality also spreads through the laryngeal consonants. For this reason, they posit an implicational hierarchy for

²⁷ Ola Orié and Bricker (2000) present a similar suggestion to explain the patterning of [h] in Yucatec Maya, which patterns as transparent in some contexts, and non-transparent in others. They propose that the transparent [h] is “represented as a consonant with laryngeal specifications only . . . , and the “strong” [h] as a velar consonant” (p.307). The authors recognize that speakers need synchronic data in order for a distinction in the representation of the two [h]s to be posited, and they instead consider the alternative where each has the same representation but non-transparent forms are specified as exceptions in the lexicon. See their paper for discussion of possible sources of the Yucatec Maya alternation.

compatibility with nasalization in which nasalization of laryngeal consonants imply nasalization of vowels, and nasalization of glides implies nasalization of both vowels and laryngeal consonants. An important point of this paper is the proposal that laryngeal consonants can be underlyingly specified as [+NASAL]. Walker and Pullum (1999) present data from a number of languages in which the laryngeal consonants are not only transparent to nasal spreading, but also condition it. Examples of these patterns from Arabela (Zaparoan) are shown below in (25).

- (25) Arabela
- | | | |
|----|--------------------|-------------------|
| a. | mōnũ? | ‘to kill’ |
| b. | ñj̃ ãẽãri? | ‘he laid it down’ |
| c. | hũwã? | ‘a yellow bird’ |
| d. | hẽẽgi? | ‘termites’ |

(Rich 1963, Walker and Pullum 1999)

The data in (25a,b) show that nasal stops in Arabela condition progressive nasal spreading through vowels and glides, and that nasalization is blocked by a non-glide supralaryngeal consonant. (25c,d) demonstrate that [h] can condition spreading of nasality in the absence of a nasal stop. Nasal spreading from [h] causes nasalization of all vowels and semivowels to its right, blocked by a supralaryngeal consonant. Walker and Pullum (1999) take this as evidence that Arabela’s [h] is underlyingly specified as [+NASAL]. They also present similar data from a number of languages in which [h] can condition nasal spreading, but in which nasalizing [h] contrasts with a non-nasalizing variant, further supporting the proposal that the nasality of [h] can be phonemic. These languages include Kwangali (Kavango; Ladefoged and Maddieson 1996), Aguaruna (Jivaroan; Payne 1974, Trigo 1988), and Seimat (Austronesian; Blust 1997, 1998).

As for the phonological status of glottal stop in nasal spreading languages, Walker and Pullum (1999) propose that it too can carry a specification of [+NASAL]. When nasality spreads through glottal stop in Sundanese they argue that it has become phonologically [+NASAL].²⁸ Unfortunately, there is no Sundanese data available for glottal stop that parallels the Arabela [h] data; glottal stop does not itself condition nasality in the absence of a nasal consonant. Thus, we cannot determine whether it is possible for glottal stop to be underlyingly [+NASAL], only that it can surface as nasal (under the assumption that spreading is always strictly local (Gafos 1999, among others)). Moreover, the proposal that glottal stop can be specified as [+NASAL] faces the challenge that nasality on glottal stop does not always cause recoverable acoustic cues; during full closure at the glottis, no evidence will be available for nasality. However, if the acoustic energy added to the speech stream via nasal airflow is what allows the SPM to posit the

²⁸ In contrast, an AP account would argue that the glottal stop is neither [±NASAL] underlyingly, but instead is overlapped by the velum lowering gesture associated with the conditioning nasal. Only when the glottal stop conditions nasal spreading, as is the case for the Arabela [h], can we claim that the *segment* glottal stop is [+NASAL] in the sense that it is comprised of coordinated glottal and velar gestures.

presence of the velum lowering gesture for nasal segments, it is difficult to see how this gesture could be posited by the SPM for glottal stop in the absence of nasal airflow.²⁹ In response to this challenge, Walker and Pullum (1999) propose that “sounds can be detected not only through their acoustic properties but also through their effects on neighboring segments.... A child ... could easily discover that a glottal stop is nasal: all that would be required is an identifiable nasal spreading process in the language” (p. 776).

Walker and Pullum’s (1999) proposal that allophonic patterns can result in the perception of phonological features for which there is no direct local acoustic evidence in the speech stream is analogous to the proposal sketched above regarding the SPM’s perception of gestures based on stable allophonic patterning. In order to further illustrate how the presence of an allophonic paradigm might provide evidence to the SPM to posit the a gesture that despite the lack of acoustic cues for its presence, we present an example from a hypothetical language based on discussion and data in Walker and Pullum 1999 (p. 776):

- (26) a. mĩ mẽ mã mõ mũ
 nĩ nẽ nã nõ nũ
 b. pi pe pa po pu (*pẽ.)
 ti te ta to tu (*tẽ)
 c. ʔi ʔe ʔa ʔo ʔu
 d. ʔĩ ʔẽ ʔã ʔõ ʔũ

In this hypothetical language, nasality is non-phonemic on vowels as nasal vowels are always accompanied by the presence of nasal stops. This is shown in the comparison between the forms in (26a) and the forms in (26b). Based on the data in (26a,b) the learner will posit that the nasality of the vowel is an artifact of the fact that the nasal stop is partially specified as having a velum lowering gesture. Thus, vowel nasality will be taken as a conclusive indication that the conditioning consonant is specified for a velum lowering gesture, and that non-nasality conclusively indicates the lack of a velum lowering gesture. Now consider a situation in which the learner is presented either with the data from (26c) or the data from (26d). Given (26c), in which the presence of a glottal stop does not condition vowel nasality, the speaker will conclude glottal stop lacks a velum lowering gesture. In contrast, the data in (26d), in which the presence of a glottal stop does condition vowel nasality could lead the learner to posit a gestural representation

²⁹ Cohn (1993) showed that even in the context of nasal spreading through a glottal stop, nasal airflow is reduced during the glottal stop. However, it is still possible that reduced nasal airflow for a lenited glottal stop (e.g. one not reaching full closure) might exhibit acoustic evidence for velum lowering; Note that [h] does not face the problem of lack of acoustic evidence for nasality, as Cohn (1993) showed that nasal airflow can continue throughout an [h]. Presumably, then, nasal and non-nasal variants of this consonant are distinguished acoustically, and this is sufficient for learners to construct distinct gestural representations of [h] either with or without the velum lowering gesture

for glottal stop that includes a gesture of velum lowering. This will be the outcome regardless of the fact that there is no direct acoustic evidence for velum lowering on glottal stop due to the fact that there is no nasal airflow; the speaker will still posit the ‘nasal’ glottal stop if the segment participates in a stable allophonic relation with non-phonemic nasal vowels. The reasoning here is quite similar to that which was presented above to explain how a learner might posit the secondary gesture in a complex glottal stop.

In fact, it has been shown previously in the literature that the perceptual system is influenced by top-down linguistic information, for example from contextual, lexical and paradigmatic patterns. One example comes from the phenomenon of phoneme restoration, in which subjects perceive words accurately despite the fact that a sound has been removed, obscured by noise, or replaced by noise (for more discussion see Samuel 1996, and references therein). Furthermore, these subjects fail to be aware of the fact that the utterance has been altered. These experiments show that the SPM does not always rely solely on the acoustic signal to determine what gestures were produced. Instead, information from other sources (lexical, paradigmatic) can influence the SPM to posit the presence of gestures even when there is no direct acoustic evidence for their presence. Likewise, stable allophonic patterns have also been shown to influence the formation of gestural representations. For example, data from Beddor *et al* 1986 and Krakow *et al.* 1988 showed that the treatment of the acoustic effects of contextual nasalization (low frequency energy near the first formant) was influenced by whether the conditioning nasal was present; speakers attributed the coarticulatory effect to the nasal consonant when it was present, and to vowel height distinctions when it was not. This is a case where the SPM fails to posit the presence of a gesture (velum lowering) even when the acoustics do provide evidence for its presence, because an alternative (vowel height) analysis was available. These phenomena show that data from context and allophony can trick the SPM into both positing a gesture when there is no acoustic evidence for its presence (Phoneme Restoration), or failing to perceive a gesture when there is acoustic evidence for its presence.

