EXCRESCENT NASAL CODAS IN BRAZILIAN PORTUGUESE: AN ELECTROPALATOGRAPHIC STUDY

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ABSTRACT

While a brief or lightly-articulated nasal consonant has long been reported after word-final nasal vowels in Brazilian Portuguese (BP), little is known about its place of articulation or factors contributing to its occurrence. The results of an electropalatographic (EPG) study indicate that the consonant's emergence is most likely tied to the tongue position of the nasal vowel and that its place is either post-palatal or velar. The occlusion is more likely to occur after high and front vowels than low and back vowels (insofar as this occlusion can be assessed by EPG). This suggests that the articulation of the consonant is epiphenomenal; it is conditioned by the lowered velum and the raised tongue body or by the acoustic consequences of these events.

Keywords: nasal vowels, stop excrescence, Brazilian Portuguese, EPG

1. INTRODUCTION

While widely attested in Romance languages [18] the emergence of a nasal coda after word-final nasal vowels in Brazilian Portuguese (BP) has been confirmed only partially by experiments. It is unclear whether the phenomenon is motivated by perceptual confusion or transitory linguopalatal contact due to velic lowering and/or tongue raising. Oral flow stoppage strongly suggests the presence of oral occlusion at the end of BP nasal vowels; high nasal vowels are more likely to manifest this occlusion [19]. However, because oral flow may be stopped by glottal occlusion, as well, previous aerodynamic work provides only an indirect and partial account of the phenomenon. More direct evidence of oral occlusion, along with the consonant's place of articulation will be presented here using EPG (electropalatography). It should be noted that conventional EPG does not extend to the soft palate, where linguopalatal contact associated with the BP excrescent nasal coda may sometimes occur.

Reports of a nasal consonant after a word final nasal vowel in BP words like *fim* /fĩ/ 'end' are frequent [1, 10, 13, 15, 16, 19]. The sound has been described as a velar regardless of vowel context [12]. [1] claims it is alveopalatal after front vowels and velar after back vowels.

2. METHODS

2.1. Speakers

Participants were three female speakers of Brazilian Portuguese with a median age of 30. Speaker 1 is from Rio de Janeiro, Speaker 2 is from São Paulo, and Speaker 3 is from Salvador.

2.2. Materials

Test items were either monosyllabic words or polysyllabic words with stress on the last syllable; nasal vowels were always in final position (for a complete list see [19] p. 54–55). There were nine tokens for each of the five vowels. These were repeated three times for a total of 135 (9×5×3) tokens per speaker. Speakers produced tokens in the carrier phrase, *Digo* ___ *agora* 'I say ___ now'. Due to the possibility of velic mistiming, the onset of the final word in the carrier phrase had to be a vowel. In addition, a low vowel in this position decreased the possibility that the contact pattern of the coda, if it emerged, would be confounded with the contact pattern of a following high / front vowel.

2.3. Instrumentation

Speakers wore custom-fitting Reading-style artificial palates [7]. EPG data were gathered at 100 Hz using an Articulate Instruments WinEPG system [5, 22]. Audio was sampled at 22.05 kHz. Audio and EPG data were compiled into Matlab data structures.

2.4. Annotation

Using custom-written software running in Matlab 2009b, data were annotated with two boundaries based on the sound pressure signal. For example, in the phrase *Digo atum agora* ‘Say tuna now’ a boundary was placed at the beginning of the nasal vowel [ũ] and at the end of the first vowel in *agora*. The nasal coda was expected to appear somewhere in this portion of the signal. Annotated vowel sequences are provided in Figures 1 and 2. The time-averaged EPG patterns in these annotated regions are provided in Figure 3.

Figure 1: Audio signal and EPG contact indices corresponding to /ĩa/ in the utterance *Digo aipim agora* ‘I say sweet cassava (*Manihot aipi*) now’ uttered by Speaker 2. Squares = complete occlusion (when value is 1); circles = CAI; filled diamonds = CCI. Annotation boundaries are marked with dashed vertical lines.

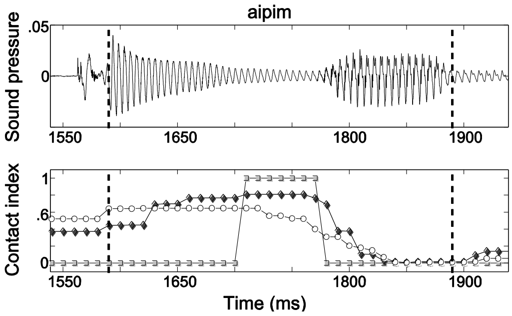


Figure 2: Audio signal and EPG series corresponding to /ẽa/ in the utterance *digo quem agora* ‘I say who now’. Conventions as in Figure 1.

