A multi-slice rtMRI analysis of horizontal tongue narrowing in English laterals

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Lateral consonants are complex segments that are generally characterized as coronal constrictions produced so as to allow airflow paths along the sides of the tongue, or lateral channels (Stevens, 1998). One hypothesis about the creation of side channels is that they result from narrowing the front part of the tongue, causing the retraction of the sides of the tongue from the molars. A second hypothesis, not incompatible with the first, is that lateralization is achieved by tilting the tongue to one side of the oral cavity, as is shown in recent EMA studies (Katz etal. 2017; Ying etal. 2021). In English, indirect evidence for the narrowing hypothesis has been provided by the observation that laterals are produced with a gesture advancing the tongue tip towards the teeth and a second gesture retracting the tongue dorsum (Sproat & Fujimura 1993; Browman & Goldstein, 1995). The two gestures in opposite directions serve to lengthen the tongue, and because of the tongue's incompressibility (Fujimura & Kakita, 1979), this lengthening could contribute causally to tongue narrowing (as hypothesized by Browman & Goldstein, 1995), or could also be a consequence of narrowing induced by other tongue muscles (Sproat & Fujimura, 1993). However, there has been no direct evidence for a systematic relation over time between those gestures and narrowing of the tongue. The present study investigates whether tongue narrowing correlates over time with the unfolding coronal and uvular constriction in English laterals, using multi-slice rtMRI imaging.

Target stimuli consisted of CVC words involving a lateral consonant (either word-initial or final), a variety of vocalic contexts and a labial consonant, in different prosodic boundary contexts (no boundary, phonological phrase or intonational phrase). The full list of stimuli is given in Fig. 3.

Data processing and measurements: Two rtMRI imaging slices were used for the analysis – the classic mid-sagittal slice and an additional axial/oblique slice, defined by a line along the mid-sagittal plane between two anatomically referenced anchor points: the inferior surface of the upper lip and the intersection between the spinal cord and the C2-C3 intervertebral disk (Llorens Monteserin etal., 2017). The resulting oblique slice is shown in Fig. 1 (left). Tongue width as well as coronal and uvular constrictions were measured using a region of interest (ROI) analysis (Blaylock, 2021) on the oblique and midsagittal images (Fig. 1). Frames of interest (i.e., length of the target words) were determined based on the acoustic timestamps extracted manually in Praat. Example time functions of tongue width are shown in Fig. 2. Individual measures of coronal and uvular constriction, as well as their product (CORONAL x UVULAR), together with syllable position, prosodic boundary and vowel position were used as independent variables in a multiple regression analysis to predict the value of tongue width.

Preliminary results (from one of the three recorded participants) show that tongue width is negatively corelated with the combined measure of coronal and uvular constrictions (Est. ~ -0.121468, Std. Err ~ 0.004273, t-value ~ -28.425; p ~ 2e-16) and positively with their individual measures (p ~ 2e-16). Tongue width is larger in onset vs. coda laterals (Est. ~ 0.0344506, Std. Err ~0.00390, t-value ~ 8.817, p ~ 2e-16) and in front vs. back vowel contexts (Est. ~ 0.028624; Std. Err ~ 0.00387; t-value~ 7.386; p ~1.63e-13). No effect of prosodic boundary was found.

Discussion: Results point to a systematic relation between tongue width and tongue tip and tongue dorsum gestures of the lateral. Tongue width negatively corelates with the paired coronal-uvular constrictions indicating the coordination of both gestures of the lateral results in tongue narrowing. A more detailed gestural and acoustic analysis, correlating tongue narrowing to intersegmental gestural timing in laterals as well as to formant transitions is underway, and will shed more light on how side channels are achieved and how they relate to the acoustic signal.

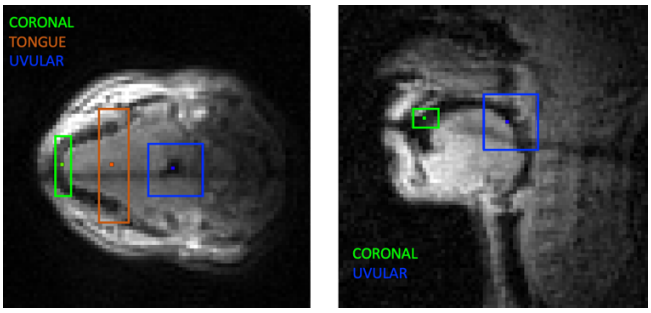

Figure 1: Regions of interest (ROI) for the oblique and mid-sagittal MRI slices.

