Laryngeal Timing in Ixcatec Consonants

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Questions

1. What are the phonetic properties of consonants in Ixcatec?
2. How does word position affect the durational properties of consonants?
3. What explains the variability in the production of glottalized consonants?

Roadmap

1. Background on Ixcatec and glottal timing
2. Phonetic Study 1: Investigation on effects of duration and word position on glottalization/aspiration.
3. Phonetic Study 2: Investigation on effects of word position on glottal timing in obstruents and sonorants.
4. Discussion on explanations for glottal timing differences.

Ixcatec

- Oto-Manguean (Popolocan) language spoken in Santa María Ixcatlán, Oaxaca, Mexico.

- Moribund (4 very fluent speakers, 4 semi-fluent speakers)
- Short phonological description (Fernández de Miranda, 1959) and larger dictionary (Fernández de Miranda, 1961).
- Current work part of larger description of the phonetics and phonology of Ixcatec.

Ixcatec Phonology

- Complex system of 50 consonants, where stops, fricatives, affricates, approximants, nasals, prenasalized stops, and prenasalized affricates all have glottalized and aspirated variants. Liquids do not.

- 5 vowel system with contrastive nasalization:
  /i, e, a, o, u/, /ĩ, ẽ, ã, õ, ũ/.

- Three contrastive tones: High (V́), Mid (V), and Low falling (V̀)
  [ʃʰé] '*large*', [tʰẽ] '*palm leaf*', [ʃʰè] '*sin*'

- All syllables are open, with few consonant cluster onsets
  (/s/+stop, /ʃ/+stop).

	Bilabial	Dental	Alveopalatal	Palatalized	Velar	Labialized Velar	Glottal
Stop		t		t^{j}	k	k^{w}	ʔ
Asp.		t^{h}		t^{jh}			
Glot.		$t^{ʔ}$		$t^{jʔ}$	$k^{ʔ}$	$k^{wʔ}$	
Prenasalized		nd	ɲdʒ	nd^{j}	ŋg		
Asp.		^{h}nd	^{h}ɲdʒ		^{h}ŋg		
Glot.		^{ʔ}nd	^{ʔ}ɲdʒ	$^{ʔ}nd^{j}$			
Fricative	ɸ β	s	ʃ				h
Asp.			$ʃ^{h}$				
Glot.	$ɸ^{ʔ}\sim β^{ʔ}$		$ʃ^{ʔ}$				
Affricate		ts	tʃ				
Asp.		ts^{h}	$tʃ^{h}$				
Glot.		$ts^{ʔ}$	$tʃ^{ʔ}$				
Nasal	m	n		ɲ			
Asp.	^{h}m	^{h}n		^{h}ɲ			
Glot.	^{ʔ}m	^{ʔ}n		^{ʔ}ɲ			
Approximant				j		w	
Asp.						^{h}w	
Glot.				^{ʔ}j			
Lateral Approximant		l					
Trill		r̥ r					

The status of glottalized consonants

- Glottalized consonants are clusters of two segments (Fernández de Miranda, 1959), e.g. /t+h/ [tʰ], /ʃ+ʔ/ [ʃˀ].
- If true, must stipulate why sonorants are pre-glottalized and pre-aspirated while obstruents are post-glottalized and post-aspirated. This timing difference is a typical pattern in languages with glottalized consonants (Silverman, 1997).
- Furthermore, a "cluster" analysis must stipulate why (with few exceptions) most "clusters" contain glottal consonants.
- Reasonable to assume that glottalization and aspiration are features associated to single complex segments.

Positional effects

- Position within a word or phrase alters the phonetic structure of sounds.
- Effects observed for consonant duration and magnitude (Keating et al., 2000), the degree of vowel coarticulation (Cho, 2004), and the degree of gestural overlap in consonant clusters (Byrd, 1996).
  - Prosodically-weak positions > greater coarticulatory influence from surrounding speech sounds, more gestural overlap.
  - Prosodically-strong positions > less coarticulatory influence from surrounding speech sounds, less gestural overlap.

Positional effects, cont.

- Positional effects in a related language Trique, where final syllable prominence is associated with phonetic lengthening (DiCanio, 2008, 2010).
- To what extent does word position influence the durational properties of Ixcatec consonants?
- How does the timing of aspiration and glottalization compare with other languages which have been investigated? e.g. (Cho and Ladefoged, 1999; Kingston, 1990; Wright et al., 2002; McDonough and Wood, 2008)

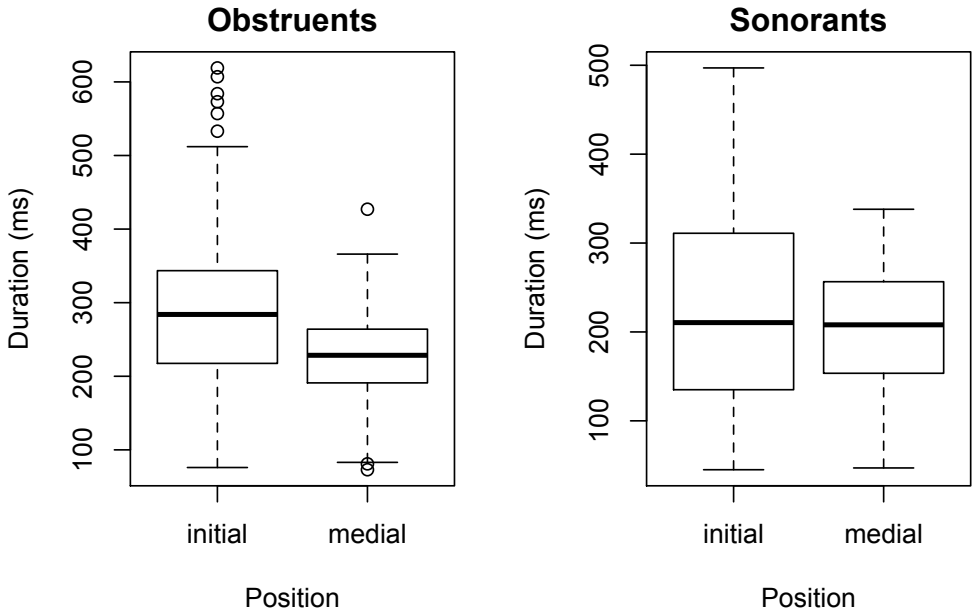
Experiment 1: Methodology

- Acoustic recordings of two most fluent speakers.
- Comparison of 41 consonants (plain, glottalized, and aspirated) surfacing in word-initial and in word-medial position (intervocalic).
- 82 words elicited in carrier phrase: [nítʃana X tʃíniké] '*I say X again.*'. Middle 3 of 5 (or best 3 of 5) productions used for analysis.
- 82 words x 2 speakers x 3 repetitions = 492 tokens.

Measurements

- Measured duration of components of obstruent (closure, burst, VOT, frication).
- Measured duration of components of sonorant (constriction, stop duration, and duration of aspiration/glottalization).
- Results analyzed with a linear mixed-effects model (lmer) with Position (initial, medial) and Laryngeal category (plain, glottalized, aspirated) as fixed effects and with Speaker as a random effect.
- Markov-Chain Monte-Carlo estimation of p-values (pvals.fnc).