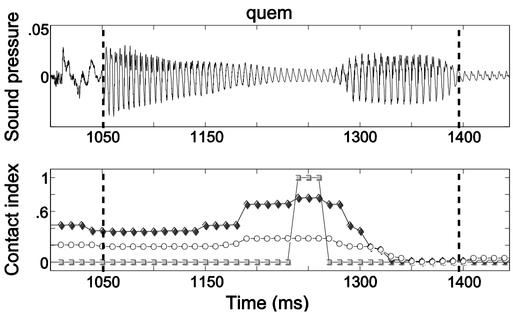
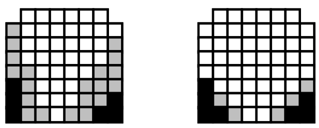


Figure 3: EPG contact pattern during annotated regions shown in Figures 1 (a) and 2 (b). Black indicates sensor activation in more than 80% of frames in the region; gray = 40-80%; unfilled = less than 40%. Complete occlusion is not visible because it occurs during less than 40% of the frames in each time series.

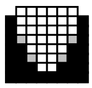
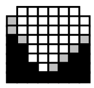
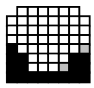
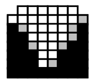
(a) *aipim* (b) *quem*



2.5. Measures

Complete occlusion in the EPG signal was defined as “full electrode activation on one or more rows” of the artificial palate [9]. Both the presence and duration of complete occlusion were computed. In addition, the contact anteriority index (CAI) and contact centrality index (CCI) of the articulation were computed during the complete occlusion, when it occurred [4]. A CAI value approaching 1 indicates contact of all sensors on the first (most anterior) row of the palate; a CCI value approaching 1 indicates contact of all sensors in the two center columns (the sagittal midline) of the palate. Thus, CAI is related to place of articulation and CCI is related to consonantal constriction. Ensemble-averaged linguopalatal configurations (Figure 4) of the occlusion, when present, were generated following conventions used by [17].

Figure 4: Ensemble-averaged linguopalatal configurations of the occlusion associated with /ĩ/ (S1, S2, and S3) and /ẽ/ (S2). Conventions as in Figure 3. Only occluded tokens (e.g., 15 tokens of S1 /ĩ/) are included in the averages.

S1	S2		S3
/ĩ/	/ĩ/	/ẽ/	/ĩ/
			
N=15	N=27	N=17	N=14

3. RESULTS

3.1. Frequency of occlusion

Table 1 gives counts of occlusive and non-occlusive tokens, as well as the percentage of occlusive tokens for each nasal vowel, organized by speaker. For all three speakers, the vowels /ã õ ũ/ manifested no linguopalatal occlusion.

Table 1: Counts and percentages of occlusive tokens for each nasal vowel by speaker.

Vowel	Speaker 1	Speaker 2	Speaker 3
/ ã/	0/27	0/27	0/27
/ẽ/	0/27	17/27 = 63%	0/27
/ĩ/	15/27 = 56%	27/27 = 100%	14/27 = 52%
/õ/	0/27	0/27	0/27
/ũ/	0/27	0/27	0/27

For Speaker 1, only /ĩ/ manifested occlusion (in 56% of tokens). For Speaker 2, /ẽ/ manifested occlusion in 63% of tokens; all tokens of /ĩ/ manifested occlusion for this speaker. For Speaker 3, only /ĩ/ manifested occlusion (in 52% of tokens). The low vowel / ã/ never manifested occlusion on the artificial palate, nor did the back vowels /õ/ and /ũ/. Vowel height was significantly associated with occlusion [$\chi^2(405,4)=197$, $p<0.001$].

3.2. Linguopalatal configuration

Figure 4 presents the ensemble-averaged linguopalatal configurations for the occluded portion of /ĩ/-tokens (Speakers 1, 2, and 3) and /ẽ/-tokens (Speaker 2). The point of occlusion generally corresponds to the posterior-most row of the palate, which is customarily labeled 'post-palatal' [4]. It is possible that the occlusion is still more posterior than the EPG data reflect (i.e., velar), since the occlusion could conceivably occur behind the artificial palate, on the surface of the soft palate. Greater anterior contact for /ĩ/ is observed; this pattern is expected based on the forward projection of the tongue during /i/ [2].

The average length of occlusion associated with /ĩ/ was 77 ms for Speaker 1 (SD = 37), 130 ms (SD = 28) for Speaker 2, and 92 ms (SD = 32) for Speaker 3. The mid-close vowel /ẽ/ manifested an occlusion of 65 ms (SD = 31) for Speaker 2. In a one-way ANOVA with length of occlusion as dependent variable and vowel quality as predictor, length of occlusion was significantly associated with vowel quality [$F(1,71)=16$, $p<0.001$].

