Nasal Coda Restoration in Brazilian Portuguese

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ABSTRACT

Certain dialects of Brazilian Portuguese (BP) show signs of nasal coda restoration (NCR). Results of an instrumental study suggest that stressed, word-final nasal vowels terminate in a velar nasal stop, though word-final nasal stops are presumed to be banned in BP. Four BP speakers uttered words ending in a stressed nasal vowel. A split flow mask sampled nasal and oral airflow. Complete oral occlusion is shown to occur after high nasal vowels. Duration of closure is greater after high vowels than mid and low vowels and greater after high back vowels than high front vowels. This suggests the occlusion is epiphenomenal: the lowered velum and tongue dorsum are in closest proximity during periods of velopharyngeal aperture when the tongue position is both [+HIGH] and [+BACK]. The principal moving articulator may in fact be the lowering velum instead of the rising tongue dorsum, an indication of *velic* closure.

1. INTRODUCTION

1.1 The status of nasal vowels in BP

BP has a series of five nasal monophthongs and five nasal diphthongs: /ĩ ẽ ɐ̃ õ ũ/ and /ɐ̃ũ ɐ̃ĩ ẽĩ õĩ ũĩ/. Nasal consonants are said to be banned in word-final position. Phonetic [m, n, ŋ] occur in this position only when followed by a homorganic stop in the next word's onset. Vowels in BP are regressively nasalized when they occur in a VN sequence. A phonological interpretation of the Portuguese nasalization facts has long been debated. At the heart of the discussion is the question, should Portuguese [+NASAL] vowels be considered inherently nasal vowel phonemes or nasalized allophones derived from underlying VN sequences? Sampson (1999:177) argues for nasal vowel phonemes by citing psycholinguistic evidence that BP speakers are unaware of the nasal consonant in VN sequences. In opposition to this claim, Lipski (1975:64) reports illiterate speakers of BP who reduce participial forms of verbs like *rezando* 'praying' to *rezano*, demonstrating the psychological reality of a nasal consonant (N), not just a nasalized vowel (otherwise, **rezão* is expected).

Thus, many claim that an underlying N conditions all BP [+NASAL] vowels. Parkinson (1983) argues against underlying N based on observations of glides that emerge between word-final nasal vowels and subsequent word-initial oral vowels. BP Speakers produce glide elements rather than glottal stops between vowels at word junctures. The glide corresponds to the first vowel in roundness. According to Parkinson, this holds in cases of hiatus between nasal vowel and oral vowel as well. In a phrase like *sem óculos* 'without spectacles,' Parkinson predicts the phonetic output [sẽj̃ɔkuluʃ]. If an underlying N existed, it would presumably prevent the emergence of a glide. In the present study, empirical evidence demonstrates that the consonant following some word-final nasal vowels is not a nasal glide but a *nasal stop* (in the sense that no air escapes through the mouth).

Nobiling (1903) was perhaps the first to posit an underlying nasal glide element after Portuguese word-final nasal vowels. He transcribed the glide as [g̃] and called it a velar nasal "without complete oral closure" (as cited in Lipski 1975:72). Over the years, the basis for his transcription has been set in the context of the phonological debate over the phonemic or allophonic status of Portuguese nasal vowels. Nobiling's transcription might have come closer than previously thought to accurately indicating complete velar closure after word-final nasal vowels.

1.2 VN Diachrony in Romance

Traditionally, vowel nasalization has been understood to fall into two stages. In the first stage, a vowel nasalizes when it is adjacent to N. This may be attributed to mistiming of the velic gesture, for the velum is a relatively slow-moving speech organ. If it lowers in preparation for an upcoming N while a vowel is still being produced, the vowel must be partially nasalized (regressive nasalization). The second stage involves the deletion of the erstwhile-conditioning N. Residual nasalization may remain after N is deleted, such that the coda-less vowel now appears phonemically nasal. In reality, the diachronic phonemicization of nasalized vowels is more complex (see Sampson 1999:26 for influential variables). VN reflexes in BP undergo a fourth stage, the reinstitution of an oral occlusion. Following Sampson (1999:260), this stage is called *nasal coda restoration* (NCR).

