Vowel glottalization as a realization of the /k/ coda: An EGG study for Bokar

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Abstract

Bokar is a Tani language (Sun, 1993) spoken at the southern margin of the Tibetan Plateau. Scarcely any description of Bokar is available apart from the works of Megu (1990) and Ōuyáng (1985), both of which are short of detailed descriptions of phonological alternations. With the help of acoustic phonetic examination, this paper aims to demonstrate a phonological alternation of glottal replacement in Bokar with first-hand data collected in Mǐlín, China: the /k/ coda, when followed by a voiced non-velar consonant, loses its oral place of articulation; the preceding vowel is in turn lengthened and glottalized vowel-medially.Preliminary inspection of formant transitions reveals that /k/ can lose its place of articulation. When /o/ is followed by a bilabial /p/ (in fact it is a sequence of a coda /p/ plus the initial of the next syllable /d/), the second formant (F2) of /o/ falls precipitously into a bilabial closure. However, when the coda is /k/ and followed by a /d/, the vowel /o/ does not show any transition for the closure of /k/. Instead, the duration of the vowel increases, and towards the end F2 rises for the alveolar closure of the /d/.As mentioned earlier, in the target alternation, the vowel is not only lengthened but also glottalized. Glottalization is here defined as non-modal phonation with a more constricted glottis, including creaky voice and stiff voice on Ladefoged' s (1973, p. 76) continuum. In most of the tokens collected, vowel glottalization is realized as stiff voice; only few tokens show creakiness. Creakiness occurs vowel-medially and can be observed in spectrograms. Stiff voice, however, is not amenable to spectrographic analysis; we therefore turn to electroglottograph (EGG) signals for its examination.Three parameters from the EGG signals, namely fundamental frequency (F0), contact quotient (CQ), and speed quotient (SQ), are used. It has been observed that glottalization is often accompanied by lower F0 (Hollien, 1974, p. 126), and more recent studies have found it to be in positive correlation with CQ and SQ, with CQ considered as the most reliable measure (see Kuang & Keating, 2014, Section II.D).EGG signals of three groups (i) /CVk-da/ 'Verb- ' , (ii) /CVk-to/ 'Verb- ' , and (iii) /CV -da/ 'Verb- ' are collected.

In group (i) glottal replacement is triggered; the vowel (V) is lengthened and glottalized. Groups (ii) and (iii) are control groups. 5 minimal pairs of /CVk/ and /CV / of different vowels are chosen (C = /p/ or /t/), and for each minimal pair, 5 tokens are recorded for each group, all pronounced by one female speaker (N = 5 × 5 × 3 = 75). None of the tokens shows creaky phonation.F0, CQ, and SQ values at the duration of the vowel (V) are extracted using the hybrid method (Howard et al., 1990, p. 207). The results are fitted individually for each group with Generalized Additive Mixed Models (GAMMs) (Wood, 2017), with duration included as a fixed effect.The results show that the /V/ in /CVk-da/ is indeed glottalized, as both CQ and SQ are significantly higher, and F0 significantly lower for /CVk-da/ than /CV -da/ for the most part of the vowel. What is worth noticing is that the point of the most constricted glottis occurs near the mid-point of the vowel' s duration, instead of the very end of the vowel. The glottalization is hence vowel-medial, which goes in line with the observation made on the few tokens that exhibit creaky phonation.The Bokar data demonstrate that the loss of a consonantal place feature is not a random diachronic accident but a phonetically conditioned process. Spectrograms map vowel lengthening and the vanishing formant transitions, and EGG traces the compensatory glottal constriction. Experimental phonetics helps to verify the precise acoustic conditions that license lenition and provides a more detailed account of its realization, shedding light on the prediction of segment erosion across languages.

Full Text

Preamble

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An EGG study for Bokar QIÚ Ào (

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a_o@pku.edu.cn Phonetic Approaches to Under-Documented Languages (With a Special Emphasis on Tibeto-Burman Languages) (Phon-UDL) Aubervilliers, Paris Sept. 18–19, 2025 * This is a Chinese name. The surname is written first.

Bokar • A Tani language (Sun, 1993), Tibeto-Burman. • Spoken at the southeastern margin of the Tibetan Plateau. • The term "Lhoba" (Tibetan: , lit. 'southerner' , previously , lit. 'barbarians; people of the Loyü area'), actually covers several different tribal groups, and Bokar is only one of them. • Population: circa. 3 000.

Sun, T. J. (1993). A historical-comparative study of the Tani (Mirish) branch in Tibeto-Burman.

Our fieldwork • Data were collected in Cáizhào (Cächö) Village, Nányī (Nänyü)

Lhoba Ethnic Township, Mǐlín (Mänling) City, Línzhī (Nyingchi) City, Tibet Autonomous Region. • Chinese:

西藏自治区林芝市米林市南伊珞巴民族乡才召村 • Tibetan:

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Previous descriptions of consonantal alternations • Ōuyáng (1985, p. 12, boldface added): • (Progressive assimilation) The coda of the preceding syllable assimilates the initial of the following syllable, e.g.: • /rok o/ 'chick' → [rokko]; • /joŋ o/ 'lamb' → [joŋŋo]. • Megu (1990): No mention of phonological alternations. • Xiè (2025, p. 28) agrees with Ōuyáng (1985). Ōuyáng, J. (1985). Luòbāzú yǔyán jiǎnzhì [A brief documentation of the languages of the Lhoba ethnic group].

