The independence of phrasal creak and segmental glottalization in American English

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In American English, prosodic creaky voice can signal the end of a phrase (Kreiman, 1982; Redi & Shattuck-Hufnagel, 2001). Creak, or glottalization, can also be segmental realizations, such as coda [t], the onset of a vowel-initial word, and [t] before a syllabic nasal (Huffman, 2005; Redi & Shattuck-Hufnagel, 2001). Garellek & Seyfarth (2016) show that phrase-final creaky voice acoustically differs from glottally-reinforced coda [tˀ], with phrasal creaky voice having lower F0 and spectral measures (H1-H2), and [tˀ] having greater noise (lower cepstral peak prominence, CPP). This study examines whether acoustic differences between phrasal creak and segmental glottalization also extend to vowel-initial and pre-syllabic nasal glottalization, and whether all of these segmental types form a class with similar acoustic properties, or whether there are acoustic distinctions. We also examine whether phrasal creak and segmental glottalization freely cooccur in utterances, or whether sentences or speakers with more phrasal creak tend to avoid the glottalized variants of segments, since cooccurrence could potentially be perceptually confusable.

Stimuli were 26 sentences read by 25 American English speakers (collected for previous research). Spectrograms were used to segment 3 types of segmental glottalization (transcribed here as [ʔ]; example in Fig 1): /t/ preceding syllabic nasals ('**sn**', e.g., *swee[ʔ]en*), before vowel-initial words ('**vi**', *in [ʔ]April*), and coda /t/ ('**t**', *repor[ʔ]*). Prosodic phrasal creak ('**c**') not attributable to segmental glottalization was marked sentence-medially and finally. 'c' was marked co-extensively with segmental glottalization if it extended beyond phonemes either immediately before or after the segmental source (e.g. 'vi+c'). For 'c' and target glottalized segments not produced as a full glottal stop, measurements for F0, H1-H2 (amplitude of the 1st and 2nd harmonics), H1-A2 (A2: amplitude of the harmonic closest to the 2nd formant), and CPP were taken with VoiceSauce.

Results shown in Table 1 and analyzed with linear mixed effects models indicate that intervals categorized as (only) phrasal creak 'c' are significantly lower in F0 and H1-H2 than the intervals labeled only as 'vi', 't', or 'sn' ($p < .01$ for all). H1-A2 values for 'sn' are lower than for 'c', 'vi', 't', consistent with glottalization being produced with concurrent nasalization (Styler, 2017). 't' is lower in CPP (greater noise) than 'c', as found in Garellek & Seyfarth (2016), but no measure distinguished 't' from 'vi'. 'sn' is longer ($p<.05$) than 't' or 'vi', which do not differ. Results also show that for each sentence, there is a positive relationship (though not significant, $\beta=.002$, $t=0.98$, $p=.33$) between the total proportion of a sentence realized with phrasal creak and the number of target segments realized as glottalized (Fig 2a). There is also a positive relationship ($\beta=.1$, $t=1.86$, $p=.07$) between the overall proportion of target segments realized glottally and the average proportion of phrasal creak in a sentence produced by a given speaker (Fig 2b). Though the positive relationships are weak, they are still important for establishing that speakers are not avoiding the co-occurrence of phrasal creak and glottalized segments.

Segmental glottalization differs from prosodic creak, but the three segmental types group together with similar properties, with the exception that [ʔn̩] is longer and produced with a lowered velum. These acoustic differences may allow glottalized segments and phrasal creak to co-occur in sentences and be easily identified without potential confusion, consistent with Garellek's (2015) finding that listeners can identify coda [tˀ] within phrasal creak.