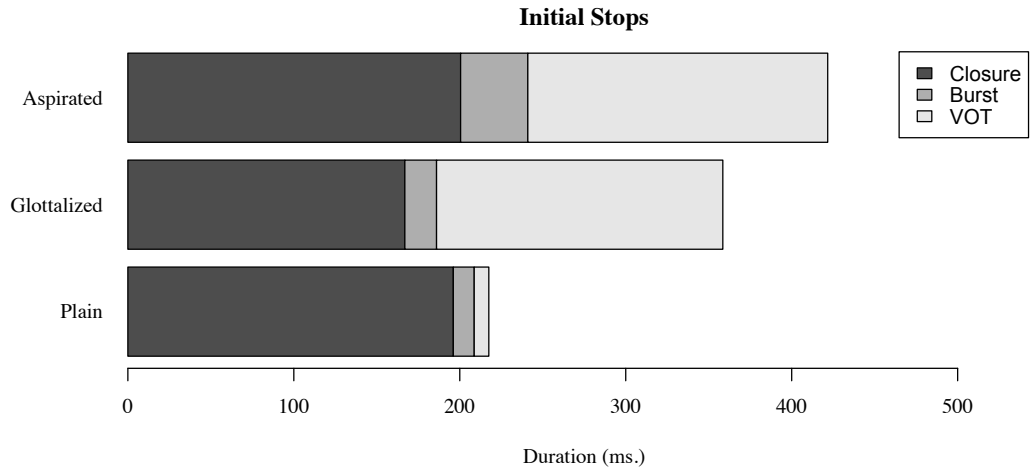
Results: Total Duration

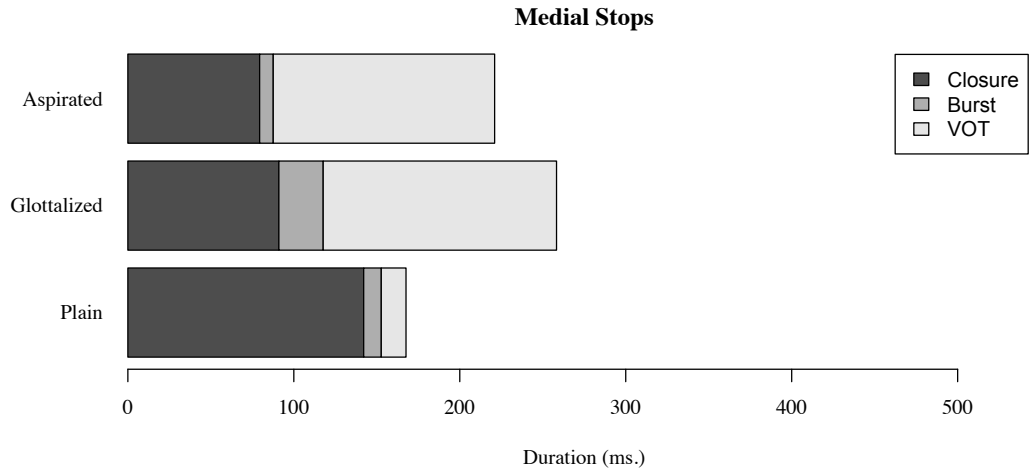


- Significant effect of word position on total consonant duration. Word-initial consonants were longer than word-medial consonants.
- Significant difference in duration between aspirated, plain, and glottalized consonants.

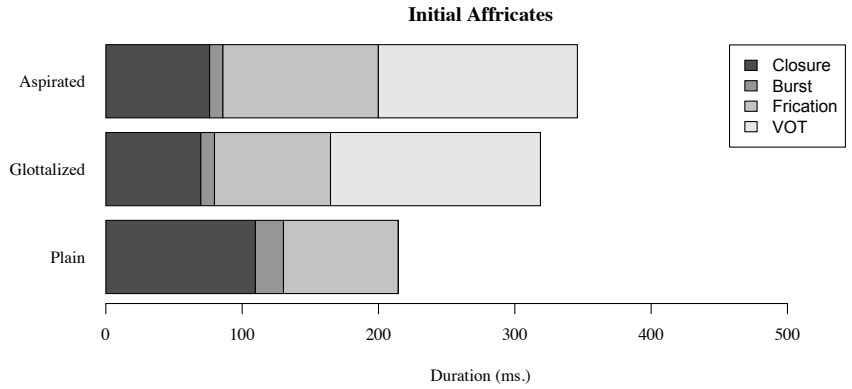
Results: Obstruents (I)

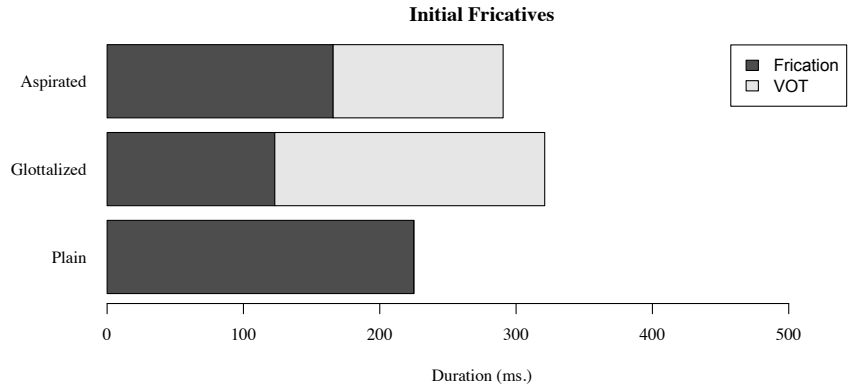
Closure and VOT significant.

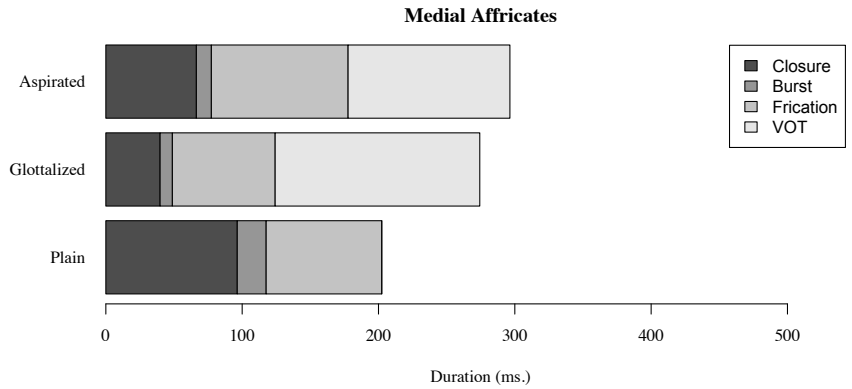


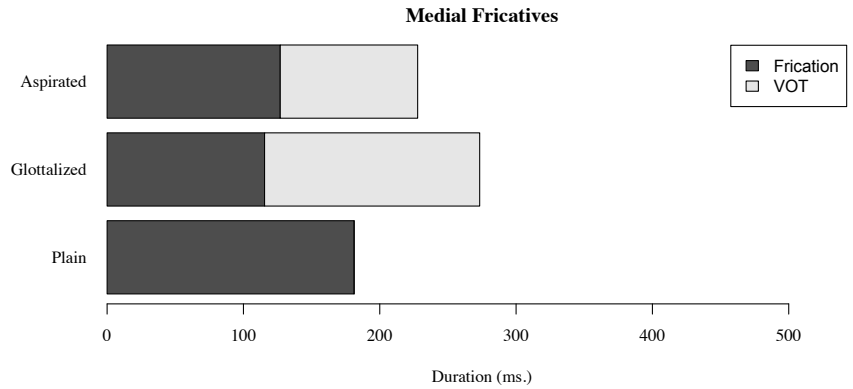


Results: Obstruents (II)



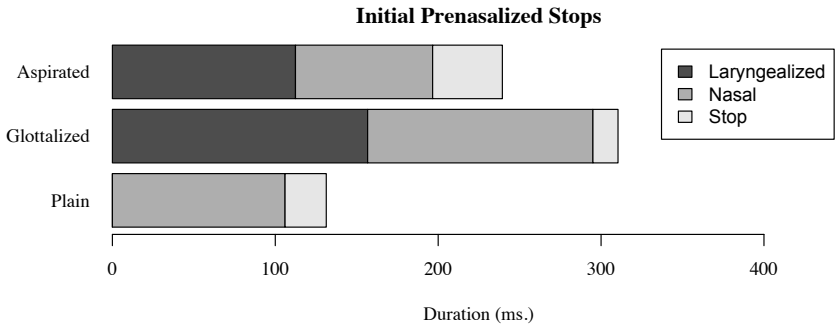


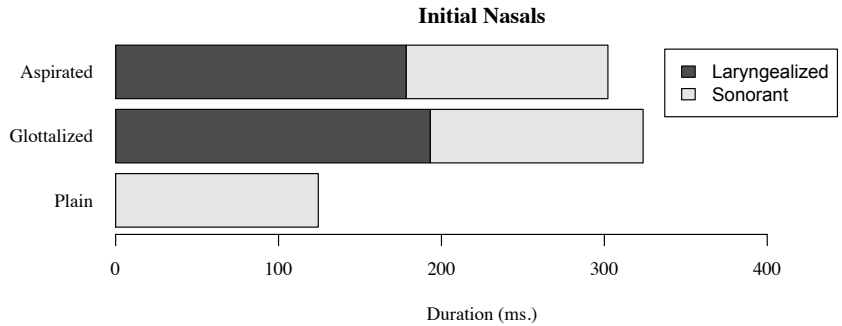


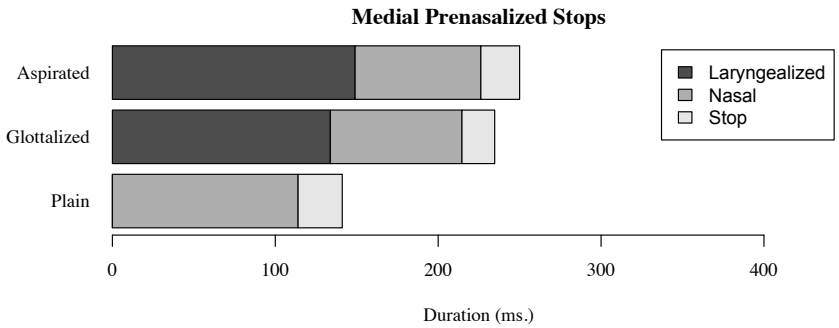


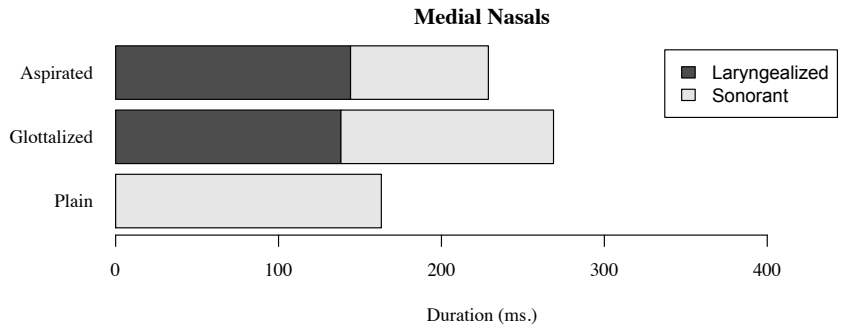
Greater positional effect on stops than on affricates and fricatives.