Megu, A. (1990). Bokar language guide. Xiè, Y. (2025). Bógá' ěryǔ yánjiū [Bokar study].

Realizations of the /k/ coda • Word-final: • /ə.jək/ [ə.jək] 'pig' , /n k/ [n k] 'to stab' ; • When followed by a vowel: • /jək.in/ [j .in] 'pig liver' , • When followed by a voiceless stop: / ak.en/ [a .en] 'to hang' ; • /rok.po/ [ok.po] 'rooster' , /n k.to/ [n k.to] 'stab!' ; • When followed by a voiceless fricative: /k/ → [k] /k/ → [ ] /k/ → [k] /k/ → [x] • /jək.sər/ [jəx.sər] 'boar' , /puk. i/ [pux. i] 'to sell secretly' ; • When followed by a voiced velar consonant: • /sak.ŋək/ [sa .ŋək] 'to sigh' , /pok. ŋ/ [pu . ŋ] 'stage' . /k/ → [ ] The /k/ glottal replacement • When the /k/ coda is followed by a voiced non-velar consonant: • /k/ + voiced stop: • /n k.bi / 'to pass to' , /sak.dəŋ/ 'to pant' ; • /k/ + sonorants: • /rok.nə/ 'hen' , /puk.jo/ 'let' s sell' , /puk.l ŋ/ 'to like to sell' .

3. The preceding vowel is glottalized.

Loss of place of articulation: F2 transitions /pok-da/ 'to jump-ipfv' (Place of /k/ lost) /pok-to/ 'to jump-imp' (Place of/k/ maintained) Loss of place of articulation:

F2 transitions /pok-da/ 'to jump-ipfv' (Place of /k/ lost) /rop-da/ 'to stand-ipfv' (Place of/p/ maintained) Vowel lengthening • Vowel length contrast in Bokar: • / ə/ 'to bring' ; • / ə / 'to carry on back' . • Vowel before a coda is always short. • Duration of the vowel (V) are measured for (N = 75): /CVk-da/ 'Verb-ipfv' , (ii) /CVk-to/ 'Verb-imp' , and (iii) /CV -da/ 'Verb-ipfv' . • Duration of V: /CVk-da/ > /CVk-to/ ($p < 0.001$); /CVk-da/ /CV -da/ ($p = 0.48$).

Glottalization (laryngealization) • Ladefoged' s (e.g., 1973, p. 76) continuum of glottal stricture: voiceless slack voice stiff voice glottal stop murmur/breathy voice [modal] voice creaky voice constricted glottis glottalized Ladefoged, P. (1973). The features of the larynx. J. Phonetics, 1(1).

Tokens with creaky voice (rare): vowel-medial F0 plummet /sak-dəŋ/ 'to pant' /rok-nə/ 'hen' 11/22 Tokens with stiff voice (common): without F0 plummet

/n k-bi / 'to pass to' /pok-da/ 'to jump-ipfv' 12/22 EGG indications of glottal stricture • Glottal constriction is indicated by: • Higher contact quotient (CQ) • CQ = closed / cycle. • Most reliable (DiCanio, 2009). • Higher speed quotient (SQ) • SQ = opening / closing. • See Kuang and Keating (2012, Section II.D) for a detailed review.

DiCanio, C. (2009). The phonetics of register in Takhian Thong Chong. JIPA, 39(2).

Kuang, J., & Keating, P. (2014). Vocal fold vibratory patterns in tense versus lax phonation contrasts. JASA, 136(5).

Analysis of the EGG signal • Hybrid method (Howard, 1995, p. 164). • Glottal closing instant (GCI):

Positive peak of the derivative of the EGG signal (dEGG) . • Glottal opening instant (GOI): where the negative going EGG signal crosses the 3/7 threshold.

Howard, D. M. (1995). Variation of electrolaryngo- graphically derived closed quotient for trained and untrained adult female singers. J. Voice, 9(2).

The data • Target group: • Control group: • 5 minimal pairs of /CVk/–/CV / verb roots are chosen (C = /p/ or /t/). /CVk-da/ 'Verb-ipfv' ; /CV -da/ 'Verb-ipfv' .

Target group /CVk-da/ Control group /CV -da/ /tak/ 'to split' /ta / 'to ask' /pok/ 'to jump' /po / 'to be good' /pək/ 'to sweep' /pə / 'to fart' /puk/ 'to sell' /pu / 'to fasten' /t k/ 'to pull' /t / 'to pick' • For each minimal pair, 5 tokens are recorded for each verb. 2 = 50 tokens in total, all pronounced by one female speaker. 15/22 Processing the data • Start and end of /V( )/ are selected manually with help of spectrograms. • CQ and SQ of each glottal cycle are extracted using a Python 3 script. • Time is normalized (duration of /V( )/ = 1). 16/22 Generalized additive mixed models (GAMMs) • Additive models (AMs) extend linear models LM prediction (LMs) by allowing smooth functions.