To summarize, the evidence suggests that lexical, paradigmatic and allophonic information can lead the SPM to posit gestural representations for an utterance that does not constitute an accurate interpretation of the acoustic cues provided. This was shown, for example, in listeners’ treatment of utterances in Phoneme Restoration experiments, and in Beddor’s *et al.* 1986 and Krakow’s *et al.* 1988 experiments on the perception of non-contextual nasalization. Similarly, this section has proposed that allophonic paradigms in Type (1) languages may be the source of the multi-gestural representation of glottal stop (as in (22) above) that the SPM posits for these languages, even in the absence of uniquely identifiable cues to the presence of a secondary (non-glottal) gesture.

Section 4.2 goes on to discuss an additional challenge to the Landmark Underspecification account of glottal stop; namely, the challenge from languages in which glottal stop is epenthesis into pre-vocalic position. This section discusses previous approaches to the pattern of glottal stop epenthesis, many of which have claimed that it is inserted prevocalically in order to satisfy the ONSET constraint. Such proposals are incompatible with the Landmark Underspecification account because glottal stop can never syllabify as an onset in this account. In section 4.2.1, I present data from glottal

stop epenthesis, further elucidating the contexts in which insertion is found. As it turns out, epenthesis of a glottal stop is actually quite limited; it is usually found in prosodically prominent syllables, or syllables whose vowels are particularly salient for lexical access (in ways to be discussed in section 4.2.1). Section 4.2.2 presents a preliminary discussion of the constraints that motivate glottal stop epenthesis cross-linguistically, suggesting that it occurs as a result of constraints on prosodic structure rather than on syllable structure.

4.2 *Glottal Stop Epenthesis in Type (2) Languages*

Many languages exhibit glottal stop epenthesis into pre-vocalic position. This epenthesis has previously been argued to occur in order to avoid a violation of the constraint ONSET (e.g. Lombardi 2002), as has been a common explanation of pre-vocalic epenthesis generally (e.g. McCarthy and Prince 1993 for Axininca Campa, among others; see also Casali 1996 for an ONSET approach to many types of hiatus resolution including consonantal epenthesis). In fact, glottal stop has been considered an unmarked epenthetic consonant cross-linguistically (Gafos and Lombardi 1999, Lombardi 2002a, Lombardi 2002b). Under a placeless account of glottal stop, its unmarkedness arises from its lack of place specification; glottal stop insertion is favored by the OT grammar because this does not add new place features to the output; constraints like $DEP_{I-O} \{PLACE\}$, or $IDENT_{I-O} \{PLACE\}$ favor glottal stop for epenthesis over any other consonant. Lombardi (2002a) presents an alternative account of the unmarkedness of glottal stop epenthesis. In her analysis, glottal stop is specified for pharyngeal features (e.g. it is not placeless). Lombardi (2002a) proposes a markedness hierarchy for place features in which pharyngeal is least marked, followed by coronal and labial, dorsal. Thus, glottal stop is preferred over other consonants as an epenthetic consonant because it does not add marked structure to the derivation, at least in comparison to epenthesis of a coronal, labial or dorsal consonant. Formally, Lombardi accomplishes this by proposing the anti-place constraints $*PHARYNGEAL$, $*CORONAL$, $*LABIAL$ and $*DORSAL$, and a harmonic ranking among them ($*LABIAL, *DORSAL \gg *CORONAL \gg *PHARYNGEAL$).

The data from glottal stop epenthesis poses a challenge to the Landmark Underspecification proposal. This challenge arises due to one important consequence of landmark underspecification, namely that glottal stop fails to syllabify as an onset, in every context. Thus, under this proposal prevocalic epenthesis of a glottal stop cannot be analyzed as ONSET-motivated. Rather, we must attribute the epenthesis of glottal stop to other factors. The purpose of this section is to suggest one alternative approach to explaining glottal stop epenthesis, one that can be reconciled with the Landmark Underspecification proposal.

Section 4.2.1 presents data from Type (2) glottal stop epenthesis, much of which was collected in Lombardi's (2002) careful study of glottal stop epenthesis. Interestingly, glottal stop epenthesis seems to be unmarked in certain limited environments, but elsewhere it is actually unavailable. Analyses that argue that glottal stop is the least marked epenthetic consonant have failed to notice one important point regarding the

distribution of epenthetic glottal stop; overwhelmingly, glottal stop epenthesis is limited to prominent positions (as measured by prosodic or lexical salience). Data to be presented in section 4.2.1 will show that glottal stop is more likely to occur in prosodically prominent positions (phrase initial, before a stressed syllable) than before prosodically weak syllables (phrase medial, before an unstressed syllable). For example, glottal stop is epenthesized in prevocalic position in English but only in phrase initial syllables (e.g. [æpəʔ] vs. [ðI jæpəʔ]). Similar examples are observed for Arabic, Selayarese, Czech, Kisar and Koryak (Lombardi 2002a; Mithun and Basri 1986, Kučera 1961, Christensen and Christensen 1992, Kenstowicz 1976). Another example comes from Standard German, in which glottal stop is epenthesized before stressed onsetless syllables but not before unstressed onsetless syllables (before which no consonant is epenthesized, Alber 2001). Also, glottal stop is more likely to be epenthesized before lexically salient vowels (e.g. those whose identity is most important for lexical access; root initial vowels vs. suffix initial vowels), and between identical vowels more than between non-identical vowels. This is shown in data from Standard and Southern German and Malay, which each show a preference for glottal stop epenthesis at the prefix-root boundary in comparison to the suffix-root boundary. Furthermore, glottal stop epenthesis may occur in languages that already have phonemic glottal stop (as in the Arabic and Kisar data from 4.12.1), but these epenthesized glottal stops are also found in limited prosodic positions.

The discussion in section 4.2.1 presents data to illustrate the fact that glottal stop epenthesis is limited to positions that share a common set of properties; prosodic prominence and lexical salience. Based on this observation, section 4.2.2 suggests that the constraints that motivate glottal stop epenthesis govern prosodic configurations, rather than syllabic configurations. Crucially, epenthesis of a glottal stop into prevocalic position is not motivated by the constraint ONSET. This is suggested by the fact that, in each case, the glottal stop is not inserted into onsetless syllables across-the-board but only into those onsetless syllables that are also prominent or salient. Thus, I propose that the data from Type (2) languages are not proper counterexamples to the proposal that glottal stop is not an onset. Instead, I propose that glottal stop epenthesis in these languages is motivated by constraints on prosodic configuration, and that these constraints do not enforce any particular phasing relation to obtain between the epenthesized consonant and the vowel. The result is that glottal stop is an optimal epenthetic candidate in response to these prosodic constraints, but not an optimal epenthetic consonant in response to a violation of constraints on syllabic structure (ONSET, NOCODA).

While further research is necessary to determine the exact nature of the constraints motivating epenthesis in Type (2) languages, I outline a possible OT account of prosodically-motivated glottal stop epenthesis. Here, I suggest that it may have arisen from a phonologization of strengthening effects at the beginning of prosodic domains. Thus, initially glottal stop epenthesis was phonetic rather than phonological. Subsequently, this effect was phonologized, resulting in phonological glottal stop insertion into domain initial position. The two remaining contexts for glottal stop insertion, though non-initial, are also characterized by prominence (either prosodic or lexical); these are the positions of stressed syllables and root initial position. I do not develop a detailed analysis of these environments here, but note that a non-ONSET

account of glottal stop epenthesis may also be available to explain insertion in these positions.