NCR is not without exemplars in Romance, where it occurs in Old Gascon, Provençal, and Galician (see Sampson, 1999:146, 150-151, 207 for examples). NCR has resulted in the loss of unconditioned nasal vowels in Galician, where the phenomenon began occurring as early as the fourteenth century. Regarding NCR dialects of Italian, Sampson (1999:260) remarks that the restored nasal coda is "of variable duration and degree of occlusion," reminiscent of Nobiling's (1903) characterization of Portuguese [g̃] as an

 ISBN 1-876346-48-5

engma lacking complete oral closure. However, in neither case are empirical data submitted to demonstrate the degree of oral occlusion. Northern Italian data suggest that stress and length enhance the potential for NCR. In Bolognese, Hajek (1991) argues that the restored nasal consonant is actually the second mora of a long unconditioned nasal vowel which first developed into a glide and then "hardened" into a full nasal consonant. The current study gives a phonetic explanation for this so-called hardening.

2. Experimental methods

To better understand the nature of velic aperture in the articulation of BP nasalized vowels, aerodynamic measurements were taken in the UC Berkeley Phonology Laboratory. The subjects in the study were three female speakers and one male speaker of BP, all 20-30 years old. Three of the subjects (two females and a male) were from São Paulo and one (female) was from Bahia. Comparable results from a pilot study involving a female speaker from Minas Gerais are not reported here.

Measurements of oral and nasal airflow supply indirect evidence of soft palate movement. Other more invasive techniques are more difficult to implement, as they may cause discomfort to the subject. Acoustic techniques for measuring nasalization are complicated by the fact that no single acoustic property correlates with nasalization (Cohn 1990:26).

Two pressure transducers, one at the oral and one at the nasal exit, can convert pressure fluctuations into time-varying electrical signals. A split flow mask, in which oral and nasal chambers are separated, allows the simultaneous recording of these signals. The mask covers the face from the chin to the bridge of the nose. A divider between the chambers rests on the upper lip, sealing the two compartments. A Rothenberg split flow mask produced by Glottal Enterprises was used in the present study.

Potential difficulties in obtaining reliable data from the device are discussed by Cohn (1990:29). Leakage might occur between the nasal and oral cavities, the mask might adversely affect normal jaw movement, or an adequate seal might not form against the speaker's face. To minimize these possibilities, the technique for using the mask was demonstrated to consultants and a series of trials was performed. During recording, when the mask slipped off the mouth or nose (easily detected by a flat line in the signal), the utterance was recorded again.

An acoustic recording of the utterances was made in synchrony with the aerodynamic recording. Though the mask diminished the quality of the audio signal, robust distinctions (e.g. between stop closures, fricatives, and vowels) could still be retrieved. These distinctions provided useful landmarks for segmenting the aerodynamic records. The subjects inserted tokens into a carrier phrase, thus controlling the intonation pattern and providing a frame in which to locate the segments under investigation.

Absolute values of oral airflow in ml/s were obtained by calibrating the oral component of the split flow mask. The nasal component of the mask was not calibrated. Strictly speaking, the relationship between nasal and oral airflow can be determined without calibration as long as positive and non-positive flow can be deduced. Zero-points are identified by finding periods in the signal where zero flow is expected to occur based on physiological and aerodynamic principles (e.g. no nasal flow during fricatives; no oral flow during stop closures). Nonetheless, by feeding known amounts of airflow into the mask, the electrical output (mv) from the oral transducer was translated into ml/sec. The relationship between these amounts of flow and the transducer output resulted in a linear equation whose correlation coefficient equaled 0.999.

Next, the aerodynamic signal was parsed into phonetic segments in order to judge the length of nasal occlusions and make inferences about their perceptual salience as a function of time. A few principles were helpful in isolating nasal coda consonants. First, it was important to know where to look for them. The search began at the end of the high oral flow of the nasal vowel under question. During positive oral flow of the vowel, nasal flow was also positive (by definition, a nasalized vowel). Second, it was necessary to establish at what point in the aerodynamic record oral airflow reached 0 ml/s. Once this oral zero was pinpointed, a measurement of duration was taken from oral zero to the next oral zero. Non-positive oral flow during a period of simultaneous positive nasal flow was taken to indicate a nasal consonant.

Since nasal flow was not calibrated, the nasal zero value (when the velum was presumed to be closed) had to be deduced by referring to physiological and aerodynamic principles of speech production. For example, a number of nasal minima sampled during an oral fricative could be averaged and the resulting figure was used as a reference point for nasal zero.

The example in Figure 1 is a recording of the word *atum* 'tuna.' The abrupt increase in the nasal signal at about 1100 ms indicates a nasal vowel. During this period of nasalization (at about 1300 ms) oral flow is non-positive for approximately 68 ms.