AM prediction • Linear model: yi = $ $0 + βxi + ϵi, where ϵi ~ • Additive model: yi = $ $0 + f(xi) + ϵi, where f is the (0, σ); linear combination of the basis functions {bi}, and ϵi ~ (0, σ): • Generalized additive models (GAMs) introduce the f(x) = $ $1b1(x) + $ $2b2(x) + ⋯+ βk −1bk − 1(x). link function g. g(μi) = $ $0 + f(xi), where μi = yi, and yi ~ EF(μi, ϕ). • GAMMs: GAMs with mixed effects.

Wood, S. N. (2017). Generalized additive models: An introduction with R (2nd ed.). linear combination Basis functions (k = 5) The results • Both CQ and SQ are significantly higher for most part of the vowel /V/ in /CVk-da/. • The maximum points of CQ and SQ occur near the mid point of the vowel' s duration. 18/22

Conclusions

• The /V/ in /CVk-da/ is indeed glottalized. Higer CQ, SQ for the most part of the vowel. • Creakiness is an "occasional side effect" of glottalization, as is in Mazatec (Oto-Manguean) and Mpi (Loloish) (Blankenship, 2002). Only few tokens exhibit prototypical creakiness. • In the target group, glottalization occurs vowel-medially, not vowel-finally, despite the fact that it is a compensatory strategy for the loss of a coda. The point of most constricted glottis (highest CQ & SQ) occurs near the mid point; When creaky phonation is observed, the creakiness occurs vowel-medially.

Blankenship, B. (2002). The timing of nonmodal phonation in vowels. J. Phonetics, 30(2).

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Journal of the International Phonetic Association, 39(2), 162–188. https://doi.org/10.1017/S0025100309003 • Howard, D. M. (1995). Variation of electrolaryngographically derived closed quotient for trained and untrained adult female singers. Journal of Voice, 9(2), 163–172. https://doi.org/10.1016/S0892-1997(05)80250-4 • Kuang, J., & Keating, P. (2014). Vocal fold vibratory patterns in tense versus lax phonation contrasts. The Journal of the Acoustical Society of America, 136(5), 2784–2797. https://doi.org/10.1121/1.4896462 • Ladefoged, P. (1973). The features of the larynx. Journal of Phonetics, 1(1), 73–83. https://doi.org/10.1016/S0095-4470(19)31376-2 20/22

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The model • Fitted with R version 4.5.0 (R Core Team, 2025) using the bam function from the mgcv package (Wood, 2011). y ~ s(no, bs = "cr") + s(no, traj, bs = "fs" , xt = "cr" , m = 1, k = 5) • Value of an EGG parameter at normalized time ti of a token u:

F0, CQ, or SQ value of token u at time ti Intercept yi,u = β + f(ti) + fu(ti) + ϵi,u.

Smooth fixed effect of time t Random effect of token u at time ti (random smooth) Error terms ϵi,u ~ i.i.d. (0, σ), R Core Team. (2025). R: A language and environment for statistical computing.

Wood, S. N. (2011). Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. J. R. Stat. Soc. Ser. B Stat. Methodol., 73(1).

F0 tracks & predictions • Low F0 is caused by glottalization, not vise versa. (F0 reference at 220 Hz) 24/24 Vowel-medial glottalization • Vowel-medial glottalization is not uncommon: • Glottalization as an allophonic cue of tonal contrast: • Mandarin Chinese: shǎngshēng (T3) (e.g., Ding & Helbig, 1996, p. 514); • Vietnamese: ngã tone (C2) (e.g., Vu et al., 2002). • Contrastive glottalization: • Coatzospan Mixtec (Oto-Manguean): "echo vowel" (Gerfen, 1996, Chapter 3). • However, it is yet to be documented (to the best of our knowledge) as the result of glottal replacement of a consonnant.

Ding, H., & Helbig, J. (1996). Sprecher- und Kontextbedingte Varianz des dritten Vokaltones in chinesischen Silben:

Eine akustische Untersuchung [Speaker- and context-conditioned variance of the third tone in Chinese syllables:

An acoustic study]. Vu, N. T., d' Alessandro, C., & Rosset, S. (2002). Acoustic and electroglottographic measurements: A phonetic study of Vietnamese tones.

Gerfen, H. J., Jr. (1996). Topics in the phonology and phonetics of Coatzospan Mixtec.

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Figure 8

Figure 1: Figure 8

Figure 9

Figure 2: Figure 9

the Royal Statistical Society Series B: Statistical Methodology, 73(1), 3–36. https://doi.org/10.1111/j.1467- 9868.2010.00749.x 26/24

Figures