LOCATION AND SIZE OF CONSTRICTION IN VELAR SOUNDS IN PARISIAN FRENCH

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1. Introduction

Contextual fronting of velar stops has been reported in various languages, such as French [1-3], Greek [4], and English [5]. Typically, a velar stop is realized more frontally before a front vowel, with the most pronounced fronting and greatest contact occurring in /i/ contexts and the least in /a/ contexts; Liker and Gibbon [6] demonstrated this using Electropalatography (EPG) data with English speech. Interestingly, French has been reported to show a unique pattern where velar stops are fronted before the low back vowel /ɑ/ [6] as well, a finding recently supported by Islam & Gick [7] through rtMRI data of Parisian French. While fronting before front vowels can be attributed to predictable phonetic effects, the fronting before /ɑ/ negates an explanation based on pure phonetic assimilation. Rather, this could be an indication that the fronting is present in all contexts.

Although extensive research has explored contextual velar fronting in French, few studies have investigated the place of articulation (PoA) across all velar contexts to determine whether there is systematic across-the-board fronting in all phonological environments. Given that the velar stop is articulated more frontally before a low back vowel, it is plausible to predict a general shift in the location of constriction in all velar stops in French. Therefore, we examined the PoA of French (Parisian) velar stops (/k/ and /g/) in various contexts, including before both front and back vowels.

2. Method

2.1. Data

The study involved the assessment of 10 healthy native French speakers from the French rtMRI speech corpus, which consists of an equal number of male and female speakers aged between 21 to 37 years [8]. None of the speakers had reported speech or hearing impairments at the time of recording.

Using the French rtMRI video corpus, we extracted frames corresponding to the peak constrictions in both the voiceless and voiced velar stops ([k] and [g]) that occur before the vowels [i], [y], [ɛ], [o], [u], and [a]; the preceding vowel was always [a]. We also selected frames for three additional segments: the labiovelar approximant [w], the high back vowel [u], and the uvular fricative [ʁ].

We included the sound [w] as a reference category for velar constriction since, descriptively speaking, [w] has a velar constriction (in addition to a labial one); this was confirmed via our visual inspection of the MRI frames. We then compared the constriction location in [k] and [g] with reference to [w]. We also predicted that [w] and [u] would show similar constriction locations; [ʁ] was included as a reference point for the constriction farthest back in the oral cavity. Table 1 presents a summary of the selected tokens.

Table 1: Token types and environments

Seg.	n_token	Environments
k	95	[a_i], [a_a], [a_ɛ], [a_o], [a_u]
g	50	[a_i],[a_a], [a_y], [a_o], [a_u]
w	41	[b_a], [f_a], [p_a]
u	39	[p_f], [p_p], [b_f], [b_ʃ], [f_#], [v_#]
ʁ	42	[a_a] or [o_a]

2.2. Procedure

After selecting the frames of interest, we manually traced two contours in each of the frames using a drawing tablet. As shown in Fig. 1, the hard palate was traced in green, while the tongue was traced in yellow. We then extracted the two contours using OpenCV in Python, and then determined the location of the narrowest location between the two lines based on the Euclidean distance. We used this location (in a two-dimensional X-Y space) as a measure of the constriction location for the segment in the frame. Statistical analyses of the data were performed using R [9].

Figure 1: Transverse head X-ray with palate position in green and tongue position in yellow.

3. Results

Fig 2. looks at the location of constrictions measured in the study in a two-dimensional X-Y plane. The X-axis represents the frontness in the vocal tract with fronter articulations to the left; the Y-axis represents the height of the constriction location. Both the X and Y data were z-score normalized within each speaker. As the figure shows, [ʁ] has a PoA that is furthest back in the oral cavity, completely distinctive from

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other fronter constrictions, for all the speakers. Among the other sounds, both the velar stops have fronter distributions compared to the labiovelar [w] and the high back vowel [u].

To provide a clearer picture of these sounds PoA, Fig. 3 presents the distributions for only the X-axis values in side-by-side boxplots. It provides a clear indication that all velar stops tend to have a fronter PoA compared to the labio-velar approximant [w] or the high-back vowel [u]. These differences were all confirmed to be statistically significant via a linear mixed-effects model that included fixed effects for segments and random intercepts for individual speakers.

While the above analysis confirms that velar stops had fronter PoA irrespective of their contexts, Fig 4. provides a detailed representation of the contextual difference. As the figure shows, predictable patterns in contextual fronting of velars are still retained where velars before front vowels are generally fronter than the ones before the back vowels.

Finally, we also looked into the size of the constriction as the PoA by measuring the Euclidean Distance (ED) between the two contours; Fig. 5 presents the findings. The figure mostly shows expected patterns where stops have smaller openings than fricatives, approximants, and vowels. However, the approximant [w] shown in Fig. 5 was revealed to have a significantly greater opening than the vowel [u], which is contrary to expectation.

4. Conclusion

The examination of rtMRI data in this study reveals an across-the-board shift in PoA in velar stops. Irrespective of their phonological context, all velar stops, voiced and voiceless, have fronted articulations completely distinct from velar articulations, compared to the labio-velar consonants, a finding that has not been reported before. The study also reveals that the approximant [w] can have a wider opening in the vocal tract compared to [u]; future studies could look into the explanations for this finding.

Acknowledgments

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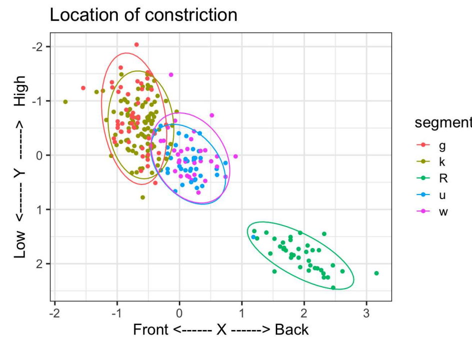

Figure 2: Location of constriction in an X-Y space

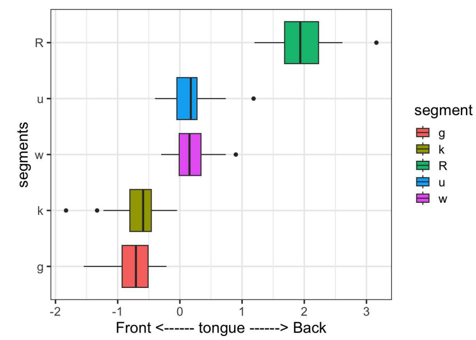

Figure 3: Location of constriction in segments

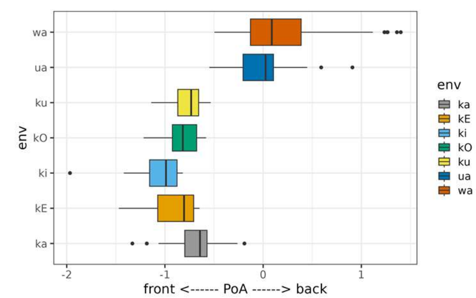

Figure 4: Contextual fronting in velar stops

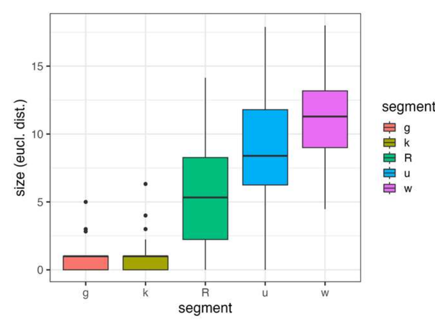

Figure 5: Size of constriction in segments

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