4.2.1 Data from Type (2) Glottal Stop Insertion

It is generally assumed that English exhibits glottal stop epenthesis into word initial position before an underlyingly vowel initial syllable in order to provide an onset to the vowel. The distribution of glottal stop is limited in English, as evidenced by the fact that it does not provide an onset to onsetless syllables word internally, and often not word initially in connected speech. Consider the data below in (27):

- (27) a. ‘apple’ [ʔæpət]
 b. ‘the apple’ [ðɪ ʔæpət] ~ [ðɪ jæpət]
 c. ‘cooperation’ [kou.wapəˈreɪʃɪn] / *[kou.ʔapəˈreɪʃɪn]
 d. ‘instantiation’ [ɪnstænsi.jeɪʃɪn] / *[ɪnstænsi.ʔeɪʃɪn]

(27a) shows that in the isolation form of a vowel initial word, glottal stop does precede the initial vowel. (27b) shows that the phrasal form of a vowel initial word may either be preceded by a glottal stop or a glide, with the latter form being more common in connected or casual speech. In fact, the glottal stop variant pronunciation in (27b) is more common under emphasis, and may actually be treated as an instance of the pronunciation of the vowel initial word in isolation, thus falling into the pattern exemplified by (27a). Interestingly, Polish shows similar patterns to English regarding the interaction of emphasis and glottal stop epenthesis: while Polish does not exhibit glottal stop epenthesis in general, it is inserted before vowels in the context of emphasis (*Ależ leje!* [ʔa.leʃ] ‘What rain!’, *Adam to zrobił?* [ʔa.dam] ‘Don’t tell me Adam did it!’; Rubach 2000). Interestingly, Rubach (2000) discussion of this pattern is similar to the one ultimately proposed here; “the descriptive facts are clear: a glottal stop is an emphasis marker.”

As for word internal adjacent vowels, glides are uniformly epenthesized before vowel initial syllables, (27c,d). It should be noted that the glottal stop may reappear in the pronunciation of word internal onsetless syllables, but only under strong emphasis. For example, one could imagine correcting a mispronunciation of (27d) by saying ‘*It’s pronounced [ɪnstænsi.ʔeɪʃɪn], not [ɪnstænsi.ʔouʃɪn].*’ The data from English suggest that an ONSET analysis is, at the very least, insufficient to explain the pattern of glottal stop epenthesis; this constraints predicts epenthesis into all onsetless syllables, and does not predict a distinction between casual vs. emphatic speech.

Interestingly, not only is glottal stop limited to word initial position in English, Dilley et al. 1996 also showed that the amount of glottalization in word initial position is not uniform. Their findings show that the amount of glottalization varied with prosodic

context, with greater degrees of glottalization on words at the beginning of intonational phrases, and for words with pitch accents. Similar findings were presented in Pierrehumbert and Talkin 1992, in which it was shown that the laryngeal consonants tended to be lenited (lower magnitude) in weaker prosodic positions (e.g. before accented vs. reduced vowels). Furthermore, Pierrehumbert and Talkin's (1992) data showed that prevocalic glottal stop was often so reduced as to not be noticeable; for example, their results showed "stressed syllables had a high percentage of noticeable /ʔ/s in all positions, reduced syllables had a low percentage except at a[n initial – MLB] phrase boundary" (p. 114). The fact that glottalization in English is influenced by prosodic factors suggests that the role that it plays in word initial position may itself be prosodic, not syllabic. In other words, initial glottal stop is not a syllabic onset at all and its presence satisfies some prosodically motivated constraint. We return to this suggestion in section 4.2.2.

Like English, many other languages exhibit glottal stop epenthesis into word initial position just so long as the word edge coincides with a phrase edge. Here, I present data from Selayarese, Arabic, Czech, Kisar and Koryak:³⁰

(28) Selayarese

- a. [ʔinn] 'this'
 b. [ʔaapa inn] 'what is this'

(Mithun and Basri 1986, Lombardi 2002a)

Arabic

- c. ʔis.maq 'listen'
 b. qaa.la.tis.maʔ 'she said 'listen!'
 (Lombardi 2002)

Czech

- e. ʔoperovat 'to operate' vs. v-operovat 'to transplant'
 f. ʔučitel 'teacher' vs. pod-učitel 'junior teacher'

(Kučera 1961, Lombardi 2002a)

Kisar

- g. ʔeni 'this one' → ʔenieni 'this one here'

(Christensen and Christensen 1992, Lombardi 2002a)

³⁰ Rubach 2000 also discusses Czech glottal stop insertion, but presents data suggesting that it remains present when the vowel is no longer word initial. For example, *okně* 'window' begins with a glottal stop [ʔo], which according to the transcriptions in Rubach 2000, remains when a preposition is added: *v okně* 'in the window' begins as [fʔo]. Interestingly, Rubach (2000) notes that consonants forming the cliticized prepositions (including *v* 'in', *z* 'from', *s* 'with' and *k* 'to') syllabify as onsets to the glottal stop initial word, despite the retention of the glottal stop, because the vowel epenthesis that occurs when these prepositions are affixed to consonant initial words does not occur (e.g. *v vodě* → [ve vo], but *v okně* → [fʔo]. Rubach (2000) suggests that this pattern supports two distinct levels of OT derivation, one for the word level and another for the phrasal level. The Landmark Underspecification analysis leads us to a different proposal; glottal stop is not an onset in Czech, so when present a preceding consonant will syllabify as an onset to the following vowel.

Bulgarian

c. /urnata/ → [ʔurnata] ‘the urn’
(Rubach 2000)

Russian

d. /amerika/ → [ʔamerika] ‘America’
(Rubach 2000)

Yucatec Maya

e. /arroz/ → [ʔáaroz] ‘rice’

f. /ojo/ → [ʔòohoh] ‘eye’

(Ola Orié and Bricker 2000)

The data in (27), (28) and (29) show that glottal stop epenthesis tends to be limited in its domain of application to word initial position, often failing to occur for word medial onsetless syllables. This suggests that a non-ONSET account of glottal stop insertion is possible. Further support for this position comes from the data in (27) and (28), which shows that that apparent word initial glottal stop is only exhibited phrase initially. These data suggest that the constraints that motivate glottal stop epenthesis must make reference to prosodic factors, rather than to syllabic structure.

Before going on to consider the possible motivations for glottal stop epenthesis, the data in (30) and (31) show two additional contexts in which glottal stop epenthesis is possible, namely in stressed syllables (Standard German) and at the prefix-root boundary. The data from Standard German (30a-d) show that glottal stop is epenthesized before word medial onsetless vowels when these are stressed (30a,b) but not when they are unstressed (30c,d). The data in (30e,f) show that word medial glottal stop epenthesis is never exhibited by Southern German, regardless of whether the vowel is stressed or not. Finally, (30g,h) show that Tugun (Austronesian) also exhibits glottal stop epenthesis before a stressed vowel (and word initially).³³

(30) Standard German

a. cha.ʔó.tisch ‘chaotic’

b. Kò.ka.ʔín ‘cocaine’

c. sáu.er ‘sour’

d. krè.a.tív ‘creative’

Southern German

e. cha.ó.tisch ‘chaotic’

f. Kò.ka.ín ‘cocaine’

(Alber 2001)

³³ Thanks to Mark Donohue (p.c.) for bringing my attention to these examples.

