A FIBERSCOPIC ANALYSIS OF NASAL VOWELS IN BRAZILIAN PORTUGUESE

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ABSTRACT

This paper examines velar movements during the production of the nasal vowels /ɐ̃, ĩ, ũ/ in Brazilian Portuguese (BP). Velum movements were measured for a female Brazilian speaker using fiberscopic video-recording synchronized with acoustic recording. The nasal vowel (V_n) was placed in initial, medial and final positions in nonwords with the following structure: $\mathbf{V_n}C_oV_o$, $C_o\mathbf{V_n}C_oV_o$, and $C_oV_oC_o\mathbf{V_n}$. The oral vowel V_o was /a, i, u/ and the oral consonant C_o= /p/, /b/ or /f/. Our results based on fibroscopy confirm that (i) a nasal "tail" (/N/) is clearly observed in 85% of nasal vowel productions, (ii) the nasal tail is about the same length as the previous part of the vowel. This suggests that (iii) when V_n is in medial or final position, the maximum lowering of the velum is free to occur either before the nasal tail or during it.

1. INTRODUCTION

According to the UPSID database, about 20% of the world's languages use nasality as a means to create vocalic contrasts [9]. Brazilian Portuguese (BP) is one of them. While the pharyngeal port is generally closed during phonation, the feature [nasal] is realized by velum lowering resulting in opening of the velopharyngeal port.

Portuguese is a language with five nasal monophtongues /ɐ̃, ẽ, ĩ, õ, ũ/ and four nasal off-gliding diphtongues /ɐ̃w̃, ẽj̃, õj̃, ũj̃/, here unconditioned according [14]. The nasal vowels are phonetically complex and the phonological status of which is controversial. For some authors, there are no phonological nasal vowels in BP, but a sequence of two phonemes: an oral vowel, contextually nasalized by a following nasal archiphoneme (/V/+/N/) ([2] [4] [6] [10]). Thus, [ˈsĩ^{n}tɐ] *cinta*, 'sash', is phonologically transcribed as /ˈsiNta/. The nasal archiphoneme /N/ nasalizes the preceding vowel (or at least part of it) and has more than one phonetic realization. It is generally homorganic with the following consonant ([^{m}] before [p, b]; [^{n}] before [t, d]; [^{ɲ}] before [ʃ, ʒ, tʃ, dʒ] and [^{ŋ}] before [k, g]. Furthermore, the preceding vowel, which is contextually nasalized, can be diphthongized, especially in word-final position (*e.g.*, [ˈsõ^{ŋ}] or [ˈsõw̃^{ŋ}] "som" 'sound', /ˈsoN/; [ˈsẽ^{ɲ}] or [ˈsẽj̃^{ɲ}] "sem" 'without', /ˈseN/). In these cases, the consonantal nasal archiphoneme is phonetically realized as homorganic with the preceding vowel. However, it also exists the possibility of the nasal archiphoneme /N/ not to be realized, and there is a lengthening of the nasal vowel ([5] [18]). Other authors consider the nasal vowel as a single phoneme (for a more detailed discussion of the different positions taken by phonologists, see [18].

Phonetically, the realization of the nasal phoneme typically has two phases: a vocalic nasal portion followed by a nasal tail ([15] [16]). [12] studied nasal vowels in BP by means of MRI (Magnetic Resonance Imaging) in order to view the velum position during the nasal vowels production. The vowels /ĩ, ã, ũ/ showed a lower velum position than oral vowels counterparts. The vowels /ẽ, õ/ also showed an opening of the velopharyngeal port. According to articulatory criteria, the authors suggest that there are 'fully' nasal vowels, as distinct from contextually nasalized vowels.

In the present paper, we contribute to the discussion by considering fiberscopic data. We present an articulatory analysis of the velum movement during the production of nasal vowels in BP, in order to assess the amount of velar propagation, to verify the results of Raposo de Medeiros and Demolin (2006) about the articulatory properties of the nasal vowels. The characteristics of the nasal tail and the moment when the velum lowers in BP will also be evaluated. From a fiberscopic video recording, the propagation of the velar movement during the production of three nasal vowels of BP for one speaker was measured.

