Contrast and laryngeal states in Tz’utujil
A preliminary investigation

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Abstract
This paper investigates the phonetics and phonology of stop consonant allophony in the Mayan language Tz’utujil (Guatemala; ∼70,000 speakers). Tz’utujil, like Mayan languages more generally, contrasts plain voiceless stops with a glottalized stop series. The allophonic realization of this laryngeal state contrast varies dramatically by context, with prevocalic stops showing starkly different phonetic characteristics than preconsonantal or word-final stops. This paper argues that these allophonic processes are rooted in contrast preservation: allophonic variation serves to enhance both place of articulation and laryngeal state contrasts, exactly in those positions where the phonetic cues to such contrasts are jeopardized. Acoustic evidence is adduced in support of this claim, and the stop system of Tz’utujil is modeled in Dispersion Theory (Flemming 1995, Padgett 2003, Flemming 2004).

1 Background
Tz’utujil is a Quichean-branch Mayan language spoken in the highlands of Guatemala. Like Mayan languages more generally, Tz’utujil has a phonological contrast between plain and glottalized stops.

<table>
<thead>
<tr>
<th>Stop phonemes</th>
<th>Plain stops</th>
<th>Glottalized stops</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>/ p t k q ŋs ŋʃ ŋj ŋ /</td>
<td>/ p’ t’ k’ q’ ŋs’ ŋʃ’ ŋʃ’ /</td>
</tr>
</tbody>
</table>

Figure 1: Underlying Tz’utujil stops (Dayley 1985)

Dayley (1985) discusses a number of allophonic processes that apply to the system of stops in Tz’utujil. First, Dayley (1985:14) reports that plain stops are aspirated before consonants and word-finally.
(1) \[ T / \rightarrow [ T^h ] / \{ C, \# \} \]

Otherwise — i.e., prevocally — plain stops are realized as voiceless unaspirated.

(2) \[ T / \rightarrow [ T ] / \_ \]

Glottalized stops undergo allophonic alternations in exactly the same contexts. Before consonants and at the end of a word, glottalized consonants are realized as voiceless ejectives (Dayley 1985:15,33).

(3) \[ T' / \rightarrow [ T' ] / \{ C, \# \} \]

Prevocally, underlying \(/ p' t' q' /\) are typically realized as implosive \([ \text{f} \, \text{d} \, \text{z}']\); all other stops are realized as voiceless ejective.\(^1\)

(4) \[ p' t' q' / \rightarrow [ \text{f} \, \text{d} \, \text{z}'] / \_ \]

To summarize, the phonological plain vs. glottalized contrast in Tz’utujil is realized as a voiceless aspirated vs. ejective contrast preconsonantal-ly or word-finally, and as a plain voiceless vs. implosive/ejective contrast prevocally.

<table>
<thead>
<tr>
<th></th>
<th>Prevocalic allophones</th>
<th>Pre-C/# allophones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain stops</td>
<td>p t k q (\text{ts}^h) (\text{t}^h) ?</td>
<td>p(^h) t(^h) k(^h) q(^h) ts(^h) t(^h) ?</td>
</tr>
<tr>
<td>Glottalized stops</td>
<td>(\text{f} , \text{d} , \text{k}' {\text{q}' , \text{z}'}) ts' t'</td>
<td>p' t' k' q' ts' t'</td>
</tr>
</tbody>
</table>

Figure 2: Tz’utujil stop allophone distributions

1.1 Allophony and phonetic motivation

The main claim of this paper is that these allophonic alternations in the Tz’utujil stop system are not arbitrary: stop allophony enhances phonetic cues in exactly those contexts where such cues would be obscured, thereby improving the recoverability of underlying contrasts. This paper thus falls in line with recent work in Dispersion Theory (Flemming 1995, Padgett 2003, Flemming 2004), in that it attempts to find “explanations for allophonic processes...rather

\(^1\)Dayley (1985) claims that prevocalic \(/q'/\) only optionally becomes \([\text{d}]\). The impressionistic findings discussed in §2 support this claim.
than simply stating them...[since] allophonic processes at least sometimes serve the goal of contrast preservation” (Padgett 2003:187).

If the allophonic processes discussed in §1 are motivated by the preservation of phonetic cues, which cues are relevant? One possibility is that these allophonic alternations are driven by the need to preserve place of articulation contrasts. As is well-known, cues to place of articulation are more robust in CV transitions than in VC transitions (e.g. Fujimura, Macchi, and Streeter 1978, Steriade 2001). Since preconsonantal and word-final stops have only VC transitions, we can reasonably hypothesize that cues to stop place are weak in those contexts. These positions — preconsonantal and word-final — are of course exactly the contexts that trigger allophonic stop aspiration in Tz’utujil (1). An important point here is that the spectral properties of burst noise and the duration of aspiration carry reliable cues to major place (e.g. Johnson 2003:141-4; Cho and Ladefoged 1999). Consequently, the presence of allophonic aspiration should at least somewhat improve the perceptibility of stop place. Allophonic aspiration thus enhances the recoverability of underlying stop place contrasts, in precisely those positions where place cues are weakest.

This phonetic account of allophonic aspiration seems quite reasonable when we consider only one dimension of contrast, namely place of articulation. The problem with such idealization is that contrast is inherently systemic (e.g. Hura, Lindblom, and Diehl 1992): maintaining contrast along one phonetic dimension might threaten contrast along another dimension. As discussed at the outset, Tz’utujil stops in fact contrast along two dimensions: place and laryngeal state. We should ask, then, whether allophonic aspiration preserves or endangers the plain vs. glottalized laryngeal state contrast in Tz’utujil.

In preconsonantal and word-final position, the underlying plain vs. glottalized /T T’/ contrast is phonetically realized as a voiceless aspirated vs. voiceless ejective [T T’] contrast. There is some reason to believe that ejective stops might be perceptually confusable with voiceless aspirated stops. For one, ‘classic’ ejective stops typically have a higher VOT and overall duration than plain voiceless stops (Lindau 1984, Wright, Hargus, and Davis 2002, Gallagher under review). One possibility, then, is that voiceless aspirated stops and homorganic ejectives should be perceptually confusable due to the greater similarity of their VOTs. On the other hand, Wright et al. (2002) found that the /t t’/ contrast in Witsuwit’en was more confusable for speakers than the /th t’/ contrast. The results of Wright et al. (2002) are not predicted by the simplistic VOT-based theory of perceptual confusability just sketched.

