VOWEL-INITIAL WORDS AND GLOTTALIZATION: A CORPUS STUDY OF CHICHICASTENANGO K'ICHE'

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ABSTRACT

Although word-initial glottal stops and glottalization are extensively observed in Mayan languages, the exact distribution is debated. This acoustic study measures full glottal closures as well as several measures of glottalization in each third of each word-initial vowel in a corpus of naturalistic speech from the Chichicastenango dialect of K'iche'. Results show that full closures occur only in a minority of cases and are more likely on words with initial stress or in IP-initial position. Words following a pause or a vowel or with initial stress show greater cues to glottalization only in the first part of the vowel or with decreasing effect sizes over the course of the vowel, consistent with coarticulation with a word-initial glottal segment. Words in IP-initial position, in contrast, show consistent glottalization cues across the vowel, suggestive of an IP-initial phonetic effect or boundary marker.

Keywords: Glottalization, corpus phonetics, K'iche' (Mayan)

1. INTRODUCTION

Word-initial glottalization and glottal stops on otherwise vowel-initial words are attested across the Mayan language family, including in K'iche', spoken in the Guatemalan highlands by around 900,000 people [1]. Influenced by the commonly repeated generalization that all roots or words must begin with a consonant in Mayan languages [2, 3], many descriptions of K'iche' take auditory perception of word-initial glottalization as evidence for the presence of glottal stops. However, the exact distribution of these glottal stops is debated, including whether they are phonemic [4] or epenthetic [5, 6] and whether they occur on all otherwise vowel-initial words [4, 7] or only in certain environments, such as on non-prefixed vowel initial roots [5] or on stressed monosyllables or words that are utterance-initial or preceded by a vowel [6].

This paper describes the results of an acoustic study of word-initial glottal stops and glottalization in K'iche' using a corpus of naturalistic speech from the Chichicastenango dialect. Two main questions are addressed: Where do full closures and glottalization occur? And is the time course of these cues consistent with the existence of a word-initial glottal stop segment?

2. METHODS

2.1. The corpus

The data comes from a corpus of 2 hours and 40 minutes of naturalistic, narrative speech recorded in 2018-2019. The two male speakers and 10 female speakers range in age from young adults to elders and all come from the town or vicinity of Chichicastenango, Guatemala, a dialect area that has been historically understudied. Speakers were asked to discuss a particular topic, such as local history and traditions, recipes, or traditional stories, and were allowed to speak freely for as long as they wished. Speakers were recorded using a Zoom Hn4 digital recorder at a sampling rate of 44.1 kHz, using either the internal microphone or connected to a Shure SM10A headset microphone. The recordings were transcribed in the K'iche' orthography and (if the speaker consented) archived in the Archive of the Indigenous Languages of Latin America [8].

2.2. Inclusion criteria and segmentation

Every word in the corpus that begins with a vowel or glottal stop in the transcription was included in this study, with the exception of any uncertain transcriptions, for a total of 2628 tokens. In the segmentation of word-initial vowels, the boundaries between vowels and consonants were marked primarily with reference to the intensity curve: where the amplitude begins to increase adjacent to a fricative, at the sudden jump in amplitude next to a voiced stop or sonorant, after the burst/aspiration for a preceding voiceless stop and at the offset of voicing for a following voiceless stop. Changes in formants and antiformants were used as a secondary indicator as needed. The boundary between two vowels in hiatus was located at the middle of the formant transition, and secondarily at the location of the sudden change in the intensity curve. When ambiguous, the midpoint of the whole VV interval was used. Word-initial diphthongs, found in the corpus only in the Spanish borrowings /ue.bon/ 'lazy' and /auk.si.liar/ 'assistant', were segmented together as one vowel unit. A full glottal closure was segmented separately from the word-initial vowels when it consisted of either at least 20 ms of silence or a single glottal pulse followed by silence which altogether lasted at least 20 ms (see [9, 10] for similar metrics). Other periods of laryngealized voicing were included in the vowel.

2.3. Measurements

A Praat [11] script was used to measure spectral tilt (H1-H2, H1-A1, H1-A2, H1-A3), periodicity (average HNR, jitter, shimmer), intensity minimum and pitch minimum, as well as the first two formants as these affect spectral tilt measures [12, 13]. The measurements were taken in each third of the vowel, or for very short vowels in three partially overlapping segments that each were the duration of the inverse of the pitch floor used for measurements of that vowel. In order to ensure the most accurate measurements of F0 and other dependent measures, the pitch range was varied as needed for each speaker and vowel. After finding a range mostly suitable for a given speaker, each vowel was visually inspected using those settings and if necessary individual adjustments were made to the pitch floor, pitch ceiling and voicing threshold until Praat accurately located the pitch pulses in that vowel. These specialized settings were then used in the script to take the final measurements.