Tugun		
g.	filu.ʔáí	‘casava’
h.	ʔako.ʔána	‘little finger’
<i>(Hinton 1991)</i>		

The data in (30) show that while the context for glottal stop insertion in Standard German is not limited to phrase or word initial position, both contexts are characterized by prosodic prominence. Thus, I propose that with further study we may develop a non-ONSET account of glottal stop epenthesis before stressed vowels, one that is compatible with the Landmark Underspecification proposal.³⁴

A final context for glottal stop epenthesis is before prefixes and at the prefix-root boundary. This pattern is shown for Standard and Southern German in (31a-e) and in Malay in (32). As shown in (31a-e), glottal stop is epenthesized before vowel initial prefixes and roots in both Standard and Southern German. (31a,b) show that glottal stop is epenthesized before vowel initial prefixes and roots, and (31c-e) shows the availability of resyllabification in fast speech contexts (middle column). Alber (2001) notes that resyllabification is possible in both Standard and Southern German, but is more likely in the latter.

(32)	Standard and Southern German		
a.	ver.-ʔánt.wor.t-en		‘to take the responsibility’
b.	ʔán.-ʔer.-kèn.nen		‘to acknowledge’
c.	ʔán.-ʔer.-kèn.nen	ʔá.n-er.-kèn.nen	‘to acknowledge’
d.	ʔEr.-ʔéig.nis	ʔE.r-éig.nis	‘event’
e.	ʔum.-ʔár.men	ʔu.m-ár.men	‘to embrace’
<i>(Alber 2001)</i>			

One important pattern in Standard and Southern German is that glottal stop epenthesis fails to occur at the root-suffix boundary; thus, we see an asymmetry of the treatment of prefix- vs. suffix-initial vowels in German. A similar asymmetry is exhibited by Malay (Austronesian; Onn 1980, Durand 1986, Lombardi 2002a). In this language vowel

³⁴ It should be noted that an ONSET analysis of the patterns in (28)-(31) is not impossible, and simply requires the positing of additional constraints to account for the failure to epenthesize consonants in certain word medial contexts. For example, Alber (2001) proposed an ONSET analysis of glottal stop epenthesis in Standard and Southern German in which she posited an ONSET {STRESS} constraint that requires all stressed vowels to have an onset. She accounts for the divergent patterning between Standard and Southern German by proposing a distinct hierarchical rankings for Standard and Southern German among three constraints, namely ONSET {STRESS}, CONTIGUITY and ONSET (see Alber 2001 for more details of this approach). Thus, the main point of this discussion is not that an ONSET approach is not available, but that it is unnecessary. Furthermore, I propose that the ONSET approach is also not favored in the light of its incompatibility with the independently motivated Landmark Underspecification account.

sequences at the stem-suffix boundary are separated through insertion of an agreeing glide, or of glottal stop between identical vowels, or sequences of [aV]. Thus, glottal stop epenthesis is limited in its appearance at the stem-suffix boundary to environments in which epenthesis of an agreeing glide is not possible (e.g. [a] final stems), and it is also limited to the now familiar context of identical vowels. Most interesting for the purposes of this discussion is the distribution of glottal stop at the prefix-stem boundary. In this environment, glottal stop epenthesis is the only possible response to a vowel sequence:

(32) Malay

- | | | | | |
|----|-------------|---|-------------|---------------------|
| a. | /di-pukul/ | → | [dipukol] | ‘to beat, passive’ |
| b. | /di-daki/ | → | [didaki] | ‘to climb, passive’ |
| c. | /di-ikat/ | → | [diʔikat] | ‘to tie, passive’ |
| d. | /di-angkat/ | → | [diʔangkat] | ‘to lift, passive’ |
| e. | /di-ukir/ | → | [diʔuke] | ‘to carve, passive’ |

(Lombardi's (2002a), (21))

The data in (32) are analogous to the data from German, in which the patterns of glottal stop epenthesis also showed a distinction between the prefix-stem boundary and the stem-suffix boundary, with only the former exhibiting glottal stop epenthesis. I suggest that this pattern may arise from the fact that prefix and root initial contexts are more salient for lexical access than suffix initial contexts; accurate identification of the former is necessary for identification of the word as a whole, but identification of the latter is made easier by the fact that the preceding context provided by the root limits the possible suffix choices. In this case, epenthesis of a glottal stop may have the result of protecting salient vowels from coarticulatory effects from adjacent consonants, thus aiding in the identification of the vowel and the word itself.³⁵

This section has shown that the contexts in which glottal stop epenthesis is available cross-linguistically are, contrary to conclusions from previous work, actually quite limited. I have also shown that the limiting factors include prosodic factors and lexical salience. Based on the data from glottal stop epenthesis in Type (2) languages, I conclude that glottal stop is not an unmarked epenthetic consonant across-the-board. Instead, I suggest that it is unmarked only when inserted in response to prosodically

³⁵ It is suggested here that glottal stop may be inserted before salient vowels because it serves to block vowels from coarticulatory effects from other consonants. One reason why this configuration might lead to more accurate vowel identification would be because the post-glottal vowel reaches its canonical steady-state formant structure without perturbation from coarticulatory effects that might obscure the identity of the vowel. However, some data suggests that insertion of a glottal stop before a lexically salient vowel may not actually be effective in isolating the vowel from coarticulatory effects from adjacent consonants; Bessell (1992) notes that vowels flanking the glottal stop will show coarticulatory effects from consonants adjacent to the glottal stop. Further research on this issue is needed, in particular to determine the isolatory effects of a full glottal stop vs. the lenited glottal stop that is common in casual speech cross-linguistically. It is possible that only the former realization is truly effective in obscuring coarticulatory effects, so long as full closure overlaps the period of formant transition conditioned by the preceding supralaryngeal consonant (e.g. C in C?V).

motivated constraints. In response to pressure from syllabic constraints, glottal stop is never a satisfactory epenthetic consonant because it fails to satisfy the requirements of these constraints.

Section 4.2.2 presents a brief discussion of the possibility that prosodic constraints motivate glottal stop epenthesis in Type (2) languages. Future research is necessary to determine the exact formulation of these constraints, but this section suggests that it serves a boundary marking function that arose out of a phonologization of domain initial strengthening effects. This function holds of phrase-initial environments. I further suggest that apparent glottal stop epenthesis before phrase medial vowels (e.g. under emphasis (27c,d)) should be subsumed under the analysis of phrase-initial contexts, under the assumption that strong emphasis destroys the expected phrasal cohesion; a word boundary is more likely to coincide with a phrase boundary under emphasis, as in the glottal stop variant pronunciation of (27b).

At the same time, I do not claim that each environment for glottal stop epenthesis has the same prosodic motivation, but rather that each can be handled with a non-ONSET account. As for non-emphatic medial contexts for glottal stop epenthesis, namely before stressed syllables and before prefixes and roots, I do not discuss these patterns in detail in section 4.2.2.³⁶ For now, it suffices to note that each has important characteristics (prosodic prominence and lexical salience) that distinguishes it from positions in which glottal stop epenthesis is unavailable. Crucially, these same positions are not distinguished by presence or absence of an onset, as predicted by an ONSET approach. Thus, though an alternative to the ONSET account is not presented in section 4.2.2 for these contexts, it can easily be argued that one is available that may be elucidated with further study.

4.2.2 *A Prosodic Account of Glottal Stop Epenthesis in Phrase-Initial Position*

In the previous section, I propose that an ONSET analysis of glottal stop epenthesis in Type (2) languages is neither necessary nor sufficient. Instead, I propose that the motivation for glottal stop epenthesis is a prosodically motivated constraint. Let us begin by considering what might be the source of such a constraint.