Results: Sonorants (I)

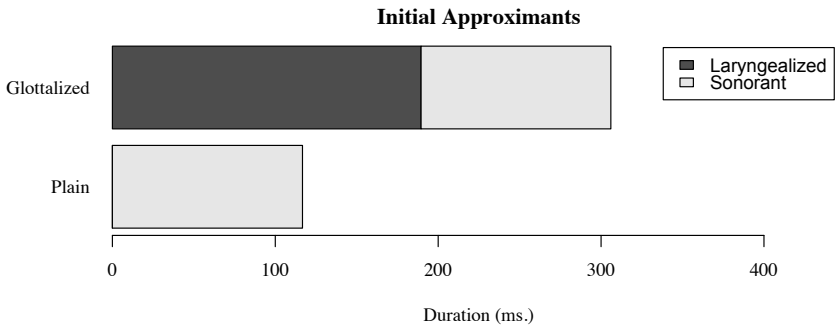


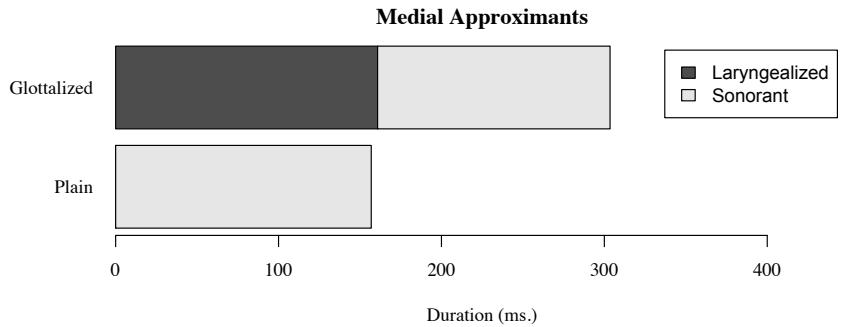






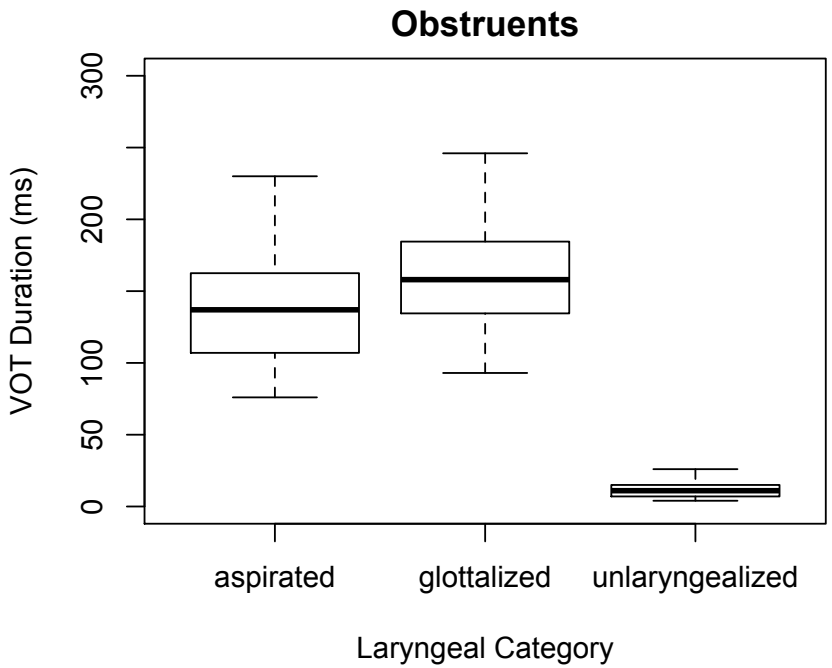
Results: Sonorants (II)

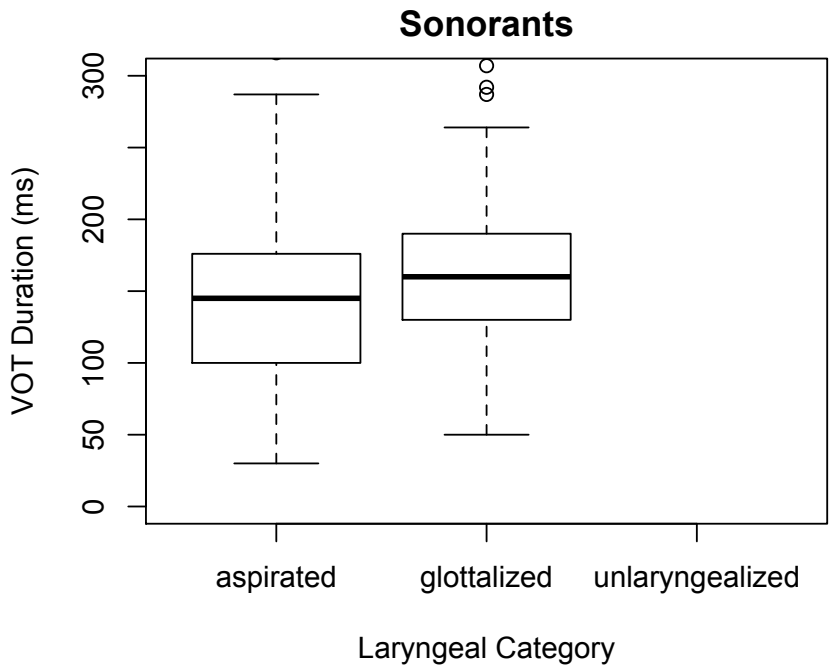




- Laryngealized sonorants shorter in medial position than in initial position. Plain sonorants *longer* in medial position than in initial position.
- Unlike obstruents, durational changes occur mostly in the duration of glottalization/aspiration.

Duration of Glottalization and Aspiration





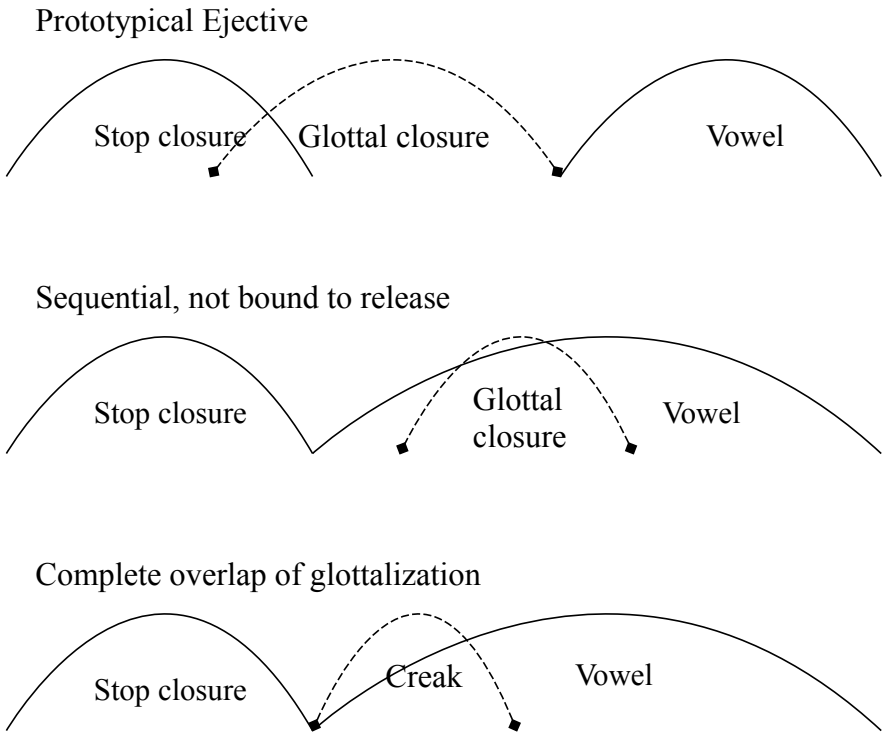
- Across all consonant types, long VOT values observed (125 – 160 ms).
- Glottalized consonants slightly longer than aspirated consonants.