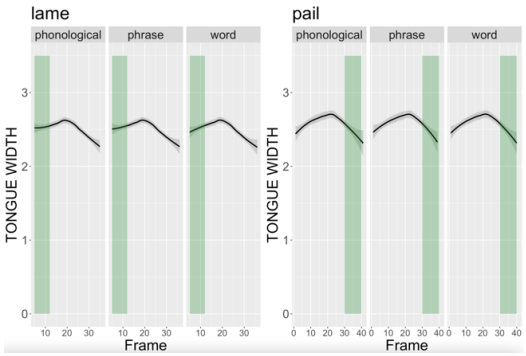

Figure 2: Tongue width values over time in words *lame* and *pail* indicating tongue narrowing during the lateral (in green).

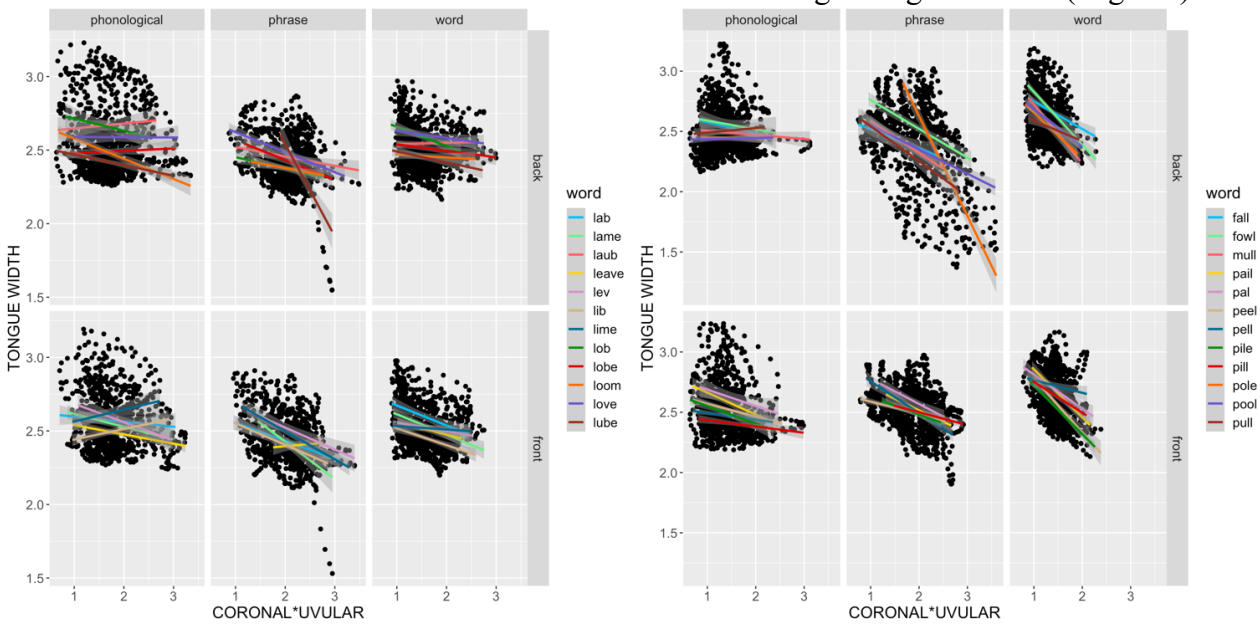

Figure 3: Tongue width as a function of coronal and uvular constriction in onset (left) and coda (right) tokens per prosodic context (word, phonological or intonational phrase boundary) and vowel position (back and front).

Selected references: **[1]** Browman, C. P., & Goldstein, L. (1995). Gestural syllable position effects in American English. Producing Speech: Contemporary Issues, 19–33. **[2]** Blaylock, R.; 2021, VocalTract ROI Toolbox. https://github.com/reedblaylock/VocalTract-ROI-Toolbox. **[3]** Fujimura, 0. & Kakita, Y. 1979. Remarks on quantitative description of the lingual articulation, In Frontiers of speech communication research (S. Ohman & B. Lindblom, editors). London: Academic Press. **[4]** Katz, W., F.; Mehta, S.; Wood, M.; & Wang, J.; 2017. Using electromagnetic articulography with a tongue lateral sensor to discriminate manner of articulation, JASA, 141(1). **[5]** Llorens Monteserin, M.; Byrd, D., Goldstein, L. & Narayanan, S.; 2017. Indexing tongue profile narrowing for English using 3D volumetric MR imaging. 174t Meeting of the ASA **[6]** Stevens, K., N. 1998. Acoustic phonetics, The MIT Press, Cambridge, Massachusetts. **[7]** Sproat, R., & Fujimura, O. (1993). Allophonic variation in English/l/and its implications for phonetic implementation. Journal of Phonetics, 21(3), 291–311. **[8]** Ying, J.; Shaw, J., A.; Carignan, C., Proctor, M.; Derrick, D., & Best, C., T.; 2021. Evidence for active control of tongue lateralization in Australian English /l/, Journal of Phonetics, 86.