

**PERCEPTION OF QUÉBEC FRENCH NASAL VOWELS
BY BRAZILIAN LEARNERS: A PILOT STUDY**

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Abstract

This pilot study aims at comparing the phonetic structure of Québec French (QF) and Brazilian Portuguese (BP) nasal vowels and at assessing the perception of QF nasal vowels by BP learners. It is shown that the structure of the phonetic systems of these vowels is different in QF and BP, and hence has an influence on the cross-linguistic perception (identification) of QF nasal vowels. More specifically BP speakers often misidentify QF [œ̃], [ã̃] and [ẽ̃], probably because of the organization of their native perceptual magnets for nasal vowels.

Résumé

Cette étude pilote vise à comparer la structure phonétique des voyelles nasales du français québécois (FQ) et du portugais brésilien (PB) et à évaluer la perception des voyelles nasales du FQ par des apprenants brésiliens. Il est démontré que la structure des systèmes phonétiques de ces voyelles est différente en FQ et en PB, et par conséquent a une influence sur l'identification des voyelles nasales du FQ par les participants lusophones. Plus spécifiquement, les locuteurs du PB identifient souvent incorrectement [œ̃], [ã̃] et [ẽ̃], probablement à cause de l'organisation de leurs aimants perceptifs natifs pour les voyelles nasales.

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Introduction

Perception of acoustic features is essential to identify, discriminate and interpret the sounds of speech. One important influence on the perception of the sounds of a second language (L2) is the sound structure of the native language (L1 ; Best, 1995; Flege, 1995; 2002; Frieda & Nozawa, 2007). For example, Kuhl and her colleagues (Kuhl, 1992; Kuhl & Iverson, 1995; Conboy & Kuhl, 2011) have shown that linguistic experience in infancy has a major influence on individuals' future abilities to learn a L2, using different brain imaging and behavioural techniques. This means that native linguistic experience shapes the way we perceive native as well as non-native speech sounds.¹

The experiment in this paper examines the perception of Québec French (QF) nasal vowels by Brazilian Portuguese (BP) speakers. Both of these languages have contrastive nasal vowels in their phonemic inventories.² In QF, the system comprises 4 contrastive nasal vowels – /ẽ, ã, õ, œ/ – as shown with the minimal pairs in Table 1. The orthography of the words is written between chevrons (<>).

Table 1. Minimal pairs for QF oral vowels and nasal vowels.

Oral vowels	Nasal vowels
<pas> [pa] / [pa]	<paon> [pã] / [põ]
‘step’	‘peacock’
<beau> [bo]	<bon> [bõ]
‘pretty, beautiful’	‘good’
<athée> [atē]	<atteint> [atẽ]
‘atheist’	‘reached’
<je> [ʒe] / [ʒœ]	<(à) jeûn> [(a)ʒœ]
‘I’	‘to have eaten or drunk nothing’

In BP, there are 5 contrastive nasal monophthongs: [ĩ, ê, ẽ, õ, ã]. Examples of minimal pairs are provided in Table 2. These minimal pairs show the phonological status, within a functional framework, of nasal vowels in both QF and BP. BP also has contrastive nasal diphthongs and conditioned nasal vowels. These properties of the vocalic system of BP will not be described here. The interested reader can refer to Azevedo (2005).

¹ This is also known as the transfer hypothesis in which a foreign language's sounds are automatically transferred or filtered through the native sound system and mapped to the native categories (Troubetzkoy, 1938).

² Not all authors necessarily agree on the phonological status and mental representation of nasal vowels in Portuguese (Azevedo, 2005; Mateus & D'Andrade, 2000; Wetzels, 1997). To simplify our phonetic analysis of the nasal vowels, we will use a functional framework in which a semantic change that occurs when changing one phoneme is sufficient to establish the phonological status of phonemes.

Table 2. Minimal pairs for BP oral vowels and nasal vowels.

Oral vowels	Nasal vowels
<cito> ['sɪtɔ] 'I cite'	<cinto> ['sĩtɔ] 'belt'
<teta> ['tɛtɛ] 'breast (animal)'	<tenta> ['tẽtɛ] 'he tries'
<la> ['lɛ] 'there'	<lã> ['lẽ] 'wool'
<popa> ['pɔpɛ] 'poop of a boat'	<pompa> ['põpɛ] 'snob'
<juta> ['ʒutɛ] 'jute'	<junta> ['ʒũtɛ] 'together'

In a situation of language contact, such as when BP speakers learn QF, the transfer hypothesis predicts that BP speakers would correctly perceive (identify and discriminate) the nasal vowels of QF because they already possess contrastive nasal vowels in their phonemic inventory that are phonologically similar to those of QF. However, Fraga (2004) writes that: “for most Brazilian learners of French as a foreign language... /ã/ and /ẽ/ are one phoneme”³ (our translation of Fraga, 2004: 86) contrary to the prediction of the transfer hypothesis. Also, very little research has been made on the acquisition of French nasal vowels because of “the complexity of the relationship between the articulatory, acoustic and auditory properties of nasal vowels in French” (Detey et al., 2010). Our research questions are as follows:

- (1) What factors influence the perception of the QF nasal vowels by BP learners of QF?
 - (1.1) What are the acoustic properties/cues of nasal vowels in QF and BP relevant to their accurate perception cross-linguistically?
 - (1.2) What are the phonological/perceptual aspects to consider in a situation of BP speakers learning QF nasal vowels at a beginning/intermediate level?