Discussion (I)

- Strong effect of position in word on duration of consonant.
- Strong difference between laryngeal category duration.
- Significant interaction between Position X Category. Glottalized consonants underwent greater durational changes due to position than others.
- VOT values for aspirated and glottalized stops are similar to higher VOT languages like in Athabaskan languages (McDonough and Wood, 2008) and Tlingit (Cho and Ladefoged, 1999).
- How do these positional differences influence the degree of coarticulatory overlap?

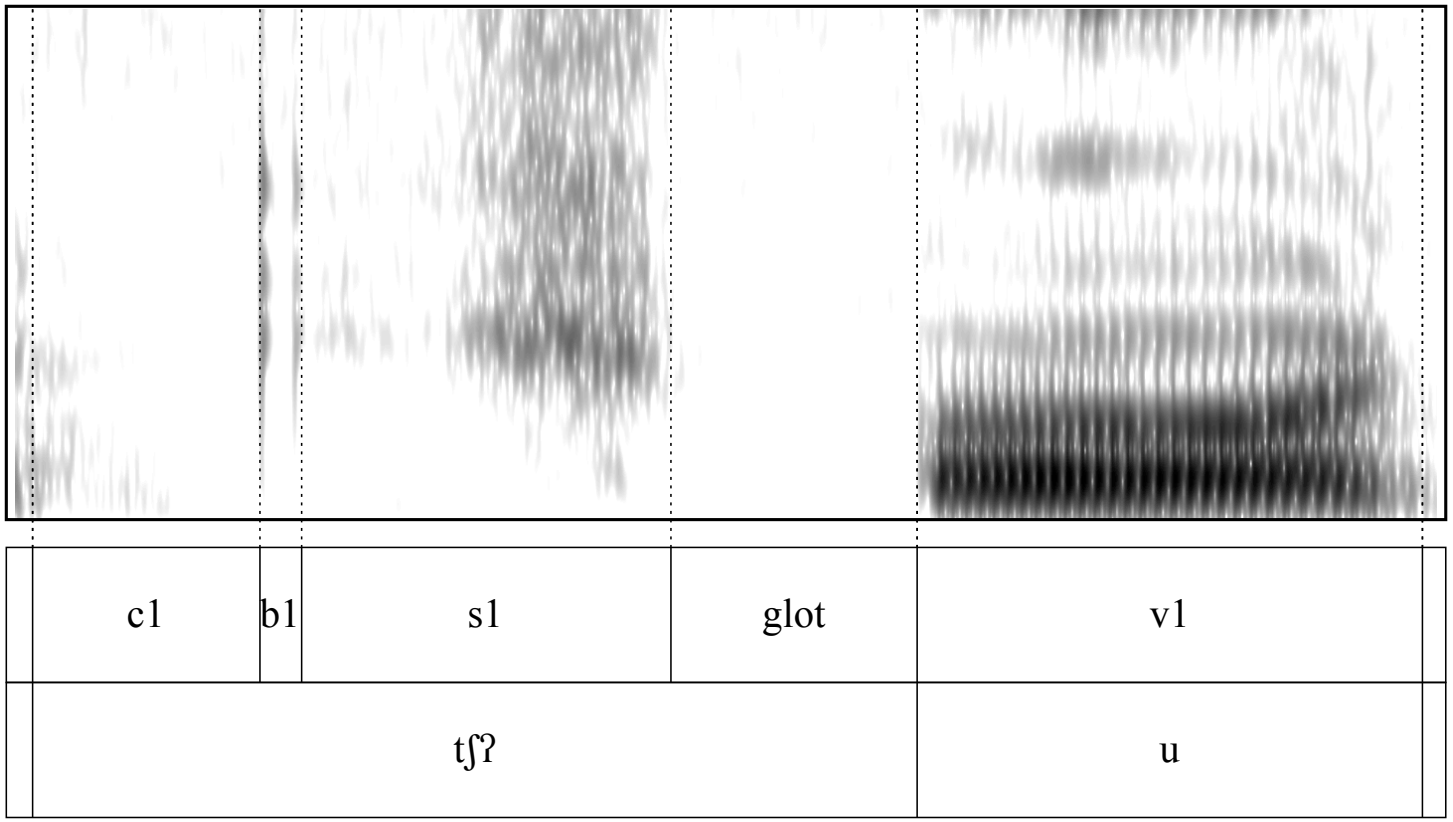
Variability in timing of glottalization

- While sonorants are pre-glottalized and obstruents are post-glottalized, there is substantial variability in how much glottalization may overlap on the adjacent vowel and in how glottalization is realized.



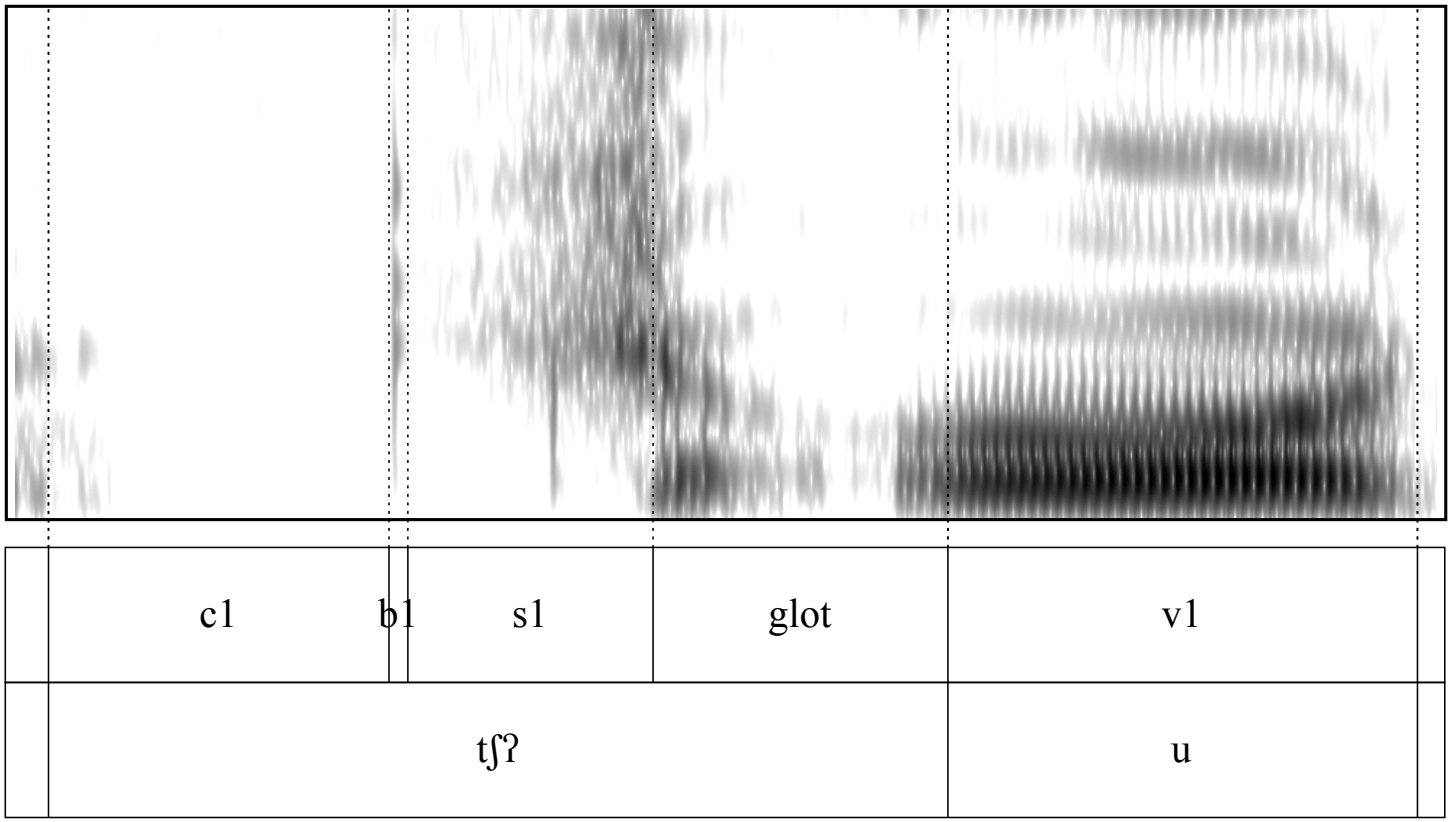
Glottalization - Obstruents (I)

[tʃ'u] '*chocolate*'



