A FIBERSCOPIC ANALYSIS OF NASAL VOWELS IN BRAZILIAN PORTUGUESE

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ABSTRACT

This paper examines velar movements during the production of the ‘fully’ 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, f/. Our results confirm that (i) an acoustic nasal ‘tail’ N is clearly observed in 85% of V_n productions, (ii) when present, N is about half as long as the previous part of the vowel, and (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, leading to much variability.

1. INTRODUCTION

Portuguese has five nasal monophthongs /ɐ̃, ẽ, ĩ, õ, ũ/ and four nasal off-gliding diphthongs /ɐ̃w̃, ɐ̃j̃, õj̃, ũj̃/, [7]. The nasal vowels $\mathbf{V_n}$ are phonetically complex and their phonological status remains controversial.

Phonetically, $\mathbf{V_n}$ typically has two phases: a vocalic nasal portion (thereafter V), followed by a nasal tail (thereafter N) ([8, 9]). N is characterized by the presence of energy in the low frequencies. Furthermore, $\mathbf{V_n}$ are longer than their oral counterparts (the extra lengthening is often put down to the presence of N [9]). Raposo de Medeiros & Demolin (2006) suggest from MRI (Magnetic Resonance Imaging) data that $\mathbf{V_n}$ display the behavior of ‘fully’ nasal vowels, as in French [6], as opposed to contextually nasalized vowels.

For some authors [2, 5], there are no phonological nasal vowels in BP, only a sequence of two phonemes: a (contextually partly or fully nasalized) /V/ followed by a nasal archiphoneme /N/. [ˈsĩ^{n}tɐ] *cinta*, ‘sash’, is phonologically transcribed as /ˈsiNta/. The nasal archiphoneme /N/ 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 **/V/** 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/). Word-finally, /N/ is phonetically realized as homorganic with the preceding vowel. /N/ may not be realized, and its absence is compensated by a lengthening of V. According to Wetzels [11], nasal vowels in BP behave phonologically as bi-moraic sequences consisting of an oral vowel and a nasal mora /VN/. (See [11) for a discussion of the different positions phonologists have taken with regard to nasal vowels in BP).

The aim of our study was to supplement Raposo de Medeiros & Demolin’s study by (i) analyzing the acoustic duration of V and N, and (ii) investigating the relative timing of the velum movements and the acoustic onset and offset of V and N.

2. METHODOLOGY

2.1. Speaker and corpus

One female Brazilian speaker (38-year-old, resident in the Rio Grande do Sul) recorded 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 $\mathbf{V_n}$ = /ɐ̃, ĩ, ũ/, C_o = /p, b, f/; $\mathbf{V_n}$ = /ɐ̃, ĩ, ụ̃/ and V_o = /a, i, u/, and where $\mathbf{V_n}$ is stressed. The nonwords are placed in the carrier sentence “Diz ___ pra ele” ([ˈdʒis ___ ˈpɾaˈelɪ]) ‘Say ___ for him’. Each sentence has been repeated twice (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, and fixed to the nostril with elastoplast. A Sony ECMT15 microphone was attached to the endoscope, close to the subject's mouth. Audio signals and video sequences were simultaneously recorded with the Mediastrobo workstation TMOS (ATMOS, 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 position was estimated visually from each image. The reference position (R_f) (Fig. 1, left image) was taken during respiration phase, where the velum is maximally lowered. The difference between R_f and the actual measured position during speech (fig.1, left image) indicates the velum displacement (Ht). Hence, relative measures of velar movements are obtained. The criteria used to label the velar movements correspond to the presence of V_n, i.e. “beginning of lowering - maximum lowering - end of the rise” were the same as those proposed in [1].

3. QUALITATIVE OBSERVATIONS AND MEASUREMENTS

Spectrographic analysis confirms that the presence of N is not obligatory. When present, the beginning of N was marked at the disappearance of F2 at the end of V and the end of N at the time when the lower frequencies disappeared (see Fig. 3).

The durations of (i) V, (ii) N (whenever present), (iii) the anticipation of the velar movement before the production of V, (iv) the carryover of the velar movement after N and (v) the distance between the beginning of V and the maximum lowering of the velum were measured (see Fig. 4).

