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Observations of the Velopharyngeal Closure Mechanism in Horizontal and Lateral Directions from Fiberscopic Data

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ABSTRACT

The present study is concerned by the spatio-temporal coordination between the movements of the lateral pharyngeal walls (LPW) and the movements of the velum. There are two objectives: first, to investigate velum and LPW movements, and second to determinate if there is a correlation between these movements in the production of the velopharyngeal mechanisms in speech. It was found that for our two subjects, there was a close correlation between velum and LPW movements. It was also discovered that the movements for opening the velopharyngeal path for a nasal vowel was influenced by the identity of the preceding oral vowel, independently from the intervening consonant, and that there was vowel-to-vowel assimilation for what concerns the studied movements.

1. INTRODUCTION

In speech, the primary function of the velopharyngeal port is to modulate the degree of coupling between the oral and nasal cavities so as to produce distinct nasal and oral sounds. Several components create velopharyngeal port closure, namely the velum, the lateral pharyngeal wall (LPW, see figure 1) and the posterior pharyngeal wall (PPW) which together form a three-dimensional muscular valve known as the velopharyngeal sphincter [15]. Inter-speaker different velopharyngeal closure patterns were described by [14] and [4] who considered the existence of more than four types of velopharyngeal closure patterns, depending on the amplitude of LPW movements. One of the pattern is the sphincteric strategy which consists of the combination of the velum with LPW and the posterior pharyngeal wall (PPW), and forms a three-dimensional muscular valve

Velopharyngeal mechanisms have been studied primarily in terms of velar rise and fall. Some authors ([6] [9] [11] [12]) studied the LPW movements and found that the LPW moves during the production of the oral vowels. Kelsey et al. found "...there is more displacement of the LPW during the low vowel /a/ than during the high vowel /i/..." [6].

If the distance between the LPW is smaller for /a/ than /i/ (the sphincter is more close for /a/), then we could explain why /a/ can be produced with a lower velum, as often observed, without nasal airflow, maintaining the phonological contrast between oral and nasal /a/ possible. The purpose of the present study is to determine whether or not there is a close correlation between horizontal and

lateral velar movements, whether the different vowels, oral and nasal, behave differently (since there is a great difference in their order of apparition and disappearance in sound changes) and to investigate the effects of segmental context on velar movements, in particular whether or not there is some kind of vowel harmony.

2. METHODOLOGY

2.1 SUBJECTS

Two adults, (one male and one female, 24 and 28 year old) belonging to the sphincteric strategy served as subjects. They speak Parisian French.

2.2 CORPUS

The speech samples consist of isolated vowels and CVC \tilde{v} CV sequences, where C=[d,l,n,t,s,z], \tilde{v} =[\tilde{a} , \tilde{e} , \tilde{o}] and V=[i,a,u,y]. The sequences were embedded in the frame sentence; "Dites_____trois fois" ("Say_____three times"). This is a part of a large study in progress [1].

2.3 INSTRUMENTATION

Velopharyngeal movements were recorded by the second author with an Olympus Enf-P4 fiberscope linked to a cold light and a small camera (Olympus OTV-SF), shooting 25 frames per second. The endoscope was positioned behind the hard palate (see Figure 1):



Figure 1 : Position of endoscope and resulting image.

2.4 MEASUREMENTS

From video data, we measured velar rising/falling movements as well as LPW displacements in the velopharyngeal port region. We selected a frame wherein the velum was maximally low and the LPW maximally open (breathing position) to calibrate our measurements. Measurements were made at 10ms intervals and plotted with interpolation between the points [2]. The resulting curves were linked with the sound files as show in Figure 2.

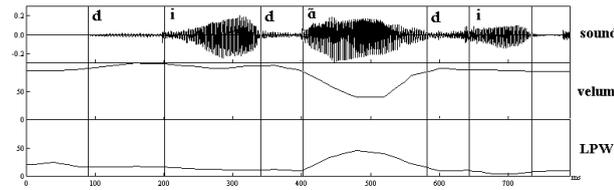


Figure 2: The sequence [didãdi] aligned in time: 1. Acoustical signal, 2. movements of the velum, 3. distance between LPW (Phonedit 3.2) [5].