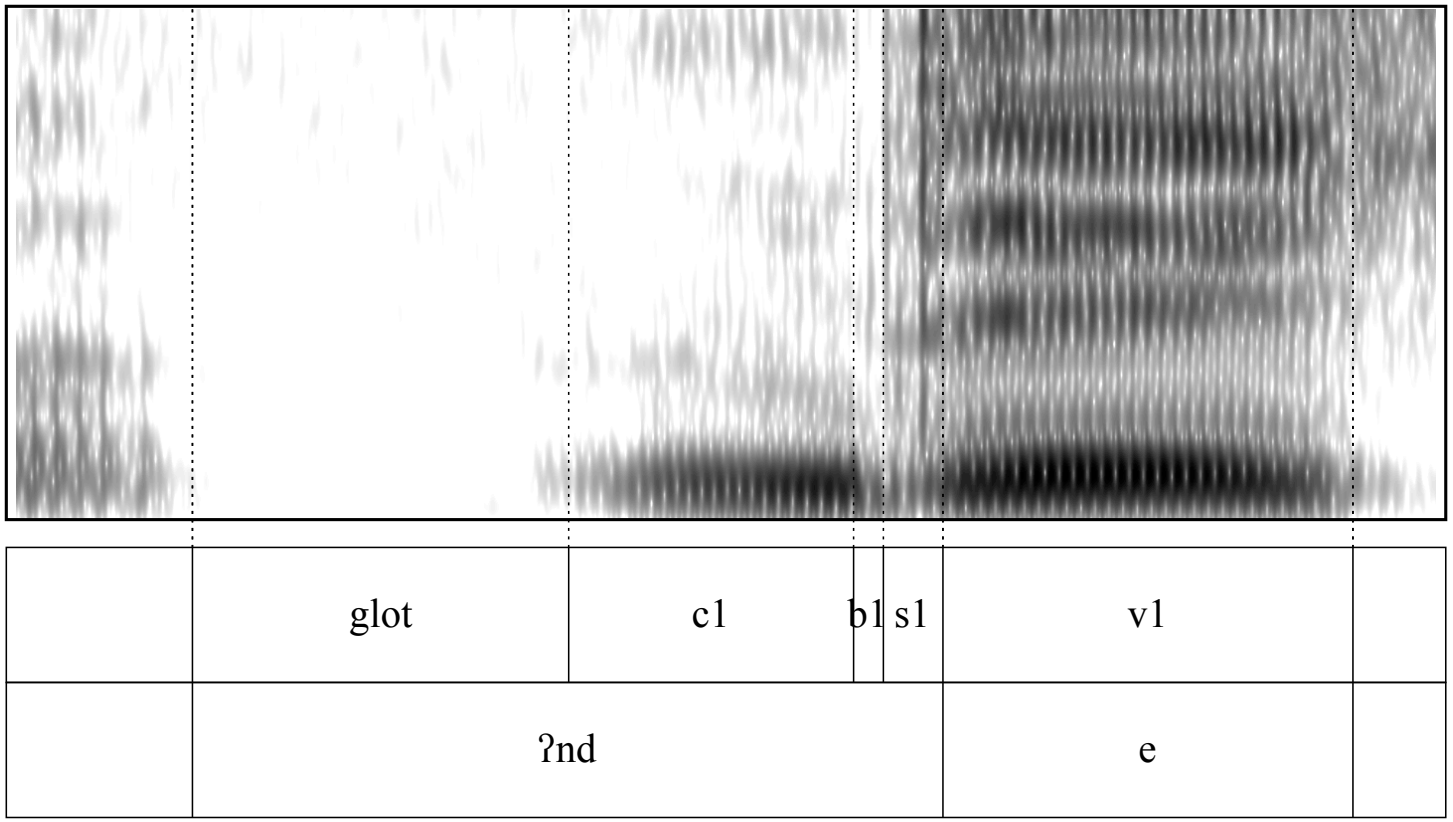
Glottalization - Obstruents (II)

[tʃ(u)ʔu] '*chocolate*'



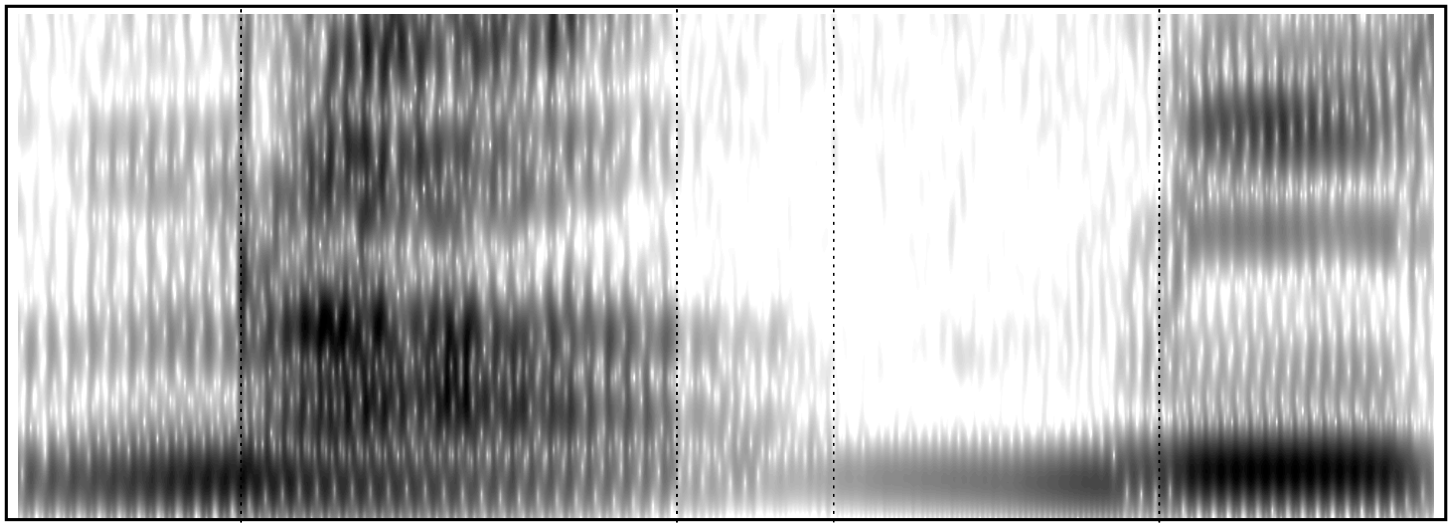
Glottalization - Sonorants (I)

[ʔnde] '*gum*'



Glottalization - Sonorants (II)

[nàʔmí] '*father*'



c1	v1	glot	c2	v2
n	a	ʔm		i

Hypotheses on variation in glottal timing

- For sonorants, the degree of coarticulatory overlap is sensitive to word structure.
- Greater overlap of glottal gestures in medial position than at word-boundaries.
- St'át'imcets has pre-glottalization in onset position, mid-glottalization intervocalically, and post-glottalization in coda position (Bird et al., 2008).

Ejectives and glottal timing

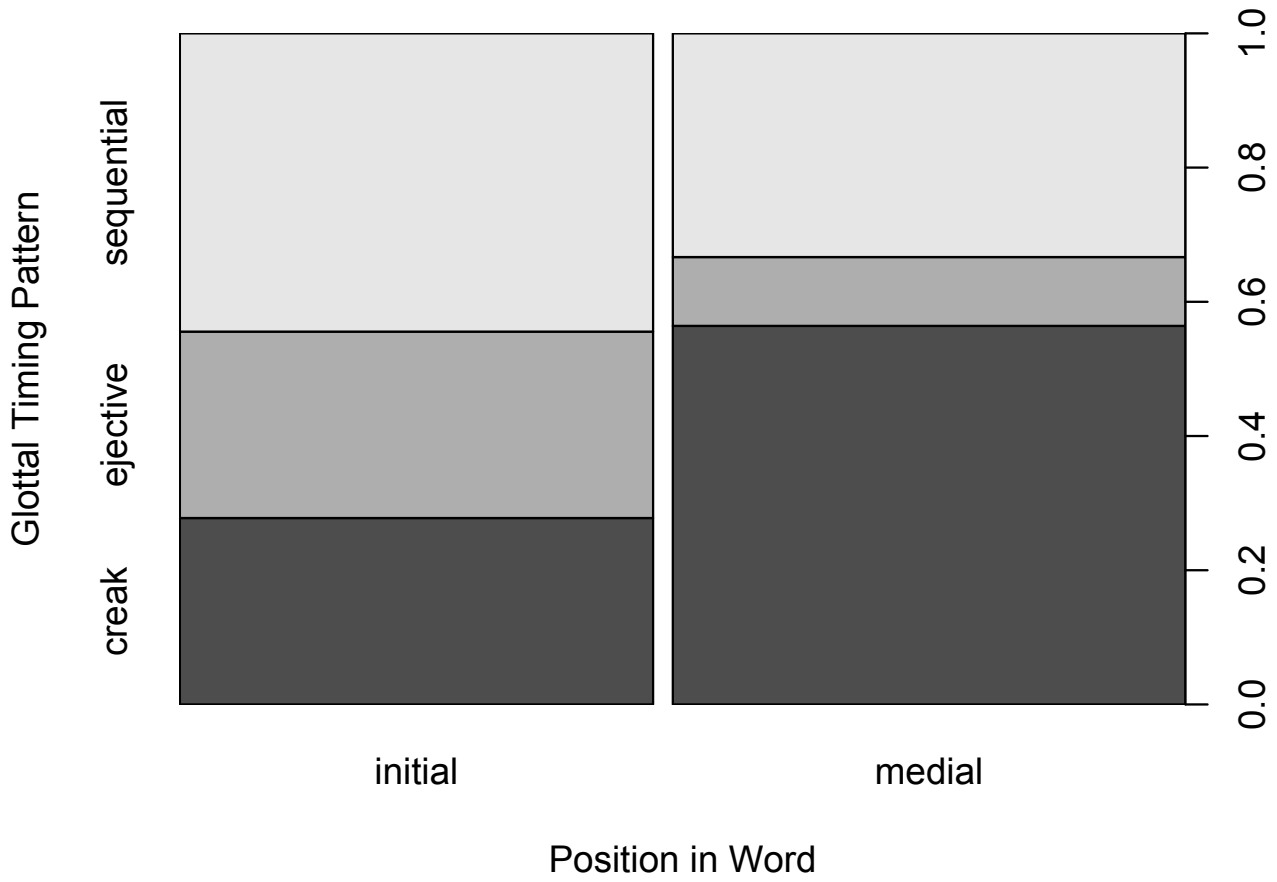
- Durational differences between *stiff* and *slack* ejectives (Kingston, 1985; Wright et al., 2002).
- Stiff: silent period between consonant release and vowel, long VOT, sharp amplitude rise on vowel. Onset of vowel is modal or tense.
- Slack: short VOT, creaky voice, slow amplitude rise on vowel.
- If sequential timing of glottalization requires a longer durational window, might changes in the duration of consonants due to word position affect the realization of glottalized consonants?

