VELAR MOVEMENTS FOR TWO FRENCH SPEAKERS

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ABSTRACT

This study compares velar movements for nasal vowels and consonants; it investigates contextual nasalisation; and it provides new data on how nasalisation is affected by speech rate. Velar position is measured with an electromagnetic articulatograph (EMA) for two French speakers. Our results confirm that (i) nasal vowels are produced with a lower velum height than nasal consonants; (ii) the contrast between nasal and oral vowels is maintained in nasal context; (iii) velum height targets for nasal and oral segments show some overlap, especially sequences of nasal consonant + oral vowels or [l, ʁ]; and (iv) nasal vowels have a relatively longer duration which is preserved under rapid speech rate.

Keywords: velar position, EMA, nasal, speech rate

1. INTRODUCTION

The binary feature /±nasal/ is produced by the lowering of the velum, which connects the nasal passage to the oral tract. Different velar positions have been observed during the production of oral vowels [4]. Photodetection studies demonstrate a link between the height of the oral vowels and the position of the velum. The velar position observed in low vowels can even be so low as to imply an open velopharyngeal port [4, p.34]. Very importantly, such a slightly open velopharyngeal port may not be sufficient to induce a nasal percept [7]. A previous study using EMA shows that the velum position for nasal vowels is lower than for nasal consonants [10].

The opening and closing phases of the velopharyngeal port involved in the production of nasal consonants also tend to nasalise the adjacent vowels. The degree of coarticulated nasality is language-specific [4, 5] and could depend on the phonemic inventory. Some phonemes do not allow the spreading of nasality, especially plosives, which only allow a slight velopharyngeal port opening: less than 0.1 cm^2 [12]. Therefore, when a nasal vowel follows a plosive, it is produced in part as an oral vowel [8].

Contextual nasalisation is the diachronic origin of French nasal vowels [9]: nasal vowels originate in the anticipation of velar movement during the vowel preceding a nasal consonant, and the elision of this consonant.

Some issues remain well worth investigating: synchronically, how is the phonemic contrast between oral and nasal vowels maintained at the articulatory level, given that nasal vowels can become partly oralised whilst oral vowels can become partly nasalised? What are the specific targets involved, and what contextual variations do they undergo? How does speech rate influence the amplitude of velum movements? Which diachronic changes could emerge from the pool of variation?

2. ARTICULATORY MEASUREMENTS

To investigate the intrinsic height of the velum for oral vs. nasal phonemes (consonants and vowels), and its variation as a function of neighbouring phonemes, we measured the velar movements in VCV sequences for all phonemes in French. One part of the corpus focuses more specifically on the contrast between nasalised oral vowels and nasal vowels. The influence of speech rate is investigated for the sequences tV and tVt under three speech rates.

2.1. Corpus and speakers

The first part of the corpus is made up of [#VCV#] sequences, in order to measure velar position for each French consonant ([p t k b d g f s ʃ v z ʒ ʁ l m n]), whatever the vocalic context: oral [i e a o u] or nasal [ɛ̃ œ̃ ɑ̃ ɔ̃] (the second of these four exists in Belgian French but not in Parisian French; see below). These sequences also allow for the analysis of velar positions during oral and nasal vowels whatever the consonantal context.

The second part of the corpus focuses on the effect of contextual nasalisation on oral vowels in French as compared to nasal vowels, using sequences [C_nV], [VC_n] and [C_nVC_n]. C_n is the nasal consonant [n], chosen because the alveolar occlusion is more visible on the apex coil of EMA than the lip closure during [m]. V is one of [i y u e o ɛ œ ɔ ɛ̃ œ̃ ɔ̃ ɑ̃]. These sequences were embedded in a carrier sentence: “Vous dites ___ trois fois”, i.e. ‘You say ___ three times’.

The third part of the corpus focuses on the amplitude of the movements of the velum as a function of speech rate. We use real words, in the belief that it can be conducive to a clear, ‘natural’ production. The sequences [tV] and [tVt], embedded in a carrier sentence: “Dites __ trois fois” (‘Say __ three times’), were pronounced at three different speech rates (slow to fast). To obtain approximately the same rate for the two speakers, we provided an indication as to the desired speech rate by means of a metronome.

Two female speakers (S1 and S2) without known vocal pathology or upper respiratory infections at the time of the study were recorded. Speaker S2 is a native of Belgium; S1 is native of France, and therefore does not have /œ̃/ in her phonemic inventory; the corpus was modified accordingly for S1.

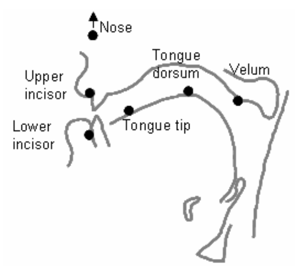
2.2. Instrumentation

The articulatory movements were recorded with an electromagnetic midsagittal articulograph (EMA Carstens AG100). Six coils were attached with the medical glue used by dentists and fixed on different articulators (see Figure 1). A Cyanoveneer glue was used for the skin and mucous membrane, and a CG Fuji 1 glue for the tongue.