2. METHODOLOGY

2.1. Speaker and corpus

One female Brazilian speaker (38-year-old, resident in the Rio Grande do Sul) recorded the corpus. The corpus is composed of three nasal vowels /ɐ̃, ĩ, ũ/ ($\mathbf{V_n}$) in nonwords of disyllabic structure $C_o\mathbf{V_n}C_oV_o$, $C_oV_oC_o\mathbf{V_n}$ and $\mathbf{V_n}C_oV_o$, with C_o = /p, b, f/; $\mathbf{V_n}$ = /ɐ̃, ĩ, ṵ̃/ and V_o = /a, i, u/. The nonwords are placed in the carrier sentence "Diz ___ pra ele" ([ˈdʒis pĩ^{m}pi ˈpɾaˈelɪ]) 'Say ___ for him', and each sentence has been repeated two times (n=54).

2.2. Data acquisition

Velopharyngeal movements were recorded with an Olympus ENF-P4 fiberscope linked to a cold light source and a video camera (Olympus OTV-SF) at a rate of 25 frames per second. The fiberscope was introduced through the left nostril, without local anesthesia. The endoscope was placed just above the velopharyngeal opening. A Sony ECMT15 microphone was attached to the endoscope, close to the subject's mouth. Audio signals and video sequences were simultaneously recorded directly with a computer by ATMOS platform set (http://www.atmosmed.de). The acoustic signal was sampled at 48 kHz in 16 bits resolution.

2.3. Analysis of the fiberscopic data

The velum movement was estimated visually from each image. The reference position was obtained from an image where the velum was maximally low, during respiration phase. In Figure 1, the left image shows the reference point (R_f). The right image indicates a frame during speech, which illustrates a measure of velum displacement (Ht). In this way, relative measures of velar movements are obtained. These movements are synchronized with the acoustic signal. The criteria used to label the velar movements were the same as those proposed in [1]: the beginning of the velar lowering is extracted during the first step of the strong depression from a complete velar cycle (lowering-maximum lowering-end of the rising). The end of the rising is also marked when the velum has a stable position (see Figure 2).

Figure 1: Left: velum position in respiration (maximal velopharyngeal opening) used as a reference position (Rf). Right: image obtained during speech, velar movement is estimated as Ht (measured in pixels).

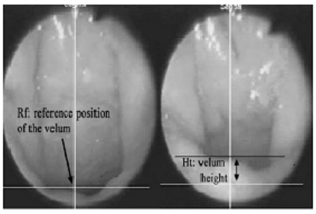
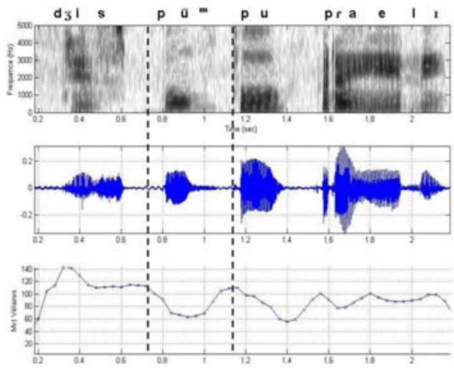


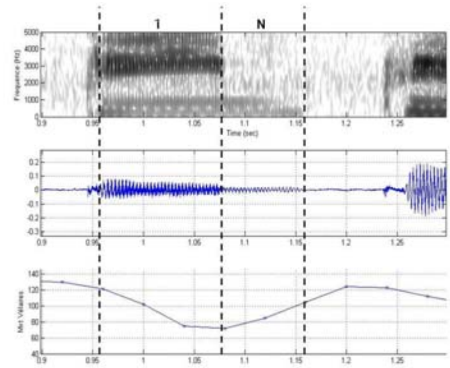
Figure 2: Interpolation of data to estimate the velar movement for the sequence: “Diz pumpu pra ele” ([ˈdʒis pũ^{m}pu ˈpɾaˈelɪ]); ‘Say pumpu for him’. The dotted lines (complete cycle) indicate the beginning of the lowering of the velum and the end of the rising.