2.4. Categorization

Each word was classified according to the following factors, including those mentioned in the previous literature as relevant to the occurrence of word-initial glottal stop: syllable count (monosyllabic or polysyllabic), stress position (stress on initial syllable or no), word origin (Spanish loan or no), morpheme type (root or prefix), following a glottalized (ejective or implosive) consonant or glottal stop (yes or no), following a vowel (yes or no), following a pause (yes or no), intonational phrase position based on existence of IP-final boundary tone on the preceding word (initial or non-initial), word initial morpheme, and text (recording code).

2.5. Hypotheses

If a given factor promotes the realization of a glottal stop at the beginning of an otherwise vowel-initial word, then there should be a significantly higher rate of full glottal closures preceding those vowels and/or significantly higher rates of acoustic cues to glottalization in the early part of the vowel (lower spectral tilt, lower HNR, higher jitter and shimmer, lower minimum intensity and pitch). If this glottalization is found throughout the vowel, it must come from a different source. Thus, based on the previous descriptions, higher rates of glottalization cues are expected in the beginning of the vowel for words following a word ending in a vowel or pause [4, 6], for words that are initial in the IP [6], for words that are monosyllabic and have initial stress [6], for roots [5], and for Spanish borrowings [5].

2.6. Statistical analysis

Results were analyzed in R [14] with linear mixed effects models using the package lme4 [15]. A separate model was made for each acoustic measure in each third of the vowel as well as another model for full closures.

In the first phase each model included syllable count, stress position, word origin, morpheme type, preceding glottalized consonant, preceding pause, preceding vowel, IP position, F1 and F2 as fixed effects and initial morpheme and text as random effects. It was found that the variables syllable count, word origin and morpheme type yielded no or almost no significant effects, and were thus eliminated from the model. In the second phase, each model included the random effects, the remaining fixed effects (IP position, stress, preceding pause, preceding glottalized consonant, preceding vowel), and additionally each possible interaction of these fixed effects. The baseline categories for each factor were IP-medial, no initial stress, no preceding glottalized consonant, no preceding pause, and no preceding vowel.

3. RESULTS

3.1. Full closures

Excluding words following a pause, where it is difficult to locate an initial glottal closure, full closures occur in 8.8% of the data. This raises to 11.8% for those following a vowel, 13.63% for those following a glottalized consonant, 15.7% for those IP-initial, and 20.8% for those with initial stress.

The results of the statistical analysis show significant positive effects of IP position and stress (more full closures). The interaction between the two is negative. The two effects do not stack: only unstressed vowels show a greater rate of full closures when IP-initial (stressed vowels do not), and only IP-non-initial vowels shows a greater rate of full closures when stressed (IP-initial vowels do not).

3.2. Acoustic cues to glottalization

The following tables summarize the results of the statistical models for each measure and each of the fixed effects. Only the coefficients of significant effects (with $p < 0.05$) are shown in the tables; blanks indicate no significant effect. Effects consistent with glottalization (negative effect for spectral tilt, HNR, intensity minimum and pitch minimum and positive effect for jitter and shimmer) are shaded in gray. E.g., in Table 1 -8.198 is the coefficient of the effect of preceding glottal(ized) consonant on H1-A1 in the first third of the vowel, and is shaded in gray because it is in the direction of glottalization.

Table 1 shows the results for words that are immediately preceded by word ending in a glottalized consonant or glottal stop. Overall this table shows a negative effect of spectral tilt only in the first third of the vowel.

Measure	1st third	2nd third	3rd third
H1-H2			
H1-A1	-8.198		
H1-A2	-5.107		
H1-A3	-3.516		2.783
HNR			
Jitter			
Shimmer			
Intensity min			
Pitch min			

Table 1: Effects for preceding glott. consonant

Table 2 shows the effects for words immediately preceded by a word ending in a vowel. The negative effect of spectral tilt extends throughout the vowel, with the absolute value of the coefficients decreasing over time. Aperiodicity is greater only in the end of the vowel.

Table 3 shows the significant effects for words that are immediately preceded by a pause. Spectral tilt, periodicity, intensity and pitch all show effects consistent with glottalization only in the beginning of the vowel.

Measure	1st third	2nd third	3rd third
H1-H2	-2.194	-1.402	
H1-A1	-6.310	-3.748	-1.591
H1-A2	-4.381	-2.234	
H1-A3	-4.657	-3.092	
HNR	1.892	-1.081	-1.001
Jitter		0.013	0.013
Shimmer			
Intensity min	2.160		
Pitch min	-14.678	-12.357	

Table 2: Effects of preceding vowel.

Measure	1st third	2nd third	3rd third
H1-H2		2.427	2.117
H1-A1	-2.557	2.546	2.394
H1-A2		2.656	2.072
H1-A3		3.416	2.445
HNR	-2.875	-2.551	
Jitter	0.029		
Shimmer	0.102	0.069	
Intensity min	-5.423		1.353
Pitch min	-9.715		9.378

Table 3: Effects of preceding pause.

Table 4 shows the significant effects for words that have stress on the initial syllable. There is an effect consistent with glottalization for every measure except for the pitch minimum, but these are found only in the first third of the vowel.

