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 Nam and Saltzman 2003, Nam 2004, Goldstein 2005, 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 [?] appears in all syllabic positions and is not obviously ‘transparent,’ (2) languages in which the distribution of [?] 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

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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 Onset(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-

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 ?V sequences is an illusion of the transitivity of a phasing relationship that holds between the three elements (C-to-V, and ?-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.

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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 Onset(Rev.) are too low ranked to force repair of ?V 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.

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been attributed both to the placeless-? analysis and to the pharyngeal-? 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.
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-vocalically 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. ʔlibra ‘a needle’
b. qaa.lat.ʔlibra ‘she said ‘a needle’’

(Lombardi 2002a)

Selayarese
c. [ʔinn] ‘this’
d. [ʔaapa inn] ‘what is this’

(Lombardi 2002a)

English
e. [ʔæpɔl] ‘apple’
f. [ði ʔæpɔl] ~ [ði jaپɔl] ‘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

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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. yeʔsop ‘he will gather’
c. yahmo:d ‘he will turn’
d. yofmad ‘he is made to stand’
e. yehzaq ‘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 Hidjazi 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. säbär-ä  ‘he broke (something)’
b. fänäwä  ‘it decayed’
c. ?axälä  ‘it was enough’
d. bälä_fkä  ‘you have eaten’

(Anaiza Bedouin Arabic)
e. /katab/  \[\text{[kitab]}\]  ‘he wrote’
f. /jamal/  \[\text{[jimal]}\]  ‘camel’
g. /?akal/  \[\text{[?akal]}\]  ‘he ate’
h. /habit/  \[\text{[habit]}\]  ‘became flat (hair)’
i. /fazam/  \[\text{[fazam]}\]  ‘he invited’

(Hayward and Hayward 1989)

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))
Maltese

a. ni-kteb

b. ti-kteb

c. na-ʔsam

d. ta-hrab

Palestinian Arabic

e. [yi-sʔa] [yi-saʔa] ‘copy’
f. [yi-blaʔ] [yi-balaʔ] ‘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].

Hebrew

a. /malk/ \rightarrow [melek] ‘king, my king’
b. /qudʃ/ \rightarrow [qōdeʃ] ‘holiness’
c. /tuʔr/ \rightarrow [toʔar] ‘form, his form’
d. /baʔl/ \rightarrow [baʔal] ‘master’

(McCarthy 1994)

Another example of the low vowel–laryngeal/guttural association comes from the Cushitic language D’Opasunt, 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.\(^5\)

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\(^5\) The forms in (7) follow the orthographical conventions in Hayward and Hayward (1989), where the phoneme that may alternately be realized as [e, a, æ] is written as ‘A’. Bracketed vowels are the surface instantiations of this underlying vowel.
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 \([\text{PHARYNGEAL}]\), 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 \([\text{GUTTURAL}]\)). Note that, within the AP in OT framework adopted here, we must reanalyze the feature \([\text{PHARYNGEAL}]\) 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).

\(^{6}\) 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:

\[(iii)\quad \text{pag-yoyo-en} \rightarrow \text{pagyoyowen}\]

\[\text{pagyoyo?en}\]

\[\quad \text{`to cause to play with a yoyo'}\]

\[(\text{Lombardi 2002a})\]
(8) Tamil
   a. /iruṭṭ/ → [yiruṭṭu] ‘darkness’
   b. /uuciy/ → [wuusi] ‘needle’
   c. /aacay/ → [ʔaase] ‘hope’

   (Christdas 1988 and Lombardi 2002a)

Ilokano
   d. /babáwi-en/ → [babawyén] ‘regret-goal focus’
   e. /sáño/ → [pag-sanwén] ‘to cause to face forwards’
   f. /básə/ → [basəʔén] ‘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’o/ → [yint’o] ‘you (sg.) are crying’
   b. /uzə/ → [wuza] ‘his soul’
   c. /xt’o/ → [husso] ‘he is crying’
   d. /a/ → [ha] ‘yes’
   e. /ait’oh/ → [hait’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/ → [peerasee] ‘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 Snchitsu?umshtsn (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) Snchitsu?umshtsn