The *Native Language Magnet Model* (NLM; Kuhl & Iverson, 1995) claims that once a critical period is reached early in life, our perception of speech sounds is dictated by our language experience. This model also claims that:

as a result of the emergence of neural maps to perceive the speech signal, perceptual representations are stored in memory, and these are the basis of the learner’s development of sound production. Because perceptual mappings differ substantially for speakers of different languages, the perception of one’s primary language is completely different from that required by other languages (Escudero, 2005; p. 120-121)

The predictions of NLM are provided in (2); those in (2.1) and (2.2) are formulated with respect to the research questions guiding the present research, which were given in (1), (1.1) and (1.2):

³ /ã/ and /ẽ/ are the equivalents, in European French, for /ā/ and /ē/ in QF. Fraga’s (2004) study mainly concerned pronunciation teaching and not the acoustics or the phonological perception of French and BP nasal vowel. Hence we decided to verify if this conclusion is applicable to QF.

- (2) The factors of influence on the perception of QF nasal vowels by BP adult speakers are mainly perceptual, and perception is driven by the acoustics of sounds transformed by the ear into neural information automatically mapped to the “default” L1 phonological system.
- (2.1) BP speakers rely on the same acoustic cues as QF speakers, namely a) formant flattening (loss of spectral energy) below 1000 Hz, and b) contraction of the phonetic space occupied by nasal vowels when compared to oral vowels. However, the acoustics of QF and BP nasal vowels are different and speakers’ perceptual systems are organized differently depending on their native language.
- (2.2) BP speakers’ perceptual magnets are organized differently than those of QF speakers. As long as the mapping of QF nasal vowels is filtered through the BP speakers’ native phonetic system, QF nasal vowels are not categorized correctly and identification of the nasal vowels is incorrect.

Section 1 contains a review of some pertinent literature on the influence of the L1 on the perception of a L2’s sound system, more precisely how perception was assessed, what the correlates for perception of nasality are, and what the acoustics and phonology of BP and QF nasal vowels are. Section 2 presents a pilot experiment on the perception of QF nasal vowels with BP speakers. In section 3, we will discuss the results of the experiment (section 3.1), the methodology and methods used in the experiment (section 3.2) as well as the implications for theory and teaching (section 3.3).

1. Review of literature

1.1 Methods for testing speech perception

Many researchers have examined the cross-linguistic perception of segments. For example, LaCharité & Prévost (1999) used those two kinds of behavioural tests to examine the influence of the native language and teaching on the acquisition of some English consonants with QF speakers. They used an AX test for segment discrimination and an ABX test for segment identification. In the AX test, the participants had to decide if the two auditory stimuli that were presented were identical or not. The objective of this test was to determine if the francophone learners of English were able to phonetically discriminate pairs of English words such as <thrill>[ˈθrɪl]~<trill>[ˈtrɪl]. The time interval between the two stimuli was short enough not to allow lexical access to the phonological representation (below 500 milliseconds; Werker & Logan, 1985). In the ABX test, one word of a minimal pair was pronounced and participants had to determine which word had been pronounced. For example, the words <heat> and <eat> were written and the word <heat>[hit] was pronounced. The participants had to circle the word they thought had been pronounced. This test was made in order to force the participants to access lexically – phonological representation – the presented words and verify if identification of the studied contrasts was good or poor. The authors point out that the AX test was administered before the ABX test: in order to phonologically identify words correctly, participants must be able to perceive or phonetically discriminate the contrasts that distinguish the words of a minimal pair.

1.2 Perception of vowel nasality

Beddor (1993) reviews some of the findings on the perception of vowel nasality. The author explains, among other points, what the effects of the acoustics of nasal vowels on the perception of these vowels are and what the consequences of nasalization on vowel quality are. She writes that “despite the variable acoustic characteristics of nasal vowels of different heights, there appears to be a vowel-independent spectral correlate: the relative prominence or flatness of the low-frequency region of the vowel spectrum” (Beddor, 1993: 173). This is the main acoustic/spectral correlate of nasality for perception.

When producing oral vowels, the velum is raised in a way that prevents air coming from the pharynx into the nasal cavity. Lowering the velum enables the air to split between the oral cavity and the nasal cavity. This explains the flattening of the low-frequency formants – i.e. loss of spectral energy like shown in Figure 1.