A major confound with this sort of armchair reasoning is that, cross-linguistically, ejectives are not a homogenous class. Lindau (1984) and Kingston (2005) divide ejective stops into two major types. The first type is the so-called ‘stiff’ or ‘tense’ ejectives, which have an intense release burst, along with long-lag VOT caused by post-release constriction of the vocal folds. Stiff ejectives induce tense or modal phonation on a following vowel, and may also raise pitch at the vowel onset. The second type, so-called ‘slack’ or ‘lax’ ejectives, have release bursts which are roughly as intense as plain stops, as well as relatively short VOTs. Slack ejectives induce lowered pitch and creaky phonation on a following vowel.

Other researchers have suggested that this two-way typology of ejectives is insufficient for characterizing the attested range of phonetic variation in ejective stops. Warner (1996), Wright et al. (2002), and Ham (2004) all argue that ejective stops in any given language may evince only some of the typical properties of stiff or slack ejectives. At present, then, the typology of ejective stops is at best incomplete and murky.
Given this uncertainty about the acoustics of ejective stops, we must first establish the actual phonetic facts of the Tz’utujil stop system before exploring possible phonetic motivations for stop allophony. The next section provides acoustic evidence that ejectives in Tz’utujil pattern with ‘classic’ stiff ejectives in the typology of Lindau (1984) and Kingston (2005); and §3 examines VOT values for Tz’utujil stop allophones.

2 Phonetics of Tz’utujil glottalized stops

In order to examine the phonetic properties of Tz’utujil stops, field recordings of two speakers of Tz’utujil (one male, one female) were downloaded from the AILLA online repository (Oxlajuj Keej Maya’ Ajtz’iib’ 2003). From these recordings I extracted 223 stops, which were coded for place of articulation, laryngeal state (plain vs. glottalized), and syllable position (onset vs. coda). I only examined /p t k q/ (and their glottalized counterparts); affricates and glottal stops were ignored.

Stops were identified with the help of two reference books: Dayley (1985), a grammar of Tz’utujil; and Dayley, Mendoza, and Mendoza (1996), a dictionary. Contextual information was also used to classify ambiguous tokens. For example, upon hearing a word that was potentially four-ways ambiguous between [ak], [ak’], [aq], and [aq’], the presence of the word [wakaf] ‘cow’ in the immediately preceding discourse was taken as evidence that the ambiguous token was in fact [ak’] ‘chicken’. Acoustic differences between plain and glottalized stops (discussed below) were also used to identify segments for the purposes of coding.

![Figure 3: Release bursts for Tz’utujil [k’] and [k]](image-url)
2.1 Ejectives

Ejective stops in Tz’utujil display a cluster of properties that strongly suggests they should be characterized as stiff ejectives. Though the relevant properties are not quantified in this paper, the impressionistic facts are sufficiently clear to warrant at least some initial claims about the phonetics of ejectivity in Tz’utujil.

First, ejective stops have a relatively intense release burst. The contrast in burst intensity between plain [k] and ejective [k’] is illustrated in Fig. 3 above. The release of an ejective is sometimes immediately followed by quasi-periodic noise (Fig. 4), which I take to be a kind of pseudo-voicing following release. The presence of this periodicity makes aerodynamic sense if Tz’utujil ejectives are stiff, with extreme compression of the air in the oral tract: upon release, supraglottal pressure will drop drastically, creating the conditions for passive vocal fold vibration, i.e. pseudo-voicing. The intensity of the release burst for Tz’utujil ejectives confirms that they do involve a significant build-up of air pressure behind the oral constriction. Further, since stiff ejectives are articulated with a tightly closed glottis (Kingston 2005:146), there is independent reason to suspect that the vocal fold adduction required for voicing is indeed present.

![Figure 4: Post-release periodicity for [k’]](image)

The existence of post-release vocal fold closure is also indicated by the length and quality of VOT following ejective stops. As shown in Fig. 5, after the release burst of an ejective there is a long period of silence before the onset of voicing for the following vowel. This post-burst silence suggests that that the vocal folds are completely shut until the beginning of voicing.

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*Kingston (2005:146) reports that K’iche’, a closely related Mayan language, has slack ejectives.

*The segmental transcriptions provided in these figures follow standard Mayan orthography rather than IPA conventions. The Mayan orthographic system is largely phonemic, with the following departures from the IPA consonant system: the velar fricative /x/ is written j; the palato-alveolar fricative /ʃ/ is x; the palatal approximant /j/ is y; the affricates /tʃ/ and /ts/ are ch and tz; the glottal stop /ʔ/ is an apostrophe; and glottalized consonants are written with an apostrophe as well, e.g. b’, k’, etc.
The coarticulatory effects that Tz’utujil ejectives have on following vowels also point toward a stiff-type articulation. At least some of the time, F0 is raised following the release of an ejective (Fig. 6). This acoustic effect is presumably another consequence of the high vocal fold tension required for the articulation of a stiff ejective (see Kingston 2005 for extensive discussion of the interaction of laryngeal state and tone).

In terms of phonation type, Tz’utujil ejectives generally induce modal voice on following vowels. Informally, I take modal voicing to be signaled by closely-spaced, even vertical striations throughout the vowel, which indicate regular glottal pulses, as in Fig. 7.
This is not an absolute correlation; vowels following ejective stops are occasionally found with some degree of non-modal phonation as well, marked by irregular, widely spaced glottal pulses (see Fig. 8). At least impressionistically, it is difficult to determine whether this sort of non-modal phonation represents tense voice or creaky voice (see Gordon and Ladefoged 2001 for some discussion of acoustic differences between tense and creaky phonation). Since Tz’utujil ejectives resemble stiff ejectives in all other respects, I assume that this is tense phonation.