3. RESULTS

Since some difference were observed between the two subjects, individual results are reported.

3.1 VELUM VERSUS LPW MOVEMENTS FOR ORAL VOWELS

Figure 3 and Figure 4 represent the results for isolated and continuous speech, respectively.

A first observation: subject 1 has a smaller nasal cavity than subject 2. This explain why there is a larger distance between the two LPW for subject 2. The absolute amplitude of movement of the LPW seems then to depend on the size of the nasal cavity, being larger for subject 2.

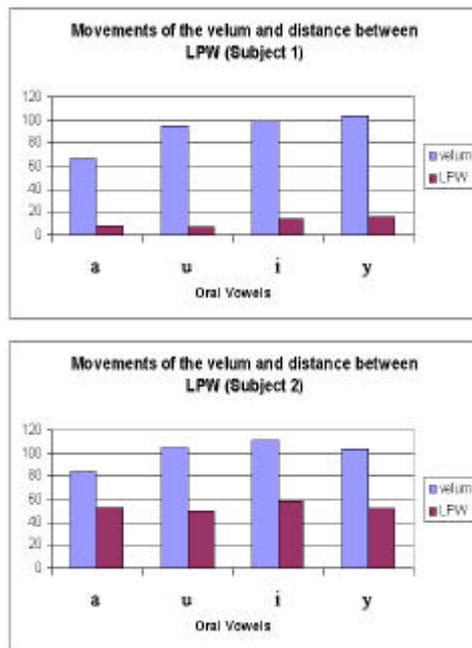


Figure 3: Mean of movement amplitude of the velum and distance between LPW for oral vowels in isolation. (LPW: high vertical bar = LPW is open. Velum: high vertical bar = velum is high).

A second observation: as expected, /a/ is the vowel pronounced with the lowest velum for the two subjects in both conditions. For what concerns the three other vowels, the results reveal that /u/ is the vowel with smaller distance between LPW.

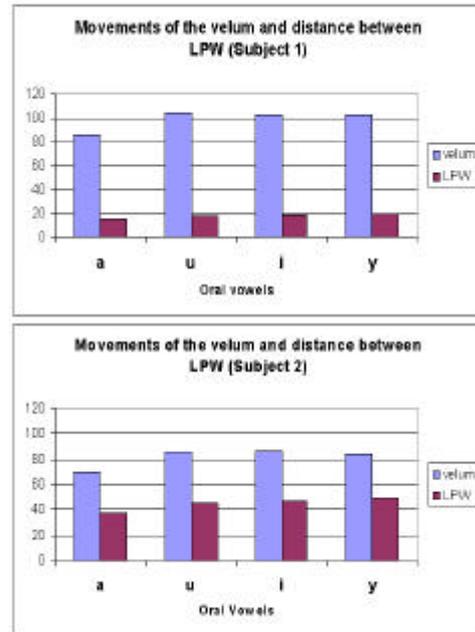


Figure 4: Mean of movement amplitude of the velum and distance between LPW for oral vowels in connected speech.

For what concerns LPW displacements, we observe that /a/ is pronounced with a smaller LPW movement in context for both and in isolation for subject 1 (the velum height in context: LPW (/a/) = 15 pixels, LPW (/i/) = 18, LPW (/u/) = 17 and LPW (/y/) = 19).