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<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>$u$-$t$e$q^w$</td>
<td>‘it’s bright red’</td>
</tr>
<tr>
<td>b.</td>
<td>$t$a$q$-nt$^g$</td>
<td>‘he touched it’</td>
</tr>
<tr>
<td>c.</td>
<td>$s$étt-nt$^g$</td>
<td>‘he twisted it’</td>
</tr>
<tr>
<td>d.</td>
<td>ne$^e$-$s$átt$^i$-e?q$s$-n</td>
<td>‘crank (on a car)’</td>
</tr>
</tbody>
</table>

In Sn, vowels immediately adjacent to a faucal consonant are limited to [e,a,o], (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

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>ye$^e$-e.soop</td>
<td>‘he will gather’</td>
</tr>
<tr>
<td>b.</td>
<td>he.he.ziiq</td>
<td>‘he strengthened’</td>
</tr>
<tr>
<td>c.</td>
<td>yaфа.mood</td>
<td>‘he made stand’</td>
</tr>
<tr>
<td>d.</td>
<td>ya.ha.lom</td>
<td>‘he dreams’</td>
</tr>
</tbody>
</table>

Ge’ez

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>e.</td>
<td>ya?ammin</td>
<td></td>
</tr>
<tr>
<td>f.</td>
<td>yilihhik</td>
<td></td>
</tr>
<tr>
<td>g.</td>
<td>yaфаqqib</td>
<td></td>
</tr>
<tr>
<td>h.</td>
<td>yisihhit</td>
<td></td>
</tr>
</tbody>
</table>

(Gafos and Lombardi 1999)

(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, and Herzallah 1990, among many others. Interested readers should see, for example, Bessell 1992 (among others) 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].
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 [ʕ, h, x, ʔ, 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.  \(d\chi^w\text{ol}\) ‘come in!’
b.  \(nq^w\text{ol}\) ‘copy down!’
c.  \(rg^w\text{o}d\) ‘sleep’
d.  \(n\text{f}\text{os}\) ‘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.  \(\text{f}\text{ena}T\) ‘haversack’
b.  \(\text{w}\text{ar}\text{eq}\) ‘gold’
c.  \(\text{fara}F\) ‘clan’
d.  \(\text{d}3\text{uh}\text{ut}\) ‘direction’


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 (Guaykuruan). In Toba, echo vowels are inserted following velars, uvulars and [?] 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-ronaq-wa → laronaGawa ‘his brother-in-law’
b. ña-soGok-ji → ñasoGogoji ‘my patios’
c. hi-qa?-ji → hiqa?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 [?] 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 [?] also conditions regressive vowel lowering. 11

(16) Sn. (Flathead Variety)
a. q’e?fìn ‘shoe’
b. q’a?fìn-sqá(χe?) ‘horseshoe’

(Bessell 1997)

Sn. (unspecified variety)
c. /cën-θec-ipleʔ-n/ → [canθecipleʔon] ‘fishline’

(Bessell 1992)

11 Bessell (1997) identifies the data in (16a, b) as being from the Flathead variant of Sncitsuʔumshtsn (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 Sncitsuʔumshtsn. 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 Sncitsuʔumshtsn 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 /a/ and /a/ [by] elicit[ing] 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  Uvulars  Pharyngeals  Laryngeals

[+DORSAL]  [+DORSAL]  [+PHARYNGEAL]  [+PHARYNGEAL]  [+RHADICAL]

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 [RHADICAL]. McCarthy (1994) himself identifies the Tigre data in (14) as problematic for the pharyngeal-I account, and also notes the problematic case that Tigre [?] and [?] 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 [RHADICAL] spread from the pharyngeal(ized) segment onto a [+PHARYNGEAL] [?], we could presumably retain the originally proposed feature representation.
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-? and the pharyngeal-? 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].

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 [?] 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.

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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 Sichitsuʔumshtsn (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)).
Another example of [ʔ] being treated distinctly depending on whether it is epenthetic or not comes from Selayarese, in which [ʔ] is epenthesized 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 2002).

