Similar, Yet Different: Acquisition of Brazilian Portuguese Nasal Vowels by Spanish-English Bilinguals

Ann Aly Bailey

1. Introduction

1.1. Objectives and background

The current study provides acoustic data of Brazilian Portuguese (BP) vowels as produced by native BP speakers and Spanish-English bilinguals who speak BP as a third language (L3). There are few studies that examine the acoustic characteristics of the BP vowel inventory or post-L2 acquisition and there are currently no studies that provide acoustic data and analysis of BP learners. The current study aims to add to the existing literature on Portuguese phonetics by providing an analysis of BP monophthongs with data from both native speakers and Spanish-English bilinguals who have learned BP as an L3 in a university setting.

1.2. Key differences between Spanish and Portuguese phonology

Although Spanish and Portuguese have common historical roots, they diverge in several aspects of their historical development, particularly with respect to their vowel inventories. Both languages underwent phases of vocalic reduction from Latin, but the historical processes concerning vowels diverge from this point. Spanish continued its vocalic confluences and converted the mid-open vowels /ɛ/ and /ɔ/ into the diphthongs /i̯e/ and /u̯e/, respectively, but these mid-open vowels were maintained in Portuguese (Penny 2002; Pharies 2007). Over time, as the smaller vocalic inventory in Spanish began to stabilize, Portuguese also developed contrastive nasal vowels as a result of weakening and assimilation of nasal consonants in coda position (Mateus and D'Andrade 2000). This process resulted in both nasal monophthongs and diphthongs that contrast with their oral counterparts. Examples of this contrast are as follows:

(1)	***lá*** 'there'	[la]	***lã*** 'yarn'	[lɐ̃]
	seda 'silk'	[ˈse.dɐ̃]	***senda*** 'footpath'	[ˈsẽ.dɐ̃]
	lido 'read' (participle)	[ˈli.dʊ]	***lindo*** 'beautiful'	[ˈlĩ.dʊ]
	cotar 'to quote'	[ko.ˈtaɾ[1]]	***contar*** 'to count'	[kõ.ˈtaɾ]
	mudo 'mute'	[ˈmu.dʊ]	***mundo*** 'world'	[ˈmũ.dʊ]

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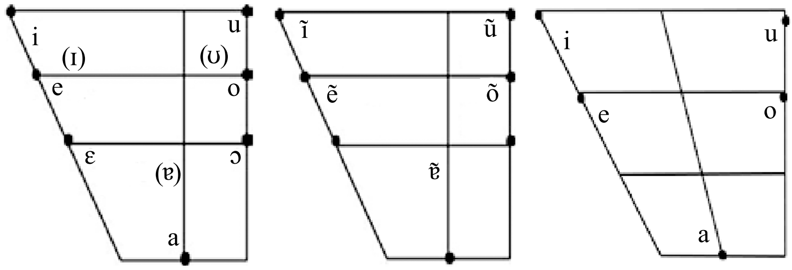
[1] Pronunciation of word-final 'r' in BP varies by region. The variant shown is common in southern Brazil, where the majority of the current study's participants were recorded. Please refer to Azevedo (2005) for a full description of the seven rhotic variants found in Brazil.

The following charts, based on those by Barbosa and Albano (2004) and Martínez-Celdrán (2003) display the present-day vowel inventories of and BP[2] and Spanish[3], respectively[4]:

(2)



a. BP oral vowels b. BP nasal vowels c. Spanish vowels

2. Characteristics of nasal and nasalized vowels: Observations and empirical studies

2.1. Cross-linguistic observations

Nasal vowels have several unique acoustic characteristics. Sampson (1999) describes the most common characteristics of nasal vowels, which include lower intensity in the first formant (when compared to oral vowels), extra formants (also called *nasal formants*) that can appear at variable frequencies, formants with wider bandwidths, and anti-resonances (or anti-formants), whose sharp dips in intensity can cancel and change the resonance patterns that would be expected in the formant structure of oral vowels. Figures 3ab below show a spectral slice taken from the BP vowels /a/ (3a) and /ɐ̃/ (3b). The circled area highlights the difference in intensity around the first formant.