To summarize, ejective stops in Tz’utujil pattern with stiff ejectives along a number of acoustic parameters, including burst intensity, VOT duration, VOT quality, F0 perturbations, and phonation type.
2.2 Implosives

Two main criteria distinguish implosive stops in Tz’utujil from their ejective counterparts: (i) very low VOT, often below 5 ms, including some occasional prevoicing; and (ii) creaky voice and/or lowered F0 on a following vowel. Prevoicing can be seen in Fig. 9, which shows non-prevoiced and prevoiced [ɓ] within a single word. Examples of creaky voice and lowered F0 in a vowel following [ɓ] are given in Figs. 10 and 11, which are taken from a single token of b’eeey ‘road’.

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4The claim that implosives correlate with lowered F0, rather than raised F0, conflicts with earlier research like Greenberg (1970) and Ohala (1973), but is in accord with the findings of Frazier (2009) for Yucatec Maya.
To be sure, it’s not quite clear whether the lowered F0 found following some implosives is a direct result of the implosive articulation itself, or whether lowered F0 is a consequence of the creaky phonation induced by the implosive on a subsequent vowel (e.g. Gordon and Ladefoged 2001:387). More research is needed to determine whether the F0 lowering associated with prevocalic implosives is independent of creaky phonation in the same context.

Prevocalic glottalized stops are realized as implosive to different degrees, depending on place of articulation. Prevocalic glottalized /p'/ is basically always realized as the voiced implosive [b], at least in the data I have examined. The uvular /q'/ is variably realized as implosive [É], exactly as reported by Dayley (1985:15) (see Fig. 12).  

\[5\]

The glottalized coronal /t'/ was never obviously imploded in the tokens I found; even those tokens with low VOTs (∼10ms) still had a relatively intense burst release, which I take to

\[5\]The instance of [É] in Fig. 12 has a surprisingly long VOT and intense release burst for a putative implosive consonant. Nevertheless, the clear presence of prevoicing strongly argues against taking this segment to be the ejective [q'].

![Figure 11: Implosive [b] lowering F0](image1.png)

![Figure 12: Prevoiced implosive [É]](image2.png)
be a good indicator of an ejective rather than implosive articulation (e.g. Ladefoged and Maddieson 1996:82).

The fact that /p'/ is preferentially realized as an implosive is unsurprising. Ejective [p'] is cross-linguistically rare, while [ɓ] is typologically the most common implosive (e.g. Greenberg 1970). These asymmetries have a clear aerodynamic source: bilabial consonants have a relatively large oral cavity, which is conducive to the low supraglottal pressure characteristic of implosives, but anathema to the high supraglottal pressure required for ejectives.

Somewhat more surprising is the observation that Tz’utujil has implosive [ɗ] while also disfavoring or even lacking implosive [ɓ]. Implosive [ɗ] is more common cross-linguistically than velar [ɡ] or uvular [ɔ], due to exactly the same aerodynamic factors that favor implosive [ɓ]. Of course, this conclusion may be premature, as only six instances of prevocalic /t'/ were found in this study.6

This concludes the discussion of the phonetics of Tz’utujil glottalized stops. The next section compares VOT values for plain and glottalized stops in different prosodic positions.

Figure 13: Allophonically aspirated /t/ in tinaamit ‘town’

3 Comparison of VOTs

Recall the question that began this investigation: does the allophonic aspiration of plain stops in Tz’utujil endanger the underlying contrast between plain and glottalized stops? As a first step toward an answer, I measured the VOT values of all 223 stops that were coded for the purposes of this study. For prevocalic stops, VOT was measured from the beginning of the release burst to the onset of voicing in the following vowel. For preconsonantal stops, the end of VOT (more accurately, burst noise/aspiration) was taken to be the onset of the following consonant. Stops showing prevoicing were recorded as having extremely small positive VOTs (<0.5ms). VOT for utterance-final stops was measured from release to the

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6The small n for prevocalic /t'/ can be partially attributed to the fact that word-initial /t'/ is relatively uncommon in Tz’utujil (see Dayley et al. 1996).
cessation of any speech-related acoustic noise. Word segmentation was aided by the fact that Tz’utujil has almost exceptionless word-final stress (Dayley 1985:29).

Despite my best attempts at identifying the place and laryngeal state of these stops, non-English sounds (ejectives, /q/, etc.) were no doubt periodically miscategorized in this study. The data is also noisy and variable, with small n’s for some categories, so most results reported here represent trends rather than statistically significant generalizations.

### 3.1 Mean VOT values

Looking first at the plain stops, we find that preconsonantal and word-final plain stops are indeed allophonically aspirated, at times dramatically so. Fig. 13 illustrates the phenomenon with an example of allophonic aspiration of word-final /t/. Coda plain stops show allophonic aspiration at every place of articulation considered in this study, as Fig. 14 makes clear.

![Figure 14: Allophonic aspiration of plain stops](image_url)
As a point of reference for the extent of this aspiration, Lisker and Abramson (1964) report that initial aspirated \([p^h t^h k^h]\) in English have average VOTs of 58ms, 70ms, and 80ms respectively. In comparison, the mean VOTs of Tz’utujil \([p^h t^h k^h]\) are 74ms, 78ms, and 66ms (see Table 1 at the end of this section). Though these values are somewhat higher than in English, the 66ms average for \([k^h]\) is puzzling, given the strong cross-linguistic tendency for velar stops to have longer VOTs (Cho and Ladefoged 1999). Uvular \([q^h]\) has a similarly surprising average VOT of 66ms. Finally, Tz’utujil shows higher mean VOTs for aspirated stops than most of the 18 languages discussed in Cho and Ladefoged (1999), though the velar stop is again exceptional.

Turning to the ejective series, we find that in onset position ejective stops tend to have higher VOTs than plain stops (Fig. 15). The exception is \(/p'/\), which is generally realized as the implosive \([\hat{6}]\) in onset position, with a very low VOT.

![Figure 15: VOTs for plain and ejective stops in onset position](image)

The mean VOT for ejectives varies by syllable position. Ejective \([k']\) and \([q']\) have lower
average VOTs in coda position than in onset position.