2.4. Qualitative observations and measurements

A qualitative study suggests that the nasal vowel in BP may be acoustically composed by a vocalic part followed by a nasal tail. The criteria of segmentation for the nasal tail was estimated at the disappearance of F2 at the end of the vowel and the end of the nasal tail when also the lower frequencies disappear (see Figure 3). In the first section, we also observed the presence or not of the nasal tail for each production.

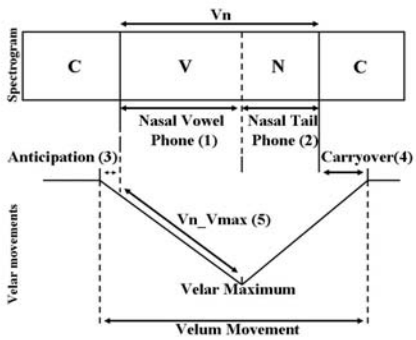
Figure 3: For example the nonwords “pimpi” placed in the sentence “Diz pimpi pra ele” ([ˈdʒis pĩ^{m}pi ˈpraˈelɪ]),‘ Say pimpi for him’.



We also measure the anticipation and the carryover of velar movements. In a study of French nasal vowels, [1] reveals that nasal vowels in French show a strong anticipation and a strong carryover of velar movements before and after the production of nasal vowels (which, by the way, often display a nasal tail), confirming also the universal tendency proposed by [11] and tentatively explained in [3].

We measure the durations of the (1) nasal vocalic phone, (2) nasal tail (consonantal) phone, (3) the anticipation of the velar movement before the production of the nasal vocoïd, (4) the carryover of the velar movement after the nasal tail and (5) the distance between the beginning of the nasal vowels and the maximum lowering of the velum (see Figure 4).

Figure 4: Illustration of the 5 durational measurements.



3. RESULTS

3.1. Presence of nasal tail in our corpus

Our results show that nasal tail is present in 85% of cases. In 8 cases out of 18 cases, in the context of the fricative /f/, we did not find a nasal tail, according to our criteria: part of the fricative may have been nasalized, but the lack of F1 may it difficult to identify it as a nasal tail. It seems that it is more difficult to find the nasal tail when the nasal vowel is followed by an unvoiced fricative consonant. [1] shows that fricatives are less permeable of the propagation of the nasality.

3.2. Acoustic length of nasal vocalic phone

Table 1: Mean and Standard Deviation (among parentheses) of the acoustic length (msec) of nasal vocalic phone analyzed for position in the nonword (n=6).

Vocalic Phone	Position in the Nonword		
	initial	median	final
[ɐ̃]	190 (39)	175 (31)	248 (41)
[ĩ]	174 (42)	155 (20)	198 (60)
[ũ]	103 (20)	136 (35)	164 (31)
Average length	156 (50)	155 (32)	203 (55)

As expected, the open vowels and the vowels in final position are longer than close vowels and vowels in non-final position.

3.3. Acoustic length of the nasal tail phone

Table 2 and Table 3 show the nasal tail is longer before /f/ than /p/ in final position.

Table 2: Mean and Standard Deviation (among parentheses) of the acoustic length (msec) of the nasal tail phone depending on consonantal context.

Vn	Nasal Tail Phone - Consonant Context		
	/p/	/b/	/f/
/ɐ̃/	88 (23) n=6	80 (15) n=6	81 (25) n=2
/ĩ/	86 (20) n=6	81 (20) n=6	71 (57) n=4
/ũ/	100 (32) n=6	91 (15) n=6	110 (15) n=4

Table 3: Mean and Standard Deviation (among parentheses) of the acoustic length (msec) of the nasal tail phone depending position in the nonword.

Vn	Nasal Tail Phone - Position in the Nonword		
	initial	median	final
/ɐ̃/	80 (12) n=4	90 (6) n=4	82 (27) n=6
/ĩ/	78 (17) n=4	60 (32) n=6	102 (24) n=6
/ũ/	88 (14) n=6	90 (23) n=4	117 (22) n=6

The acoustic nasal tail (average length: 88msec) is shorter than the three nasal vowels, independent of the context or position in the nonword (see Table 4).

Table 4: Mean and Standard Deviation (among parentheses) of the acoustic length (msec) of the nasal tail and nasal vowel phones independent of the context position in the nonword.