Glottal Timing Study

- Obstruents: *ejective*, *sequential*, *creak*
  (no overlap - partial overlap - complete overlap)
- Sonorants coded similarly.
- Glottal timing strategy examined in relation to word position and total duration in a linear mixed effects model with speaker as a random effect.
- Prediction: The degree of overlap of glottalization on adjacent sounds is sensitive to changes in the durational window of the consonant, so changes in duration due to word position will affect the realization of glottalization.

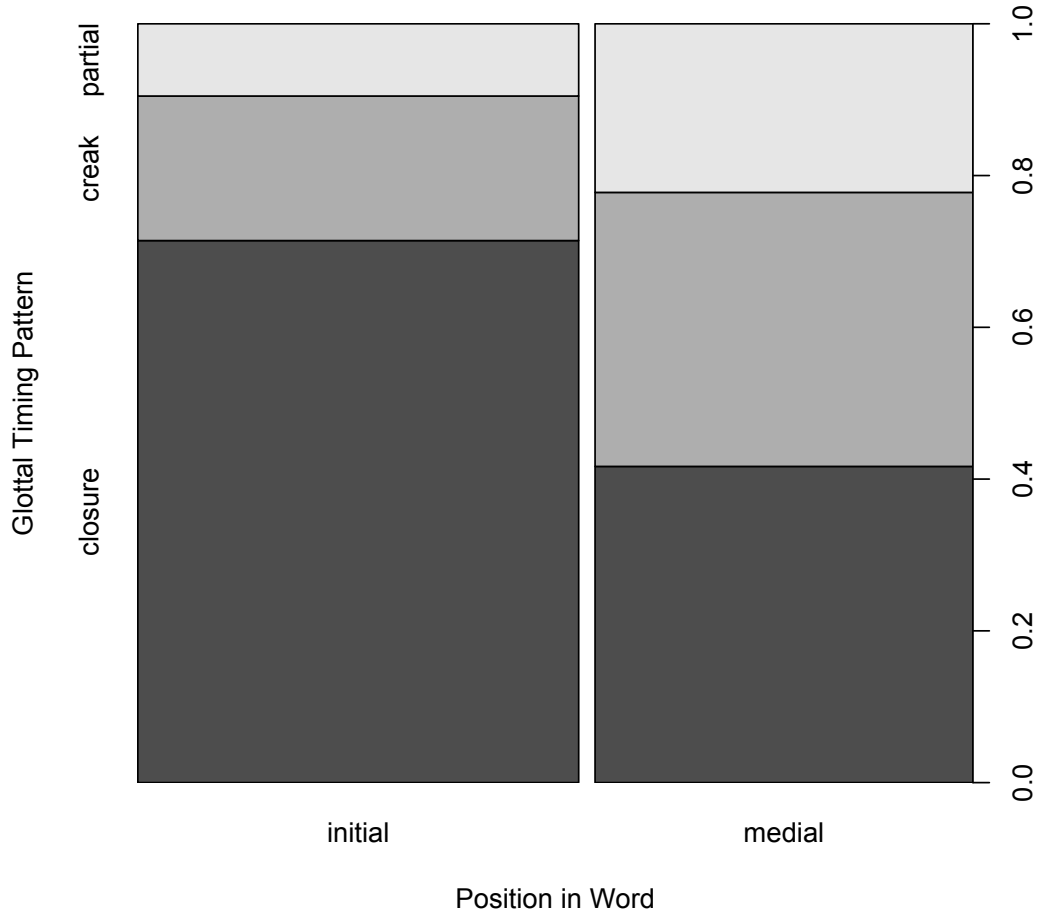
Results: Obstruent Glottal Timing (I)

Significant effect of position on glottal timing. More ejective or sequential ordering in word-initial position than word-medial position.



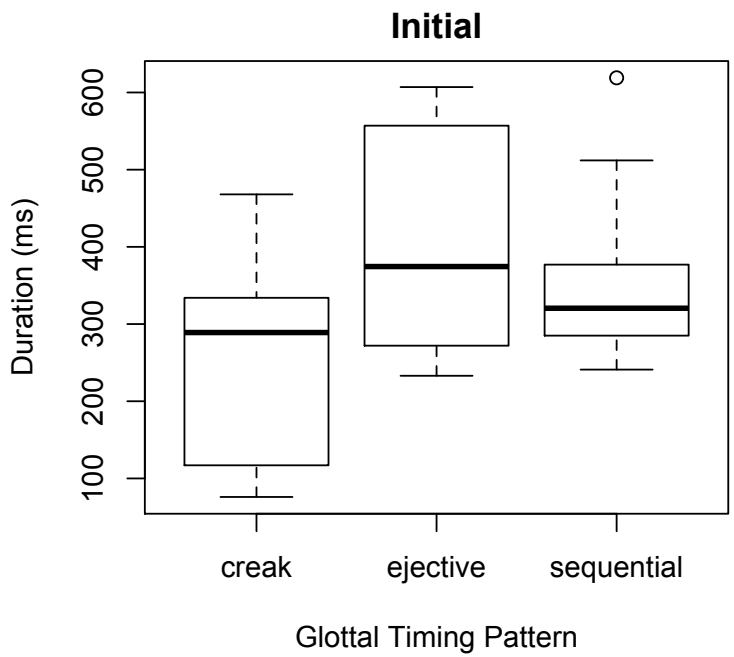
Results: Sonorant Glottal Timing (I)

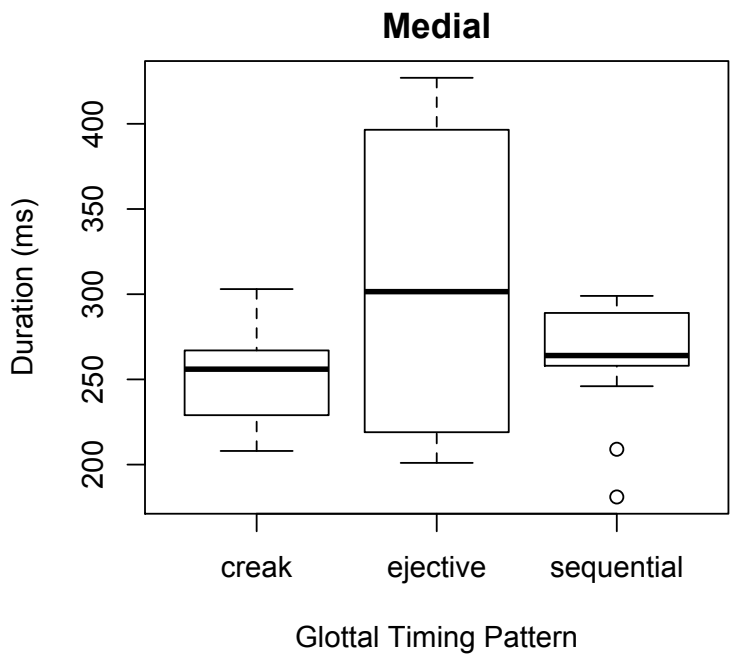
Significant effect of position on glottal timing in sonorants as well. Less overlap in word-initial position than word-medial position.