As for the initial source of pre-vocalic glottal stop in phrase-initial position, it is likely that it is a grammaticalization of a cross-linguistic tendency for strengthening of elements in initial position of prosodic units. As was noted above, Dilley *et al.* (1996) found that the amount of glottalization on word initial vowels in English was greater for words that were also initial in the intonational phrase than for word initial vowels in

³⁶ Note that Pierrehumbert and Talkin (1992) and Dilley *et al.* (1996) have already noted that syllables with word-initial onsetless syllables are more likely to exhibit greater degrees of glottalization than are word-initial syllables that are not accented. The fact that pitch accent can condition stronger glottalization in English suggests that an analysis may be available of the Standard German data in which pre-stress glottal stop insertion arose out of analogy with a phonetic pattern of strengthening in accented syllables. Furthermore, Pierrehumbert and Talkin (1992) showed that effects of stress and accent on realization of /h/ and /ʔ/ were additive; as they note “accent affected the gestural magnitude both for main stressed and reduced syllables within the accented word, but it affected stress syllables more” (p116).

lower domains. Their research also showed that glottalization increased for vowels in accented position. Thus, when the word boundary coincides with successively higher prosodic constituents, pre-vocalic glottal stop is realized as stronger. See also Pierrehumbert and Talkin (1992) for discussion of similar results.

The pattern exhibited by word initial glottalization in English, is, in fact, an instance of a far wider tendency for elements in domain initial position to be ‘stronger’ than the same elements in other positions, and for the results to be additive. In general, elements in phrase initial position are also more likely to reach their specified target; as Fougeron (2001) notes, “they are especially resistant to reduction or lenition process” (p.2, following Brunot and Bruneau 1937, Bourciez and Bourciez 1964, Bell and Hooper 1978, and Ohala and Kawasaki 1984).³⁷ This pattern has been recognized in the literature as a strengthening of initial segments. Furthermore, the effect of domain initial strengthening is variously realized depending on the segment, for example as tighter consonantal constriction or increased inter-articulator contacts in segments in initial position. Note that each effect can easily be incorporated into an AP account in which segmental strengthening is reanalyzed as gestural strengthening, for example as greater stiffness for initial gestures.

The domain initial strengthening effect has been examined in a number of languages, for example in English, Korean, French and Taiwanese, for example by Fougeron and Keating 1997, Cho and Keating 2001, Fougeron 2001, and Keating *et al.* 2003, among others. While Fougeron and Keating 1997, Cho and Keating 2001 and Keating *et al.* 2003 focus on strengthening effects on alveolar nasals and voiceless stops ([n] and variants of [t]), Fougeron (2001) notably addresses strengthening effects on a range of French consonants and vowels ([t, k, n, l, s] and [i, ɑ̃]). Fougeron (2001) discusses the articulation these sounds at various prosodic levels, including syllable initial, word initial, accentual phrase initial, and intonational phrase initial contexts. Her results demonstrate that initial segments are stronger than final segments, and that the amount of domain initial strengthening was greater for elements initial in hierarchically more prominent domains. In other words, strengthening was greater for elements that were in the left edge of multiple domains than it was for elements that were in the left edge of single (syllable/word) domains. For example, the consonants [t, k, n, l] exhibited increased linguopalatal contact in initial position, which continued to increase with higher prosodic boundaries (though there was variation among the consonants as to which prosodic boundaries conditioned differences in strengthening). This is illustrated by a difference in the realization of strengthening of [n] vs. [l]; there is cross-speaker increase in linguopalatal contact for [n] for each successively higher prosodic boundary, but for [l] contact increases between the word-initial and accentual phrase-initial domains but it does not increase significantly between the accentual and intonational phrase-initial domains.

Of particular interest are the patterns that Fougeron’s (2001) data exhibit regarding strengthening effects on domain initial vowels in French; increased glottalization on these vowels was exhibited with higher prosodic domains. Unlike English, French does not

³⁷ Note that stressed vowels pattern with phrase-initial elements in that they are also less likely to be lenited or reduced than their weak counterpart (unstressed syllables and phrase-medial position). This may eventually help to account for the fact that stressed syllables and phrase-initial syllables pattern together with respect to glottal stop insertion.

exhibit productive glottal stop epenthesis in word initial positions. This is reflected in the fact that Fougeron's (2001) data showed that word initial vowels in lower prosodic positions (coinciding with the word, but not with any higher boundary) never showed glottalization. All the same, Fougeron's (2001) data shows that glottalization on domain initial vowels increases with each successive domain, paralleling English data from Pierrehumbert and Talkin 1992 and Dilley *et al.* 1996. Thus, the data from French show that domain initial strengthening is one phonetic source of glottalization on an initial vowel, even when a glottal stop is not phonologically present. One possible reason why strengthening of a vocalic gesture in higher prosodic domains might result in glottalization might be strengthening of the glottal constriction associated with the vowel's vocal fold vibration.³⁸ This effect would be analogous to the increased linguopalatal contact shown in the data from French consonants. F

Fougeron (2001), following Straka (1963) and Fujimura (1990), suggests that domain initial strengthening might result from increased articulatory force in terms of strengthening of the muscles involved in achieving consonantal or vocalic constriction. Similar discussion can be found in Pierrehumbert and Talkin 1992, in which it is shown that gestural magnitude for /h/ and /ʔ/ increased in phrase initial position, and in Dilley *et al.* 1996. If initial position is associated with more force on the part of the muscles that adduct the vocal folds, for example, this might result in tighter contact between the vocal folds in the articulation of the vowel's voicing gesture. The possibility then arises that the degree of constriction observed between the vocal folds might incidentally be tighter than the ideal constriction for the production of modal phonation, instead achieving the degree of constriction associated with glottalization (e.g. creakiness).

Interestingly, Pierrehumbert and Talkin (1992) suggest a possible explanation for the fact that glottalization before vowels is greater in prosodically prominent positions (phrase initial, accented and/or stressed) that is along the lines of that suggested here. They suggest that "one might take the view that the /ʔ/ is always present, but ... the characteristic irregularity only becomes apparent when the strength and/or duration of the gesture is sufficiently great" (p 116). As I understand it, Pierrehumbert and Talkin (1992) mean that vowels in English are always preceded by the /ʔ/ segment, but that it may not always be perceptible. Another way of looking at it is that the potential for glottalization is always present for vowels, and it appears when the vowel in a prosodically strong position (i.e. a position in which the gesture will be strengthened). This is an explanation along the lines of the one discussed in the last paragraph, in which it is not necessary that there be a separate glottal segment (or gesture) present for glottalization to appear. Furthermore, this is what I suggest below is a precursor stage to the phonologization of glottal stop epenthesis.

I suggest that glottal stop epenthesis in phrase-initial position in English began as phonetic domain initial strengthening of the sort demonstrated for French in Fougeron 2001 (and also in itself English by Pierrehumbert and Talkin (1992) and Dilley *et al.* (1996)). While this pattern began as a purely phonetic effect of increased muscle strength

³⁸ Though most AP approaches assume that voicing on sonorants is automatic, and therefore do not posit a glottal gesture associated with voicing, the data from French suggests that gestural representation of voiced elements should contain a specified glottal constriction that is less tight than the closure specification for glottal stop, but which is strengthened in initial position.

for the vocalic articulators, and increased stiffness for the vocalic gesture, it led to the percept of glottal stop in phrase-initial position. The patterns of strengthening of phrase-initial vowels were subsequently phonologized in languages like English, Arabic, Selayarese, Koryak and Kisar, which exhibit phonological insertion of glottal stop into only phrase-initial position.³⁹

Let us now turn to consider how such a phonologization account might work in OT. For the purposes of this discussion, I will posit the constraint MARK PROSODY, because the effect of glottal stop epenthesis is to mark prosodic domains. This constraint is defined tentatively as in (34); this definition is only provisional.⁴⁰

(33) MARK PROSODY: Mark the beginnings of prosodic phrases with a glottal stop

While it is beyond the scope of this paper to provide a complete account of the constraints that might have resulted from the phonologization of domain initial strengthening effects discussion in Dilley *et al.* 1996 and Fougeron and Keating 1997 might help shed light on the matter. First, Dilley *et al.* (1996) suggest that their “findings support the hypothesis that speakers actively signal the onset of a new prosodic phrase, i.e., that glottalization may be one of several cues to phrase onset” (p. 438). Thus, while the formulation of the constraint in (33) may need refining, it seems to be on the right track. Additionally, Fougeron and Keating (1997) discuss several ways in which articulatory strengthening at phrase initial position might be beneficial to listener. Their suggestions, in their own words, are given in (34). Note that (34b) is quite similar to the suggestion presented in Dilley *et al.* 1996. (35) presents one additional benefit to glottal stop insertion before salient vowels (particularly lexically salient vowels). This section was originally suggested in section 4.2.1.