3.2 VELUM VERSUS LPW MOVEMENTS FOR NASAL VOWELS

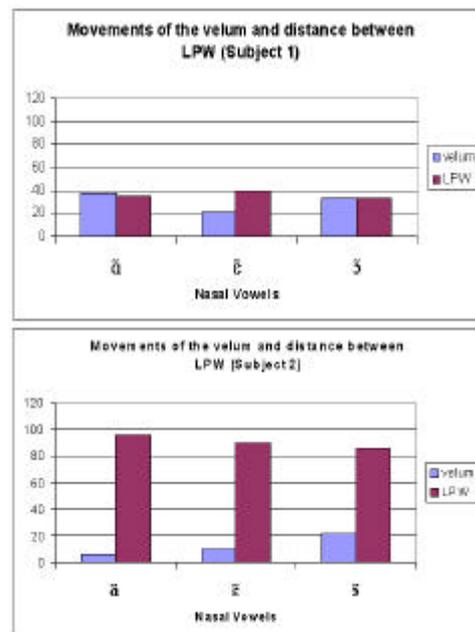


Figure 5: Mean of movement amplitude of the velum and distance between LPW for nasal vowels in isolation.

There is not a great difference between the LPW displacements between the three nasal vowels for the two subjects. For both, õ/ is the vowel with the smallest distance between LPW. There is however a difference in

velar movements. For the speaker 1, /ɛ̃/ is the vowel with the lowest velum and it is /ɑ̃/ for the subject 2. For both, /ɔ̃/ is the vowel with the highest velum.

For subject 2, but not subject 1, there is an excellent inverse correlation; velar movements move in the opposite of LPW movements.

Next, we observe velum movements and LPW distance in connected speech.

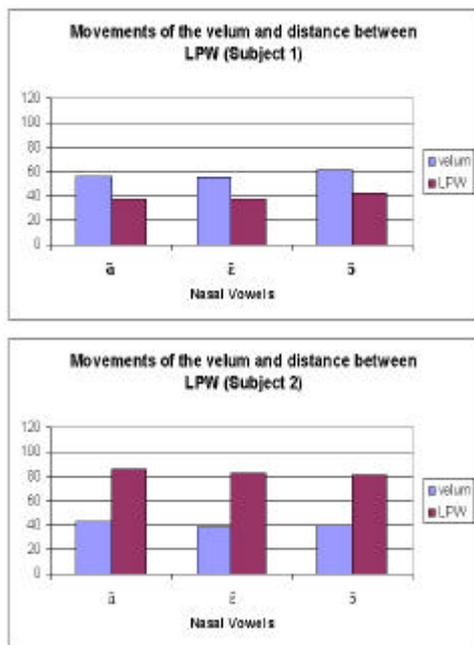


Figure 6: Mean of movement amplitude of the velum and distance between LPW for nasal vowels in connected speech.

The mean reveals no difference between the three nasal vowels concerning the distance between LPW. For subject 1, we notice that the velum is higher for /ɔ̃/ than /ɛ̃/. For subject 2, the results reveal no difference for velum movements between the three nasal vowels.

Note that there is a more variability of velum and LPW movements for nasal vowels in isolation than in connected speech. As often observed, isolation enhances the intrinsic difference between the vowels.

And finally, there is a more variability for velum movements for oral vowels than nasal vowels.

3.3 CORRELATION BETWEEN VELUM AND LPW MOVEMENTS

Of particular interest is the correlation of velum movements with LPW displacements. We observed the timing of opening and closing movements of the velum compared to LPW displacements.

The results show anticipatory movements of the LPW and velum in all cases, and the movements continue after the nasal vowel.

In the most cases, LPW acts in synchrony with the velum. So it completes action of the closure of the velum (as illustrated in Figure 7).

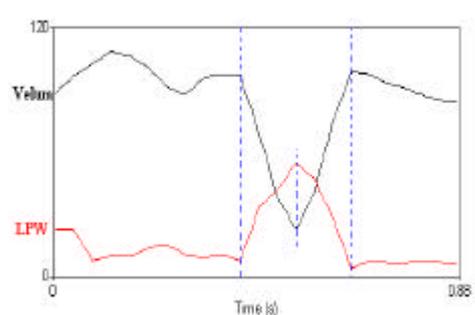


Figure 7: Example of perfect synchrony for the movements of the velum and LPW ([dadɛ̃da], Subject 1).

