Acoustic Analysis of the Production of [m] and [n] in Codas by Brazilian Students

Marcia Regina Becker

Federal University of Paraná, Brazil
marcia.r.becker@terra.com.br

1. Introduction

In the process of acquisition of a second language (L2), difficulties inevitably arise in the production of certain phones/sounds in its inventory. The word interlanguage was coined to designate the learner's language during the process of acquisition of the L2, or, as Ellis puts it (1994:16): "[interlanguage is] a transitional system reflecting the learner's current L2 knowledge." In the case of phonology, specifically, the fact that the learner's first language influences the acquisition of the phonology of the second is widely accepted (Eckman, 2004:515).

According to Flege's (1995) *Speech Learning Model* (*SLM*), which is based on similarities and equivalences between the two languages – the mother tongue (L1) and the L2 - equivalent or similar sounds are the most difficult to produce, because the learner perceives them as being the same sounds as in his/her L1, and not a new category.

The production of the phonemes [m] and [n] in coda position can be considered as cases in which there are difficulties, if we take Portuguese as L1 and English as L2. The point is that Brazilian learners generally transfer to English the knowledge they have of the Portuguese phonic system and its orthographic conventions, tending to produce nasalized vowels, without making the distinction between [m] and [n] at the end of syllables.

The objective of this research was to identify through acoustic analysis what is produced by Brazilian pre-intermediate learners of English in codas of monosyllables which have the sequence vowel + nasal consonant ([m] and [n]), using minimal pairs whose contrast lies precisely in the nasal sound, with two distinct environments preceding the vowel ([æ] and [ɪ]), and with silence after the nasal to avoid problems of co-articulation, very common with nasals. Acoustic analysis was preferred over auditory analysis because the contrast between final [m] and [n] is difficult to hear even for native speakers. The analyses are mainly comparative, with the use of the productions of two native speakers, who compose the control group.

2. Theoretical considerations

2.1 Nasalization

Nasalization of some sounds occurs in both Portuguese and English. We will concentrate on nasal consonant sounds, which are produced when the *velum* is lowered, so part of the air which comes from the lungs is forced to go to the oral cavity, where two of the articulators produce a complete obstruction to the passage of this air.

2.1.1 Nasal consonant sounds in Brazilian Portuguese (BP)

Three are the types of obstruction of the articulators in the oral cavity, resulting in the three nasal consonants which occur in BP: [m] – bilabial , [n]- alveolar, and [ɲ] – palatal.

The segments [m] and [n] are uniform in all dialects of BP (Cristófaro Silva, 2003:33). The bilabial occurs in the beginning of words ("mar" [sea]), and in the middle, following a consonant in another syllable ("norma" [norm]) or in a position between vowels ("homeopatia" [homeopathy]). The environments of occurrence of the alveolars are similar.

It is very important to mention that the graphemes "m" and "n" occur at the end of syllables (inside words – "limpo" [clean], "santo" [saint] - and word-finally - "fim" [end] -), without corresponding to the phonetic articulation of the segments [m] and [n] .

2.1.2 Nasal consonant sounds in English

In English, there are also three nasal consonants. The obstructions for the first two - bilabials and alveolars - are similar to Portuguese. The third case, the velar [ŋ], does not occur in PB.

2.2 Acoustic studies

The main articulatory characteristic of nasal consonant sounds is that they are produced by using two resonance chambers – the oral and the nasal, making them a unique and complex class. They also have the influence, like other consonants, of the vowel context, and its interaction in terms of place and manner of articulation. An additional complication lies in the fact that there are big differences in the shape of the nasal tract, which means that the results of the spectral analysis of a speaker may not give an accurate prediction of what may be observed in other speakers (Krakow & Huffman, 1993:41-42).

Fujimura (1962:1871) was a pioneer in the acoustic studies of nasal consonants. His studies were based on the nasal murmur (the acoustic segment associated with the exclusively nasal radiation of the sonorous energy). The results of his studies gave us one of the spectrographically differentiating characteristics of the nasal consonants; that is, it showed us that the anti-formant (associated with valleys of energy in the spectrum) for the bilabial is between 750 and 1250 Hz, and for the alveolar between 1450 and 2200Hz, the vowel environment in which the nasals occur being responsible for the extreme limits in the frequency measurements. However, a big problem is that the literature indicates that the anti-formants are extremely difficult to find and measure.