The energy displayed in the vocal tract is split between two cavities and this repartition of energy has an influence on the spectral envelope of nasal vowels.

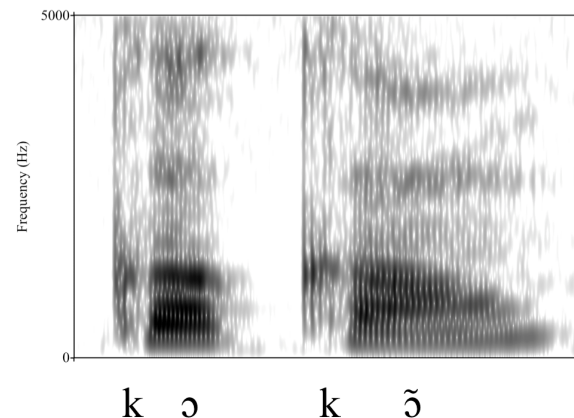


Figure 1. Spectrum of the QF word *cocon* [kəkõ] pronounced by a female native speaker of QF.

In the French word <cocon> [kəkõ], the first vowel is oral and the second is the nasal correspondence of the first vowel. The spectrogram of this particular word enables us to see what the differences in the spectral envelope between oral and nasal realizations of the “same” vowel are. The formants of the nasal vowel [õ] are more diffuse than the formants of the oral vowel [ɔ]. Formants are clearly cut in the first part of the spectrum and it is not the case in the second part of the spectrum. Johnson (2003) also shows that the nasal formants, oral formants and anti-formants that are created by the coupling of the two cavities have different frequencies and have a great influence on the spectral shape of nasal vowels. Hence, the lower region of the spectrum (around F1, below 1000 Hz) is shifted depending on the degree of nasalization, the position of the lips and tongue (oral formants), etc. There is a complex interplay between these coupling frequencies.

Beddor also correlates these acoustic features with the perception of nasal quality. For example, the presence of nasal formants lowers the F1 of low vowels, which typically have higher F1. Low nasal vowels are then perceived as higher vowels. The opposite happens for non-low vowels. Yet, it has not been shown experimentally that nasality or nasalization has a major influence on vowel backness in comparison to vowel height, except for a tendency to retract front vowels. The author writes that “[t]hese effects amount to a contraction of the perceptual vowel space and lead one to expect that, when nasal vowels are compared to each other, the perceptual distance between any two nasal vowels would be less than that between the corresponding two oral vowels” (Beddor, 1993: 183).

1.3 Acoustics and articulation of QF and BP nasal vowels

Delvaux et al. (2002) give a description of the articulatory and acoustic properties of European French (EF) nasal vowels, more precisely of Belgian French.⁴ In this dialect, nasal vowels are articulated in a different way than corresponding oral vowels depending on the quality of the nasal vowel. For example, the lip rounding of [õ] is more pronounced than that of [ɔ]. Speakers also tend to make a backing of the tongue body in the pharynx when pronouncing nasal vowels (Delvaux et al., 2004). The position of the velum also varies depending on the nasal vowel. For example, the velum is lower when speakers pronounce [ã] than [õ]. These articulatory characteristics have an influence on the acoustics of nasal vowels. Delvaux et al. (2002) write that: “the acoustic correlate of velum lowering is essentially the level of intensity: nasalized (and perhaps

⁴ EF is often considered to be the standard variety of French.

nasal) vowels undergo a general loss of energy compared to their oral counterparts” (our translation; Delvaux et al., 2002: 359). The authors also write that some formants (F2 for female participants, F3) may even “disappear” from the acoustic spectrum. Speakers then tend to slightly modify the articulation of nasal vowels in order to compensate for the loss of acoustic information.

Martin et al. (2001) have devoted an article to the nasal vowels of QF. For the purpose of this study, we will focus on the acoustic aspects of nasal vowels that are described in this article. The first important acoustic aspect of QF nasal vowels is the diphthongization of the vowels. In their corpus, 24 % (1026/4240) of the nasal vowels are perceived as diphthongized by the transcribers. QF nasal vowels are also fronted compared to EF nasal vowels: EF / $\tilde{e}$ / is pronounced [$\tilde{e}$] in QF, EF / $\tilde{a}$ / is pronounced / $\tilde{a}$ / in QF and EF / $\tilde{\alpha}$ / is pronounced [$\tilde{\alpha}^{\text{f}}$] in QF. Formant values are different for male and female speakers: frequencies are lower for male than for female speakers. Also, male speakers generally have a smaller ‘phonetic space’ than female speakers for nasal vowels, i.e. their phonetic quadrangle is more compact (see Simpson & Ericsson, 2007).

In an unpublished dissertation, Sousa (1994) describes and characterizes the nasality of vowels in BP. She uses acoustic data extracted from the recordings of four native male speakers of BP and gives a detailed acoustics overview of their production of nasal vowels.

Figure 2 illustrates the average quadrangle for the nasal vowels of the four BP speakers in Sousa (1994) once converted into Barks.