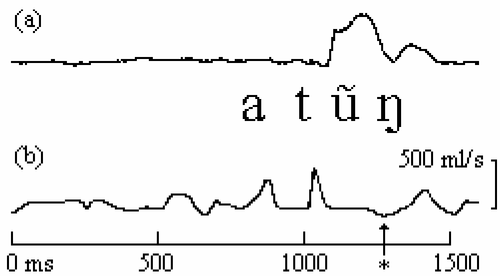

Figure 1: (a) Nasal and (b) oral flow; (*) indicates oral occlusion during velar nasal (-30 ml/s).

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3. Results

Data gathered from the aerodynamic records indicate a significant degree of oral occlusion after some BP nasalized vowels. The duration of the oral occlusion varied across vowels, tokens, individual speakers, and dialects. In some tokens, oral occlusion was not manifested at all. Variance seems to be linked to vowel quality and dialect. Oral occlusion was only weakly attested in the speech of the subject from Bahia, suggesting that NCR is a dialectal feature of BP. The mean durations of [ŋ] after different vocalic contexts for the São Paulo dialect are given below, along with their frequency of occurrence:

Vowel	Oral Occlusion	Tokens with Occlusion
[ũ]	39 ms	67% (n=8/12)
[ẽ]	23 ms	58% (n=7/12)
[ĩ]	22 ms	56% (n=10/18)
[õ]	2 ms	8% (n=1/12)
[ɐ̃]	2 ms	7% (n=1/15)

4. Discussion

An unanticipated result of the study was that oral airflow during [ŋ] did not stay at zero, but sometimes dipped down to a maximum of -30 ml/s before gradually climbing up to another oral zero. Evidence shows a slight drop in nasal airflow at the opening of the velopharyngeal port before nasal consonants. This may be attributed to a minute pressure drop as the air in the nasal cavity is rarified by the lowering action of the velum and the concomitant expansion of the nasal cavity. Until the seal between the pharyngeal wall and the velum is completely broken, the pressure in the nasal cavity runs negative. An analogous phenomenon may be posited for the oral cavity during the production of velar consonants. Describing four stages in the process of velar closure may help elucidate the matter (J. Ohala, personal communication). The first stage is the approach, in which the tongue dorsum rises to meet the velar place of articulation. The second stage involves contact between the tongue dorsum and velum, initially with minimal surface area. The third stage is compression of the tongue body against the velum, resulting in an increasing contact surface area. The fourth and final stage is decompression, in which the surface area decreases gradually to zero (i.e., the seal is broken).

During the first three stages of the articulatory event, the trajectory of the tongue body is forward. Oral airflow is positive in stage 1 then it drops to zero in stages 2 and 3. In stage 4, negative airflow is detected by the split flow mask. This is explained by a fine-grained analysis of how the seal between tongue body and velum is broken. The tongue body does not pull away from the velum instantaneously. Instead, it peels off, gradually decreasing the surface area, beginning at the front and pulling back. This rarifies the air in the oral cavity, creating negative pressure and causing weakly ingressive airflow. Once the seal between the tongue and velum is broken, egressive oral flow resumes.

There are at least three physiological accounts that can explain the significant oral occlusion that occurs after BP word-final nasalized vowels. (Oral closure at the bilabial and coronal places of articulation is ruled out based on visual observation of consultants speaking without the mask). First, the tongue dorsum may rise to meet the velum as for a canonical velar stop. Second, the velum itself may lower to meet the tongue body. J. Ohala (personal communication) has referred to this articulation as *velic* closure. Third, the articulation may involve the rising tongue body and lowering velum meeting somewhere in the middle. The results of this analysis do not conclusively favor either the second or third articulatory possibility with regard to each other. However, some evidence does suggest that the articulatory gesture is indeed velic, not velar.

Recall that the period of oral occlusion is longest during the high vowels, [i] and [u] (see below for a discussion of the anomalous behavior of closure after [e]). Occlusion is shorter after the mid-close vowel [o], and still shorter for the low central vowel [ɐ]. Closure occurs more frequently in the high vowel contexts, while in mid-close and low central environments oral occlusion takes place in a significantly smaller percentage of tokens. Since the tongue body is already raised for the articulation of the high vowels, the velum (already lowered to produce vowel nasalization) would be required to descend only slightly more in order to produce a velic nasal after [i] or [u]. The fact that a longer oral occlusion occurs after the back vowel [u] than even the front vowel [i] also motivates the argument that the oral occlusion is closely associated with the movement of the velum.

