Voicing in Canadian French obstruents: a laryngeal and lingual ultrasound study

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Background. Vocal fold vibrations are more difficult to achieve during obstruents than sonorants due to the aerodynamic voicing constraint (AVC), i.e., the fact that a build-up of air pressure in the supraglottal cavity during oral closures reduces the transglottal airflow [1,2]. The AVC can be circumvented by a number of voicing adjustment gestures that expand the supraglottal cavity actively (tongue-root advancement, tongue-body lowering, larynx lowering) or passively (reduction of muscle contraction in the supraglottal tract), or allow air to leak out of the supraglottal cavity (oral or nasal leakage) [3,4,5,6,7].

Research questions. Previous studies on voicing adjustment strategies in French have found that initial voiced stops are often realized with nasal leakage and cavity expansion [8,9,10], although no significant difference in larynx height has been observed between voiced and voiceless stops [10]. In the current study, we look at the vertical displacement of the larynx and at tongue root/body position in Canadian French 1) to determine if these voicing adjustments are used significantly, 2) to assess the amount of interspeaker variation and 3) to establish if there is a correlation between the use of voicing adjustment gestures and closure voicing duration of voiced obstruents.

Methodology. We recorded an audio signal as well as laryngeal and lingual ultrasound videos of 13 native speakers of Canadian French as they read a list of sentences containing word-initial, phrase-medial sonorants, voiced and voiceless fricatives and voiced and voiceless stops. Laryngeal ultrasound videos (see Figure 1) were recorded first, followed by lingual videos. The vertical movement of the larynx was measured using optical flow analysis [11,12]. The movement of the tongue root and tongue body was analyzed by tracking distinct fanlines across consecutive ultrasound images [13,14].

Results. Results reveal that there is normally more pronounced larynx lowering in voiced obstruents, and that it tends to be greater in voiced stops than in voiced fricatives, as expected. The larynx begins to lower during the preceding vowel, reaches its lowest position near the middle or end of the closure and reverts to its default position during the following vowel. Figure 2 presents these larynx movement results for stops only. Tongue-related maneuvers display much more interspeaker variation than larynx movement. Tendencies show that the tongue root is more advanced in voiced stops than in voiced fricatives and slightly more for /d/ than /b/. This forward movement is more prominent for obstruents preceding high vowels /i/ and /u/ compared to the low vowel /a/. Significant tongue-body lowering is observed for both voiced stops and voiced fricatives only preceding the vowel /a/. Finally, larynx lowering is strongly correlated with the duration of vocal fold vibrations in voiced obstruents. A similar but weaker correlation is found for tongue-root advancement and a significant correlation in the opposite direction is observed for tongue-body lowering in /d/ and /v/, likely due to a natural elevation as the tongue root advances.

Conclusion. Overall, this study suggests that larynx lowering is a highly efficient strategy to circumvent the AVC in Canadian French but that some speakers may also resort to lingual adjustments. Additional strategies that are known to play a role, such as nasal or oral leakage, were not considered in the current study [8,9,10].

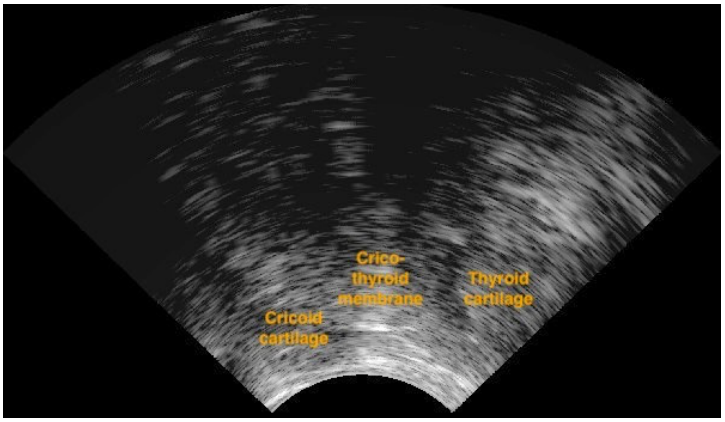

Figure 1. Sample laryngeal ultrasound image with relevant structures indicated.

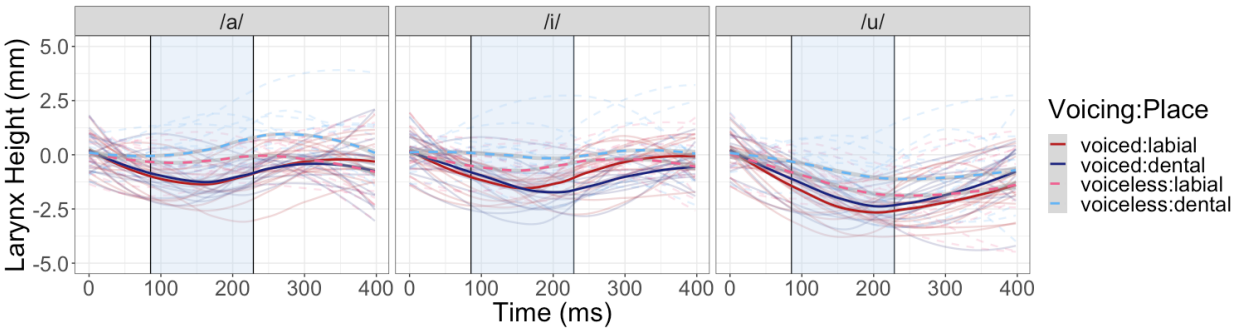

Figure 2. Mean (dark lines) larynx movement during production of voiced and voiceless stops. The blue rectangle indicates the closure which is flanked by the preceding vowel /a/ and the following vowel as labeled above each plot. Pale lines are individual speakers' trajectories.

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