Figure 1: Left: Rf, upper part of the velum during respiration. Right: during speech. Velum height is estimated as Ht (measured in pixels).

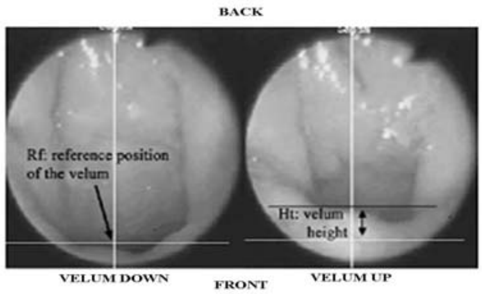


Figure 2: Top: spectrogram. Middle: acoustic signal. Bottom: Ht in the utterance: “Diz pumpu pra ele” ([ˈdʒis pũ^{m}pu ˈpɾaˈelɪ]); ‘Say pumpu for him’. The dotted lines indicate the beginning and end of the complete lowering-rising cycle for the production of Vn.

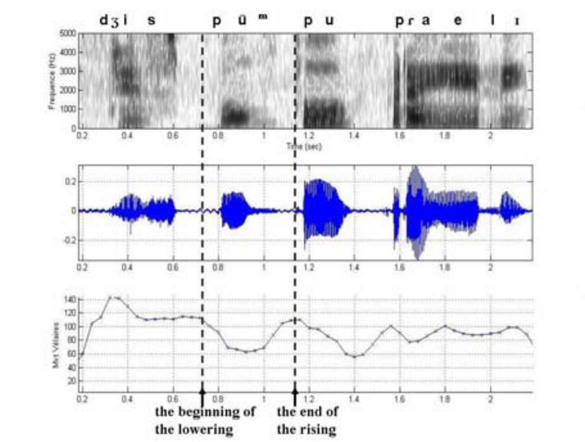


Figure 3: The same as Fig.2 for the nonword “pimpi” placed in the utterance “Diz pimpi pra ele” ([ˈdʒis pĩ^{m}pi ˈpɾaˈelɪ]),‘ Say pimpi for him’.

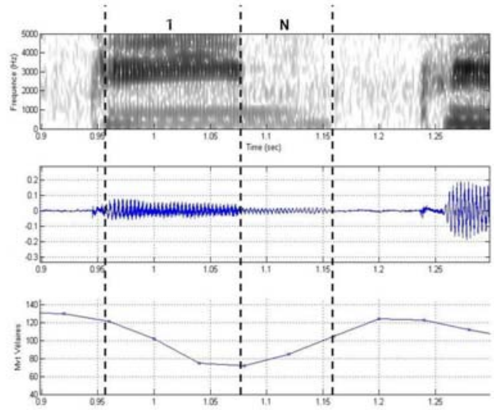
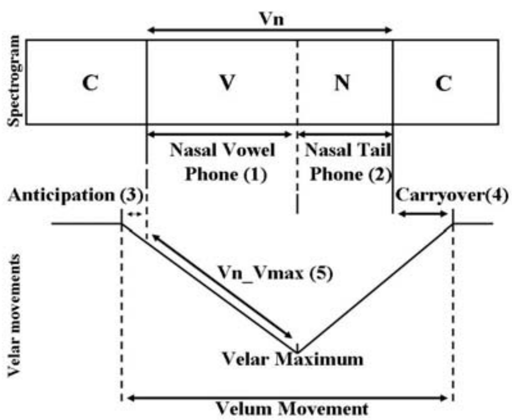


Figure 4: Illustration of the 5 measured durations.



4. RESULTS

4.1 Duration of V and N

Presence/absence of N: Our results show that N is present in 85% of cases. Out of the 18 cases where N is missing, 8 are $\mathbf{V_n}$ followed by /f/.

Acoustic length of V: As expected, the open vowel [ɛ̃] and the vowels in final position are longer respectively than closed vowels [ĩ] and [ũ]; they are also longer than the other vowels in initial and median position (see Table 1).

Table 1: Mean and Standard Deviation of the acoustic length of V (n=6), in milliseconds.