Another important characteristic of the nasal consonants is that there is a "nasal formant", which frequently occurs between 200-300 Hz, while a third characteristic is that the nasal formants tend to be dumped, that is, they have large bandwidths, which reflects a rapid rate of absorption of sonorous energy.

Very few studies mention nasal consonants in the interlanguage of Brazilian learners of English. The only acoustic study found (Monahan, 2001:23) points out that "BP regressively assimilated nasalization onto a vowel from a nasal consonant in coda position and deleted the nasal consonant". Kluge (2004), in experiments of production and perception of nasal consonants (by ear), came to the same conclusion.

3. Method

For this experiment, the production of ten pairs of words (minimal pairs, Table 1) was recorded. The informants were ten adolescents, students of English at pre-intermediate level, five boys and five girls. All words were monosyllabic, and the nasals were preceded by two vowels of distinct qualities: [æ] and [ɪ].

Table 1. Minimal pairs used in the research

	[m]	[n]
[ɪ]	dim	din
	gym	gin
	Pim	pin
	skim	skin
	Tim	tin
[æ]	cam	can
	dam	Dan
	gram	gran
	jam	Jan
	Pam	pan

The control group was made up of two American adolescents, a boy and a girl, who had been living in Brazil for less than a year at the time of the recordings, all of which were made in a studio.

Three repetitions of each word of the *corpus* by each of the informants were recorded, making 600 words for the students and 120 words for the control group. Data were analyzed using PRAAT, version 4.4.30.

4. Results

Because of the lack of specific references about acoustic data of nasals in codas, the analysis of the data obtained with the control group was much more detailed, so that we could, based on the results of such analysis, define one or more parameters for the analysis of the production of the Brazilian learners.

After analyzing the relative duration of the nasal consonants (obtained by dividing the average value of the duration of the nasal murmur by the total duration of the target word), the three first formants of the vowel preceding the nasal, and the three first formants of the nasal (specifically the nasal murmur) of the data from the control group, the values of the second formant (F2) of the nasal proved to be the most consistent ones. For all the words in the *corpus*, in each of the three repetitions, for both informants, the figures related to F2 were consistently higher for [n] than for [m], for the same pair. This was therefore the parameter used to distinguish between [m] and [n]. Ladefoged had already observed the fact that, when the lips close to produce [m], the second formant of this consonant lowers its frequency (Ladefoged, 2001:54), but he did not make a comparison with the production of [n].

The comparison of the production of the learners was, then, based on the analyses of the minimal pairs: For a student to have produced an alveolar, his/her production should be similar to the production of a native speaker (the boy learners were compared to the boy native speaker, and the girl learners with the girl native speaker); that is, F2 of the nasal murmur of [n] should have been higher than F2 of [m] for the same pair, and the difference between these two formants should be greater than 100 Hz.

The symbols shown from Tables 2 to 7 were:
"✓": difference between F2[n] and F2[m] ≥ 100 Hz, which means the learner's production was similar to that of the native speaker with whom he/she was being compared;
"☒": F2 [m] ≥ F2 [n]. Opposite result to that obtained with the native speaker;
"=" : F2 [n] > F2 [m], but the difference was smaller than 100 Hz, and therefore considered acoustically indistinguishable.

The percentage (%) indicates the percentage values of similarity, difference or indistinguishability which occurred in the experiment for each minimal pair.

