TOWARDS AN ACOUSTIC DESCRIPTION OF BRAZILIAN PORTUGUESE NASAL VOWELS

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ABSTRACT

This study investigates the acoustic properties of nasal vowels in stressed syllables in Brazilian Portuguese (BP) according to experiments conducted at the State University of Campinas (UNICAMP). We concentrate here on the acoustic features of BP nasal vowels as opposed to BP oral vowels.

Data analysis concerns frequency (Hz) of the main vocalic formants as well as duration (ms).

INTRODUCTION

Nasality constitutes an important cue to the distinction of both consonants and vowels in Brazilian Portuguese (BP). The BP vocalic system in stressed syllables comprises seven distinctive oral vowels ([a, e, ɛ, i, ɔ, o, u]) and five distinctive nasal vowels ([ɐ̃, ẽ, ĩ, õ, ũ]). All those vowels occur in minimal pairs v x ṽ, such as [kata] x [kɐ̃ta] ('cata' x 'canta' = "he/she picks s.t. up" x "he/she sings") or [pita] x [pĩta] ('pita' x 'pinta' = "he/she smokes a pipe" x "dot"). Those are surface phonetic distinctions; there is actually a controversy as to the phonological status of nasal vowels in BP. This controversy, however, does not directly involve the acoustical descriptive framework presented in this paper.

Portuguese has non-distinctive nasal vowels as well, as in [sẽɲa] ('senha' - "password") and [sĩma] ('cima' - "over"). In these cases we may say that vowel nasality derives of anticipatory lowering of the velum to produce the following nasal consonant. Such an anticipation does not explain, however, the behavior of Brazilian phonetically distinctive nasal vowels. These vowels may appear both in nasal and non-nasal environments, what means they are not dependent on a following nasal consonant to be nasalized by BP speakers.

ACOUSTIC DESCRIPTIONS OF VOWEL NASALITY

Phoneticians have reported nasality in vowels as a rather difficult descriptive problem. The coupling of the oral and the nasal tracts involves a wide range of acoustic effects, depending on voice quality, oral and nasal tract volume and shape, degrees of coupling, etc. The nasal cavity introduces extra formants (poles) as well as anti-formants (zeros) in the acoustic output of vowel articulation. The extra poles and zeros change considerably the spectra of nasalized vowels when compared to similar oral vowels.

Some of the major acoustic changes, as reported by House & Stevens [1], Pickett [2], Curtis [3] and Hawkins & Stevens [4], are:

a) an extra pole-zero pair in the vicinity of F1 that interferes with this formant; b) general formant damping; c) weak formants and anti-formants surrounding F2 and F3.

Brazilian nasal vowels have traditionally been described in auditory terms. Early attempts of acoustic description of these sounds (Cagliari [5]) were thwarted by the lack of proper hardware and software tools that could enable more precise descriptions.

THE EXPERIMENT

Our first step towards the description of nasality in BP consisted of a series of

preliminary studies featuring both nasal vowels and nasal consonants in BP words in different phrasal contexts. On the basis of those early experimental findings we built a more controlled experiment, this time featuring only distinctive nasal vowels.

The experiment consisted of [pV] monosyllables inserted in the carrier sentence "Digo ____ pra ele" ("I say __ to him"). Each [pV] monosyllable consisted of either an oral or a nasal BP vowel. The resulting sentences were uttered three times by four BP male speakers coming from different parts of the country. By means of a Kay Elemetrics Sonagraph DSP - 5.500 we analyzed the total set of 84 oral vowels and 60 nasal vowels (three sets of oral/nasal vowels per speaker).

Our analysis featured: a) frequency (Hz) of F1, F2, F3, F4 and of the first nasal formant (Fn1); b) intensity (dB) of these formants; c) duration (ms): - of the monosyllables; - of vowels. For nasal vowels, we also measured the duration of the remarkable spectral changes observed in the end of most of the utterances. Such spectral changes were called "nasal murmurs".

We managed to compare formant intensity measures through a normalization procedure that set the F1 intensity value of each analyzed vowel as the reference to its other formant values.

Thus, if the [a] F1 intensity value were (-29 dB) and [a] F2 = -33 dB / [a] F3 = -44 dB, we would have:

$$\Delta\, RI\, F2 = IF2 - IF1 = -33 - (-29)$$
$$\Delta\, RI\, F2 = -4\ dB$$

$$\Delta\, RI\, F3 = IF3 - IF1 = -44 - (-29)$$
$$\Delta\, RI\, F3 = -15\ dB$$

(I=intensity; RI=relative intensity)

Formant frequency analysis featured mainly 300 Hz and 150 Hz filters (sporadically involving 59 Hz and 117 Hz filters as well).

[pV] coarticulation was isolated whenever possible and non-included in vowel duration values.

After instrumental analysis we conducted a series of Student t-tests and variance analyses considering nasality, vowel quality and observation, in an attempt to extract a possible vowel nasality pattern. Those tests were conducted on the data for: a) F1 frequency; b) F2 frequency; c) vowel duration with and without the nasal murmur.

EXPERIMENTAL RESULTS

Formant frequency and intensity analyses

Although the BP oral subsystem has seven vowels and the nasal subsystem has only five, formant frequency and intensity analyses indicate that the relations among the vowels within each subsystem remain stable in spite of nasality. There is considerable difference, however, when similar vowels of each subsystem are compared in pairs, as in [po] x [põ], [pɔ] x [põ] and [pa] x [pɐ̃].