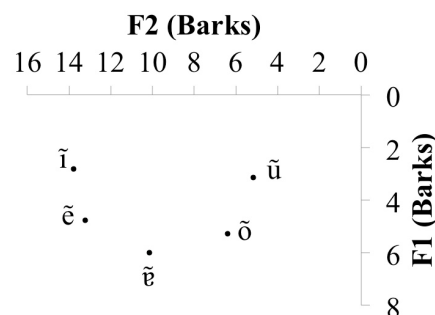


Figure 2. Nasal vowels quadrangle for average values in Barks from Sousa (1994).

Sousa (1994) writes that, in general, nasal vowels of BP contain two parts: a nasal vowel and a nasal murmur (nasal resonance without a special vowel quality that is automatically associated with the nasal vowels). In relation to the corresponding oral vowels, the author says that [$\tilde{e}$] is acoustically closer to oral [ϵ] than [e] and that [$\tilde{o}$] is acoustically closer to oral [ɔ] than [o]. Nasalization of [e] and [o] is accompanied by lowering these vowels, so the author concludes that the realization of these two vowels is variable.

2. Experiment

This experiment was conducted in order to answer the two specific research questions given in (1.1) and (1.2) to verify the predictions made in (2.1) and (2.2), and to discuss and improve the methods and methodology used to answer those questions. To do so, QF speakers and BP speakers were recorded and an acoustic analysis of the production of nasal vowels in both languages was made. The analysis was conducted using different functions of Praat and formalized using Bark units (Zwicker, 1961) to normalize and thus facilitate inter-participant comparison. The BP participants were assessed with an ABX perception test, similar to that used by LaCharité & Prévost (1999), with nasal vowels. The test was conceived using Praat. A control group of two QF listeners was also assessed with the ABX perception test to make sure it was valid. Participants are

described in section 3.1, QF and BP word corpora are described in section 3.2, used tests are explained in section 3.3 and the results of experiment are presented in 3.4.

2.1 Participants

Four native speakers of QF were recorded for the acoustic analysis of QF nasal vowels and for conceiving the ABX test. None of them reported an auditory or speech problem. Two of the speakers, MF and MR, were male participants with a university level of education. MF was 24 years old at the time of recording. He had an advanced level of knowledge in English⁵ and intermediate knowledge in Spanish and Italian. He was working part-time as a teaching assistant in a *francisation* program at Laval University at the time of recording. MR was 55 years old at the time of recording and had an intermediate level of knowledge in English. This participant had no experience in teaching or with immigrants. The two other speakers of QF, FC and FS, were female participants with a university level of education also. FC was 28 years old at the time of recording. She was working part-time in the same *francisation* program as MF. She had advanced levels of knowledge in English and Spanish. FS was 24 years old at the time of recording. She had an advanced level of knowledge of English and an intermediate level of knowledge in Arabic. She had no particular experience in teaching or with immigrants.

Two native speakers of BP took part in this study. Both of them were from the area of Belo Horizonte (southeast Brazil, in the province of Minas Gerais) and were students in a *francisation* program. The two participants had the same linguistic background, which is an intermediate level of knowledge of QF as the only L2 they know. None of the BP participants had an auditory or speech problem. They had been living in Québec City for less than one year. One participant, MC, was a male speaker of 32 years old who had an undergraduate degree in administration, and the other participant, FK, was a 29-year-old female speaker who also had an undergraduate degree.

The control group for the perception test was composed of two QF native listeners. Neither of them had an auditory or speech pathology known at that time. One, MJ, was a male listener who was 25 years old at the time of listening with no training in language teaching or phonetics. The other participant, FJ, was a female graduate student in linguistics who was 25 years old at the time of listening. She had a university degree in teaching French as a second language and had experience in working with immigrants in a *francisation* program as MF and FC.

Some QF speakers had no training in phonetics or experience in second language teaching while other participants had some experience in this area. We decided to record teaching assistants of French as a second language classes because most of the French input immigrants receive is in the *francisation* class.⁶ We also decided to record untrained QF native speakers in order to have a good idea of the input the students are provided with outside the classroom.

2.2 Materials

One corpus of French words and one corpus of Portuguese words were conceived for the recordings.

The words in the French corpus were chosen depending on two parameters: presence of the nasal vowels in an open or a closed syllable, and the position of the syllable containing the nasal vowels in the word – i.e.

⁵ The participants themselves judged their levels of knowledge of second or foreign languages in a background questionnaire they filled out before the recording session.

⁶ Out of 33 students surveyed in two different *francisation* groups, 3 (9,1%) claim to use French OFTEN or ALWAYS at home while 30 (90,9%) claim to use it SOMETIMES, RARELY or NEVER. Inversely, 3 (9,1%) students claim to use French SOMETIMES, RARELY or NEVER at school while 30 (90,9%) claim to use it OFTEN or ALWAYS. This probably means that the most part of the native QF input for students in this *francisation* class is provided by teachers or teaching assistants, and not necessarily outside the class.

word-initial or word-final position. Fifteen words were selected on the basis of these two parameters and one non-word was invented in order to have every vowel in every context.