Figure 16: VOTs for ejective stops by syllable position

One explanation for these lowered coda VOT values has to do with the nature of the VOT interval for ejectives. Recall from §2.1 that VOT for Tz’utujil ejectives is essentially a period of silence preceding the onset of vowel voicing. In phrase-final position, then, the post-burst VOT period for ejective stops is simply inaudible. The inclusion of phrase-final ejectives in this tally is thus partially responsible for the depressed coda VOT values found in Fig. 16.

If we compare the VOTs for Tz’utujil ejectives to those reported by Cho and Ladefoged (1999:222), we find that these VOT durations are actually quite small: the lowest mean VOT for an ejective given in Cho and Ladefoged (1999) is 46ms, which is higher than the mean value for all Tz’utujil ejectives except onset \[q’\]. On the other hand, Wright et al. (2002) found a mean VOT of roughly 33ms for Witsuwit’en /t’/, with the average VOT for individual speakers dropping as low as 25ms. I have little to say on this point, except that such low VOT values might suggest that Tz’utujil ejectives are not really canonical stiff
ejectives (see Wright et al. 2002 for closely related discussion).

<table>
<thead>
<tr>
<th>Stop type</th>
<th>p</th>
<th>p'</th>
<th>t</th>
<th>t'</th>
<th>k</th>
<th>k'</th>
<th>q</th>
<th>q'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset</td>
<td>12</td>
<td>5</td>
<td>17</td>
<td>27</td>
<td>31</td>
<td>40</td>
<td>27</td>
<td>51</td>
</tr>
<tr>
<td>Coda</td>
<td>74</td>
<td>13</td>
<td>78</td>
<td>—</td>
<td>66</td>
<td>21</td>
<td>66</td>
<td>22</td>
</tr>
</tbody>
</table>

Table 1: Mean VOTs (in ms) for Tz’utujil stops by syllable position

3.2 VOTs and contrast

The crucial question here is whether allophonic aspiration makes underlying plain stops more or less similar to coda ejectives in their surface acoustic properties. In other words, we should ask what the plain vs. glottalized contrast would look like in coda position if allophonic aspiration did not occur. One way of answering this question is to look at the VOTs for plain onset stops. I assume that plain voiceless stops would have roughly the same VOT in coda position as they in fact have in onset position. Under this assumption, we can compare the VOTs of plain onset stops with the VOTs for ejective coda stops in order to get a sense of what the stop system of Tz’utujil would look like without allophonic aspiration.

It turns out that coda ejectives and onset plain stops have very similar VOTs — much more similar, in fact, than coda ejectives and coda aspirated stops. As shown in Table 2, for any given place of articulation the mean VOTs for coda ejective and onset plain stops differ by no more than 10ms. In contrast, the mean VOTs for a coda ejective and coda aspirated stop differ by at least 44ms.

<table>
<thead>
<tr>
<th>Stop Place</th>
<th>Coda ejective vs. Onset plain</th>
<th>Coda ejective vs. Coda aspirated</th>
</tr>
</thead>
<tbody>
<tr>
<td>p</td>
<td>1</td>
<td>62</td>
</tr>
<tr>
<td>t</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>k</td>
<td>10</td>
<td>45</td>
</tr>
<tr>
<td>q</td>
<td>5</td>
<td>44</td>
</tr>
</tbody>
</table>

Table 2: Coda aspiration improves VOT distinctions (in ms)

It would appear, then, that allophonic aspiration makes the VOT space for Tz’utujil stops less crowded than it would have otherwise been in coda position. We can represent this information graphically by superimposing the mean VOT values for voiceless aspirated stops...
on top of the mean VOT values for coda ejectives and onset plain voiceless stops. In Fig. 17, the black dots/lines indicate differences between coda ejective stops and plain onset stops; while the yellow dots/lines mark differences between coda ejective stops and aspirated coda stops.

Fig. 17 demonstrates that for all four places of articulation allophonic aspiration exaggerates the VOT difference between plain and glottalized stops, which would otherwise be rather indistinct in coda position (nothing can be said about /t/ because I found no instances of coda /t’/). The effect becomes a bit more clear if we collapse the data across place of articulation, as in Fig. 18.

On the basis of these results I tentatively conclude that allophonic aspiration does not endanger the plain vs. glottalized contrast in Tz’utujil. If anything, allophonic aspiration enhances the underlying laryngeal state contrast. Without aspiration, coda plain stops would have VOTs very similar to those of coda ejectives. By hypothesis, the lack of a clear VOT
difference between plain and glottalized stops in coda position would presumably give rise to greater perceptual confusability. Thus, in one fell swoop, allophonic aspiration preserves contrast along two dimensions: place and laryngeal state.

A similar explanation can be given for the allophonic realization of glottalized stops as voiceless ejectives in preconsonantal and word-final position. Ejectives have higher VOTs than implosives, as well as a more salient release burst. As a result, place cues for preconsonantal and word-final ejectives should be more easily recoverable than place cues for implosives in the same positions. In other words, all coda stop allophony in Tz’utujil can be understood as maximizing the perceptual distinctiveness of place and laryngeal state cues, in exactly those positions where such cues are threatened by the lack of CV transitions. We might even hypothesize further that the unusually short VOTs found for Tz’utujil ejectives (§3.1) are related to the pressure to maximize VOT differences between plain and glottalized stops in coda position.7

A caveat is in order, however. Without carrying out a perceptual study of some sort, we cannot conclude that coda stop allophony actually improves the distinctiveness of place or laryngeal state cues. For example, if we consider onset position alone (Fig. 15), it’s not even clear that VOT is a reliable cue for distinguishing plain stops from ejectives prevocally. Other cues — burst intensity, post-burst silence, F0 perturbations, phonation type, etc. —

7Note that in Witsuwit’en, which also has low VOT values for ejective stops, /t t’/ is more confusable than /tʰ t’/ (Wright et al. 2002, §3.1)
may be more important than VOT for cuing the plain vs. glottalized contrast in Tz’utujil, in onset and coda position alike. The hypotheses put forward in this paper thus await experimental confirmation.