³⁹ Another possibility is that the *causes* of strengthening were phonologized, for example increased stiffness for the vocalic gesture became phonologically specified for all domain initial and prosodically prominent vowels. Under this approach, glottal stop is actually never epenthesized in this position, but the uniform percept of epenthesis arises from the uniformly higher specified stiffness for initial gestures. This is a quite attractive possibility, and further research will determine if other facts about the gestures in initial position will accord with this explanation.

⁴⁰ The formulation of this constraint in its current state appears ad hoc, but is simply a place-holder for the actual constraint. That is, it is proposed that there exists a constraint or constraints with the *effects* of (34), but that further research is required to exactly determine its formulation. Note, however, that it is necessary to specify that (34) requires glottal stop insertion in order to rule out insertion of other consonants. Possible future revisions of this constraint might include such changes as redefining it to specifically apply to vowel initial phrases, or to specify the phasing relation that must hold between the inserted consonant and the following vowel (so long as the phasing relation specified makes no reference to the ONSET or OFFSET landmarks), among others.

- (34) a. Segmentation: “strengthening could help with segmentation of the signal into words and higher domains.”
- b. Identify Boundaries: “the degree of strengthening could possibly tell the listener about the strength of the prosodic boundaries.”
- c. Lexical Access: “if initial strengthening enhances the segment-specific articulations of consonants and vowels, then it could enhance cues that aid in identifying each segment.”

(Fougeron and Keating 1997, p. 3738)

- (35) a. Lexical Access 2: epenthesis of a glottal stop may have the benefit of protecting salient vowels from coarticulatory effects from adjacent consonants, thus aiding in the identification of the vowel target (and therefore, the word).

Any of these possibilities could be on the right track, and which one of these analyses (or any other) is correct will help to determine the formulation of the OT constraint that is satisfied by insertion of a glottal stop. Whatever the ultimate formulation of the constraint that motivates glottal stop epenthesis, the following discussion shows that positing a constraint with the *effects* of (33) allows us to account for glottal stop epenthesis in initial position.

The forms in (36) repeat data from English, which showed that glottal stop is inserted into word initial position only when this position coincides with a phrase boundary. (36a) shows an example in which we have a determiner-noun sequence, but these words fail to be parsed into the same prosodic phrase because of strong emphasis on the noun. One framing context for such an utterance is shown in (36b), in which contrastive stress falls on the vowel initial word. (36c) shows an alternate pronunciation of the determiner-noun sequence, in which an agreeing glide is inserted at the determiner-noun boundary. A framing context in which it would be natural to produce (36c) is shown in (36d); in this case, the determiner and noun are parsed into the same phrase, whose initial element is the word ‘I’. Phrase boundaries are shown with set brackets.⁴¹

⁴¹ Another common pronunciation of determiner + vowel initial word exhibits coalescence of the two vowels: [ðæpəʔ].

- (36) English
- | | | | |
|----|----------------------------------------|------------|-----------------|
| a. | ‘the apple’ | [ðɪ ʔæpəl] | Emphatic Speech |
| b. | {I want the {apple}}, {not the orange} | | |
| c. | ‘the apple’ | [ðɪ jæpəl] | Casual Speech |
| d. | {I want the apple} | | |

I propose to explain the distinct treatment of vowel initial words that coincide with phrase boundaries vs. those that are initial by positing a competition among constraints on prosodic and syllabic structure, and on consonant insertion and glide formation. I suggest that MARK PROSODY is undominated in English, thus accounting for the fact that it conditions glottal stop epenthesis when a vowel initial syllable coincides with the boundary of a prosodic phrase. This constraint dominates DEP_{L-O} (C), which can explain why glottal stop insertion is an appropriate response to an otherwise fatal MARK PROSODY violation. Note additionally that the formulation of MARK PROSODY specifies that insertion of a supralaryngeal consonant is not sufficient to satisfy this constraint – we must make this stipulation for the time-being, leaving its justification to future study.

Furthermore, I claim that the constraint ONSET_(REV.) is dominated by both MARK PROSODY and DEP_{L-O} (C). This ranking results in the observed pattern that no supralaryngeal consonant is inserted in response to an onset violation. Finally, I propose to rank ONSET >> *DOUBLE LINK (which prohibits a single element from being linked to two prosodic positions), to account for the fact that onset violations are repaired by glide formation in English (i.e. not by glide epenthesis).⁴² Note also that glide formation does not occur in English phrase initial contexts because there is no preceding vowel that could syllabify as an onset to the word initial syllable. The proposed constraint ranking is shown in (36):

- (36) MARK PROSODY >> DEP_{L-O}(C) >> ONSET (R) >> *DOUBLE LINK

The tableaux in (37) show that the constraint ranking in (36) can account for the different treatment of word initial onsetless syllables in English depending on their position in the prosodic word. The phrase-initial and phrase-medial contexts are examined here together, in the upper and lower halves of the tableaux in (37), labeled (37A,B), respectively.

⁴² Under this approach, glides are not epenthed before onsetless syllables. Rather, the preceding vowel is syllabified as both a nucleus to one syllable and as an onset to the next. Such a configuration is easy to handle in autosegmental terms in which syllabification is the result of abstract organization, but is more difficult to incorporate into AP in which syllabification results from phasing relations that hold among gestures. In AP terms, this may be incorporable as a phasing relation in which a V₁ ONSET –to– V₂ ONSET relation holds. Rather than realize the vowels simultaneously, we have the percept of V₁ both as a nucleus and an ONSET. Further study is required to see if this approach is feasible, and most importantly if it accords with the actual articulatory patterns observed.

(37) The Treatment of Word Initial Onsetless Syllables in English: phrase-initial (37A), and phrase-medial (37B)

(A) Input: /æpəʔ/	MARK PROSODY	DEP _{L-O} (C)	ONSET (R)	*DOUBLE LINK
1. [æp...	*!		*	
2. [tæp...	*!	*		
3. [jæp...	*!	*		
☞ 4. [ʔæ		*	*	
(B) Input: /ði ₁ æpəʔ/	MARK PROSODY	DEP _{L-O} (C)	ONSET (R)	*DOUBLE LINK
1. /ði ₁ æp...			*!	
2. /ði ₁ tæp...		*!		
3. /ði ₁ j _x æp...		*!		
☞ 4. /ði ₁ j ₁ æp...				*
5. /ði ʔæp...		*!	*	

The tableaux in (37) demonstrate that the proposed constraint ranking can account for the distinct treatment of vowel initial syllables in English depending on whether they are phrase-initial or phrase-medial. For example, tableau (37A) shows that only epenthesis of a glottal stop preceding a phrase-initial onsetless syllable will survive due to the high-ranked MARK PROSODY constraint. Thus, the fully faithful candidate in (1) and the consonant epenthesized forms in candidate 2 and 3 are all ruled out by fatal violations of MARK PROSODY. The winning candidate instead is the glottal stop epenthesized form in (4), which survives despite having violated the DEP_{L-O}(C) constraint because all competing consonants have already been ruled out.

Turning to the phrase-medial context in (37B), the proposed ranking can predict the appropriate winning candidate, namely the one that has undergone glide formation (candidate 4). Crucially, because the structural conditions specified by MARK PROSODY

(e.g. phrase-initial position) are no longer present, this constraint no longer chooses the glottal stop epenthesized form (candidate 5). Instead, the high-ranked constraint DEP_{I-O} (C) is now the decisive constraint, ruling out all consonantal epenthesis, resulting in fatal violations for Candidates 2, 3, and 5. As this candidate shows, the winning form is the one in which an onset is provided to the word-initial vowel through means other than consonant insertion; in this case, the repair is glide *formation* through double linking of the underlyingly preceding vowel as an onset to the following syllable.