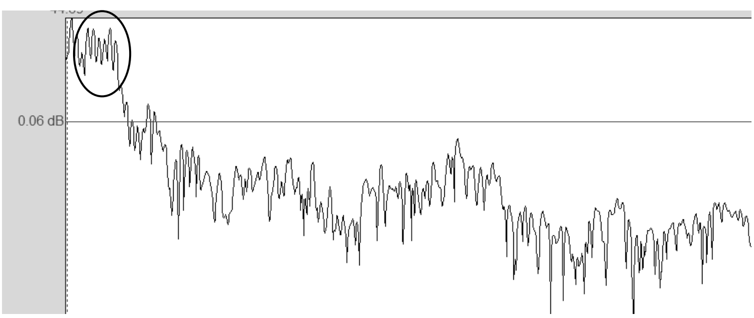


Figure 3a. Spectral slice of BP oral vowel /a/

[2] The vowels in parentheses in the BP charts indicate reduced vowels.

[3] Although Spanish does not nasal vowels like BP, it does contain nasalized allophones, which will be further discussed.

[4] Although the current study's participants are L2 English speakers, the current study makes no assumptions about the possible effect of English on their L3 BP production for two reasons: first, both English and Spanish contain vowel nasalization only at the allophonic level, which makes phonemic nasal vowels a novel form both language backgrounds; and second, research from L3 morphosyntax (such as Montrul et al 2011 and Rothman 2011) provide evidence for a privileged status of Spanish in L3 Portuguese transfer, regardless of order of Spanish acquisition.

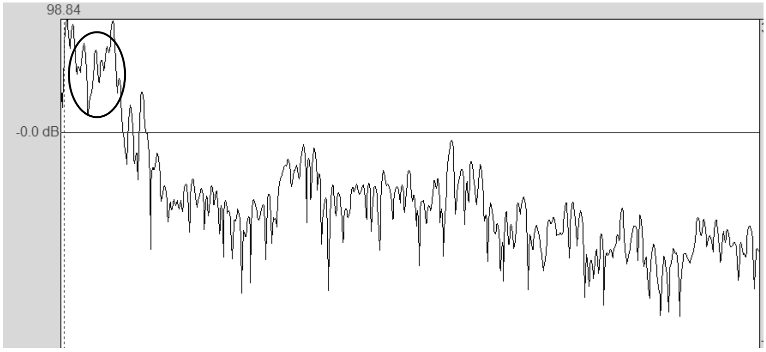


Figure 3b. Spectral slice of BP nasal vowel /ɐ̃/

Another acoustic characteristic of nasal vowels that the current study will make reference to is a *nasal murmur*. Gigliotti de Sousa (1994) uses this term to refer to the shortened consonant-like segment that follows nasal vowels in *regressive nasalization* in BP, which refers to contexts in which an orthographic nasal consonant follows the vowel (such as *santos*, 'holy' as opposed to *mãe*, 'mother', which is *progressive nasalization*). Different from a full nasal consonant, a nasal murmur is realized with weaker intensity and has a much shorter duration than a nasal consonant. Although the terms *progressive* and *regressive nasalization* usually imply that the underlying representation of the vowel is oral and receives its nasality via co-articulation with a nasal consonant, the present study assumes that BP nasal vowels have an underlying nasal representation that differs from oral vowels and allophonic nasalization (henceforth referred to as *nasalized vowels*), which refers to non-contrastive nasality, as seen in Spanish and English. The terms *regressive* and *progressive nasalization* will be used in the present study to describe the presence and directionality of an orthographic nasal consonant. The spectrograms shown below in Figure 4ab visually display the differences between a full nasal consonant in a nasalized (allophonic) context in Spanish (marked 'n' in Figure 4a) and a nasal murmur in a nasal context in BP (marked 'n.m.' in Figure 4b).