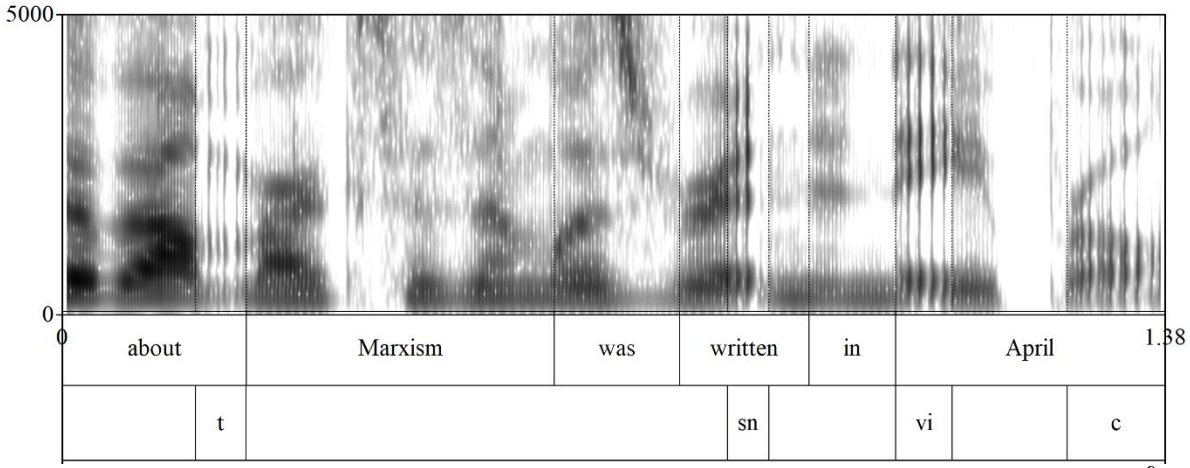

Fig 1. The sentence "A book about Marxism was written in April" annotated with coda [t$^{?}$] 't', vowel-initial glottalization 'vi', [t$^{?}$] before syllabic nasal 'sn', and phrasal creak 'c'.

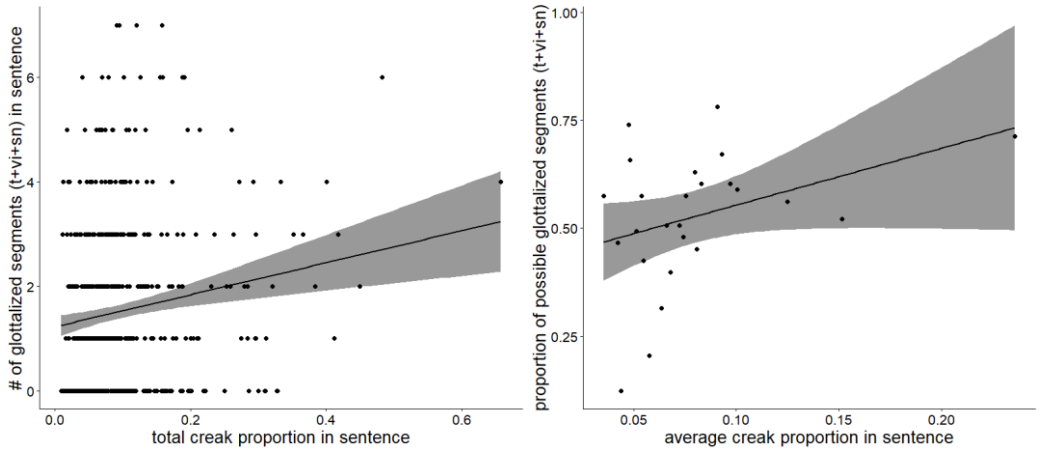

Fig 2. (a, left): Total proportion of a sentence produced with 'c' by the number of glottalized segments in the sentence. (b, right): Average proportion of 'c' produced in a sentence by the proportion of possible glottalized segments realized with glottalization, by participant.

	F0	H1-H2	H1-A2	CPP	Duration
Phrasal creak 'c'	133	-1.58	16.8	18.4	--
Syllabic nasal 'sn'	142	-0.298	12.9	18.4	76.5ms
Coda [t] 't'	158	1.01	15.8	17.7	61.8ms
Vowel initial 'vi'	148	0.308	15.3	18.3	70.3ms

Table 1. Voice quality measurements for creaky & glottalized intervals and duration for glottalized segments

Garellek, M. (2015). Perception of glottalization and phrase-final creak. *JASA, 137*(2), 822–831. **Garellek, M., & Seyfarth, S.** (2016). Acoustic differences between English /t/ glottalization and phrasal creak. *Proceedings of Interspeech 2016*, 1054-1058. **Huffman, M.** (2005). Segmental and prosodic effects on coda glottalization. *JPhon, 33*, 335–362. **Kreiman, J.** (1982). Perception of sentence and paragraph boundaries in natural conversation. *JPhon, 10*, 163-175. **Redi, L., & Shattuck-Hufnagel, S**. (2001). Variation in the realization of glottalization in normal speakers. *JPhon, 29*(4), 407-429. **Styler, W.** (2017). On the acoustical features of vowel nasality in English and French. *JASA, 142*, 2469–2482.