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 diagramed in (4), section 3.2.1, and are repeated in (20).\(^\text{15}\)\(^\text{16}\) (20a,b) shows the gestural score for a simple

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\(^{15}\) Here, the phasing relation exhibited between the pharyngeal gesture and the glottal one is specified as \(\text{[?]-TARGET-to-[?]}\) 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 \(?C/\tilde{C}\) 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]:
   \[\text{GLOTTIS: CD} = \{\text{CLOSED}\}\]

b. \[
\begin{array}{c}
\text{GLOTTIS:}
\end{array}
\]

   \text{GLOTTAL CLOSURE}

c. [ʔ] with secondary pharyngeal constriction:
   \[
   \begin{array}{c}
   \text{TONGUE ROOT: } \text{CL} = \{\text{PHARYNGEAL}\}, \text{CD} = \{\text{CLOSED}\} \\
   \text{GLOTTIS: CD} = \{\text{CLOSED}\}
   \end{array}
   \]

d. \[
   \begin{array}{c}
   \text{TONGUE ROOT:}
   \end{array}
   \]

   \[\text{TR: CLOSURE} \quad \text{(TARGET TR = TARGET G)}\]

   \[\text{GL. CLOSURE}\]

   \[
   \begin{array}{c}
   \text{GLOTTIS:}
   \end{array}
   \]

   \[
   \begin{array}{c}
   \text{GL. CLOSURE}\end{array}
   \]

e. [n]:
   \[
   \begin{array}{c}
   \text{TONGUE TIP: } \text{CL} = \{\text{ALVEOLAR}\}, \text{CD} = \{\text{WIDE}\} \\
   \text{VELUM: CD} = \{\text{WIDE}\}
   \end{array}
   \]

f. \[
   \begin{array}{c}
   \text{TONGUE TIP:}
   \end{array}
   \]

   \[\text{TT: CLOSURE} \quad \text{(TARGET TT = TARGET VL)}\]

   \[
   \begin{array}{c}
   \text{VL: WIDE}
   \end{array}
   \]

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. 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 ONSET(REV.), for reasons discussed more fully above in section 3.3.2. Thus, it falls out that a language ranking ONSET(REV.) high will also exhibit repair of Vx?Vy sequences, whether it be coalescence to Vx 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 ONSET(REV.) constraint, repair is necessary.

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 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

---

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 laryngeoscopy analysis shows that it is possible that laryngeal segments can contain both glottal and tongue root gestures.

18 To review, the constraint ONSET(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.
V?V 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:\textsuperscript{19}

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

\begin{enumerate}
  \item \textbf{TONGUE ROOT:} \quad \text{CL} = \{\text{PHARYNGEAL}\}, \quad \text{CD} = \{\text{CLOSED}\}
  \textbf{GLOTTIS:} \quad \text{CD} = \{\text{CLOSED}\}
  \textbf{TONGUE BODY:} \quad \text{CL} = \{\text{PALATAL}\}, \quad \text{CD} = \{\text{NARROW}\}
  \item \textbf{TONGUE ROOT:} \quad \text{TR CLO.}
  \textbf{GLOTTIS:} \quad \text{G.:CLO.}
  \textbf{TONGUE BODY:} \quad \text{TB: \{NARROW\}}
  \item \{\text{TR ONSET} = \text{TB ONSET}\} \quad \& \quad \{\text{GL. TARGET} = \text{TR TARGET}\}
\end{enumerate}

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\textsubscript{(REV.)} constraint. This particular phasing relation is the source of the lack of repair in V?V 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.\textsuperscript{20}

\textsuperscript{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.