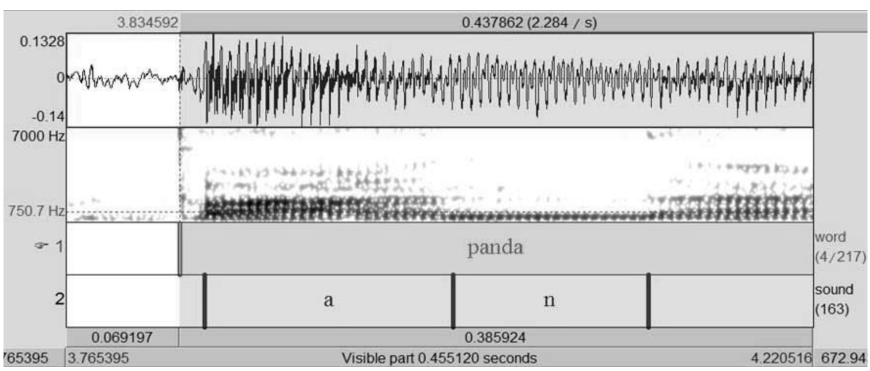


Figure 4a. Spectrogram of Spanish nasalized vowel and consonant

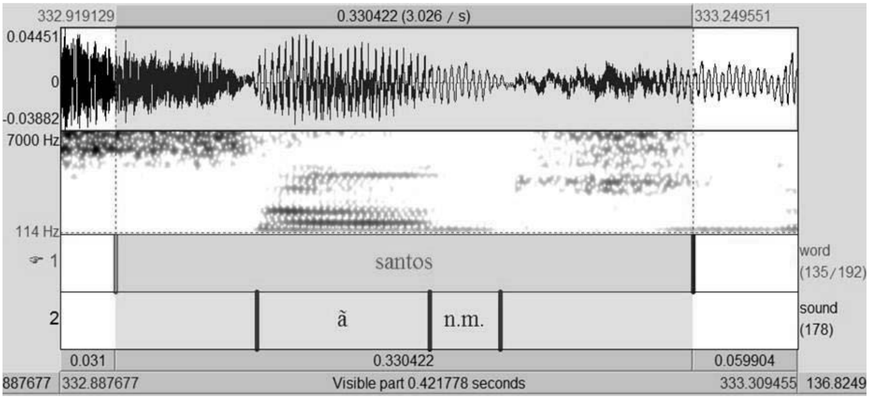


Figure 4b. Spectrogram of BP nasal vowel and murmur

2.2. Nasal(ized) vowels in Portuguese and Spanish

The following sections will discuss relevant empirical studies that have examined the acoustic and articulatory characteristics of nasal vowels in BP and nasalized vowels in Spanish.

2.2.1. Nasal and nasalized vowels in Portuguese

Kelm (1989) investigates the acoustic differences between /a/ and /ɐ̃/ in the controlled speech of thirty male BP speakers from São Paulo. The results revealed a significant difference in tongue height and advancement between the oral and nasal /a/ in a normal speaking rate, where the nasal vowel was both higher and more fronted than its oral counterpart. In high-velocity speech, the /ɐ̃/ centralized and was significantly higher than the /ɐ̃/ in a normal speaking rate. With regards to duration, /ɐ̃/ was shorter in duration than its oral counterpart.

Gigliotti de Sousa (1994) also researches acoustic features of both nasal and oral vowels of twelve male BP speakers from various regions. Tokens used include both nonce and real words in carrier sentences. Results showed that nasal vowels were longer than their oral counterparts[6]; nasal murmurs were present in most of the nasal vowels analyzed; the intensity of nasal vowels was lower and less variable than that of oral vowels; and that /õ/ and /ẽ/ had the highest level of variability as well as a tendency to diphthongize when compared to their oral counterparts.

Apart from acoustic differences, there are also articulatory differences between nasal and nasalized vowels. Fails (2011) measured the airflow through the oral and nasal cavities during the production of oral and nasal(ized) vowels in Spanish and BP. The results of Fails (2011) revealed that BP nasal vowels have a higher level of nasal airflow than Spanish nasalized vowels, and that only one phonological environment in the Spanish data (CVN#) resulted in a comparable level of nasality to Portuguese nasal vowels. Medeiros (2011) also investigated the airflow and duration of nasal and nasalized vowels, but only with data from BP. Similar to Fails (2011), Medeiros (2011) found higher levels of nasal airflow for nasal vowels than nasalized vowels, as well as different targets of nasality with respect to duration; nasality (in terms of airflow) began sooner in nasal vowels and comes to a high peak during the murmur portion, whereas increased airflow in nasalized vowels begins later in the vowel and plateaus at a lower level during the nasal consonant that follows.