### 3.3 Kinds of codas

Not all coda plain stops are aspirated to the same extent in Tz’utujil. The data I have collected suggests that phrase-final (i.e. pre-pausal) codas are aspirated to a much greater extent than phrase-medial codas.

![Graph showing VOT (ms) for plain stops by position](image)

**Figure 19: Degrees of coda aspiration**

These findings are reminiscent of a number of boundary-sensitive phonetic phenomena, in particular the cumulative domain-edge articulatory strengthening effects discussed in e.g. Fougeron and Keating (1997) and Hsu and Jun (1998).

The fact that phrase-final codas are more strongly aspirated than phrase-medial codas provides a clue to the diachronic origin of allophonic aspiration. With regard to a very similar phenomenon in Yucatec Maya, AnderBois (to appear) argues that right-edge allophonic aspiration represents the phonologization of voicing-related articulatory pressures. It is well known that there are gradient phonetic tendencies toward domain-final devoicing...
and/or creaky voice, which are often related to the supposed difficulty of maintaining voicing throughout large prosodic units or utterances (e.g. Blevins 2004). According to AnderBois (to appear), these phonetic pressures are occasionally phonologized, resulting in categorical phrase-edge effects (e.g. aspiration, [h]-epenthesis, etc.). AnderBois dubs such right-edge allophony final laryngeal strengthening.

There are at least two diachronic accounts that are consistent with this view of allophonic aspiration in Tz’utujil. First, we might assume that allophonic aspiration first occurred in phrase-final position — where it had phonetic motivation — and was only later extended to phrase-medial position, where phonetic motivation is lacking. Once domain-final phonetic aspiration became allophonic — i.e., once it was phonologized (Hyman 1976) — speakers were free to exploit aspiration in other positions. The impetus for extending allophonic aspiration to phrase-medial codas would be the now-familiar phonetic pressure to protect place and laryngeal state contrasts in perceptually vulnerable positions.

A second potential diachronic account is one relying on exemplar representations. As suggested in this paper, aspirated voiceless stops have more reliable place and laryngeal state cues than plain voiceless stops. As a result, any individual token of an aspirated stop should be more easily categorized (i.e. stored as an exemplar) than a corresponding unaspirated stop (e.g. Wedel 2004). Over time, this ‘categorization bias’ should lead to a greater representation of aspirated coda stops in the overall exemplar space. If the production of a particular word is influenced by all of its stored exemplars, including those exemplars that have final aspiration, then aspiration might eventually generalize from phrase-final to phrase-medial position simply in virtue of the interconnected nature of exemplar representations. The phonetic effects of domain-final laryngealization would thus be indirectly phonologized via the process of exemplar storage and production (Wedel 2004). This account is ‘non-teleological’ in the sense that allophonic aspiration emerges from language use, rather than an explicit grammatical pressure to preserve contrasts.

Though I don’t believe there’s sufficient evidence to decide between these two accounts, the phonetically-detailed nature of exemplar representations might suggest an exemplar-based explanation is better equipped to handle the gradient effects of aspiration shown in Fig. 19. However, in §5 I provide a formal analysis of allophonic aspiration in Dispersion Theory that is capable of capturing gradient aspiration in a synchronic phonological grammar.

4 Further phonological issues

4.1 Prosodic position or phonetic context?

Till this point I have characterized the preconsonantal and word-final environments for stop allophony as being equivalent to coda position. This is an oversimplification of the phonotactics of Tz’utujil. In particular, Tz’utujil allows word-initial stop clusters, e.g. xtkamsaj na ‘he’ll kill it’ Dayley (1985:84). Though I found no clear examples of these clusters in the data I examined, Dayley (1985:14) claims that the first stop in such clusters is eligible for allophonic aspiration.
Allophonic aspiration in initial stop clusters (Dayley 1985:14)

a. /t-kam-i/ → [tʰkami] ‘that he die’

b. /tʃ-paan/ → [tʃʰpaan] ‘in it’

The question, then, is whether allophonic aspiration is best defined in terms of a unified prosodic position (i.e. stops are aspirated in coda position) or in terms of a disjunctive phonetic context (i.e. stops are aspirated before consonants or word-finally).

The aspiration of apparent onset stops in (5) certainly suggests that allophonic aspiration should be characterized in terms of phonetic context rather than syllabic position. A complication with this argument is that the syllabification of these initial stop clusters isn’t quite clear. For one, initial consonant clusters only arise under morphological concatenation. Tz’utujil roots begin with at most one consonant (Dayley 1985:31), so initial consonant clusters only occur when a monoconsonantal prefix attaches to a consonant-initial root. Further, there are only a handful of such monoconsonantal prefixes in Tz’utujil. One possibility, then, is that the first stop in initial consonant clusters isn’t actually an onset, but an extrasyllabic consonant, or even a nuclear consonant heading its own syllable.

Note, though, that the initial aspirated stops in (5) cannot be sensibly claimed to occupy a coda position. Since that is exactly what would have to be said to preserve a syllable-position based account of allophonic aspiration in Tz’utujil, I conclude that stop allophony in Tz’utujil must be defined by phonetic context rather than syllabic position. For the sake of brevity I will continue to use ‘coda position’ as a somewhat misleading shorthand for preconsonantal and word-final position.

4.2 Articulatory accounts

This discussion has so far assumed that stopallophony in Tz’utujil has a perceptual motivation. Could an articulatory explanation account for the same range of facts? This section contains some brief speculations about alternative articulatory analyses of the facts presented in the preceding sections.

One possibility is that prevocalic and preconsonantal/word-final stops in Tz’utujil differ in the relative timing of stop articulators. Previous research suggests that the magnitude of a given gesture, and its exact coordination with other associated gestures, can vary by syllable position and/or phonetic context (e.g. Sproat and Fujimura 1993, Kochetov 2006). All voiceless stops require the coordination of at least a laryngeal gesture and an oral constriction. Further, unaspirated voiceless stops involve more precise synchronization of these two gestures than is necessary for aspirated voiceless stops (see Vaux and Samuels 2006:§3.2 for discussion). Thus, allophonic aspiration in Tz’utujil might be attributable to a difference in intergestural timing: if the oral and laryngeal gestures required for voiceless stops are less...
tightly coordinated in coda position than in onset position, we should expect coda stops to show greater mean VOT values, i.e. greater degrees of aspiration.

