The affinity of low vowels and glottal stops: an articulatory model and a perceptual investigation

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An investigation of phonological phenomena involving glottal stops and vowels shows that the presence of glottal stops influences the quality of the surrounding vowels: the vowels are lowered (Rose, 1996). For example, in Klallam (a Coast Salish language), non-low vowels /i u ə/ are lowered to [ɛ o a], respectively, when followed by [ʔ]: /p'íxʷŋ/ is pronounced as [p'ɛʔxʷŋ] 'overflow'/'overflowing' and /šúpt/ as [šóʔpt] 'whistle'/'whistling' (Thompson et al., 1974).

Furthermore, it appears that glottal stops and low vowels are likely to co-occur from a typological point of view. Supportive evidence comes from various types of phonological processes. For example, in Besleney (an East Circassian language) the epenthetic vowel [ə] is realized as [i] in the context of palatalized consonants, as [u] in the environment of labialized consonants and as [a] adjacent to gutturals including laryngeals (Paris, 1974; Rose, 1996). Lillooet (a Salish language) shows a clear coarticulation-induced variation in schwa-epenthesis: /ə/ changes to [ɔ] before labialised uvular/pharyngeal sounds, and to [ɪ] between coronal sounds. However, if a glottal stop follows the schwa, then the schwa changes to [a] (Shaw, 1994). In Karanga and Zezuru (dialects of Shona, a Bantu language) vowel hiatus is resolved in the following way: if the second vowel is /i/ or /e/, a glide [j] is inserted between the vowels. Where the second vowel is /u/ or /o/ a glide [w] is epenthesized. However, if the second vowel is /a/, then the glottal stop appears (Mudzingwa, 2010).

The consistency with which this co-occurrence can be found in the most diverse languages leads to the assumption that it might be the result of a very general property of human articulatory and/or perceptual capacities. In fact, we will hypothesize that (i) co-ordination of low vowels and glottal stops is mediated by epilaryngeal stricture and that (ii) glottalized vowels are perceived lower in their height.

Regarding (i) we present an articulatory model that can account for the relationship between low vowels and glottal stop. Following laryngoscopic observations of Edmondson & Esling (2006) and the conception discussed in Moisik and Esling (2011), the claim is that the epilaryngeal tube provides the basis for understanding how lingual state influences glottal state. The relationship is defined by the action of three articulatory components that induce epilaryngeal stricture: (i) tongue and epiglottis retraction; (ii) larynx raising; and (iii) contraction of plicating intralaryngeal muscles of the larynx (the thyroarytenoid, thyroepiglottic, and aryepiglottic muscles). In this model, epilaryngeal stricture operates as a function of these three key parameters in a gradient fashion: creakiness and glottal stop involve moderate levels of component activation, while greater degrees of activation yield aryepiglotto-epiglottal narrowing and ultimately will produce full closure of the entire epilaryngeal tube.

Since the overall mechanism is synergistic, low vowels facilitate epilaryngeal stricture on account of the lowered lingual mass displacing the epiglottis posteriorily towards the aryepiglottic folds. Mechanically, the epiglottis, ventricular folds, and vocal folds contact and compress into each other. Mechanical contact entails the possibility of coupling and damping which will influence vocal fold dynamics. Evidence from laminography (Hollien and Allen, 1971) of creaky phonation and laryngoscopy (Esling and Harris 2003) and laryngeal ultrasound (Moisik, Esling, Bird, and Lin, 2011) of glottal stop provides empirical support that this coupling occurs (also see Laver 1980: 123). We predict then that lower vowels will tend to engage the coupling mechanism more so than for higher vowels. Furthermore, the model entails that causality can operate in both directions: lingual retraction can induce epilaryngeal stricture and sounds that are primarily a function of epilaryngeal stricture can bias vowel lowering on the phonetic and, evidently, phonological level.

Further research into this bidirectional nature of epilaryngeal stricture will be important in further substantiating the theoretical model.

Regarding (ii) we will present the results of two perceptual experiments on glottalized and non-glottalized vowels. We hypothesized that vowels are perceived lower in their height if they are glottalized. In order to test our hypothesis we conducted a perceptual experiment with a non-glottalized and a glottalized German continuum *b[i]ten-b[e]ten* (‘to offer’- ‘to pray’). A trained native German speaker was recorded speaking the words without glottalization. Glottalized variants of these manipulated utterances were created by lowering f0 of [i] and [e] to 50Hz resulting in the perception of a creaky vowel (Pierrehumbert and Frisch, 1997). Then two continua were created, one from the non-glottalized variants of the two words and one from the glottalized variants by interpolating between the two speech samples in equal steps using an algorithm by Mitterer et al. (2011). 23 German subjects took part in an identification test in which they were asked to indicate whether they perceived words from these continua as *b[i]ten* or *b[e]ten*. The data show very clearly that subjects perceive *b[e]ten* more often, i.e. earlier in the continuum, than *b[i]ten* if the vowel is glottalized (LMM, $p<.001$). A similar experiment was carried out with 19 German subjects on a back vowel contrast using the words *[u:]hren-[o:]hren* ('clocks' – 'ears'). In line with the first perception experiment, subjects perceived the lower vowel more often on the glottalized than on the non-glottalized continuum (LMM, $p<.001$).

In summary, the co-occurrence of glottal sounds and low vowels in the different world languages can in part be explained along articulatory lines by virtue of the operation of the epilaryngeal tube outlined in our model. Furthermore, the results of perceptual experiments indicate that the co-occurrence of glottal sounds and low vowels cross-linguistically could potentially originate in a reinterpretation of glottalized higher vowels as lower ones.

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