Table 2. Summary of the results – pairs [æ] - girls

	CAMxCAN	DAMxDAN	GRAMxGRAN	JAMxJAN	PAMxPAN	% general
% ✓	60	40	60	60	40	52
% ☒	20	0	20	0	0	8
% =	20	60	20	40	60	40

Table 3. Summary of the results - pairs [æ] – boys

	CAMxCAN	DAMxDAN	GRAMxGRAN	JAMxJAN	PAMxPAN	% general
% ✓	20	20	20	0	40	20
% ☒	40	0	40	40	20	28
% =	40	80	40	60	40	52

Table 4. Summary of the results - pairs [æ] – boys and girls

	CAMxCAN	DAMxDAN	GRAMxGRAN	JAMxJAN	PAMxPAN	% general
% ✓	40	30	40	30	40	36
% ☒	30	0	30	20	10	18
% =	30	70	30	50	50	46

Table 5. Summary of the results – pairs [ɪ] - girls

	DIMxDIN	GYMxGYN	PIMxPIN	SKIMxSKIN	TIMxTIN	% general
% ✓	80	60	60	40	40	56
% ☒	0	20	20	40	40	24
% =	20	20	20	20	20	20

Table 6. Summary of the results – pairs [ɪ] - boys

	DIMxDIN	GYMxGYN	PIMxPIN	SKIMxSKIN	TIMxTIN	% general
% ✓	40	20	0	60	40	32
% ☒	60	20	60	40	60	48
% =	0	60	40	0	0	20

Table 7. Summary of the results – pairs [ɪ] – boys and girls

	DIMxDIN	GYMxGYN	PIMxPIN	SKIMxSKIN	TIMxTIN	% general
% ✓	60	40	30	50	40	44
% ☒	30	20	40	40	50	36
% =	10	40	30	10	10	20

Thus, the general percentage (that is, for the productions of boys and girls) in terms of similarity with the productions of the native speakers was 36 % for the pairs [æ], and 44 % for the pairs [ɪ].

5. Conclusions

One of the main purposes of this study was to define a parameter which could be used acoustically to identify whether a production was a segment [m] or [n] in a coda, since the analysis by ear of bilabials and alveolars in codas is very controversial. This aim was achieved, bearing in mind the limited conditions of this research: F2 of [n] proved to be always higher than the F2 of [m].

By comparing the learners' productions with those of the native speakers, it was shown that 40% of the target words produced by the learners were acoustically similar to those produced by the native speakers, 27% of the words showed an F2 with opposite results to those of a native speaker, while a third of the productions were acoustically indistinguishable (F2 of [m] and F2 of [n] showing very close frequencies, though F2 [n] was higher than F2 [m]).

In relation to the preceding vowels, 44% of the words with [ɪ] produced by the learners were similar to the words produced by the native speakers, whereas only 36% of the words with [æ] proved to be similar.

Nevertheless, it is clear that failure to distinguish between final nasal consonants is a typical characteristic of BP-English interlanguage, and one that needs to be given greater attention in the classroom, because of the large number of monosyllabic minimal pairs in English which are distinguished solely by the place of the final nasal.

References

Cristófaro Silva, T.(2003). *Fonética e fonologia do português.* São Paulo: Contexto.

Eckman, F. R. (2004). From phonemic differences to constraint rankings: Research on second language phonology. *Studies in Second Language Acquisition, 26*, 513-549.

Ellis, R. (1994). *The study of second language acquisition.* Oxford: Oxford University Press.

Flege, J. E. (1995). Second language speech learning: Theory, findings and problems. In W. Strange (Ed.), *Speech perception and linguistic experience: Issues in cross-language research* (pp. 233-277). Timonium, USA: York Press.

Fujimura, O. (1962). Analysis of nasal consonants. *Journal of the Acoustical Society of America*, *34*(12), 1865-1875.

Kluge, D. C. (2004). *Perception and production of English syllable-final nasals by Brazilian learners.* Unpublished Master's thesis, Universidade Federal de Santa Catarina, Florianópolis, Brazil.

Krakow, R.A., & Huffmann, M. K. (1993). Instruments and techniques for investigating nasalization and velophrayngeal function in the laboratory: An introduction. In M. K. Huffman, & R. A. Krakow (Eds.), *Nasals, nasalization and the velum* (pp. 3-59). San Diego, USA: Academic Press.

Ladefoged, P. (2001). *Vowels and consonants: An introduction to the sounds of languages*. Malden, MA: Blackwell.

Monahan, P. J. (2001). *Evidence of transference and emergence in the interlanguage*. Retrieved 05 August 2007, from http://roa.rutgers.edu/files/444-0701/444-0701-MONAHAN-0-0.PDF.