Measure	1st third	2nd third	3rd third
H1-H2	-1.622		
H1-A1	-4.045		
H1-A2	-3.409		
H1-A3	-2.783		
HNR	-2.277		2.450
Jitter	0.023		
Shimmer	0.068		
Intensity min	-2.695	1.564	
Pitch min			34.437

Table 4: Effects of initial stress.

Table 5 shows the significant effects for words that are initial in the intonational phrase. There are negative effects to spectral tilt that extend throughout the vowel, with similar coefficients throughout. Additionally, there are positive effects of jitter and shimmer and negative effects to pitch, intensity and HNR, all consistent with greater glottalization, though these are located only in the beginning and middle of the vowel.

Measure	1st third	2nd third	3rd third
H1-H2			-2.024
H1-A1	-2.881	-2.854	-1.996
H1-A2			
H1-A3		-1.625	-1.567
HNR	-2.074	-3.040	
Jitter	0.025	0.031	
Shimmer	0.074	0.042	
Intensity min	-1.572	-1.070	
Pitch min		-9.179	

Table 5: Effects of IP-initial position.

Finally, some interactions were significant, mostly of the measures of periodicity, pitch and intensity. These primarily reflect cases where synergistic forces do not stack (e.g. IP-initial position leads to lower HNR only for words not preceded by a pause, as preceding pause itself already lowers HNR), where the experimental factors result in potentially contrary forces (e.g. stress itself may result in increased pitch/intensity but glottalization in a decrease) or where a particular effect is enhanced when combined with stress (e.g. the increase in jitter in the first third of stressed vowels preceded by a vowel does not also occur for unstressed vowels).

4. DISCUSSION

The results showed two distinct types of effects on the glottalization cues: while the effects of stress, preceding pause, preceding glottalized consonant and preceding vowel are localized (or strongest) at the beginning of the vowel, the effects of IP-initial position are found throughout the vowel. This is exemplified in Figure 1. The stressed vowel in /ˈʊts/ ‘good’ on the left has visible glottalization in the first part only, while the IP-initial vowel /a/ in the focus marker /a.ˈre/ on the right, produced by the same speaker, shows visible glottalization throughout.

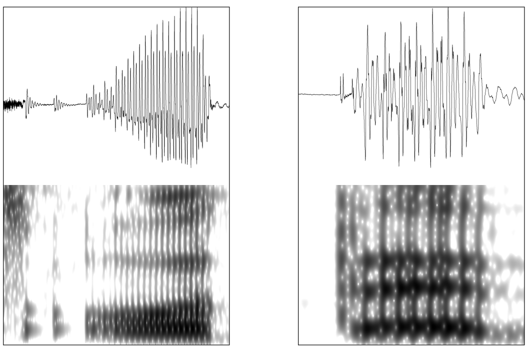

Figure 1: Initial vowels in ˈuts (left), a.ˈre (right)

The localized effects of initial stress and preceding pause and the consistently decreasing effects of preceding vowel, as is shown by their similarity to the results for a preceding glottalized/glottal consonant, are consistent with the result of coarticulation with a word-initial glottal segment. Full glottal closures are also significantly more likely on words with initial stress. No support was found for an effect of word origin or morpheme type (c.f. [5]). This provides support for Larsen’s [6] description of word-initial glottal stop as occurring only on words that are stressed and monosyllabic (i.e. have initial stress), utterance-initial, or preceded by a word ending in a vowel. However, if the target of this initial glottal gesture is in fact a stop, it is often reduced in naturalistic speech, as full closures only occur in a minority of cases. The prototypical realization of this glottal segment is not a stop at all but rather glottalization of an adjacent vowel.

IP-initial position, in contrast to the other factors, results in glottalization cues that persist strongly throughout the whole vowel. This is not consistent with the effects of an initial glottal segment, but rather must be a phonetic or phonologized effect of this initial prosodic position, which marks the left edge of intonational phrases. There are also higher rates of full closures in IP-initial position; these may represent greater strengthening of this IP-initial glottal constriction gesture. This IP-initial glottalization contrasts with a domain-final spread glottis gesture found in K’iche’ and related languages which results in aspiration of stops, devoicing of sonorants and [h] insertion on vowel-final words [16, 17]; combined, these two forces maximize the contrast in voice quality between initial and final position, enhancing the boundary between them.

Each of the significant factors - stress, prosodic position, and preceding context - have been previously identified as relevant to similar alternations of word-initial glottal stops and glottalization in the cross-linguistic literature. However, these previous studies have been mostly focused on heavily studied (Indo-)European languages such as Dutch [18], English [19, 20, 21], German [22, 23, 24], Finnish [25] and Maltese [26]. Thus, this study extends previous research by showing similar patterns in an unrelated and understudied language.

5. ACKNOWLEDGMENTS

I would like to thank all of the K'iche' speakers who are represented in the corpus, without whom this work would have been impossible. I would also like to thank Scott Myers, Brandon Baird, Paige Erin Wheeler and the members of the UT Austin Research in Phonetics and Phonology and Research in Documentary, Descriptive and Historical Linguistics research groups for helpful feedback on this project.

This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. 000392968. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

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