\textsuperscript{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, ŋ, a], for the sake of simplicity specifying these gestures of [E, G, P, A], respectively.
Hypothetical [eʔi]: \[ \text{TARG}TE\{G\} = \text{TARG}TE\{P\}, \text{ONSE}T\{P\} = \text{ONSE}T\{A\} \]

<table>
<thead>
<tr>
<th>Input …eʔi</th>
<th>(\text{DEPI-O (C)})</th>
<th>(\text{MAXI-O (C)})</th>
<th>(\text{ONSE}T{R})</th>
<th>(\text{NoDIPHTHONG})</th>
</tr>
</thead>
<tbody>
<tr>
<td>…eʔi (\text{TARG}TE{G} = \text{TARG}TE{P}) (\text{ONSE}T{P} = \text{ONSE}T{V})</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
</tr>
<tr>
<td>1. eʔti (\text{ONSE}T{T} = \text{ONSE}T{A}) (\text{TARG}TE{G} = \text{TARG}TE{P}) (\text{OFFSET}{V} = \text{ONSE}T{P})</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
</tr>
<tr>
<td>2. eʔ (\text{OFFSET}{E} = \text{ONSE}T{P}, \text{TARG}TE{G} = \text{TARG}TE{P})</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
</tr>
<tr>
<td>3. jʔi (\text{TARG}TE{G} = \text{TARG}TE{P})</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
</tr>
<tr>
<td>4. eʔi (\text{TARG}TE{G} = \text{TARG}TE{P})</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
</tr>
<tr>
<td>5. eʔi (\text{TARG}TE{G} = \text{TARG}TE{P}) (\text{ONSE}T{P} = \text{ONSE}T{A})</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
<td>(\ast)</td>
</tr>
</tbody>
</table>

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 \(\text{DEPI-O (C)}\) 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 \(\text{MAXI-O (C)}\), 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 \(\text{CV PHASING}\) (see discussion in section 3.3.4).

Candidate 3 has undergone diphthongization, thus violating \(\text{NoDIPHTHONG}\) 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 \(\text{CV}_{1}V_{2}\) the crucial phasing relations that hold are \(\text{ONSE}T\{C\} = \text{ONSE}T\{V_{1}\}\) and \(\text{ONSE}T\{C\} = \text{ONSE}T\{V_{2}\}\). I propose that the observed contour from \(V_{1}\) to \(V_{2}\), and the fact that
diphthongs pattern as single segments, results from the competing phasing relation that holds between \( V_1 \) and \( V_2 \), namely \( \text{OFFSET: } \{V_1\} = \text{ONSET: } \{V_2\} \). 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\(_{\text{(REV.)}}\) constraint is not present. In this candidate, the second vowel lacks an onset and incurs a violation of ONSET\(_{\text{(REV.)}}\).

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\(_{\text{(REV.)}}\) 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. 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). Moreover, this analysis can also

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\(^{21}\) 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

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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 [ʃi[p], ʃi[t], ʃi[k]] (‘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 [?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.\textsuperscript{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]\textsuperscript{26} 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\textsubscript{2}. Lowering of F\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{1} in the context of a pharyngeal. Alwan (1986) specifically notes raising of F\textsubscript{1} in the context of formant transitions from a pharyngeal, as she mentions a fall of F\textsubscript{1} from the raised initial position to the steady state of the vowel. Pharyngeally conditioned raising of F\textsubscript{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\textsubscript{1} and lowering of F\textsubscript{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\textsubscript{1} was more pronounced for [a,i] than for [u]. As for their F\textsubscript{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\textsubscript{2} lowering data for Arabic [u].\textsuperscript{25}

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

\textsuperscript{25} Though the Shank and Wilson (2000b) data presented in their Figure 2 (p. 6) appear to indicate a drop for F\textsubscript{2} on [a], and one that is in fact larger than the drop for [i] or [u], Wilson (to appear) indicates that his
In addition to showing that [渝] conditions coarticulatory effects on F₁ and F₂, Shank and Wilson (2000b) note a lowering effect for F₃ on all vowels. Ahousaht Nuuchahnulth [渝] 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 [渝] (actually an epiglottal stop) is obligatorily preceded by a glottal stop. In terms of manner of articulation, Shank and Wilson (2000a) argue that [渝] 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 [渝] 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). 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 [a] 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