This section has so far shown that, given the right prosodically motivated constraint, we can easily account for the fact that glottal stop epenthesis is limited to syllables initial in prosodic domains without proposing that epenthesis occurs in response to a violation of ONSET_(REV.). Therefore, this discussion has also shown that it is possible to explain Type (2) glottal stop epenthesis without forsaking the proposal that glottal stop cannot syllabify as an onset, as per Landmark Underspecification.

4.3 Conclusion: Landmark Underspecification is compatible with the patterning of Type (1) and Type (2) glottal stop!

This chapter has presented data from two types of languages that present apparent counterexamples to the proposal that glottal stop cannot syllabify as an onset. These were identified as Type (1) and Type (2) languages; the former are languages in which glottal stop is stably present in all positions (pre-, post- and intervocalic), and do not exhibit transparency of glottal stop (or at least, glottal stop patterns with other consonants when it is transparent). Among the Type (1) languages discussed in this chapter include: Snchitsuʔumshin (Salish), Toba (Guaykuruan), Ge'ez (Ethiopic), the Semitic languages of Hebrew, Tiberian Hebrew, Tigrinya, Tigre and variants of Arabic (Standard, Anaiza Bedouin, Palestinian, and Moroccan) and the Cushitic languages of Iraqw, Qafar and D'opaasunte.⁴³ The data from Type (1) languages poses a challenge to the Landmark Underspecification because this proposal leads us to predict transparency and temporal variability of glottal stop that is not exhibited by Type (1) glottal stop.

In response to the challenge posed by the Type (1) data, we proposed that the Landmark Underspecification account of the glottal gesture can be upheld if we propose that this gesture be accompanied by a supralaryngeal gesture in Type (1) languages. Thus, glottal stop is a complex segment in Type (1) languages, and is analogous to other gestural configurations that lead to the percept of 'segmenthood' (e.g., just as gestural overlap between a velum lowering gesture and a tongue tip closure leads to the percept of the segment 'n'). In this configuration, the glottal gesture still fails to syllabify as an onset to the following vowel, and the secondary pharyngeal gesture plays the role of onset instead. Therefore, the syllable headed by the vowel in a hypothetical Type (1) ?V sequence has an onset; specifically, the secondary gesture plays this role. This accounts

⁴³ See discussion in section 4.1 for references. Also note that Type (1) patterning of glottal stop is found in many of the Semitic and Cushitic languages beyond those shown here (see McCarthy 1994, Hayward and Hayward 1987, and references therein for further discussion).

for the fact that repair of an expected ONSET violation does not occur in Type (1) ?V or V?V. Furthermore, the fact that the glottal gesture is anchored to the secondary gestural through underlyingly specified gestural phasing relations accounts for the observed lack of temporal variability for Type (1) glottal stop. In this approach, the secondary gesture is cohesively anchored to the vowel through an in-phase coupling, and the percept of a similarly cohesive phasing between the glottal stop and the following vowel is an illusion resulting from the phasing relations that anchor the glottal gesture to the secondary gesture.

The patterning of glottal stop in Type (1) languages contrasts with that presented in section 4.2 for the Type (2) languages; in the latter languages glottal stop is not underlying, but is instead epenthesis pre-vocalically. This pattern appears to contradict the main finding of the Landmark Underspecification account of glottal stop, namely that glottal stop always fails to syllabify as an onset; many previous analyses of glottal stop epenthesis have in fact claimed that it occurs exactly to repair an ONSET violation. Section 4.2.1 presented data from some Type (2) languages that illustrated that an ONSET analysis of glottal stop insertion is neither necessary or sufficient. This conclusion was made based on evidence from the limitations on glottal stop epenthesis in languages like English, Selayarese, Arabic, Czech, Kisar, Koryak, Standard and Southern German, Yucatec Mayan and Malay.

The data in section 4.2.1 showed that the environments in which glottal stop epenthesis is available in Type (2) languages can all be characterized by sharing the properties of prosodic prominence and lexical salience. Crucially, the environments in which epenthesis is possible vs. when it is not are not distinguished by the presence or absence of an onset. For this reason, the ONSET account is at least not sufficient; further stipulations must be posited to explain why onsetless syllables in non-prominent positions remain unrepaired. Moreover, the ONSET approach is unsatisfactory because it not only cannot easily incorporate the insight that prosodic concerns govern glottal stop epenthesis, but it is also incompatible with Landmark Underspecification, a proposal which was shown to explain the patterning of glottal stop in a much wider range of languages. Thus, rather than abandoning Landmark Underspecification in the phase of the patterning of Type (2) glottal stop, section 4.2.2 proposed that the motivation for glottal stop insertion is prosodic in nature. While this section's discussion of the exact formulation of the constraints that motivate glottal stop epenthesis was only tentative, I suggested that it resulted from a phonologization of phonetic domain initial strengthening effects (see section 4.2.2 and footnotes therein for more discussion).

5.0 Conclusion

This dissertation has addressed the asymmetry that exists between the patterning of the laryngeal and supralaryngeal consonants. Most well-known among the patterns that exemplify this distinction is the phenomenon of laryngeal transparency, in which laryngeal consonants are distinguished from the supralaryngeal consonants by allowing feature spread across them. In chapter 2, I presented data from a number of other patterns, arguing that one traditional response to patterns of laryngeal transparency – the ‘placeless’ account – could not readily be extended to account for additional, non-transparency, patterns. Focusing on the patterning of glottal stop throughout, I introduced data from such phenomena as required identity- and hiatus resolution-across-glottal stop, restrictions on the syllabic positions in which glottal stops are found, and the failure of sequences with glottal stop to be realized as sequential. This latter pattern, in particular, was suggested to be problematic for the placeless-? analysis because this approach cannot handle certain of glottal stops temporal characteristics (for example, the fact that vowel intruded forms ($V?C \rightarrow V?^VC$) are treated as single syllables; see Hall 2003 and chapter 2 for more discussion). In response, I proposed that a satisfactory analysis that unifies each of the aforementioned patterns was only possible if we adopt a theoretical framework that can incorporate insights from the temporal characteristics of sound. Chapter 3 went on to provide such an analysis, incorporating certain main assumptions of Articulatory Phonology (Browman and Goldstein 1986, et. seq.) in OT (Prince and Smolensky 1993) (e.g. speech sounds specified in terms of abstract gestures).

The proposal set forth in chapter 3 was that learners develop gestural representations for utterances based on the acoustic cues provided by the articulation of those gestures; if the production of a gesture causes no recoverable acoustic cues, then the learner does not posit its presence. In this discussion, I also advanced the proposal that learners posit the internal structure of gestures in terms of their gestural landmarks based on the available acoustic information. This proposal captured the observation that, for canonical stop consonants, physical events in the articulation of a gesture correspond directly to acoustic events in the speech stream. Because these physical events are the concrete correlates of the abstract gestural landmarks, the corresponding acoustic cues provide the learner with the necessary evidence to posit the gestural landmarks.