The words in the Portuguese corpus were selected depending on the position of the syllable bearing the nasal vowels in the word (word-final or word-initial) and the stress (or not) of the vowel. The corpus contained 19 words with contrastive nasal monophthongs.

2.3 Method

The QF speakers were asked to pronounce the series of 16 French words twice, yielding 32 realizations per participant. Recordings were made with a *Zoom H4n* digital recorder. The participants produced 124 correct QF nasal vowels. BP speakers were asked to pronounce the list of 19 Portuguese words once. The participants produced 34 correct BP nasal vowels that are analyzed in the present study. Formants of the QF and BP nasal vowels were extracted in Praat using the spectrographic and spectral functions *Formant listing* and *View spectral slice*. Nasal vowels productions of QF speakers were segmented (with the preceding consonant) using Praat and saved as unique .wav files in order to construct the perception test.

For the perception test, we decided to assess the listeners with an “expanded” version of an ABX test, in the way LaCharité & Prévost (1999) did for their identification task. Once all the individual .wav files (124 total) were segmented and saved in a file, they were inserted in a script used for ABX tests in Praat. The participants were shown how to accomplish their task with a pre-test. The participants had to listen to one realization of a QF nasal vowel and click on buttons that appeared on the screen of a computer, which had the French orthographic correspondences for each vowel. For each sound, the participants also had to rate the confidence with which they gave the answer; they were asked: “In your opinion, was the sound easy to identify?” This measure will be interpreted as the “intelligibility rate” in subsequent sections. The easier the vowel was identified, the lower was the score (1=very easy to identify, 5=very difficult to identify).

2.4 Analysis and results

2.4.1 Acoustic analysis

QF nasal vowels are diphthongized in certain contexts (Martin et al. 2001) so a formant measure was taken at around 20% of the duration of the vowel and at around 80% of the duration of the vowel. This is illustrated in the quadrants of QF speakers (Figures 3 to 6) with the use of arrows departing from the onset of the diphthong (first timbre) and arriving on the end point of the diphthong (second timbre).

For all participants, the diphthongs are “closing” diphthongs except for FC’s [ã]. Also, the two female speakers tend to pronounce the first timbre of nasal vowels with relatively higher F1 frequencies than male speakers: between 6,5 and 8 Barks for female speakers, and between 5,5 and 7 Barks for male speakers. [ã], [õ] and [œ]’s placement relatively to one another in the quadrangles (1st timbre) seems to be stable but [ẽ]’s

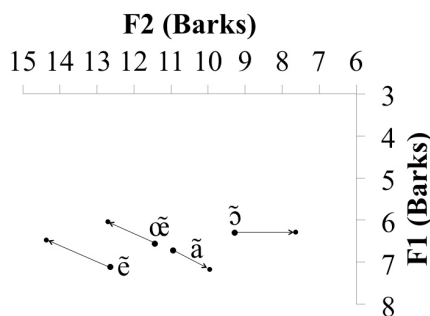


Figure 3. Nasal vowels quadrant of participant FC.

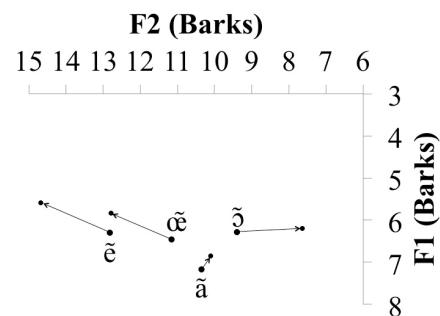


Figure 4. Nasal vowels quadrant of participant FS.

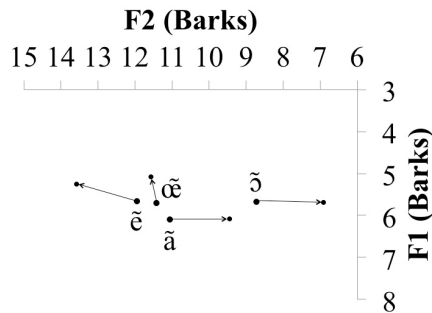


Figure 5. Nasal vowels quadrant of participant MF.

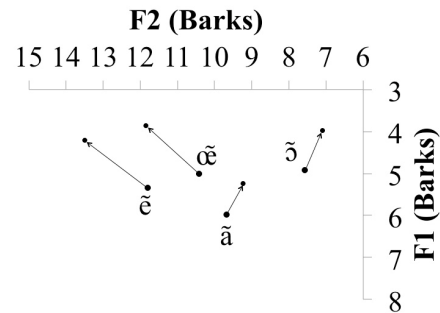


Figure 6. Nasal vowels quadrant of participant MR.

placement seems to be more variable (at the lower and most anterior – leftmost – position for FC, at the higher and most anterior – leftmost – for FS and MR, and at the higher and center position for MF).