The average CAI of the /ĩ/-occlusion was 0.74 (SD = 0.06) for Speaker 1, 0.54 (SD = 0.1) for Speaker 2, and 0.64 (SD = 0.6) for Speaker 3. Speaker 2's /ẽ/-occlusion had a much lower CAI of 0.3 (SD = 0.01). In a one-way ANOVA, CAI of occlusion was significantly associated with vowel [$F(1,71)=124$, $p<0.001$]. This reflects the relative lack of anterior contact in the articulation of the mid-close vowel with respect to the high vowel (Figure 4). For reference, [17] report a CAI of 0.86 (SD = 0.08) for Majorcan Catalan /ɲ/, which they describe as alveopalatal. [21] report an average CAI of 0.5 (SD = 0.1) for BP intervocalic /ɲ/ preceded by /e/ and followed by /a/ (an environment similar to the one used in the present study). Again for BP /ɲ/, [21] report a mean CCI of 0.4 (SD = 0.11). This suggests that the excrescent nasal coda described here (mean CCI = 0.78, SD = 0.03) is both more posterior and more occluded than BP /ɲ/ (reportedly realized as a nasal approximant) [6, 10, 20].

4. DISCUSSION

Though limited to only three speakers, each from a different dialect of BP, the present results confirm the presence of a nasal coda after the front nasal vowels of BP (particularly the high vowel). The place of this occlusion is either post-palatal or velar, suggesting that the raised tongue dorsum is responsible for the articulation. Contact between the tongue and hard palate limits the likelihood that BP's nasal coda is *velic*, i.e. articulated by the lowered velum instead of the rising tongue body, as suggested by [19]. These results do not preclude the occurrence of velar nasal codas after low and/or back nasal vowels in BP. Due to limitations in the size and shape of the conventional artificial palate, it is not clear whether the nasal vowels /ã/, /õ/, and /ũ/ terminate in a more posterior nasal consonant. It remains to be seen whether more posterior codas may be articulated in this way. Imaging techniques like ultrasound and MRI will be required to make this determination.

Airflow evidence for BP spoken in Rio de Janeiro suggests that an excrescent nasal coda is possible after /ũ/ and /õ/ (with greater frequency than after /ẽ/) but never after /ã/ [19]. Based on the present study, it seems safe to say that codas after /õ/ and /ũ/, when they occur, are most likely velar, i.e., posterior to the observational range of conventional EPG. This suggests that [1] was correct in identifying two places of articulation for the nasal coda, depending on the quality of the nasal vowel.

It is not clear why nasal consonants in BP seem to emerge preferentially after high vowels. [19] noted that the lowered velum and the rising tongue body may act synergistically, resulting in a velic consonant; there is some support for this hypothesis in reports of muscle activity during Hindi high / front vowels [3]. Tongue dorsum vertical position often shows saturation effects by contacting the soft palate during nasalization (p.c. Osamu Fujimura, February 9, 2011). This is more likely to occur for high versus low nasal vowels. The present results do not offer positive evidence that the soft palate has anything to do with the articulation of the linguopalatal occlusion. Because the artificial palate is anchored to the teeth it does not lower due to the activity of the velum. When the EPG registers tongue contact, the tongue is clearly rising to meet the palate. Of course, the post-palatal contact that registers on the artificial palate may simply be the most anterior point of a lengthier posterior occlusion that does involve the soft palate. This must be determined using an alternative imaging technique.

The relatively close acoustic and visual relationship between nasal vowels and velar nasals [8, 14] may explain why linguopalatal occlusion is tolerated for nasal vowels in BP, but it does not explain why high vowels are affected in particular.

Oral impedance is high for both nasal consonants and high nasal vowels, which may lead to similar acoustic consequences.

Finally, the 'epiphenomenal' status of the nasal coda in BP phonology should be addressed. The duration of the occlusion supports the possibility that it is not merely transitory, but may be used to cue the phonemic nasal distinction among some vowels. The present results suggest that after /ĩ/, the occlusion is on average 77–130 ms long; for /ẽ/ the occlusion is about 65 ms long. Thus, the /ĩ/-occlusion is longer than that reported for other nasal consonants of BP, including /m/ (75 ms), /n/ (47 ms) and /ɲ/ (37 ms) [11]. The length of the /ẽ/-occlusion is intermediate between /m/ and /n/. In terms of duration, this puts the excrescent nasal consonant of BP on equal footing with the phonemic nasal consonants of the language.