Results: Obstruent Glottal Timing (II)

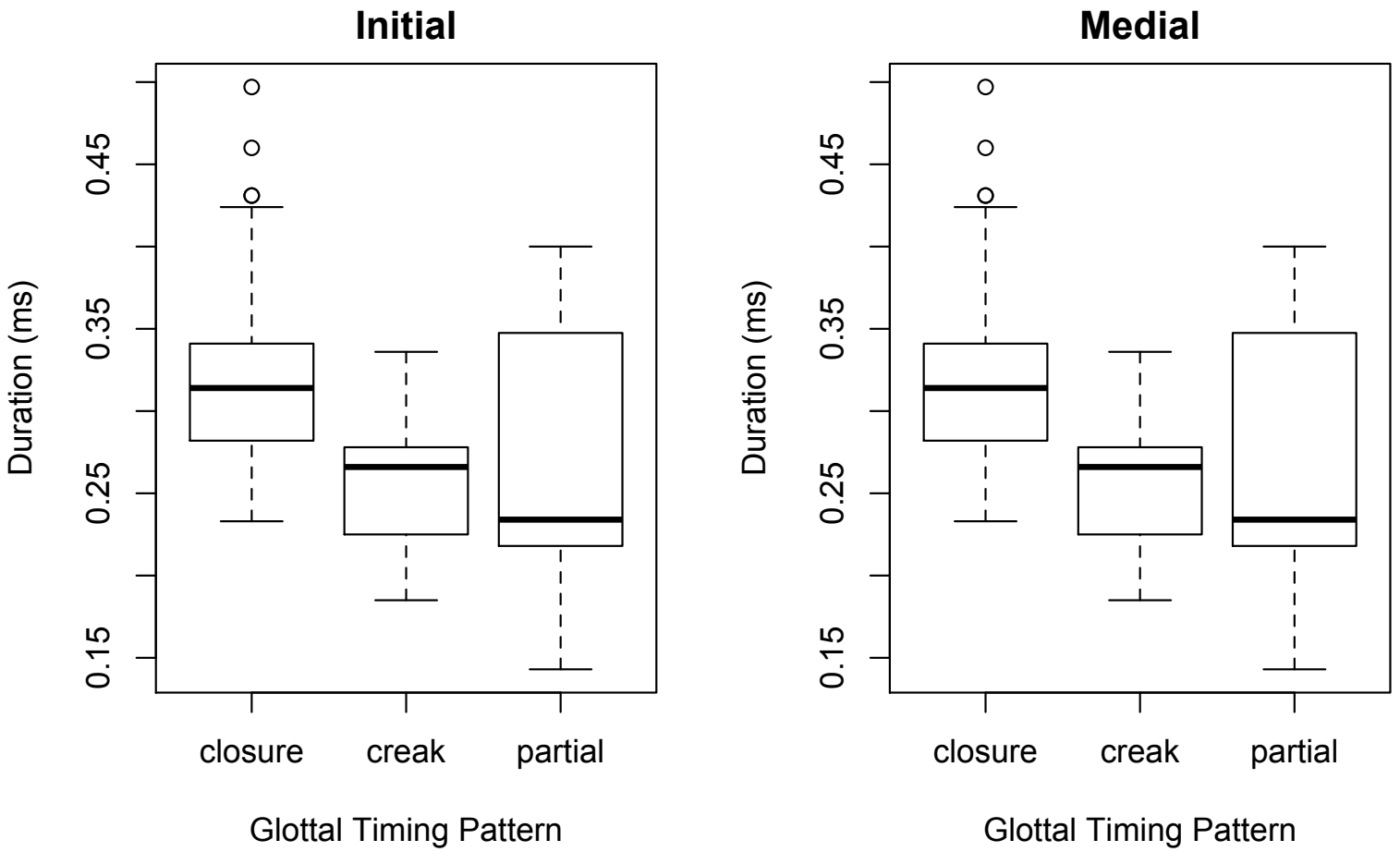
However, not simply an effect of position, but significantly of duration of consonant.





Results: Sonorant Glottal Timing (II)

Same effect for glottalized sonorants as with obstruents



Discussion (II)

- The degree of coarticulatory overlap of glottalization on the adjacent vowel in obstruents varies with duration.
- Longer duration glottalized consonants permit sequential ordering of oral and glottal gestures, while such gestures overlap in shorter duration glottalized consonants. Confirms predictions.
- Variability in temporal dynamics of glottalization is conditioned by durational changes in consonant production. Similar to findings in Byrd (1996).

Discussion (cont.)

- Stability in timing is dependent on association of glottalization with a consonant with clear gestural landmarks (Kingston, 1990; Borroff, 2007).
- Obstruents have clearer gestural landmarks than sonorants, but glottal timing in both types is conditioned by positional and durational factors.
- Glottal timing not dependent on clarity of gestural landmarks.
- This pattern is perhaps related to a larger tendency for Popolocan languages to develop contrastive vocalic phonation type from onset consonants, e.g. Mazatec (Silverman et al., 1994; Garellek and Keating, 2011).

An articulatory phonology proposal

- Can we interpret the variability in the production of glottalization in articulatory phonology?
- What are the timing relations between oral and glottal events?
- What is a stable phasing relation between oral and glottal events?

- There are two phasing relationships between laryngeal and oral gestures in consonants: in phase or anti-phase. For instance, the in-phase relation occurs in voiceless unaspirated stops. An anti-phase relation occurs in voiceless aspirated stops.

- The glottal gesture in ejectives should be anti-phase with the oral gesture, just like the spread glottis configuration for aspiration.

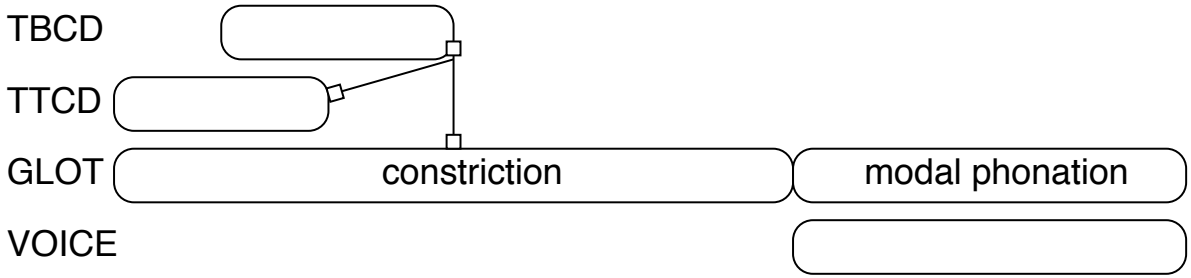
- During lenition though, changes occur in the relative timing of gestures.

Duration and gestural alignment

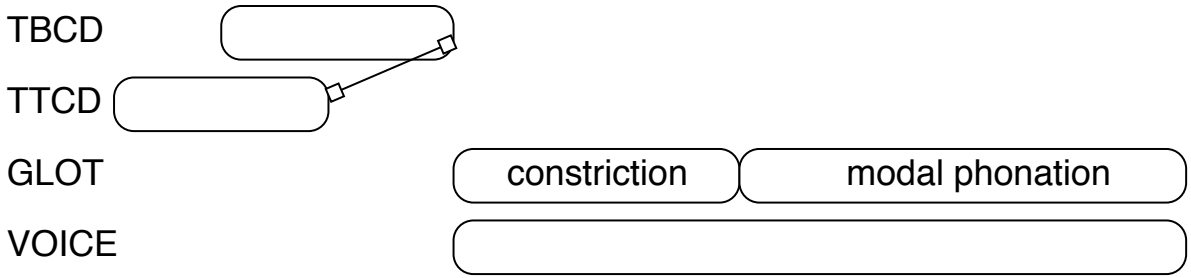
- Prosodic boundaries resist coarticulatory overlap. In gestural terms, this is accomplished by a local 'clock'-slowing gesture, called a π gesture (Byrd and Saltzman, 2003).
- Durational differences between stressed and unstressed syllables are modeled by a more general type of gesture, called a μ_T gesture (Nam et al., 2008). Local slowing gestures affect individual syllables within the foot.
- Gestural realignment due to speech-rate. At a faster speech rate, a more stable gestural phasing relation emerges (Tuller and Kelso, 1990; Parrell, 2012).
- Might duration-related changes, due to stress in Ixcatec, be responsible for the realignment of glottal gestures?

Onset of voicing coincidental with offset of glottal constriction (above), but coincidental with offset of oral constriction (below).

[tʃʾu]



[tʃu̯u]



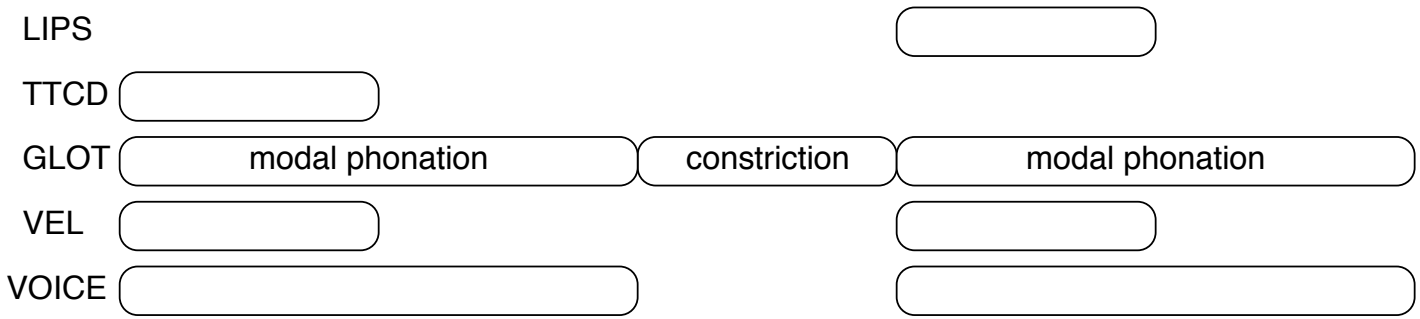
Glottal Phasing Relations: Obstruents

- Sequential timing between onset of voicing and offset of glottal constriction in ejectives. Note that voicing is typically in sequential timing with the offset of the oral release for most voiceless sounds. This is what occurs with a smaller durational window.