Variance analysis over vowel formant frequencies showed a dependency of nasality on vowel quality. Nasalization features change considerably according to the vowel with which they occur, thus rendering a consistent vowel-independent nasality pattern very hard to be achieved.

Our four speakers uttered the vowels [ẽ] and [õ] with varying degrees of opening; these vowels were also diphthongized in approximately 60 % of the utterances into [ẽʲ] and [õʷ].

Nasal vowels' formant intensity analysis showed a more leveled pattern than oral vowels', thus confirming the acoustic damping of nasal vowel formants that has been reported concerning other languages.

We found out that BP nasal vowels have a prominent nasal formant near F1; this formant accounts for the high acoustic energy level we found in the spectra of nasal vowels at low frequencies (-400 Hz). This first nasal formant (Fn1) displays constant acoustic energy level throughout the vowel and, in 87 % of the cases, its intensity was either similar to or higher than F1's. Minor nasal formants with low intensity appear in high frequencies, mainly between F2-F3 and F3-F4.

Duration Analysis

Duration analysis of BP nasal vowels showed the most interesting results.

A) Measures showed that distinctive BP nasal vowels are longer than their oral counterparts. Likewise nasal monosyllables are longer than oral ones.

B) Three distinct realization phases were identifiable in BP nasal vowels, namely: a) an oral release; b) a "nasalized phase" in which oral and nasal resonances are present; c) a "nasal murmur" phase in which nasal resonances prevail (see next page fig. 1).

C) The vowels [ĩ] and [ũ] displayed a longer nasal murmur phase than [ẽ] and [õ] (see fig. 2). The nasal murmur phase in [ɐ̃] was also considerably long, although not present in all the utterances.

Considering duration data presented in figure 2, we could assume that the greater duration of nasal vowels in relation to their oral counterparts could be credited to a greater duration of the nasal murmur phase.

One of the speakers, however, (a midwestern BP speaker) showed no final changes in the spectra of four nasal vowels (out of fifteen); his data also presented consistently shorter nasal murmurs when compared to other speakers'.

On these grounds we may assume that presence and/or duration of the nasal murmur phase may depend heavily on dialectal factors.

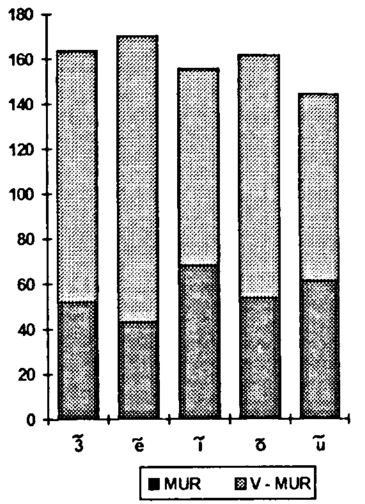

Figure 2. Nasal vowels' duration: full vowel duration, nasal murmur duration.

CONCLUSION

More studies are needed to account for all the variety of environments in which distinctive BP nasal vowels can occur (e.g., two/three syllable words, when followed by fricatives and stops, etc). Studies on dialectal and individual variation should also be carried out in order to properly portray nasalization in BP.

This study may be regarded as an initial attempt on the way to learning, within an Acoustic Phonetics framework, how nasality in Brazilian Portuguese effectively works.

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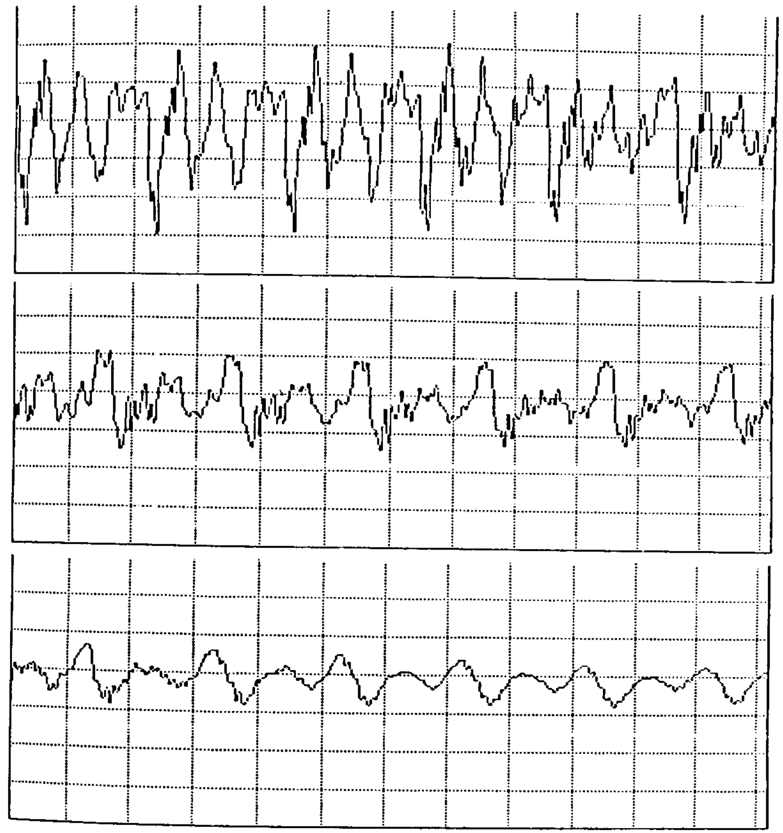

Figure 1. Waveform for vowel [ɐ̃]: phase 1 - oral release (upper), phase 2 - nasalized vowel (middle) and phase 3 - nasal murmur (lower).

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