As it turns out, this proposal has far-reaching consequences for glottal stop, for the acoustic cues provided by the gesture of glottal constriction are deficient in comparison to those provided by a canonical stop consonant. Specifically, the glottal gesture does not condition formant transitions on flanking vowels. Therefore, I proposed that the learner fails to posit the gestural landmarks of ONSET and OFFSET for glottal stop, as these landmarks are cued by the beginning and end of formant transitions on flanking vowels. I referred to this as the Landmark Underspecification proposal. By adopting Landmark Underspecification for glottal stop, a unified analysis of the patterning of glottal stop is available. This analysis draws on the observation that the ONSET and OFFSET landmarks are key points of intergestural alignment for both syllabic and sequential relations. Thus, any gesture that lacks these landmarks will fail to participate in either type of relation. For glottal stop, the result of underspecification is failure of glottal stop

to syllabify as an onset or a coda, and consequent failure of glottal stop to block hiatus in intervocalic contexts. This explains the fact that V?V sequences often undergo repair, for example in required identity- and hiatus resolution-across-glottal phenomena. Furthermore, the failure of glottal stop to participate in sequential phasing relations explains the tendency of sequences with glottal stop to be realized as non-sequential on the surface; the grammar enforces upon the sequence a non-sequential alignment as a repair of the unparsed glottal gesture.

One benefit of the Landmark Underspecification proposal, then, is that it can provide an analysis of a wide-range of data in the patterning of glottal stop. In particular, it handles certain types of data (e.g. surface non-sequentiality of underlying sequences) more easily than the traditional placeless-? account. Beyond this advantage, adopting Landmark Underspecification has several other benefits. First, its premises are quite simple and straightforward; the proposal that speakers rely on acoustic evidence to posit the presence of gestures is certainly not unprecedented. In fact, we have addressed a question that every phonological approach will eventually have to consider – how do we recover abstract linguistic information from the information provided by in the speech signal? The innovation that speakers also rely on acoustic information in order to posit the abstract landmarks for a gesture is likewise not far-fetched; in any case, some explanation is needed of how the underlying representation of a gesture comes to be specified for these landmarks. Rather than assuming that all gestures are *a priori* specified for all gestural landmarks, this analysis simply extends the proposal that the presence of recoverable acoustic cues determines the learner’s construction of underlying representation to the internal structure of gestures.

In general, the Landmark Underspecification proposal benefits from its parsimony; it required few additional proposals to account for all the patterns from chapter 2, none of them stipulative. For example, discussion of the consequences of Landmark Underspecification in chapter 3 hinged on reconsideration of the gestural underpinning of syllabic and sequential relations. In this discussion, I suggested that such a reconsideration is necessary for all constraints in AP in OT; if we assume abstract gestures as the linguistically significant units, then OT constraints must make reference to these gestures (rather than to features, which have been abandoned). Moreover, research in AP has provided confirmation of the actual temporal relations that hold between syllabically and sequentially affiliated gestures; the proposed analysis incorporates these insights into AP in OT (for example, in the $ONSET_{(REV.)}$ constraint). Thus, the proposal that the $ONSET$ and $OFFSET$ landmarks are points of alignment for both syllabic and sequential relations has both theoretical and empirical support.⁴⁴

A further proposal presented in chapter 3 was that the OT grammar conspires to require output gestures to be parsed into the global phasing relations of the utterance. This proposal was necessary in order to extend the analysis to, for example, vowel

⁴⁴ Note that the analysis presented here is not incompatible with one in which there exists abstract units of organization like the syllable, the foot, etc. (this was pointed out to me by Professor Adamantios Gafos at the defense of this dissertation). This analysis only requires that these abstract units correspond to stable modes of gestural coordination (in the same way that abstract gestural landmarks correspond indirectly to concrete physical events).

intrusion and Cʔ coalescence. However, the constraints posited (ASSOCIATE CC/CV) is an independently proposed constraint type (Davidson 2003), thus it is not unwarranted to suggest that gestural reorganization results from these constraints.

The discussion so far has addressed the benefits of Landmark Underspecification in general; to summarize, it can account for all the traditional placeless-ʔ patterns without making unwarranted stipulations. An additional advantage is that it can be extended beyond the placeless-ʔ phenomena to account for patterns that have previously been difficult to reconcile with it; for example, data from languages in which the laryngeal consonants pattern with some set of supralaryngeal consonants as a natural class (I've called this the pharyngeal-ʔ approach). Previous attempts to reconcile the placeless vs. pharyngeal dichotomy have taken two general approaches; either they assume that languages may have either placeless or pharyngeal glottal stop (McCarthy 1991a, 1994, Bessell 1992, Bessell and Czaykowska-Higgins 1992, Rose 1996) or all glottal stops are deemed pharyngeal, and placeless-type patterns result from the low-markedness of the feature [PHARYNGEAL] (e.g. Lombardi 2001, 2002a).

In section 4.1, I showed that an account of the pharyngeal-ʔ data that maintains the Landmark Underspecification proposal for the glottal constriction gesture is available. This discussion capitalized on the distinction between the gesture and the 'segment', which is a set of coordinated gestures in which the period of overlap results in the segmental percept. In this section, I argued that we need not abandon the Landmark Underspecification for the glottal constriction *gesture* as long as we allow for the possibility that the glottal stop *segment* may be comprised of multiple gestures. Under this analysis, what we perceive as a glottal stop is always comprised at least partially of a landmark-underspecified glottal gesture, but may also be coordinated with other gestures as a complex segment. I suggested that languages in which glottal stop is comprised solely of the glottal gesture will exhibit placeless-ʔ patterns, while languages in which glottal stop is a complex segment will not exhibit placeless-type patterns (transparency, restrictions on syllabic position, temporal variability, etc.).

This analysis is preferable to one in which different landmark structure must be specified for the glottal gesture depending on the language, because the production of glottal constriction will never provide sufficient evidence for the learner to posit the ONSET and OFFSET landmarks. A further advantage of this approach is that it makes use of already available modes of intergestural coordination (e.g. within segment coordination of gestures), and applies them to glottal stop. Thus, an additional benefit of the Landmark Underspecification and Complex Segment approaches is that they co-opt independently necessary gestural configurations; importantly, they do not propose idiosyncratic stipulations regarding variations in landmark structure.

This dissertation has also outlined a number of areas where future research would be informative. First, one area of research is to explore the extent to which the account of glottal stop as an extrasyllabic gesture accords with its patterning (e.g. is it weightless in coda?; can we reconcile the fact that postvocalic glottal stop conditions closed syllable allophones in languages like Palu'e but open syllable allophones in languages like Garo?)

A second avenue of exploration addresses the analysis of languages that exhibit laryngeal transparency vs. those that don't (e.g. placeless-? languages vs. type (1) languages). Future research should examine the status of the contribution of the supralaryngeal articulators that have been shown to be active during the production of glottal stop cross-linguistically; can this be characterized as resulting from separate phonologically specified gestures?; do stable temporal relations obtain between these gestures and vowels that might indicate syllabification?; are there any consistent acoustic correlates of the supralaryngeal gestures that might give the SPM sufficient evidence for their presence?

Furthermore, as part of the analysis of type (1) languages, I proposed that stable allophonic, paradigmatic, contextual or lexical information might influence the SPM to posit the presence of gestures for which there is little or no direct acoustic evidence. One prediction is that this situation is unstable over time, since loss of evidence from a certain paradigm (e.g. hypothetical loss of the consistent relationship between pharyngeality and low vowels in Palestinian, (23) in section 4.1 above), would result in loss of evidence for pharyngeality on glottal stop. In this case, the language might develop a simple glottal stop, and we expect patterns of the sort presented in chapters 1-3 to arise. Thus, future research should explore the historical development of glottal stop; do languages develop from type (1) to so-called placeless-? languages?; are there any conditions that could contribute to the historical development of a placeless-? language into a type (1) language?

While this dissertation has outlined a number of interesting questions regarding the patterning of laryngeal consonants, it is hoped that the questions left open also serve as a contribution to the future literature on Articulatory Phonology, and Articulatory Phonology in OT. For example, future research should address the question of the consequences of adopting gestures into OT in terms of the commensurability of units of representation with units of derivation; are there additional favorable consequences of being forced to re-define constraints and units of organization in gestural terms?; and, what stable modes of gestural coordination underlie other abstract units, for example the foot?

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