A concomitant prediction of this gestural phasing account of allophonic aspiration is that VOTs should show greater variability in coda position than in onset position. This prediction does seem to be borne out: Table 3 shows that coda stops are in general realized with more variable VOT values than onset stops in the Tz’utujil data analyzed here, taking standard deviations for VOT to be an index of variability.

<table>
<thead>
<tr>
<th>Stop type</th>
<th>p</th>
<th>p’</th>
<th>t</th>
<th>t’</th>
<th>k</th>
<th>k’</th>
<th>q</th>
<th>q’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset</td>
<td>4.9 (17)</td>
<td>4.1 (15)</td>
<td>9.3 (44)</td>
<td>29.2 (6)</td>
<td>15.1 (39)</td>
<td>17.4 (42)</td>
<td>7.3 (6)</td>
<td>34.1 (9)</td>
</tr>
<tr>
<td>Coda</td>
<td>69.3 (2)</td>
<td>— (1)</td>
<td>42.7 (7)</td>
<td>— (0)</td>
<td>55.4 (18)</td>
<td>12.4 (3)</td>
<td>79.0 (11)</td>
<td>18.1 (3)</td>
</tr>
</tbody>
</table>

Table 3: Standard deviations for stop VOTs (ms)
Sample size in parentheses

The same basic results hold if we sift out phrase-final coda stops, which have relatively long VOTs, from phrase-medial coda stops, which have shorter VOTs.

<table>
<thead>
<tr>
<th>Stop type</th>
<th>Plain onset</th>
<th>Aspirated coda, phrase medial</th>
<th>Aspirated coda, phrase final</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13.5 (106)</td>
<td>38.8 (20)</td>
<td>60.1 (18)</td>
</tr>
</tbody>
</table>

Table 4: Standard deviations for plain stop VOTs (ms)
Sample size in parentheses

These results should be interpreted with caution. First, the sample sizes for onset consonants are often notably larger than the sample sizes for coda consonants. The small sample sizes for coda consonants will obviously inflate the magnitude of their standard deviations for VOT, especially if the samples include potential outliers.

Second, there may be independent reason to expect VOT values for aspirated consonants to be more variable than VOTs for plain voiceless consonants. Vaux and Samuels (2006:413-5) claim that all speakers show perceptual sensitivity to a VOT boundary at roughly the same point (≈ 35ms), whether or not they speak a language with a /T Tʰ/ contrast. As Vaux and Samuels (2006) point out, this boundary is essentially identical to the long-lag VOT boundary found for voicing distinctions in languages like English. If Vaux and Samuels (2006) are correct, these facts suggest that there is an inherent perceptual partitioning of the VOT space which limits the VOT range for plain stops to about 35ms. In other words, the VOT space for plain voiceless stops is much more tightly constrained than the VOT space for aspirated voiceless stops, which has no upper bound beyond the limits imposed by our articulators. As Vaux and Samuels (2006) point out, this large VOT space means that voiceless aspirated stops are effectively quantal: VOT values can be highly variable

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This is not to say that languages draw the same VOT boundaries in production, which is clearly false (e.g. Cho and Ladefoged 1999, Ladefoged 2006:147). Vaux and Samuels (2006) are making a claim about perceptual salience, and not about universals of production.
for voiceless aspirated stops without endangering their categorization as voiceless aspirated. The same degree of variability for plain voiceless stops would lead to the misperception of many plain voiceless stops as either voiced or aspirated. Though Tz’utujil does not have a phonemic /T Tʰ/ contrast, one could imagine that high VOT variability for plain stops might lead speakers to misperceive some prevocalic plain stops as implosives.

Another issue with the intergestural timing approach to allophonic aspiration is the ‘chicken-and-the-egg’ problem: does coda variability explain allophonic aspiration, or is coda variability the result of allophonic aspiration? Given the very high mean VOTs for aspirated coda stops, I am skeptical that allophonic aspiration arises epiphenomenally from the relatively loose coordination of stop gestures in coda position. As suggested in the preceding paragraph, differences in variability might stem from contrast preservation pressures, as well as the fact that the VOT continuum is open-ended in the positive direction only. I conclude that a gestural account of Tz’utujil stop allophony is not explanatorily sufficient, though articulatory phasing may still play some role.

Articulatory pressures may, however, be at work in the allophonic realization of glottalized stops as ejectives in coda position. Greenberg (1970) observes that implosives are cross-linguistically preferred in word-initial position. Word-medial intervocalic implosives, in contrast, are often subject to allophonic processes that convert implosives into non-implosive consonants. Though word-initial and intervocalic implosives are both prevocalic, intervocalic implosives are also postvocalic. One possibility, then, is that implosives are dispreferred in postvocalic position. This putative dispreference for postvocalic implosives is almost certainly not due to perceptual considerations: intervocalic implosives should be more easily perceptible than word-initial implosives, since they have both CV and VC transitions. By elimination, then, any phonetic pressure against postvocalic implosives must be articulatory in nature.

Note, too, that coda allophony in Tz’utujil realizes underlying coda /p’/ as the phonetically and typologically disfavored ejective [p’], rather than the favored implosive [ɓ]. The distribution of these allophones is thus mystifying from a functionalist perspective, unless some other articulatory (or perceptual) factor intervenes. Further evidence that coda implosives are somehow dispreferred comes from other Mayan languages: both Yucatec Maya and Kaqchikel (which is closely related to Tz’utujil) have dialects in which coda [ɓ] is realized as [ʔ] (Melissa Frazier, Robert Henderson; p.c.). More needs to be said, of course, about why these dialects (along with Tz’utujil) still realize intervocalic /p’/ as [ɓ].

5 Dispersion Theory analysis

This section provides a formal analysis of Tz’utujil stop allophony in the framework of Dispersion Theory (DT; Flemming 1995, 2004, Padgett 2003). Though the analysis is somewhat sketchy and involves a number of idealizations, it is intended to demonstrate that Tz’utujil stop allophony can be modeled within a phonetically detailed synchronic grammar. This section assumes that readers are familiar with the basic assumptions of DT and the kinds of Optimality Theory constraints that are typically employed in DT analyses.

