COMPARING VELUM VELOCITY IN QUÉBÉCOIS FRENCH NASALS

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1 Introduction

The velum is a speech articulator which separates the oral and nasal cavities. During the production of oral sounds, the velum is raised, keeping the velopharyngeal port (VPP) closed; during the production of nasal sounds, the velum lowers, opening the VPP and allowing for sounds to resonate in the nasal and sinus cavities.

Motor control of the velum is not well understood. While closure is primarily due to activation of the levator veli palatini, it is not known if velar opening is due to active or passive control [1,2]. Examining the speed of the velum is one way to gain insight into the control of the velum. Previous literature has examined velum speed in a variety of contexts, such as velum velocity when raising versus lowering [3,4], and velum velocity in speech versus non-speech segments [5].

While previous studies have looked at velum velocity, few have compared the velocity between segment types, such as consonants and vowels. Previous studies report that there is a positive correlation between velopharyngeal openings (VPO) and velum velocity [5,6] and that French nasal consonants and nasal vowels have similar sized VPOs [7]. Based on this, we predict that there will be no significant difference in velum velocity between the production of nasal consonants and nasal vowels in French. This would suggest that the velar movement for these segments are controlled in a similar manner.

2 Method

2.1 Database and annotation

The data was taken from the Université Laval X-ray videofluorography database which included 17 X-ray video files of sentence-level speech from nine native speakers (5M/4F) of Québécois French [8]. The speakers' age ranged from 19 to 30 years.

The audio from the films was extracted and force-aligned, with any misaligned boundary manually corrected. The start and end timestamps for each segment were extracted using a Praat [9] script.

2.2 Measurement

Using the imaging software ImageJ [10], a diagonal line was drawn along the velum's path of movement (i.e., between the pharyngeal wall and the upper surface of the velum; see Figure 1). The height and angle of these lines were determined by visually inspecting a full stack of images within a video.

Figure 1: an example of the location of VPO measurement on the sagittal X-ray image.

To measure the degree of VPO, the number of black and white pixels along the diagonal line was counted. The proportion of black pixels was then normalized between 0 and 1 within each video, with 1 representing the widest opening for the film, and 0 representing no opening (see Figure 2).

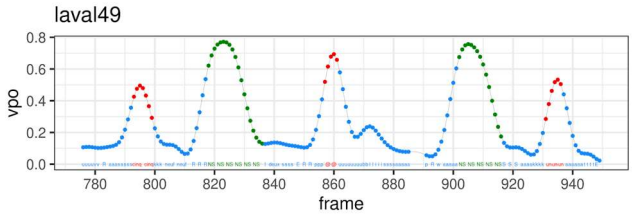

Figure 2: VPO as a function of time (frame is used as a proxy for time) blue=oral, red=nasal, green=speech pause.

To measure the velocity of velum movement, R [11] was used to fit simple linear regression models with the VPO values from each opening and closing phase separately. Slopes from the regression models were used as a proxy for velocity.

Thus, for each nasal segment, we obtained two slope values: one for the opening phase and one for the closing phase. Adjacent nasal consonants and phonemically nasal vowels were excluded due to difficulties separating the segments.

2.3 Statistical analysis

The effect of segment type (nasal consonant versus nasal vowel) on velocity was analysed using linear mixed-effects models. The fixed effects included segment type, phase (opening versus closing), duration in frames, distance (size of VPO) and sex, with random intercepts for each speaker. Using a significance level of $p = 0.05$, p values for individual predictors were obtained via model summary.

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3 Results

Figure 3 shows boxplots of velum velocity by segment type for closing and opening phases of the velum. The x-axis indicates closing or opening phase, and the y-axis shows the velocity (in arbitrary units) as obtained from the slopes of simple linear regression. Figure 3 indicates that vowels have slightly higher median velocities than the consonants in both closing and opening phases.

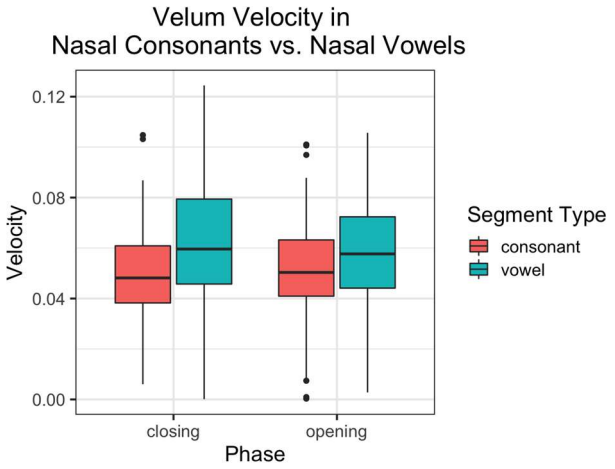

Figure 3: Boxplot comparing the velum velocity of nasal consonants and nasal vowels in opening and closing phases.

The model found significant effects for distance (β=0.14, DF=553, t=22.53, p<0.001) and duration in frames (β=-0.007, DF=567, t=-17.52, p<0.001) but there was no significant difference in velocity between nasal consonants and nasal vowels (β=0.002, DF=567, t=1.53, p=0.126). The fixed effects of sex and phase were not significant either.

4 Discussion

The results suggest that in both opening and closing phases of the velum, its velocity during nasal consonant and nasal vowel production in Québécois French remains similar. This matches our hypothesis that nasal consonants and nasal vowels would have similar velum velocities and suggests that velum movement in consonants and vowels are controlled in a similar manner. As well, the significant effects found for distance and duration in frames suggest that the larger the VPO size, the faster the velum moves, as found in [5,6].

The analysis was limited to a database from 1974, thus our results may not apply to present day Québécois French. It is likely that the non-significant effect would become significant given a larger dataset. Future work should run analyses with a larger dataset.

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