Figure 7 and Figure 8 show the nasal vowels quadrants of the two BP participants. MC's vowel space for nasal vowels tends to be more compact than that of FK. It is also worth noting that MC's [ẽ] is pronounced with lower F1 relative to other vowels than FK's. MC's [ũ] is also pronounced with higher F1 than FK's. FK's [ẽ] is pronounced with higher F1 than MC's.

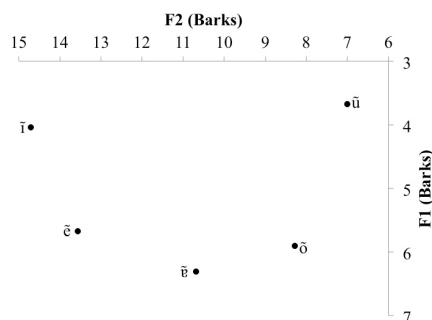


Figure 7. Nasal vowels quadrant of participant FK.

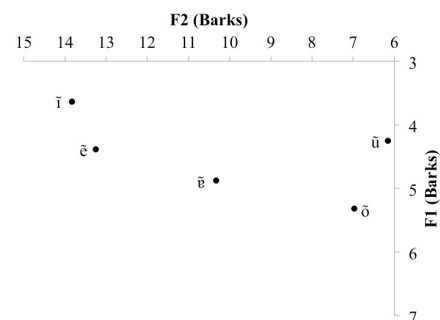


Figure 8. Nasal vowels quadrant of participant MC.

Figure 9 shows the average values for both languages, for all participants as a group. The vowel space for QF nasal vowels is smaller than that of BP nasal vowels. All the QF nasal vowels (1st timbre) tend to be pronounced with higher relative F1 than BP's.

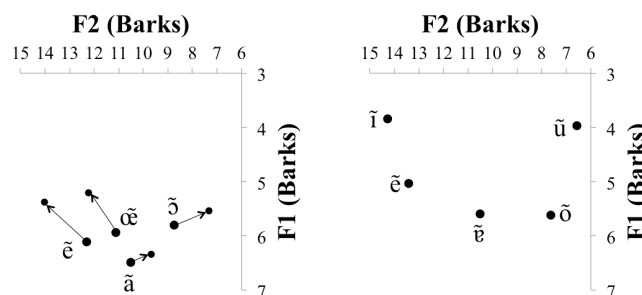


Figure 9. Nasal vowels quadrants for average values in QF (left) and BP (right), all participants.

2.4.2 Results of the perception test

The answers to the perception test by the control group were correct at 96% (98,4% for FJ and 93,5% for MJ) and the intelligibility rate was low (1,37 overall), meaning that the participants found the vowels relatively easy to identify. This validates our perception test. Table 3 presents the overall results the BP speakers.

Table 3. Results of the perception test for the experimental group of two BP speakers.

Participant	Good answers	Wrong answers	Intelligibility rate
FK	87 (70,2%)	37 (29,8%)	2,58
MC	67 (54%)	57 (46%)	3,06
Total	154 (62,1%)	94 (37,9%)	2,82

The results presented in this table show that even though they correctly identified the majority of the stimuli (62,1%), BP speakers have more wrong answers (37,9%) than QF speakers (4%). Participant FK has identified more stimuli correctly (70,2%) than participant MC (54%) and she has a lower intelligibility rate (2,58), which means that she found it easier to identify the nasal vowels than participant MC (3,06). Overall, QF speakers found that the stimuli were easier to identify (rate = 1,37) than BP speakers (rate = 2,82). One has to keep in mind that these results come from individual judgements and can be variable from one speaker to another. Particular attention will be drawn towards this question in future research.

Table 4 shows FK's results for the number of good and wrong answers and the intelligibility rate per nasal vowels.

Table 4. Results of the perception test for participant FK per nasal vowel.

Nasal vowels	Good answers	Wrong answers	Intelligibility rate
[œ̃]	4 (14,3%)	24 (85,7%)	4,75
[ã]	21 (65,6%)	11 (34,4%)	3,28
[õ]	30 (93,75%)	2 (6,25%)	1,38
[ẽ]	32 (100%)	0 (0%)	1,19
Total	87 (70,2%)	37 (29,8%)	* ⁷

Table 5 shows MC's results for the number of good and wrong answers and the intelligibility rate per nasal vowels.

⁷ As long as we do not have the same number of tokens for each nasal vowels (32 [ã], [ẽ] and [õ], and 28 [œ̃]), we cannot calculate the average intelligibility rate with the data per vowel. We would need to balance the values. Hence, the rates given in Table 3 will be considered as correct for the analysis.

Table 5. Results of the perception test for participant MC per nasal vowel.

