Quantifying gradience of epilaryngeal constriction in Levantine Arabic "gutturals": A Generalized Additive Modelling approach to ultrasound tongue contours

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Background: Arabic has a series of back consonants (uvular, pharyngealized, pharyngeal/epilaryngeal and glottal) that differ in terms of tongue configuration, degree of "retraction" and larynx rising/lowering. According to the "Laryngeal Articulator Model" (LAM, Esling, 2005; Esling, Moisik, Benner, & Crevier-Buchman, 2019), an epilaryngeal constriction leads to a raised larynx posture and induces retraction of the tongue due to constriction of the hyoglossus, with a back and down gesture. Epilaryngeal consonants have this type of constriction, whereas pharyngeal/pharyngealized show partial "retraction" and uvular show nil "retraction". This study builds on recent acoustic evidence of partial epilaryngeal constriction in pharyngealized consonants in Arabic (Al-Tamimi, 2017). We look at quantifying the gradience of epilaryngeal constriction in Levantine Arabic (LA) "guttural" consonants using Ultrasound Tongue Imaging (UTI) as a first step. **Method**: 8 LA speakers (4 males/4 females) aged 25-45 were recorded using synchronized UTI (60fps deinterlaced), acoustic and EGG data. They were asked to produce 21 consonants in Arabic in a /ʔVV$_1$CVV$_2$/ frame with three subsequent repetitions (VV = symmetric /iː aː uː/; C = plain /t d ð s z l/, velar /k ɡ x ɣ/, uvular /q/, pharyngealized /tˤ dˤ ðˤ sˤ zˤ lˤ/, pharyngeal /ħ ʕ/ and glottal /h ʔ/; n = 2034 items). **Analysis**: The UTI data presented here were first automatically splined using Articulate Assistant Advanced (AAA, version 2.18.04) (Wrench, 2018), and then hand corrected by the second author. Splines were taken at 9 time-standardized frames at 50% and 75% of V$_1$, at 0%, 25%, 50%, 75% and 100% of the medial consonant, and at 25% and 50% of V$_2$ (based on acoustic segmentation). 13698 tongue contours were splined across participants. Polar coordinates (r, φ) extracted from AAA were then analyzed using Generalized Additive Modelling, with the distance component (r) as dependent variable, interaction between consonant category (6), vowel (3) and gender (2), and within and between-subjects differences accounted for through adjustments to the angle and frame number by the fixed effects, and random effects were speaker and word, adjusted by the interaction between category and vowel for speakers and by gender for words. This adjustment allowed us to take the variations within speakers, gender, and words into account. **Results**: Figure 1 shows averaged tongue contours across vowels and time frames in each of the uvular, pharyngealized and pharyngeal in comparison with the plain category (Fig. 1, a-c). Clear differences emerge at the front and back cavities: a raised tongue tip and body in plain, with retraction in the uvular, pharyngealized and pharyngeal to various degrees. In uvular, the tongue is backed and raised (Fig. 1, a); in pharyngealized, the tongue dorsum and root are more backed with less raising than in uvular (Fig. 1, b); pharyngeal show retracted tongue root and a possible raised larynx throughout the trajectory at the end of the curve, compatible with an epilaryngeal constriction (Fig. 1, c). When comparing pharyngealized to uvular and pharyngeal, the results show uvular with a higher constriction towards the uvula and a lower tongue tip (Fig.1, d), whereas pharyngeal show lower tongue tip and body and raised larynx (Fig.1, e). Finally, pharyngeal shows a lower tongue dorsum than uvular (Fig.1, f). **Conclusion**: Our results show evidence of variation associated with gutturals when compared with the plain; result compatible with LAM. Pharyngeal consonants show "retraction" with backed and lowered tongue, and a possible raised larynx. Pharyngealized and uvular show differences with both plain and pharyngeal and between each other. Pharyngealized induces a partial epilaryngeal constriction, while uvular shows raised tongue dorsum; results compatible with a gradient epilaryngeal constriction.