Allophonic aspiration in Tz’utujil is driven by the need to preserve place and laryngeal state contrasts. I formalize these pressures with the Maintain-Contrastₙ(x) constraints
in (6).

(6) a. **Maintain-Contrast{4}(Place) (MC{4}(Pl)).**
    For any position $x$, there must be a (perceptible) four-way place of articulation contrast in $x$.

    b. **Maintain-Contrast{2}(Laryngeal State) (MC{2}(LS)).**
    For any position $x$, there must be a (perceptible) two-way laryngeal state contrast in $x$.

Readers familiar with DT will have noticed that these are non-standard MC constraints. Standard MC constraints refer to contrast along a specific acoustic dimension; clearly, place and laryngeal state are phonological abstractions, rather than physical properties of the acoustic signal. Here I take **Place** to be a cover term for the bundle of continuous acoustic cues that might distinguish place of articulation for stops, such as burst spectrum, VOT duration, or F2 at the point of stop release (Johnson 2003; Cho and Ladefoged 1999; Flemming 2001). Similarly, **Laryngeal State** encompasses burst intensity, VOT duration, and any other potential acoustic cues to the plain vs. glottalized distinction in Tz’utujil (see §2).

Three other constraints will be relevant for this analysis. The first is **$T^h \geq 50ms$/med**.

(7) **$T^h \geq 50ms$/med**
    Assign one violation mark for every non-phrase-final stop with a VOT greater than or equal to 50ms.

The main effect of **$T^h \geq 50ms$/med** will be to attenuate aspiration of phrase-medial coda plain stops. It will also play a role in preventing the aspiration of prevocalic plain stops. Since aspiration does require active abduction of the vocal folds (Ladefoged 2006:150), I assume that this constraint is grounded in effort minimization pressures.\(^{11}\)

This analysis will also make use of typical DT **Space** constraints, as in (8).

(8) **Space{40ms}(VOT)**
    Assign one violation mark for each plain/glottalized pair such that the VOT values of the two stops do not differ by at least 40ms.

Most DT analyses define **Space** constraints in terms of some proportion of the overall perceptual space along a given dimension (e.g. Padgett 2003, Campos-Astorkiza 2007). Such an approach is not viable here because the VOT continuum is potentially infinite, i.e. it is not bounded in the positive direction. As a result, I directly encode the physical duration of VOT into the definition of the space constraint in (8). This constraint will force plain stops to have relatively large VOTs when permitted (i.e. in phrase-final position), and will also contribute to the prohibition against prevocalic aspirated stops. For the purposes of this analysis I assume that the VOT values for glottalized consonants are fixed at 20ms, though this is an enormous idealization (see Table 1).

\(^{11}\)See also Zoll (1998), Smith (2005), and Flack (2009) on the parameterization of markedness constraints to particular positions, and Hsu and Jun (1998) for an example of domain-edge effects on degree of aspiration.
The final constraint relevant for this analysis is \( *T^h \).

(9) \( *T^h \)

Assign one violation mark for every instance of an aspirated stop.

The constraint \( *T^h \) penalizes all aspirated stops, and will only be active for the prevention of prevocalic aspiration. If Vaux and Samuels (2006) are correct that 35ms represents the lower VOT bound for aspirated stops, this constraint is equivalent to \( *T^h \geq 35\text{ms} \).

To begin, consider the nonce word /tak/, as it appears in phrase-final position.

(10) Full aspiration phrase-finally

<table>
<thead>
<tr>
<th>/ tak ( _v )/</th>
<th>( *T^h \geq 50\text{ms/MED} )</th>
<th>MC(_4)(PL)</th>
<th>SPACE(_{40\text{ms}})(VOT)</th>
<th>( *T^h )</th>
</tr>
</thead>
<tbody>
<tr>
<td>tak( ^h _v )</td>
<td>{ ( t=20\text{ms} ) }</td>
<td>{ ( k^h=65\text{ms} ) }</td>
<td>( t )</td>
<td>( k^h )</td>
</tr>
<tr>
<td>a. ( \text{Some} ) VOT: { ( t=20\text{ms} ) } { ( k=20\text{ms} ) }</td>
<td>( k^h )</td>
<td>( t ) ( k )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>t( ^h ak^h )_( v )</td>
<td>{ ( t^h=65\text{ms} ) } { ( k^h=65\text{ms} ) }</td>
<td>t( ^h )</td>
<td>t( ^h ) ( k^h )</td>
<td></td>
</tr>
<tr>
<td>c. VOT: { ( t^h=65\text{ms} ) } { ( k^h=65\text{ms} ) }</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t( ^h ak^h )_( v )</td>
<td>{ ( t^h=40\text{ms} ) } { ( k^h=65\text{ms} ) }</td>
<td>t( ^h )</td>
<td>t( ^h ) ( k^h )</td>
<td></td>
</tr>
<tr>
<td>d. VOT: { ( t^h=40\text{ms} ) } { ( k^h=65\text{ms} ) }</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Candidate (10a), the attested form, surfaces as optimal because it makes use of final aspiration to preserve coda place constrasts, thus satisfying MC\(_4\)(PL). The VOT value of 65ms is licensed for \( [k^h] \) because it occurs in phrase-final position. In contrast, candidate

\(^{12}\)Vaux and Samuels (2006) argue at length that aspirated voiceless stops are unmarked with respect to plain voiceless stops and voiced stops. This claim, if correct, might suggest that there should be no markedness constraint against voiceless aspirated stops in the constraint set (e.g. de Lacy 2002, Gouskova 2003). Nevertheless, there are many languages (such as the Romance languages) that make use of plain voiceless and/or voiced stops without also utilizing aspiration. Some markedness constraint dispreffering voiceless aspirated stops is thus needed to capture the full typology of stop systems.
(10b), which does not aspirate final [kʰ], is eliminated because it fails to preserve the place contrast for plain stops in final position. Importantly, even though the speaker articulates final [k], candidate (10b) is eliminated because the place cues needed to recover that [k] are not sufficiently salient. Aspiration of prevocalic /t/ is ruled out either because long-lag aspiration is banned in phrase-final position (10c), or because shorter lag aspiration is still prohibited by *Tʰ (10d). The basic intuition is that prevocalic aspiration is banned because it is superfluous, given that prevocalic stops already have robust place cues.