5. CONCLUSION

BP front nasal vowels (particularly the high vowels) frequently terminate in a post-palatal or velar nasal consonant. The results of this experiment demonstrate that the emergence of this consonant after nasal vowels is strongly tied to vowel quality and thus, presumably, to tongue position. The duration of the consonant, on par with that of the phonemic nasal stops of BP, suggests that the stop may be acoustically salient to listeners. It is still unclear whether the preferential development of the velar nasal in high vowel contexts is motivated by the acoustics of nasality, by the proximity of the tongue dorsum and lowered velum, or both.

6. REFERENCES

[1] Almeida, A. 1976. The Portuguese nasal vowels: Phonetics and phonemics. In Schmidt-Radefeldt, J. (ed.), *Readings in Portuguese Linguistics*. Amsterdam: North-Holland Publishing Company, 350-391.

[2] Buchaillard, S., Perrier, P., Payan, Y. 2009. A biomechanical model of cardinal vowel production: Muscle activations and the impact of gravity on tongue positioning. *J. Acoust. Soc. Am*. 126, 2033-2051.

[3] Dixit, R.P., Bell-Berti, F., Harris, K.S. 1987. Palatoglossus activity during nasal/non-nasal vowels of Hindi. *Phonetica* 44, 210-226.

[4] Fontdevila, J., Pallarès, M.D., Recasens, D. 1994. The contact index method of EPG data reduction. *J. Phon*. 22, 141-154.

[5] Gibbon, F.E., Yuen, I., Lee, A., Adams, L. 2007. Normal adult speakers' tongue palate contact patterns for alveolar oral and nasal stops. *Int. J. Speech Lang. Pathol*. 9, 82-89.

[6] Hajek, J. 1997. *Universals of Sound Change in Nasalization*. Oxford: Blackwell.

[7] Hardcastle, W.J., Gibbon, F.E. 1997. Electropalatography and its clinical applications. In Ball, M.J., Code, C. (eds.), *Instrumental Clinical Phonetics* London: Whurr, 149-193.

[8] Johnson, K., DiCanio, C., MacKenzie, L. 2007. The acoustic and visual phonetic basis of place of articulation in excrescent nasals. *UC Berkeley Phonology Lab Annual Report* 529-561.

[9] Liker, M., Gibbon, F.E., Wrench, A., Horga, D. 2007. Articulatory characteristics of the occlusion phase of /tʃ/ compared to /t/ in adult speech. *Int. J. Speech Lang. Pathol*. 9, 101-108.

[10] Lipski, J.M. 1975. Vowel nasalization in Brazilian Portuguese. *Can. J. Ling*. 20, 58-77.

[11] Martins, M.R.D. 1975. Vogais e consoantes do português: Estatística de ocorrência, duração e intensidade. *Bol. Fil*. 24, 1-11.

[12] Morais-Barbosa, J. 1962. Les voyelles nasales portugaises: Interpretation phonologique. *Proc. 4th ICPhS* Helsinki, 691-709.

[13] Nobiling, O. 1903. Die nasalvokale in Portugiesischen. *Die Neueren Sprachen* 11, 129-153.

[14] Ohala, J.J., Ohala, M. 1993. The phonetics of nasal phonology: Theorems and data. In Huffman, M.K., Krakow, R.A. (eds.), *Nasals, Nasalization, and the Velum*. San Diego: Academic Press, 225-249.

[15] Paradis, C., Prunet, J.-F. 2000. Nasal vowels as two segments: Evidence from borrowings. *Language* 76, 324-357.

[16] Parkinson, S. 1983. Portuguese nasal vowels as phonological diphthongs. *Lingua* 61, 157-177.

[17] Recasens, D., Espinosa, A. 2006. Articulatory, positional and contextual characteristics of palatal consonants: Evidence from Majorcan Catalan. *J. Phon*. 34, 295-318.

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

[19] Shosted, R.K. 2006. Vowel context as a condition for nasal coda emergence: Aerodynamic evidence. *J. Int. Phon. Assoc.* 36, 39-58.

[20] Shosted, R.K., Hualde, J.I. 2009. The production and provenance of palatal nasals in Portuguese and Spanish. In Colina, S., Olarrea, A.., Carvalho, A.M. (eds.), *Romance Linguistics 2009: Selected Papers from the 39th LSRL*. Amsterdam: John Benjamins.

[21] Shosted, R.K., Hualde, J.I., Scarpace, D. Accepted. Palatal complexity revisited: An electropalatographic analysis of /ɲ/ in Brazilian Portuguese with comparison to Peninsular Spanish.

[22] Stone, M. 2006. Imaging and measurement of the vocal tract. In Brown, K. (ed.), *Encyclopedia of Language and Linguistics, 2nd edition*. Amsterdam: Elsevier, 526-539.