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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.
not as high for uvulars as for the pharyngeals. For $F_2$, uvulars condition raising like the pharyngeals, with the values for $F_2$ on [a] and [ə] being within 8 Hz of the $F_2$ of the same vowel in the environment of a pharyngeal, while $F_2$ 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 $F_1$, and this is consistent with the regular phonological patterns of vowel lowering in the context of faucal consonants in this language. Pharyngeal influence on $F_2$ 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, $[\text{t}, \text{s}^w, \text{h}, \text{h}^w]$. In her table 5.27 (p. 139), Bessell (1992) distinguishes the coarticulatory effects of each of the pharyngeal consonants, but shows that $F_2$ for [ə], the only vowel present in each of the contexts, still remained high. Thus, it appears that while $F_1$ 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 $F_2$ 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 [tʰ] articulatorily closely resembles the [tʰ] 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 $F_1$ 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 $F_2$, this is less consistent in general, with both lowering and raising of $F_2$ 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, [a] (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 F₂, F₂ 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 F₂ compare to the values for these formants in non-guttural environments. Thus, it is possible that the laryngeal conditions F₂ 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 F₂ when they are next to /?/…” (p. 91). Al-Ani (1981) makes no mention of the effect of F₁ 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 F₁ for vowels adjacent to [ʕ] 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 F₁ 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 F₁ for all vowels than in the consonantal control, though it was not as high as F₁ for vowels next to pharyngeals. Moreover, there was variation in terms of how much F₁ was raised in comparison to the control, for example for [i] F₁ had raised by 41 Hz., for [a] 54 Hz., but for [u] only 8 Hz. Thus we can draw the conclusion that raising of F₁ may be a consistent global affect of laryngeal coarticulation. However, since the rise in F₁ 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 F₂ of a flanking vowel, we see that its effects are more variable than those for F₁. 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 F₂ lowering for [i] in comparison to the control, glottal stop conditions slight raising (70 Hz.). Likewise, while pharyngeals lower the F₂ for [a] by 222 Hz., lowering for the glottal stop is less extreme (39 Hz.). The pattern changes, however, for [u]; here F₂ lowers more for [ʔ] than for [ʕ] (316 Hz. vs. 241 Hz.). Note that while lowering of F₂ seems to be a common cross-linguistic reflex of pharyngeality, Nuuchahnulth differs from both Nxa’amxcin and Arabic in exhibiting F₂ lowering for [u] also, as the former languages show F₂ raising in this context. Additionally, while pharyngeal contexts in Nuuchahnulth condition across-the-board lowering of F₃, glottal stop conditions lowering of F₃ 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-blaʃ  balaʃ  ‘swallow’
   yi-ʃal  saʃal  ‘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 [ʃ, h] 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-ronaq-wa → larona Gaw 'his brother-in-law'
b. ŏna-soGok-jei → ŏnasoGogo ji 'my patios'
c. hi-qafa-ji → hiqa? 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 Orie 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 underlingly 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).

\[(25) \quad \text{Arabela}\]
\[\begin{align*}
a. \quad \text{mõnũ}? & \quad \text{‘to kill’} \\
b. \quad \text{nį eę̱ri}? & \quad \text{‘he laid it down’} \\
c. \quad \text{hũvũ}? & \quad \text{‘a yellow bird’} \\
d. \quad \text{hęęgĩ}? & \quad \text{‘termites’} \\
\end{align*}\]

\[(\text{Rich 1963, Walker and Pullum 1999})\]

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 underlingly 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]. 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 underlingly [+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

\[28\text{ In contrast, an AP account would argue that the glottal stop is neither }\pmnasal\text{ underlingly, but instead is overlapped by the velum lowering gesture associated with the conditioning nasal. Only when the glottal stop conditions nasal spreading, as is the case for the Arabela [h], can we claim that the segment glottal stop is }\text{+[NASAL]}\text{ in the sense that it is comprised of coordinated glottal and velar gestures.}\]
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 mē mā mō mū
     nĩ nē nā nō nū

b. pi pe pa po pu (*pē. )
   ti te ta to tu (*tē)