Twos coils are used as references. This study focuses on the velum coil fixed about half-way between the junction with the hard palate and the extremity of the uvula.

The coil trajectories are sampled at 500 Hz, and filtered with a low-pass filter that cuts off frequencies above 20 Hz.

Figure 1: Position of the six coils fixed on the articulators.



The trajectories of the coils are indicated in midsagittal plan by two coordinates given in centimetres. The velum height is the vertical position of the velar coil, i.e. the Y coordinate. The acoustic signal was recorded simultaneously with the microphone of the Carsten device and sampled at 44.100 Hz. The transitions between phonemes and the middle of each phoneme are labelled using the acoustic signal.

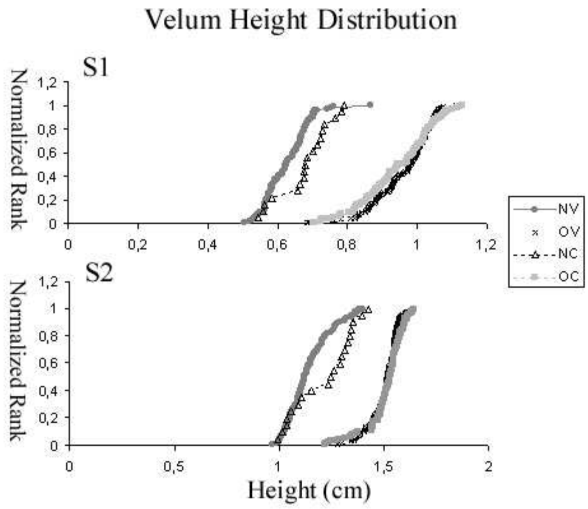
3. RESULTS

All statistical tests were based on the variance analysis ANOVA with a significance level $p<0.001$ by default.

3.1. Velum height for oral and nasal segments

Figure 2 presents the velum height distribution for four classes: oral consonants (OC; n=118 for S1 & n=141 for S2), oral vowels (OV, n=160 for S1 & n=191 for S2), nasal consonants (NC; n=18 for S1 & n=20 for S2) and nasal vowels (NV; n=114 for S1 & n=129 for S2). Velum height is the Y coordinate of the velum coil at the middle of the segment, extracted from the VCV sequences. Both oral vowels and oral consonants are produced with a similar range of velum height, no significant difference appears (S1: $F(1,283)=2.133$, $p=0.1453$ & S2: $F(1,331)=1.376$, $p=0.2415$). Nasal phonemes are produced with lower velum height for both subjects; they are clearly different from oral phonemes, with a significant difference for the oral/nasal phonemic contrast (S1: $F(1,413)=449.684$, $p<0.001$ & S2: $F(1,479)=559.772$, $p<0.001$). Nevertheless, there is some overlap between oral and nasal segments.

Figure 2: Normalised rank of velum height (cm) measured in the first part of the corpus for each class for the two speakers (top: S1 and bottom: S2).



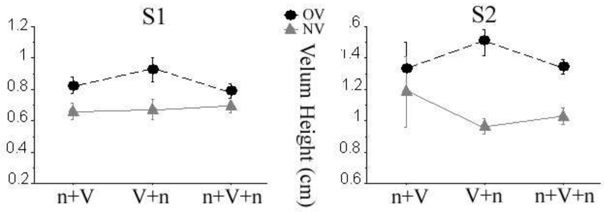
Some oral segments are produced with an open velopharyngeal port. A similar velum height is measured during the production of nasal consonants between oral vowels, and of some tokens of nasal vowels following plosives and liquids for S2. No significant difference was observed between oral consonants and oral vowels.

Nasal vowels are produced with a lower velum height than nasal consonants. Unsurprisingly, the lowest velum positions for nasal consonants are reached in nasal vowel context.

3.2. Contextual nasalisation

The velum height of contextually nasalised oral vowels (as compared to nasal ones) is obtained from the analysis of the second part of the corpus, measuring the position of the velum at the middle of each vowel for the three sequences [nV], [Vn] and [nVn] (S1: n=42 & S2: n=43). Figure 3 shows the results depending on the three positions. The oral/nasal contrast for vowels is always maintained (S1: $F(1,40)=37.305$, $p<0.001$ & S2: $F(1,41)=56.200$, $p<0.001$): the velum height observed in the nasalisation of the vowel due to the nasal context never reaches the target of the nasal vowels. Velum height seems to be higher for oral vowels followed by the nasal consonant [Vn] than for oral vowels preceded by the nasal consonant [nV], indicating that there is more carryover than anticipation. However, this tendency is not significant (S1: $F(1,17)=6.236$, $p=0.0231$ F; S2: $F(1,20)=8.770$, $p=0.0077$). It would be also interesting to establish a link between the articulatory pattern and the results of Basset *et al.* [2] which show that in spontaneous speech, the nasal airflow is propagated beyond the nasal phoneme.

Figure 3: Velum height for oral and nasal vowels followed, preceded or surrounded by the nasal consonant [n] (for both speakers).