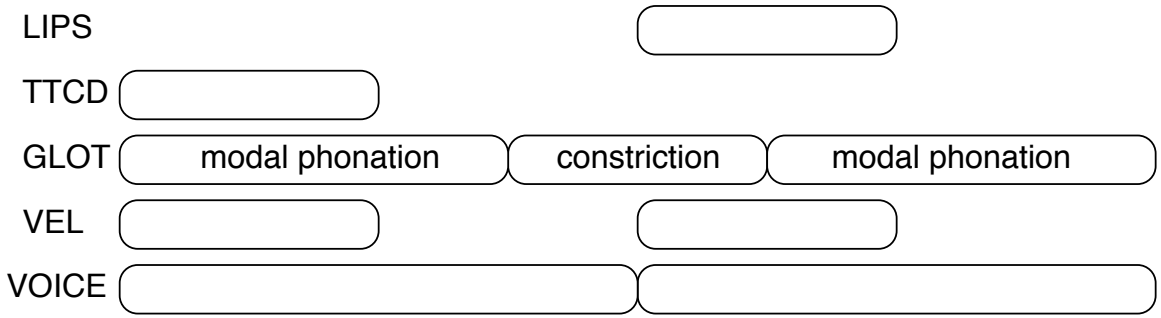
- In-phase alignment with laryngeal gesture with oral gesture is not possible, as the glottal gesture is not perceptually recoverable.

Onset of C2 oral constriction gesture coincidental with offset of glottal constriction (above), but coincidental with offset of V1 (below).

[naʔmi]



[naa̰m̰mi]



Glottal Phasing Relations: Sonorants

- In glottalized sonorants, there is a sequential timing relationship between the offset of the glottal constriction and the onset of the oral constriction in the sonorant.

- Yet, there is typically sequential timing between the preceding vowel offset and the following onset in CV.CV sequences. This is what occurs with a smaller durational window.

General ideas

- With a smaller durational window, the laryngeal gesture is not a stable landmark for gestural alignment.
- Might this be related to rate-induced changes in gestural phasing, e.g. with stress?

Laryngeal cooccurrence restrictions: Quechua

- Languages with ejectives and aspirated stops, like Ixcatec, tend to have restrictions on how many can occur within the same word (Gallagher, 2011; MacEachern, 1999).
- Quechua permits only one ejective per word and do not permit both an ejective and an aspirated stops within a word. Yet, glottal stops freely cooccur with aspirates and [h] freely cooccurs with ejectives.
- Ejectives do not occur with glottal stops and aspirates do not occur with [h].
- Motivation for this restriction is that both ejectives and aspirated stops are acoustically similar in having a long VOT (delayed release). This acoustic characteristic is treated as a parameter in the phonological grammar of Quechua (Gallagher, 2011).

The formal proposal

- Gallagher argues that the OCP targets [long VOT] within the root in Quechua. She formalizes this in OT terms. Maceachern's proposal is similar.
- GOCP[long VOT]: no two [long VOT] segments in a root
- This constraint crucially dominates identity constraints which require inputs with the [long VOT] feature to have an output correspondence.
- IDENT[long VOT]: an input segment specified as [long VOT] must have a correspondence in the output

An alternative proposal?

- Are ejectives (and aspirated consonants) restricted to prosodically-strong positions? Typically they occur word or foot-initially (Fallon, 2002). So yes.

- An alternative scenario might be that local clock-slowing gestures in prosodically-prominent positions permit a sequential phasing relation between the glottal constriction gesture and the voicing gesture.

- In prosodically-weaker positions, a more stable timing relation emerges, where the onset of the voicing gesture is sequential with the release of the oral gesture, not with the glottal gesture. The glottal gesture is produced with weaker magnitude.

- A historical scenario may have arisen where greater overlap of the glottal constriction gesture occurred on the vowel (or in-phase with the consonant). The result of this would be either a plain consonant with a non-audible glottal release or a creaky vowel.

- Deglottalization of onsets occurs in these weak environments (creak > tonogenesis or NULL).

- Synchronic phonology retains only ejectives or aspirated consonants in prosodically-strong positions.

Thank you.

Acknowledgements: Michael Swanton, Don Pedro, and Don Cipriano.

Bird, S., Caldecott, M., Campbell, F., Gick, B., and Shaw, P. A. (2008). Oral-laryngeal timing in glottalised resonants. *Journal of Phonetics*, 36:492–507.

Borroff, M. L. (2007). *A Landmark Underspecification Account of the Patterning of Glottal Stop*. PhD thesis, Stony Brook University.

Byrd, D. (1996). Influence on articulatory timing in consonant sequences. *Journal of Phonetics*, 24:209–244.

Byrd, D. and Saltzman, E. (2003). The elastic phrase: modeling the dynamics of boundary-adjacent lengthening. *Journal of Phonetics*, 31:149–180.

Cho, T. (2004). Prosodically conditioned strengthening and vowel-to-vowel coarticulation in English. *Journal of Phonetics*, 32:141–176.

Cho, T. and Ladefoged, P. (1999). Variation and universals in VOT: evidence from 18 languages. *Journal of Phonetics*, 27:207–229.

DiCanio, C. T. (2008). *The Phonetics and Phonology of San Martín Itunyoso Trique*. PhD thesis, University of California, Berkeley.

DiCanio, C. T. (2010). Illustrations of the IPA: San Martín Itunyoso Trique. *Journal of the International Phonetic Association*, 40(2):227–238.

Fallon, P. D. (2002). *The Synchronic and Diachronic Phonology of Ejectives*. Routledge: New York and London.

Fernández de Miranda, M. T. (1959). Fonémica del Ixcateco. *Instituto nacional de Antropología e Historia*, 3.

Fernández de Miranda, M. T. (1961). *Diccionario Ixcateco*. México: Instituto Nacional de Antropología e Historia.

Gallagher, G. (2011). Acoustic and articulatory features in phonology - the case for [long VOT]. *The Linguistic Review*, 28:281–313.

Garellek, M. and Keating, P. (2011). The acoustic consequences of phonation and tone interactions in Jalapa Mazatec. *Journal of the International Phonetic Association*, 41(2):185–205.

Keating, P., Cho, T., Fougeron, C., and Hsu, C.-S. (2000). Domain-initial articulatory strengthening in four languages. In Local, J., Ogden, R., and Temple, R., editors, *Papers in laboratory phonology 6*, chapter 10. Cambridge University Press.

Kingston, J. (1985). *The Phonetics and Phonology of the Timing of Oral and Glottal Events*. PhD thesis, University of California, Berkeley.

Kingston, J. (1990). Articulatory binding. In Kingston, J. and Beckman, M. E., editors, *Papers in laboratory phonology 1: between the grammar and the physics of speech*, pages 406–434. Cambridge University Press.

MacEachern, M. (1999). *Laryngeal co-occurrence restrictions*. New York: Garland.

McDonough, J. and Wood, V. (2008). The stop contrasts of the Athabaskan languages. *Journal of Phonetics*, 36:427–449.

Nam, H., Saltzman, E., Krivokapic, J., and Goldstein, L. (2008). Modeling the durational difference of stressed vs. unstressed syllables. *Proceedings of the 8^{th} Phonetics Conference of China, Beijing, China*.

Parrell, B. (2012). The role of gestural phasing in Western Andalusian Spanish aspiration. *Journal of Phonetics*, 40:37–45.

Silverman, D. (1997). *Phasing and Recoverability*. Outstanding Dissertations in Linguistics. Routledge.

Silverman, D., Blankenship, B., Kirk, P., and Ladefoged, P. (1994). Phonetic structures in Jalapa Mazatec. *UCLA Working Papers in Phonetics*, 87:113–130.

Tuller, B. and Kelso, J. (1990). Phase transitions in speech productions and their perceptual consequences. In Jeannerod, M., editor, *Attention and performance XII*. Hillsdale, NJ: Erlbaum.

Wright, R., Hargus, S., and Davis, K. (2002). On the categorization of ejectives: data from Witsuwit'en. *Journal of the International Phonetic Association*, 32(1):43–77.