When the velum lowers, opening the velopharyngeal port for nasalization of the vowel, it may continue the lowering gesture until it comes into contact with the high tongue body typical of [u] and [i]. The duration of oral occlusion is likely to be greater for [u] because it takes longer for the velum to completely separate itself from the tongue dorsum in its return to closed position. The seal between the velum and tongue dorsum for [i] will be more tangential (i.e. the seal will have a smaller surface area) because the tongue body moves farther forward for the articulation of the vowel; thus, the occlusion will be less prolonged. The lower the tongue body, the farther the velum must lower in order to occlude the oral cavity. If we argued that the principal articulator in this gesture is the tongue body rising to form a seal with the velum, there would be no principled reason to explain why nasal coda restoration is more prolonged and more common after high back as opposed to high front vowels.

The problem with this argument is, of course, the anomalous behavior of [ŋ] preceded by the mid-close front vowel [e]. In addressing this issue, it must first be noted that the measurements for [e]-contexts may not be completely reliable, as they are dependent for their significance on the speech of a single subject where oral occlusion reaches up to 85 ms. For other speakers, occlusion after [e] is practically nonexistent. It is also possible that [e] is

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behaving more like [i] (with a relatively low F1) for this speaker, though this must be proven instrumentally in a future study. Crucial evidence in such a study will include a comparison of F1 for BP [e] and [o]. The spread of [ŋ] to [e]-contexts may also indicate the expansion of NCR to environments where it is not physiologically conditioned.

Regardless of whether the consonantal closure is velic or velar, the close relationship between high nasalized vowels and [ŋ] has been established in the perceptual domain by House (1957). He found that listeners were more likely to confuse a nasalized vowel with [ŋ] than either [n] or [m]. This lends acoustic evidence to the physiological account of NCR presented here. As Ohala (1993) has argued, the seeds of diachronic sound change can often be found in synchronic variation. House's confusion study presents evidence for the synchronic confusability of the velar nasal and nasalized vowels.

The physical reality of velar closure after some BP nasalized vowels has been demonstrated here. To effect a bona fide sound change, however, it is not enough that a transitory occlusion occur. The articulatory gesture must be perceived "at face value" and then reproduced by the speech community at large. In the diachronic path towards widespread NCR, both perceptual and articulatory factors are crucial. The variable implementation of NCR in São Paulo and Bahia dialects suggests that the acoustic variability has not been universally reinterpreted by BP speakers, though the reinterpretation may be progressing more quickly in southern Brazil. After all, the acoustic cues that signal the distinction between velar nasals and nasalized vowels are not very robust, especially in word-final context where there are no post-consonantal formant transitions to enhance perception of velar closure.

Confusion between the velar nasal and nasalized vowels has been explained by Ohala and Ohala (1993) who refer to the size of the oral resonating chamber of a branched nasal resonator. The longer the oral resonating chamber, the more anti-resonances are produced. Since it has the shortest oral resonating chamber, [ŋ] is acoustically the least distinct and least consonantal of the nasal consonants. Acoustically, the velar nasal resembles a nasalized vowel. One might therefore predict that among nasalized vowels, those most likely to be confused with [ŋ] are those articulated with the shortest oral resonating chamber, i.e. those with a [+BACK] place of articulation. This prediction is borne out by the fact that, among all the BP nasalized vowels, the longest and most frequently occurring word-final velar nasal occurs at the terminus of [ũ].

6. Conclusion

NCR is not a purposeful articulation by BP speakers. The nasal coda described here is epiphenomenal: its occurrence is conditioned by momentary contact between the raised body of the tongue and the soft palate in its downward trajectory. If greater nasalization is equal to wider velopharyngeal aperture, then strongly nasalized vowels with a high tongue body are predicted to be the most susceptible to epiphenomenal NCR. NCR may come about due to the rising tongue body, the lowering velum, or both. A physiological account that unquestionably determines the principal articulator has not been possible here.

In Ohala's (1993) terminology, NCR in BP is currently a "mini-sound change." If speakers reinterpret NCR as a salient cue for vowel nasalization, they are more likely to enhance the oral closure gesture. Such enhancement might include lengthening the duration of the oral closure and strengthening the contact between velum and tongue dorsum by increasing the surface area of the seal. Key evidence that the phenomenon has advanced to the level of "maxi-sound change" might include spreading of the velar nasal to low vowel contexts and to intervocalic positions (this appears to have happened in some Portuguese-based creoles). If the phenomenon spreads, NCR may be poised to fundamentally alter the syllabic structure of BP.

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