V	Position in the Nonword		
	initial	**median**	**final**
[ɛ̃]	*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)

Acoustic length of N: N is shorter (average length: 88 msec) than V (average length: 171 msec; see Table 4), independent of the context or position in the nonword. There seems to be no compensation between V and N duration. The results concerning N duration as a function of consonant context (Table 2), and as a function of the position in the nonword (Table 3) are inconsistant: more data are needed to determine the tendencies, if any.

Table 2: Mean and Standard Deviation of the acoustic length (msec) of N depending on consonantal context.

N	Nasal Tail Phone - Consonant Context		
	/p/	**/b/**	**/f/**
/ɛ̃/	**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 of the acoustic length (msec) of N depending on its position .

N	Nasal Tail Phone - Position in the Nonword		
	initial	**median**	**final**
/ɛ̃/	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

Table 4: Mean and Standard Deviation of V and N duration, independent of the context position in the nonword.

N and V	Nasal Tail and Nasal Vocalic Phones	
/ɛ̃/	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

4.2 Timing between acoustic and articulatory events

Table 5 : Mean and Standard Deviation of the anticipation as a function of the position in the nonword of nasal vowel (n=6).

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

Anticipation: For the three nasal vowels, the anticipation of the lowering of the velar movement is greater in word-initial position than in median or final position (see Table 5).

Table 6: Mean and Standard Deviation of the carryover as a function of the position of Vn in the nonword (n=6).

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

Carryover: is more important in final position than in initial and medial positions (see Table 6) (see also [3] for French and [10] for English).

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

5. DISCUSSION AND CONCLUSION

V plus N, composing **V_n**, are acoustically longer than the corresponding oral vowels, and are known to be longer than the contextually nasalized oral vowels (nasal>nasalized>oral). The longer duration of **V_n**, as compared to **V_o** is in favour of an analysis in terms of two phonemes (/V/ + /N/) rather than a single **V_n**. Note, however, that the argument provided by length is not conclusive and raises new issues: (i) in French, **V_n** are also longer than **V_o** (and there is always a short nasal tail, not audible, at least in Parisian French); (ii) lengthening is not always observed in BP: [5] did not find systematic lengthening of **V_n** before the fricatives, in the « Carioca » dialect (though, for one speaker of the Brazilian Northeast, the appearance of N before the fricatives [s] and [ʃ] was observed by Sousa in 1994); (iii) an acoustic N is not always present, suggesting that N is not a necessary condition for the production of **V_n** ; (iv) it was observed in [5], for the "Carioca" dialect, that oral vowels and 'nasal vowels' spans (e.g. c***a***pa and c***am***pa) have approximately the same length in stressed syllables, due to a rhythmic constraints: all stressed vowels have to be of a certain length, i.e. weight-to-stress. On the other hand, in unstressed syllables (c***am***pinéiro c***a***poéira), **V_n** were found to be significantly longer than **V_o**. Furthermore, in the dialect of Rio Grande do Sul, contextual nasalization only occurs in stressed syllables. A lower velum has been observed in [10] for **V_o** preceding an nasal coda in stressed position, as compared to unstressed position for American English. Observations in [5] and [10] and our observations lead us to suggest a different state of phonologisation of the nasality feature for stressed and unstressed **V_n**: phonological nasalisation of the vowels is more advanced (but not complete) in the stressed syllables, as compared to the unstressed syllabes. Maeda (personal communication) suggested that in French, the nasality feature is coded *in parallel* with the vowel, and whereas this feature is still coded *sequentially* in BP.

Our data confirm that the anticipation of the velar movement before the nasal vowel is systematic, although this is strongly influenced by vowel position. There were strong similarities with data observed for French in [1], which were segmented using the same criteria. On the other hand, in BP, the timing of the maximum lowering of the velum is more variable than in French: it occurs either before the nasal tail or during it (see also [4], for comparative oral/nasal airflow data in BP and French concerning vowel nasalization under external emphatic stress). It would be interesting to examine further data in different BP dialects, and to compare them with similar data in languages like English and French, where the status of nasality differs.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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