Nasal vowels	Good answers	Wrong answers	Intelligibility rate
[œ]	3 (10,7%)	25 (89,3%)	4,68
[ã]	28 (87,5%)	4 (12,5%)	1,91
[õ]	26 (81,25%)	6 (18,75%)	1,34
[ẽ]	10 (31,25%)	22 (68,75%)	3,91
Total	67 (54%)	57 (46%)	*

For both participants, realizations of [œ] lead to the most wrong answers (24 (85,7%) and 25 (89,3%) for FK and MC respectively) and realizations of [õ] lead relatively low numbers of wrong answers (0 (0%) and 6 (18,75%) for FK and MC respectively). Realizations of [ẽ] lead to many wrong answers for MC (22; 68,75%), but FK only has correct answers for this same vowel. MC has a lower number of wrong answers for [ã] (4; 12,5%) than FK (11; 34,4%). Intelligibility rates seem to be correlated with the number of wrong answers (except for MC's [ã] and [õ] answers, but both intelligibility rates and number of wrong answers are low): the higher the number of wrong answers, the higher the intelligibility rate, thus lower the level of easiness of identification and intelligibility.

3. Discussion

3.1 Discussion of the results

The acoustic analysis presented in 3.4.1 enables us to answer the research question given in (1.1). Acoustics of QF nasal vowels and BP nasal vowels are different concerning their relative formant values (Figure 9). QF prototypical magnets are organized in a way that the total phonetic space of nasal vowels is a lot smaller than that of BP.⁸ All the QF nasal vowels were also pronounced lower than BP's. Following the NLM's predictions saying that L2 categories are mapped to the L1 categories, we can thus conclude that confusion of BP speakers learning QF nasal vowels may be caused by this different configuration of nasal vowels in QF.

Results in Figures 3 to 6 have also shown that the formant values of [ẽ] are variable from one speaker to another, relative to other vowels. This fact could also partly explain why "for most Brazilian learners of French as a foreign language... /ã/ and /ẽ/ are one phoneme" (translation of Fraga, 2004: 86). We think that the same affirmation is applicable to QF. Also, these figures have shown that QF nasal vowels are diphthongized, which may be another source of confusion for BP listeners.

Results showed that BP speakers gave more wrong answers than QF speakers, suggesting their difficulties in identifying QF nasal vowels. Furthermore, the intelligibility rate was higher than that of QF speakers, meaning that BP speakers found the vowels harder to identify and that the stimuli were less intelligible to them. Results of Table 3 also showed that FK's performance tends to be better than that of MC. Many

⁸ Let us recall that inter-language comparison of phonetic spaces did not take into account the dynamics of QF nasal vowels, and that this might constitute a crucial aspect of the perception of QF nasal vowels. This point will be verified in future research.

factors, such as her experience in French or the attention she gave to the test, could be used to explain why she had better results.

When looking at the results for each participant per vowel (Tables 4 and 5), one can see that [œ̃] is the vowel with the least number of correct answers for both participants. This might be explained by the fact that BP has no front rounded nasal vowel in its inventory. Participants have to create a new prototype for this vowel. Our two participants have not been exposed to QF for a long time and their [œ̃] prototypical magnet might not be created yet. For participant FK, results show that she has not given wrong answers for nasal vowels [ẽ] but that she gave 11 (34,4%) wrong answers for [ã]. This probably means that QF [ẽ] is similar to her prototypical BP [ẽ], and that QF [ã] is not similar to any of her categories.⁹ Participant MC gave more wrong answers for nasal vowels [ã] (22; 68,75%) than for [ẽ] (5; 15,6%). This probably means that his BP [ẽ] prototype is similar to the QF [ẽ] acoustically. In looking at the answers he gave to the [ẽ] stimuli of QF, 20/22 of the wrong answers were <an>, thus probably meaning that QF [ẽ] is often mapped to his [ẽ] category/prototype.

Overall, we have seen that QF [œ̃], [ã] and [ẽ] are often misidentified by BP speakers. This is consistent with what we can observe acoustically when comparing the realizations of nasal vowels in both languages. Neither participant in our study misidentified the same nasal vowels, except for [œ̃]. This might be explained by the acoustical variability of QF nasal vowels (variable height of [ẽ], diphthongization, smaller phonetic space), which has an effect on phonological identification and hence leads to different “strategies” used by speakers in order to categorize QF nasal vowels. Also, the fact that all QF nasal vowels are pronounced with relatively lower frequencies than BP’s may add to the confusion of the speakers.

3.2 Discussion of the methodology/limits

This pilot study was first conceived in order to test the methodology and methods, and improve it for further research on perception of QF nasal vowels.

We think that assessing more BP speakers would be important for future research but, as long as this experiment was a pilot study, we could not recruit more Brazilian participants mostly for a matter of time and availability of more participants. The Brazilian students in other *francisation* classes were too experienced in French to take part in our study.