Matters are a bit different in phrase-medial position. Aspiration still occurs to preserve coda place contrasts (11a,b), but is reduced to 40ms because long-lag VOT is not licensed in phrase-medial position (11a,c). Prevocalic aspiration is still banned because it is perceptually gratuitous (11d,e).

(11) Weak aspiration phrase-medially

<table>
<thead>
<tr>
<th></th>
<th>/ tak .../</th>
<th>*Tʰ ≥ 50ms/med</th>
<th>MC₄(Pl)</th>
<th>SPACE₄₀₃₃(VOT)</th>
<th>*Tʰ</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ☞</td>
<td>takʰ ...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOT:</td>
<td>{t=20ms}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>{kʰ=40ms}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t kʰ</td>
<td>kʰ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>tak ...</td>
<td></td>
<td></td>
<td></td>
<td>k!</td>
</tr>
<tr>
<td>VOT:</td>
<td>{t=20ms}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>{k=20ms}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>k! t k</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>takʰ ...</td>
<td></td>
<td></td>
<td>kʰ!</td>
<td></td>
</tr>
<tr>
<td>VOT:</td>
<td>{t=20ms}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>{kʰ=65ms}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t kʰ</td>
<td>kʰ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>tʰakʰ ...</td>
<td></td>
<td></td>
<td>tʰ!</td>
<td></td>
</tr>
<tr>
<td>VOT:</td>
<td>{t=65ms}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>{kʰ=40ms}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>tʰ kʰ</td>
<td>tʰ kʰ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>tʰakʰ ...</td>
<td></td>
<td></td>
<td>tʰ! kʰ</td>
<td></td>
</tr>
<tr>
<td>VOT:</td>
<td>{t=40ms}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>{kʰ=40ms}</td>
<td></td>
<td></td>
<td></td>
<td>tʰ kʰ</td>
</tr>
</tbody>
</table>

Finally, glottalized consonants are realized as voiceless ejectives in preconsonantal posi-
tion. Putting aside the articulatory factors discussed in §4.2, I assume that underlying /T'/ surfaces as ejective [T'] in coda position in order to improve place contrasts (§3.2), i.e. to satisfy MC₄(PL) (12a,b). Prevocalic ejectives (12c) are prohibited by low-ranked *T', which bans all ejective consonants (again, for aerodynamic or effort-based reasons). I use onset /p'/ to illustrate the action of this constraint because prevocalic /p'/ is uniformly imploded. I do not model the fact that prevocalic glottalized stops are gradiently realized as implosives, depending on place of articulation (see §2.2).

(12) Glottalized consonants are ejective in coda position

<table>
<thead>
<tr>
<th>/ p’aq’ /</th>
<th>*Tʰ ≥ 50 ms/MED</th>
<th>MC₄(PL)</th>
<th>SPACE₄₀ms(VOT)</th>
<th>*Tʰ</th>
<th>*T’</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 6aq’</td>
<td></td>
<td></td>
<td>6</td>
<td>q’</td>
<td></td>
</tr>
<tr>
<td>b. 6aq’</td>
<td></td>
<td>g’</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. p’aq’</td>
<td></td>
<td></td>
<td>p’</td>
<td>p’! q’</td>
<td></td>
</tr>
</tbody>
</table>

6 Conclusion

This paper has argued that allophonic stop alternations in Tz’utujil are driven by the need to preserve paradigmatic place and laryngeal state contrasts. In §2 I provided an initial phonetic characterization of Tz’utujil glottalized stops, suggesting that ejectives in Tz’utujil closely resemble traditional stiff-type ejectives. It was then shown that allophonic VOT variations in Tz’utujil enhance contrast in preconsonantal and word-final position, where the lack of CV transitions threatens to obscure phonetic cues to place and laryngeal state. This effect is greater in phrase-final than phrase-medial position, a fact directly captured by the formal Dispersion Theory analysis of Tz’utujil stop allophony developed in §5.

There are at least three directions for further research. The first, and perhaps most pressing, is to test the hypotheses outlined in this paper with a series of perceptual studies. Ideally, these studies should make use of Tz’utujil production data to test the perceptibility of Tz’utujil stop contrasts, using both native Tz’utujil speakers as well as speakers of other languages.

Second, the role of syllable cooccurrence restrictions in perception should be investigated. In Tz’utujil — as in many languages with glottalized consonants (MacEachern 1999, Gallagher and Coon 2009, Gallagher under review) — any two glottalized stops occurring in the same syllable must be completely identical (unless one is /p’/; Dayley 1985:31). As a consequence, the laryngeal state and place of a coda stop are at least partially predictable from the ejectivity and place of a tautosyllabic onset stop. The laryngeal cooccurrence restrictions of Tz’utujil thus build substantial, systematic redundancy into the discrimination
of coda consonants. The influence that these phonological factors exert on perception should be explored in depth.

Finally, it would appear that a number of other languages have allophonic stop distributions that mirror the Tz’utujil data discussed in this paper. Vaux and Samuels (2006:416) claim that in Nxa’mxcin and Bella Coola voiceless stops are realized as plain in onset position, and aspirated elsewhere. Many other languages realize plain stops as aspirated in word-, phrase-, or utterance-final position, including Tojolabal, Yapese, Koyukon, Hupa, Ahtna, Tlingit, Kashmiri, and Sierra Popoluca (Vaux and Samuels 2006:418-21). All of these languages are in principle amenable to the analysis provided here for Tz’utujil, namely that allophonic aspiration emerges from the repurposing of domain-final phonetic laryngealization as a tool for enhancing place contrasts. Furthermore, in some of these languages final aspiration purportedly neutralizes a phonemic laryngeal state contrast. Detailed phonetic analysis of the production and perception of stop allophones in these languages is thus in order, especially as it bears on phonological contrast preservation and neutralization.

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