Vn	Nasal Tail and Nasal Vocalic Phones	
/ɐ̃/	84 (18) n=14	204 (48) n=18
/ĩ/	80 (31) n=16	176 (45) n=18
/ũ/	99 (23) n=16	134 (37) n=18
Average length	88 (26) n=46	171 (51) n=54

3.4. Timing between the beginning of the velar lowering and the beginning of the nasal vowel

Our results show that there is a difference of anticipation depending on the position of nasal vowel (Vn) in the nonwords (see Table 5).

Table 5: Mean and Standard Deviation (among parentheses) (msec) of the anticipation depending on the position in the nonword of nasal vowel (Vn) (n=6).

Vn	Anticipation		
	initial	median	final
/ɐ̃/	262 (207)	29 (20)	103 (136)
/ĩ/	300 (84)	24 (9)	27 (25)
/ũ/	229 (38)	87 (24)	51 (31)

For the three nasal vowels, the anticipation of the lowering of the velar movement is greater in word-initial position than in medial or final position.

3.5. Timing between the end of the nasal tail and the end of the lowering velar movement (carryover)

The carryover is more important in final position than in initial and medial positions (see Table 6). We confirm the results of [7] for French and [17] for English.

Table 6: Mean and Standard Deviation (among parentheses) (msec) of the carryover depending on the position in the nonword of nasal vowels (Vn) (n=6).

Vn	Carryover		
	initial	median	final
/ɐ̃/	50 (11)	58 (32)	183 (65)
/ĩ/	64 (27)	70 (21)	150 (61)
/ũ/	49 (11)	68 (18)	106 (45)

3.6. Timing between the begin of the nasal vowels and the maximum lowering of the velum

The timing between the beginning of the nasal vowels and the maximum lowering of the velum is greater in final position (Mean=185msec; StDev=57) that in medial position in the nonword (Mean=123msec; StDev=29) (n=18).

4. DISCUSSION AND CONCLUSION

When we add the acoustic length of nasal tail, the nasal vowels with the nasal tail are acoustically longer than the corresponding oral vowels. This goes into the direction of the presence of tow phonemes instead of one, but the nasal vowels are longer than their oral counterparts in French. And the nasal vowel with the nasal tail is longer than the nasalized vowels (nasal>nasalized>oral). [10] observed for the "carioca" dialect that in stressed syllables, oral vowels and (surface contrastive) nasal spans (c***a***pa, c***am***pa) had approximately the same length, due to the willingness of all stressed vowels to be of a certain length: i.e. weight-to-stress. On the other hand, in unstressed syllables (c***am***pinéiro c***a***poéira), nasal vowels were found to be significantly longer than oral vowels. Finally, as for the nasalized vowels, since in the dialect of Rio Grande do Sul allophonic nasalization only occurs in stressed syllables, it must be clearly stated that the stress conditions for the different vowel types were the same. As was suggested by [10], it would be interesting to compare the length of the BP nasal vowels with the French nasal vowels.

According to purely phonological criteria, in BP there are no nasal vowels, but a /VN/ sequence [18]. The nasal tail (from our criteria of segmentation) is not always present in all contexts, suggesting that the nasal tail is not a necessary condition for the production of nasal vowels. [10] did not find systematic lengthening of the nasal vowels before the fricatives, in the « carioca » dialect. However, for one speaker of the Brazilian northeast, the appearence of a nasal tail before the fricatives [s] and [ʃ] was observed by Sousa in 1994. It will be interesting to examine this phenomenon in different dialects.