3.3. Movements of the velum as a function of speech rate

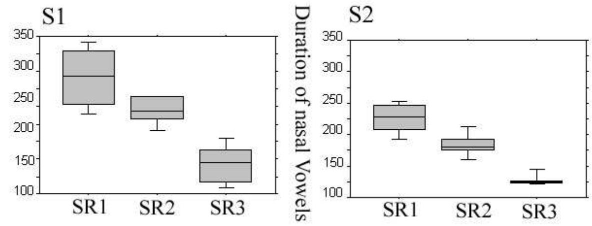
The amplitude of the velar movement is obtained from the analysis of the third part of the corpus, [tV] and [tVt]: we measure the displacement of the velum from the high position adopted for the plosive towards the nasal vowel's target. The three speech rates are noted SR1 SR2 SR3, from slowest to fastest.

3.3.1. Vowels durations

The duration of nasal vowels is fairly long (S1: SR1=291ms, SR2=243ms, SR3=168ms & S2: SR1=226ms, SR2=184ms, SR3=129ms). It is always above 100 ms, even in SR3. We take this to confirm that nasal vowels preserve a relatively longer duration even in rapid speech rate. Adda-Decker [1] indicates from Radio and read corpus that the oral vowel durations are around 60ms.

Our results show significant difference for the duration of the nasal vowels for the two speakers (n=36, $F(1,34)=9,339$, $p=0,004$), and a significant difference between SR1, SR2 and SR3 (S1: $F(1,15)=20,503$, $p<0.001$; S2: $F(2,15)=20,503$, $p<0.001$).

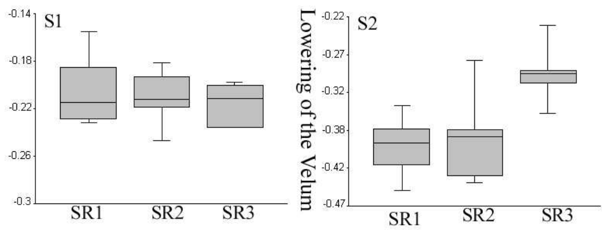
Figure 4: Duration of the nasal vowels for the three rate speech (SR1, SR2 and SR3) and for the two speakers.



3.3.2. The lowering of the velum

The amplitude of the lowering gesture is the difference between the velum position at the middle of the nasal vowel and the velum position at the burst of the first [t]. Our results show no significant difference either for the type of syllable for both speakers ([tV], n=9 & [tVt], n=9), (S1: $F(1,16)=0.198$, $p=0.6622$; S2: $F(1,16)=0.272$, $p=0.6089$) or for the word.

Figure 5: Lowering of the velum for the three speech rates (SR1, SR2, SR3) and for the two speakers.



Speech rates (SR1 & SR2) have no significant difference on the lowering of the velum for both speakers. However for S2, there is a significant difference between SR3 and the two other SR (SR1, n=6, SR2, n=6 & SR3, n=6), (S1: $F(1,15)=0.290$, $p=0.7522$; S2: $F(1,15)=6.819$, $p=0.0078$). For S2, the nasal vowel target is undershot when the speech rate increases.

3.3.3. The raising of the velum

In order to analyse the raising phase of the velum, we computed the difference in velum position between the burst of the initial [t] and the end of the nasal vowel. A significant difference for the raising of the velum emerges between [tV] and [tVt] for both speakers (S1: tV, n=9 & tVt, n=9; $F(1,16)=13.336$, $p=0.0022$; S2: $F(1,16)=17.160$, $p=0.0008$). This can clearly be put down to syllable type: in [tVt], the final raising of the velum is earlier than in [tV]. In most cases, we observed a difference across speaking rates; [tV] appear to be most affected by speaking rate: pauses get inserted at SR1 and SR2, whereas they are never observed at SR3.

4. DISCUSSION AND CONCLUSION

The contrast between oral and nasal vowels in French is known to involve secondary cues in addition to nasality (e.g. lip rounding and tongue position: [12]); it is thus an open issue to what extent the difference of velum height between the two sets of vowels is preserved in rapid speech. This study confirms that the velum position targets for nasal and oral segments are clearly distinct, even though a small amount of overlap is observed. Nasal vowels have the lowest velum positions, well apart from the positions reached for nasal consonants. This is in line with a preliminary EMA recording on a single male French speaker [10]. This goes to suggest that the contrast between nasalised and nasal vowels is maintained from the point of view of production even when oral vowels undergo contextual phonetic nasalisation.

Several studies show that nasalisation processes are language-specific [4, 11]. We therefore plan to observe the velum height with the same instrumentation for vowels in languages that do not contrast nasal and oral vowels. We would also like to test the hypothesis (suggested by the results in 3.3.2) that, in carrier sentences such as the one used here (where the target word is in focus position), our two speakers tend to preserve relatively long nasal vowels in order to reach the articulatory target—a relatively long duration is a language-independent condition to the articulatory realisation of nasal vowels, and a perceptual cue [3]. Further investigations are needed; more speakers and more data with several speech rates.

5. AKNOWLEDGMENTS

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