The table 1 shows the percentage of synchrony closure and open for subject 1 and subject 2.

	Open in the same time	Close in the same time
Subject 1	61 %	62 %
Subject 2	64 %	78 %

Table 1 : Synchronous timing between LPW and velum.

3.4 VELUM HEIGHT DEPENDING ON THE PRECEDING VOWEL

Despite some individual speaker differences noted above, we observed a strong variability of the velum for oral vowels. As a consequence, we studied the effect of the context. So we measured the velum during the nasal vowel in item CVC̃CV. We observed smaller velum height during the nasal when the following vowel is /a/ than the following vowel is an high vowel (as illustrated in Figure 8).

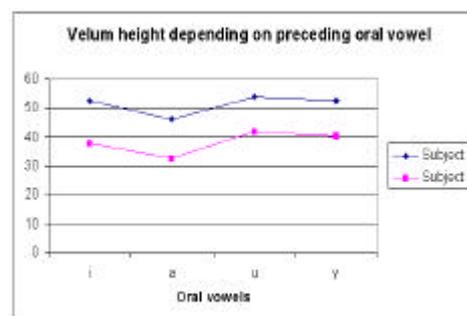


Figure 8: Velum height during the nasal vowels as a function of the identity of the preceding oral vowel (CVC̃CV).

We note the patterns of distribution are the same for the two speakers. The velum height effect discussed in 3.1 has a systematic and unexpected effect on the realisation of velum height in a following nasal vowel, despite the intervening consonant.

According to above results, we can predict that (1) velum will be the highest for the nasal vowel /ɔ̃/ in the sequence /itɔ̃/. Conversely, (2) velum will be the lowest for the nasal vowel /ɛ̃/ in the sequence (anɛ̃). The two predictions were realized for subject 2 (in /titɔ̃ti/, velum

height of / \bar{v} /=60 and in /nanēna/ velum height of / \bar{e} /=0,17). (2) was realised by the subject 1, but not (1).

4. DISCUSSION AND CONCLUSION

The results of these investigations indicate that velum and LPW movements are more variability for oral vowels than nasal vowels. Although, the movements of LPW are essentially the same for the 4 oral vowels, the tendency is to get a stronger closure for the high vowels. This is in agreement with some previous reports [11], [13] and [9] who found that the LPW was less open in the context of the high vowel (/u/, /i/) than the vowel /a/. The difference between the results of the present investigation and those report by [6], who found a stronger displacement of LPW, is probably due to the placement of the camera. [13] noted similar differences.

According to [7] [8], the observations done on prolonged, isolated vowels, may not be applicable to vowel in connected speech: there is a tendency for less closure on isolated vowels than in connected speech.

[3] found that / \bar{v} / and / \bar{a} / showed more closure than / \bar{e} / and / $\bar{œ}$ /. If the behaviour of nasal vowels is similar to oral vowels, this can explain why the nasal vowel / \bar{v} / is pronounced with a velum position higher in our study. For LPW and the velum, the movements start before the onset of the nasal vowel and stop after the offset of the nasal vowel.

In accord with [12], we found a very good correlation between LPW and the velum; The LPW act in synchrony with the velum and increase the effect of velar movements.

Phonetic context affects the velar closure characteristics for the vowels. It was demonstrated before by others that some phonemes are more resistant to assimilatory nasalisation than others (a voiceless stop is more resistant to nasalization than a nasal or a liquid). This study has shown that the movements of the velum are also influenced by the preceding vowel despite the intervening consonant. This is a case a vowel-to-vowel coarticulation [10]. Further data are needed to determinate how far velar movements depend on preceding or following phonemes. We can conclude that LPW displacements do not seem to be important for the study of velar movement in speech. For our two subjects, this is a close correlation between velum and LPW movements.

LPW are important for the study of pathology, like hypernasality. We did not observed significant differences between vowels, in isolation or in context. However, we observe a difference of height for the velum depending on the second phoneme preceding the nasal vowel.

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