c. ?i ?e ?a ?o ?u

d. Ûi Ûē Ûā Ûō Ûū

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 epenthesized 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 prevocally 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 DEPL {PLACE}, or IDENT1 {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 >> *CORONAL >> *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. [æpɔl] vs. [ɔl jæpɔl]). Similar examples are observed for Arabic, Selayarese, Czech, Kisor 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 Kisor 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’ [ʔæpəl]
b. ‘the apple’ [dɪ ʔæpəl] ∼ [dɪ jæpəl]
c. ‘cooperation’ [koʊ.wapərɛtʃən] / *[koʊ.ʔapərɛtʃən]
d. ‘instantiation’ [ɪnstænʃə.jiətʃən] / *[ɪnstænʃi.ʔetʃən]

(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! [ʔał.ле]) ‘What rain!,’ Adam to zrobił? [ʔał.ʔам] ‘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 [ɪnstænʃi.ʔetʃən], not [ɪnstænʃi.ʔouʃən].’ 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.ʔis.maʔ ‘she said ‘listen!’

(Lombardi 2002)

Czech
e. ʔoperovat ‘to operate’ vs. v-ʔoperovat ‘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 [ʔo]. 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 → [ʔo]. 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.
The data in (28) show examples from a number of languages that exhibit similar patterns of glottal stop epenthesis to the English data in (27). In these data, glottal stop is epenthesized before word initial vowels, but when a vowel initial word becomes word medial in connected speech, or due to morpheme concatenation and reduplication the glottal stop is no longer epenthesized.

Other languages also show glottal stop epenthesis in word initial position, for example Standard and Southern German. With some regular exceptions to be discussed below, glottal stop epenthesis in Standard and Southern German is limited to word initial onsetless syllables. This pattern is illustrated in (29a-c), in which word initial onsetless syllables are repaired. The Southern German example in (29a) shows that this language fails to repair onsetless syllables in word medial position. The Standard German data in (29b) show that glottal stop epenthesis is also limited to word initial position unless the medial onsetless syllable is also stressed (a pattern to which I return shortly). Bulgarian and Russian also exhibit glottal stop insertion word initially, as shown in (29c,d) respectively (Rubach 2000). Another example of word initial glottal stop epenthesis is found in Yucatec Maya (29e,f) in which glottal stop is epenthesized before word initial vowels, as illustrated by the adaptation of vowel initial Spanish loans.32

(29) Southern German
   a.   ?o.á.se   ‘oasis’

   Standard German
   b.   ?o.?á.se   ‘oasis’

(Alber 2001)

31 Kohler (1994) observes that the most common realization of post-pausal word initial onsetless syllables is glottal stop or glottalization (as opposed to a realization lacking glottal stop entirely). Note that while Kohler’s (1994) discussion of North German speakers suggests that glottal stop is more likely to be present in full or lenited form before prosodically salient vowels (e.g. phrase initial or stressed), even in these positions presence of glottal constriction is not universal; for example phrase initial vowels showed some degree of glottalization 85% of the time. This pattern suggests that glottal stop insertion in phrase or word initial position is not an all-or-nothing effect in German.

32 It was proposed by Ola Orie and Bricker (2000) that glottal stop epenthesis before word initial vowels results from a requirement that all words be consonant initial, for example as the result of a high-ranked INITIAL C constraint. I do not discuss this pattern in detail in the subsequent discussion, but suggest that it is possible that the INITIAL C constraint has different requirements than ONSET(Rev.) regarding the gestural configurations that will satisfy it (e.g. it does not require the consonant and the vowel to be phased such that their ONSET landmarks are synchronous. Thus, this explains why the presence of a prevocalic glottal stop can satisfy the constraint INITIAL C, but it cannot satisfy ONSET(Rev.). It should also be noted that Yucatec Maya exhibits a FINAL C requirement, but that this requirement is satisfied through epenthesis of an [h]. Further study will be required to explain the choice of glottal stop in initial position but [h] in final position.
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.?6.tisch ‘chaotic’
b. Kò.ka.?ín ‘cocaine’
c. sóu.ér ‘sour’
d. krè.a.tív ‘creative’