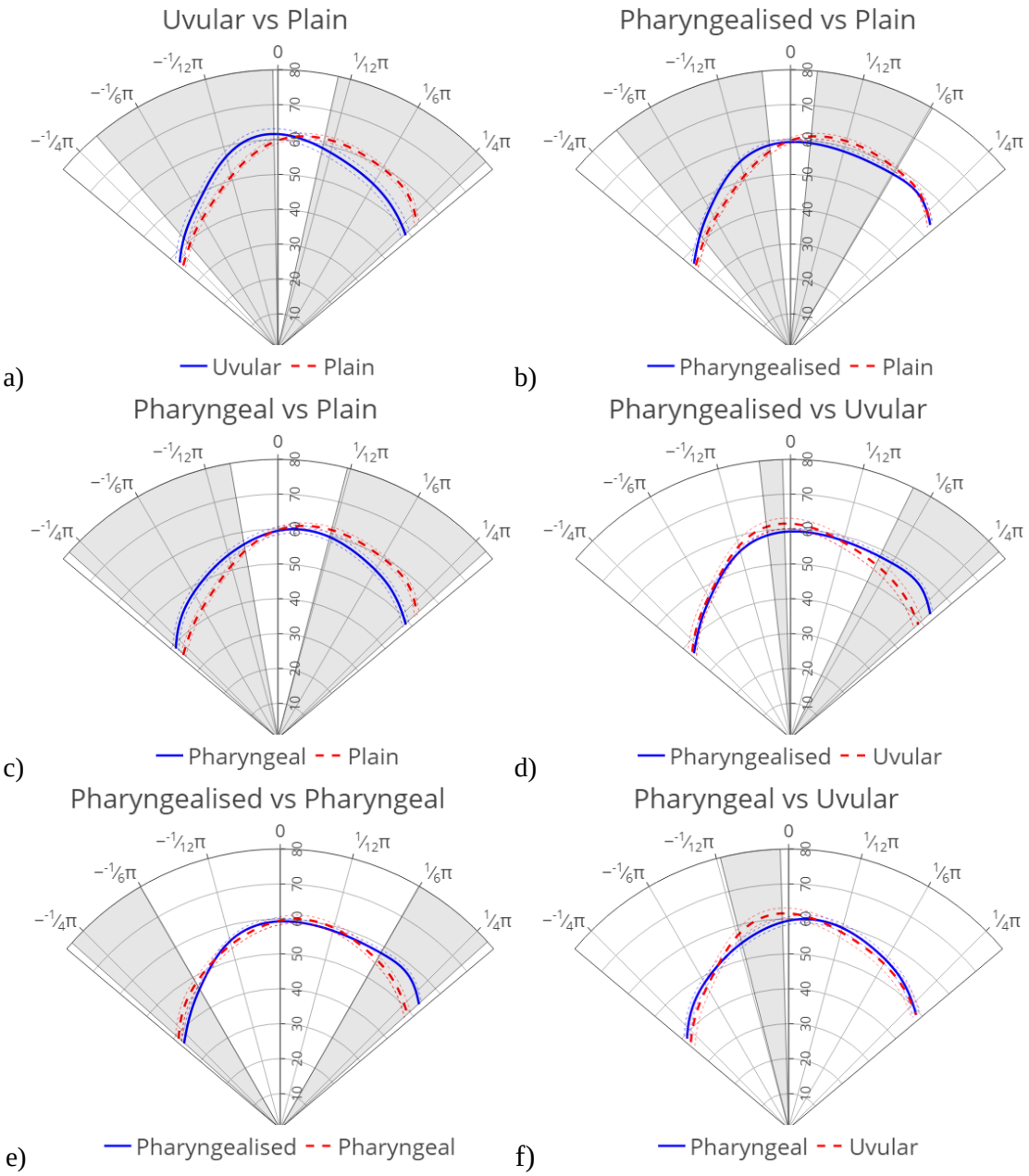

Figure 1: Averaged tongue contours across the whole VCV sequence and vowels in uvular, pharyngealized and pharyngeal in comparison with plain (a-c); between pharyngealized & uvular (d), pharyngealized & pharyngeal (e) and pharyngeal & uvular (f). The shadings indicate significance at 95% confidence interval. Tip of the tongue to the right.

References:

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