We confirmed some results of [12], as lowered velum position during the production of the nasal vowels. According to our criteria of labeling, we show that the anticipation of the velar movement before the nasal vowel is systematic, although differs depending on the position in the nonwords. Using the same method of [1], we may conclude that our measurements in median position correspond to those in the same position. In addition, our measures for the word-initial position correspond to those found by [1] in isolated vowels. This phenomenon seems not to be pertinent for the contrastive vocalic nasalization between French and BP. Data from velar position during nasal consonant and nasal vowels show that an anticipatory lowering of the velum is not sufficient to explain the apparition of nasal vowels [13]. On the other hand, the maximum lowering of the velum seems to be different in French. Nevertheless, in BP, the maximum lowering of the velum is free to occur either before the nasal tail or during it. According oral/nasal airflow data, the vowel nasalization under the external emphatic stress, was significant in [ɔ̃] French that in [ĩ] BP [8]. It suggests that the nasalization is not only a binary movement of opening and closing of the velum. The opening of the velopharyngeal port is a necessary but not efficient condition to produced a nasal vowel. The position of the secondary articulation (like tongue position or lips) [19] seem to be more important to contrast nasalization between BP and French. However, it is necessary to confirm these evidences with other speakers, oral/nasal airflow measurements (simultaneous with articulatory measurements) and formant analysis.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Amelot, A. 2004. Étude aérodynamique, fibroscopique, acoustique et perceptive des voyelles nasales du français. Ph.D. dissertation, Paris: Université Paris III, Sorbonne Nouvelle. 203p.

[2] Battisti, E. 1997. A nasalização do Português Brasileiro e a redução dos ditongos nasais átonos: uma abordagem baseada em restrições. Ph.D. dissertation, Porto Alegre: Pontifícia Universidade Católica do Rio Grande do Sul - PUC/RS. 187p.

[3] Bell-Berti, F., Henderson, J.B., Honda, K. 1981. Velar coarticulation in nasal and oral vowel environments: A comparison of English and Hindi. *J. Acoust. Soc. Am.* 69, S55.

[4] Bisol, L. 1998. The nasality, an old theme. *DELTA* 14.

[5] Cagliari, L.C. 1977. An Experimental Study of nasality with Particular Reference to Brazilian Portuguese. Ph.D. dissertation, Edinbourg: University of Edinbourg. 320p.

[6] Camara Jr., J.M. 1999. *Estrutura da Língua Portuguesa*. Petrópolis: Vozes.

[7] Fougeron, C. 1996. Variation de débit nasal en fonction de la position prosodique de [n] et [ã] en français. *Proc. Actes des XXIes Journée d'Etude sur la Parole* Avignon, 215-218.

[8] Lovatto, L.R.P. 1999. La coarticulation et la nasalisation du français et du portugais brésilien. M.Sc. dissertation, Paris: Université de la Sorbonne Nouvelle - Paris III, ILPGA. 99p.

[9] Maddieson, I. 1984. *Patterns of sounds*. Cambridge: Cambridge University Press.

[10] Moraes, J.A., Wetzels, W.L. 1992. Sobre a duração dos segmentos vocálicos nasais e nasalizados em Português. Um exercício de fonologia experimental. *Cadernos de Estudos Lingüísticos* 23, 153-166.

[11] Passy, P.E. 1890. *Étude sur les changements phonétiques et leurs caractères généraux*. Paris: Firmin-Didot.

[12] Raposo de Medeiros, B., Demolin, D. 2006. Vogais nasais do Português Brasileiro: um estudo de MRI. *Proc. IV International Congress of the Abralin 2005* Brasília. In press Revista da Anpoll.

[13] Rossato, S. 2004. Quelques statistiques sur la nasalité vocalique et consonantique. *Proc. Journées d'Étude sur la Parole* Fès, 433-436.

[14] Sampson, R. 1999. *Nasal Vowel Evolution in Romance*. Oxford: Oxford University Press.

[15] Seara, I.C. 2000. Estudo acústico-perceptual da nasalidade das vogais do Português Brasileiro. Ph.D. dissertation, Florianópolis: Universidade Federal de Santa Catarina. 271p.

[16] Sousa, E. 1994. Para a caracterização fonético-acústica da nasalidade do Português do Brasil. M.Sc. dissertation, Campinas: LAFAPE/IEL, Unicamp. 170p.

[17] Vaissière, J. 1988. Prediction of velum movement from phonological specifications. *Phonetica* 45, 122-139.

[18] Wetzels, W.L. 1997. The lexical representation of nasality in Brazilian Portuguese. *Probus* 9, 203-232.

[19] Zerling, J.P. 1984. Phénomènes de nasalité et de nasalisation vocaliques: Etude cinéradiographique pour deux locuteurs. *Travaux de l'Institut de Phonétique de Strasbourg*, 241-266.