The corpora we used in this study were elaborated following the criteria given in section 3.2. It was mentioned earlier that French has no word in which [œ̃] is found in a word-initial closed syllable, so a non-word was invented in order to fill that “lexical hole”. This led two of the four QF participants to mispronounce the target sound and this data could not be used in the study. For future research, we will leave this “lexical hole” because students will probably never be exposed to that vowel in such a syllabic context. Also, the nasal vowels were produced in isolated words. This does not necessarily reflect the pronunciation QF speakers use in connected speech. Corpora in future research could be elaborated and inserted in sentences. In the BP corpus, two words were unknown by each participant, hence four vowels could not be analyzed. In order to make sure that all the assessed speakers know the words of the corpus, it would be good to pre-approve the corpus with other native speakers of BP. Also, we think that this corpus could be expanded because it contains only 19 words with phonological nasal monophthongs. This led to only 34 realizations of nasal vowels in the present study. We think that this number of vowel is not sufficient to

⁹ No tendency was observed concerning the vowel she answered in the wrong answers. She identified [ã] as <in> one time, <on> four times and <un> 6 times, contrary to the claim by Fraga (2004).

enable generalizations. However, as long as the analysis of nasal vowels is a considerable challenge (section 2.3), we could not analyze more data in this study, mainly for a matter of time.

BP participants were not assessed with a discrimination test before the identification test, mainly for a reason of time. For future research, though, it would be important to do so. The ABX test we used was conceived only with natural nasal vowels. In order to answer more precisely the research question in (1.1), manipulations on speech stimuli could be done. Comparison of the perception of oral vowels vs. nasal vowels could also be done through a perception test. Also, answer buttons were written in regular French orthography in the test. This could have an influence on the speakers' answers because, for example, the grapheme <in> represents [ĩ] in BP and [ẽ] in QF, and the grapheme <en> leads to [ẽ] in BP and [ã] in QF. This could be another source of confusion for the BP speakers. Training with IPA symbols, for example, could be a good solution to this problem. We also decided to interpret the confidence of answer as an intelligibility rate, but we think that operationalizing intelligibility in a different way could serve future research.

3.3 Implications for teaching, theory and avenues for future research

This study has many implications for the fields of pronunciation teaching and for phonological theory. For example, we have seen that nasal vowels [œ̃], [ã] and [ẽ] are not always identified properly by BP speakers. Hence, explicitly teaching them how to accurately perceive and produce these sounds will help them in identifying better some words – such as QF <paon> [pã] and <pain> [pẽ], or <brin> [bœ̃] and <brun> [bœ̃] – and in being more intelligible to native QF speakers. Acoustic studies such as this one enables us to understand what the difficulties of BP learners of French are, hence what should be taught in priority, and why they find it so difficult.

Our study has certain implications for phonetic and phonological theories in that it gives more insights to the cross-linguistic perception of vowels. Very few studies have been made on the perception and acquisition of nasal vowels because of their particular articulatory and acoustical configuration. We think that investigating the field of nasality and nasalization will provide answers to some very important questions in linguistics. For example, Ohala (2010) questions the pertinence of separating radically phonetics and phonology. Our study shows that both are closely tied up: the perceptual (phonological) system of a speaker becomes language specific because of the phonetic and acoustic input it gets, and it becomes hard to modify this system when learning a L2. QF and BP speakers do not perceive nasal vowels' acoustical properties the same. This shows how important it is, in our opinion, to consider both phonetics and phonology when studying these questions. Articulatory Phonology (Browman & Goldstein, 1986; 1992), for example, encodes both phonetics and phonology in its representations. It would be very interesting to account for the phenomena observed within an Articulatory Phonology framework.

4. Conclusion

In conclusion, in this experiment, we decided to assess the participants with a production task (for acoustic analysis) and perception task (ABX test). In the first part of the study, we found that QF nasal vowels are variable across speakers. QF nasal vowels are diphthongized and [ẽ]'s placement in the vowel quadrant is variable. QF and BP nasal vowels are also different. QF nasal vowels tend to be pronounced lower than BP nasal vowels, and QF nasal vowels are more compact than BP's. These peculiarities of QF nasal vowels could explain why BP speakers do not perceive them properly. In the perception test, we found that [œ̃] is often misidentified by BP speakers and that [ã] and [ẽ] are either misidentified or well identified depending on the speaker. It was hypothesized that the speakers have not yet created a new category for QF [œ̃], and

that QF [ã] and [ẽ] are often confused. We can also hypothesize that for one speaker, the prototype for QF [ã] and [ẽ] is BP [ẽ], while the prototype for these nasal vowels for the other speaker is [ẽ].

We also discussed some methodological issues that arose through the process of this study. A greater number of participants, more realizations of nasal vowels in BP and a discrimination test will have to be used for future research.

Finally, some avenues of research and implications for teaching were discussed. We saw that questions such as the interface between phonetics and phonology can be partly answered with studying perception of L2 speech sounds.

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