Southern German

(Alber 2001)

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33 Thanks to Mark Donohue (p.c.) for bringing my attention to these examples.
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-\textsc{onset} account of glottal stop epenthesis before stressed vowels, one that is compatible with the Landmark Underspecification proposal.\textsuperscript{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.-\textnt.wor.t-en \quad \text{‘to take the responsibility’}

b. ?án.-\texter.-kèn.nen \quad \text{‘to acknowledge’}

c. ?án.-\texter.-kèn.nen \quad ?á.n-\texter.-kèn.nen \quad \text{‘to acknowledge’}

d. ?Er.-\textéi.g.nis \quad ?E.r-\textéi.g.nis \quad \text{‘event’}

e. ?um.-?ár.men \quad ?u.m-á.r.men \quad \text{‘to embrace’}

(Alber 2001)

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

\textsuperscript{34} It should be noted that an \textsc{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 \textsc{onset} analysis of glottal stop epenthesis in Standard and Southern German in which she posited an \textsc{onset} \{\text{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 \textsc{onset} \{\text{stress}\}, \text{contiguity} and \textsc{onset} (see Alber 2001 for more details of this approach). Thus, the main point of this discussion is not that an \textsc{onset} approach is not available, but that it is unnecessary. Furthermore, I propose that the \textsc{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/ $\rightarrow$ [dipukol] ‘to beat, passive’
   b. /di-daki/ $\rightarrow$ [didaki] ‘to climb, passive’
   c. /di-ikat/ $\rightarrow$ [diʔikat] ‘to tie, passive’
   d. /di-ankat/ $\rightarrow$ [diʔankat] ‘to lift, passive’
   e. /di-ukir/ $\rightarrow$ [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 CʔV).
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-emphtatic 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. 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 accented 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 /l/ 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, ð]). 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 increased 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. This effect would be analogous to the increased linguopalatal contact shown in the data from French consonants.

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.  

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.

(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 epenthized 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

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41 Another common pronunciation of determiner + vowel initial word exhibits coalescence of the two vowels: [ðæpəf].
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 **DEPLO(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 **DEPLO(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):

\[
\text{M A R K \text{ PROSODY} >> D E P L O(C) >> O N S E T (R) >> * D O U B L E \text{ LINK}}
\]

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 epenthized 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 \(V_1\) ONSET –to– \(V_2\) ONSET relation holds. Rather than realize the vowels simultaneously, we have the percept of \(V_1\) 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.
The Treatment of Word Initial Onsetless Syllables in English: phrase-initial (37A), and phrase-medial (37B)

<table>
<thead>
<tr>
<th>(A) Input: /æpə/</th>
<th>MARK Prosody</th>
<th>DEPI-0 (C)</th>
<th>Onset (R)</th>
<th>*DOUBLE LINK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. [æp...]</td>
<td>*!</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>2. [tæp...]</td>
<td>*!</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>3. [jæp...]</td>
<td>*!</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>4. [ʔæ]</td>
<td>*!</td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(B) Input: /di₁æpə/</th>
<th>MARK Prosody</th>
<th>DEPI-0 (C)</th>
<th>Onset (R)</th>
<th>*DOUBLE LINK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. /di₁ æp...</td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. /di₁ tæp...</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. /di₁ j,æp...</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. /di₁ j₁æp...</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. /di ?æp...</td>
<td>*!</td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

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 DEPI-0 (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 \texttt{DEP}_{C} (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 \textit{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: \textit{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: Snchitsu\?umshin (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.\footnote{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.} 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) \texttt{?V} sequence has an onset; specifically, the secondary gesture plays this role. This accounts
for the fact that repair of an expected ONSET violation does not occur in Type (1) \( V?V \) 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 epenthesized pre-vocally. 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 → V?V) 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 (Brownstein 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

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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 C? 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-? patterns without making unwarranted stipulations. An additional advantage is that it can be extended beyond the placeless-? 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-? 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-? 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-? 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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