THE EFFECT OF PLACE OF ARTICULATION ON VELOPHARYNGEAL OPENING IN QUÉBÉCOIS FRENCH NASAL CONSONANTS

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1 Introduction

There has been previous literature demonstrating an interaction between place of articulation (PoA) and velopharyngeal opening (VPO). Rochette & Grégoire (1983) [1] found that there is a greater extent of opening in the production of the French bilabial nasal consonant than the palatal. They did not however compare the alveolar PoA, and used only 2 speakers, one male and one female. This continues from a small literature suggesting that there may be a continuum of VPO targets for nasal sounds [1 - 3] as opposed to the frequently understood binary nature ([+nasal] vs. [-nasal]).

Other studies looking at VPO in French have compared phonemically nasal vowels versus consonants, and contextually nasalized vowels versus oral segments [1, 2]. However, there is still more to be explored as it relates to place of articulation. Furthermore, previous findings demonstrate differences in velar anatomy between males and females [4 - 6], leading to the consideration of potential effects of sex on VPO.

The present study seeks to explore whether PoA influences the VPO uniformly across speakers and whether sex is a contributing factor to the extent of the opening. To expand on previous research, this study will include measurements of /n/, and a greater number of sentences and speakers, which will allow consideration of potential sex effects.

2 Methods

From the Munhall et al. (1995) [7] X-ray film database, nine native speakers (five males and four females) of Québécois French at the Université Laval were selected. All of these speakers were between the ages of 19 and 30 years old.

The X-ray films, originally created by Dr. Claude Rochette, were adjusted by Munhall et al. (1995)[7], the details of which can be found in his paper. The nine speakers produced a total of 24 films with about 4000 frames each. We quantified the VPO using ImageJ [8] by counting black pixels present between the pharyngeal wall and the upper surface of the velum. This region intersects the "path of the velum and is where measurements were taken. The velum" making full contact with the pharyngeal wall is a complete closure and coded as VPO = 0. Maximal opening for each individual speaker was coded as VPO = 1. Therefore, each speaker was compared to themselves for their ratio per segment as opposed to each other.

For analysis, we ran linear mixed-effects models to assess the parameters of the research question. The p-value for significance was set at .05.

Figure 1: X-ray image of a speaker at sagittal view. The yellow line demonstrates the location of VPO measurement along the "path of the velum".

3 Results

Figure 2 indicates the average VPO ratios in each of the three phones. The y-axis represents the ratio of opening from 0 to 1 and the places of articulation are represented along the x-axis. The palatal nasal /ɲ/ is represented by 'gN'. As the figure indicates, bilabials have a higher VPO compared to palatals or alveolars while there does not appear to be a difference between the alveolars and palatal nasals.
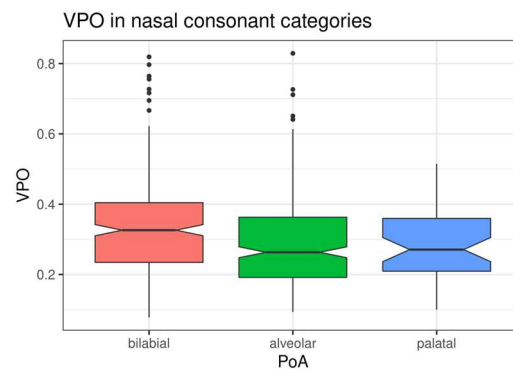

Figure 2: Boxplot of VPO in [m] (N = 285), [ɲ] (N= 48), and [n] (N = 304).

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To determine if PoA was a significant contributor to the VPO ratio in nasal consonants, we performed a linear mixed effects analysis in R [9] using *lmerTest* [10]. We fit a null model with the fixed effect of sex and a predictor model with an added fixed effect of PoA; both models included random i

ntercepts for speakers as random effects. P-values were obtained via likelihood ratio test comparing the predictor model against the null model.

Results revealed a significant effect of PoA on VPO ($\chi^2 = 25.27$, p < .001, $df = 2$). An ANOVA of the predictor model also confirmed the significant fixed effect of PoA ($F(2, 630) = 12.89$, p < .001). The model summary indicated that [m] was significantly different than [n]; however, no other differences were found significant.

We also investigated the fixed effect of sex as well as the interaction effect of PoA and sex on VPO; neither of them, however, were found significant.

4 Discussion

The findings of this study could not confirm a significant difference between the bilabial and palatal nasals, as reported in Rochette & Grégoire (1983)[1]. On the other hand, our study found a significant difference between bilabial and alveolar nasals, a comparison which was not examined before. One caveat about these results is that, though significantly larger than Rochette & Grégoire (1983), we had a small number of tokens for the palatal category compared to bilabials and alveolars. Future studies should include a balanced number of tokens for all the categories.

The lack of significant interaction between sex and VPO indicate that VPO is most likely a linguistic phenomenon and is less likely affected by physiological differences of the vocal tract. Further, sex we cannot from the current study say if the impact of PoA is articulatory or phonetic. It could be due to articulatory reasons that the more anterior closure enables a greater opening in the velum. It could also be a phonetic target that production of /m/ requires greater nasal resonance than /n/ or /ɲ/. Further studies would need to be conducted, including to determine if the difference in VPO between /m/ and more posterior nasals is cross-linguistic.

Though this study was conducted on continuous speech rather than elicited tokens, a limitation is that it was based on sentences that were read in the lab as opposed to completely natural speech. An area of further study could be to run such analyses on spontaneous speech in naturalistic settings.

5 Conclusion

The analysis through ANOVA and the likelihood ratios revealed that there is indeed an effect of PoA on the VPO within the category of nasal consonants. No effect of sex or speaker was found to provide an interaction. These results support previous literature where gradation of VPO across conditions was investigated, and it builds onto existing research by filling the gap of whether there is an effect of speaker or sex.

Though significant results were found, future research could seek to elucidate whether this difference can be explained as deriving from biomechanical or acoustic factors.

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