2.2.2. Nasalized vowels in Spanish

Unlike Portuguese, Spanish does not show a phonemic contrast between nasal and oral vowels. However, allophonic vowel nasalization (usually in a VN sequence) does exist and has different dialectal manifestations. Terrell (1975), Canfield (1981), Lipski (2004) and Hualde (2005) document the tendency for Caribbean dialects to weaken nasal consonants in coda position. This process causes

[6] The nasal murmur duration was included as part of the vowel in this study.

regressive assimilation of the nasal consonant to the vowel that precedes it, similar to coda position contexts in Portuguese (such as *pan* 'bread' being pronounced as [pã] instead of the expected [pãn]). Sampson (1999) accounts for Peninsular dialects of Spanish and states that not only do Andalusian and Extremaduran dialects contain coda position nasalization, but also nasalization not conditioned by a nasal consonant. According to Sampson (1999), the cause of this the non-conditioned nasalization is an aspirated consonant, such as the glottal fricative /h/, which can trigger nasalization in a word like *cerrojo* ('bolt'), in which /seroxo/ is realized as [se.ˈrõ.hõ]. These types of phenomena are still fairly understudied and these factors and the extent to which they contribute to vowel nasalization in Spanish are not yet fully understood.

3. Acquisition of L3 phonology: Previous studies

Whereas second language acquisition (SLA) is frequently studied, research on L3 acquisition is beginning to emerge. These studies provide valuable insights into the acquisition process of language learners who already possess more than one language from which transfer may occur. Transfer can either have a *positive* form, meaning a form from a previous language has a similar use in the new language and can be transferred and utilized successfully in the new language (e.g. inter-language cognates or pronunciation features, such as phonotactics), a *negative* form (also referred to as *interference*), in which a form (similar or not) from a previous language is incorrectly utilized in the new language (e.g. false cognates or phones with different distributions) or *regressive*, in which aspects of a newer language are transferred back to a previously learned language. Another possibility in the production of L3 speakers are interlanguage universals, which may be the result of marked forms being blocked (assuming constraint rankings of Optimality Theory, Prince and Smolensky 1997; 2004) in the learner's developing system, a claim made by Louriz (2007) when L3 English speakers (L1 Moroccan Arabic/L2 French) produced primary stress patterns not present in either their L1 or L2. Several relevant studies will be highlighted in reference to acquisition of L3 phonological features.

Gut (2010) examined the English and German production of four trilingual speakers of various L1 backgrounds to determine if transfer could be attributed to either the L1 or L2 of the participants. The results did not show direct influence of the participants' L1 on their L3 for the variables measured (vowel reduction and speech rhythm), but showed evidence for influence of the L2: participants produced reduced vowels in the L3 with compromised (or hybrid) values that could have been influenced by their L2, as three of the four speakers do not reduce vowels in their L1s (Spanish, Hungarian, and Polish). Llama et al (2010) measured the voice onset timing (VOT) of /p, t, k/ in L3 Spanish speakers (English-French and French-English bilinguals) claims that L2 is a greater factor than language typology; both groups produced similarly compromised VOTs in their L2 and L3 that were different than those produced by monolingual speakers of their L1s, although these values did not reach significance in the French-English bilingual group. Another L3 study that focuses on VOTs is Wunder (2010). In this study, a group of L1 German/L2 English/L3 Spanish participants showed evidence of compromised VOTs in both their L2 and L3, which the author claims is an effect of L1 transfer. A combined transfer source is argued for in Blank and Zimmer (2009), in which evidence of L1 and L2 influence in the acoustic features of vowels (formant values and duration) is seen in the L3 production of a group of L1 BP/L2 French/L3 English speakers.

A study that investigates a linguistic demographic similar to the present study is Cabrelli Amaro and Rothman (2010). Their longitudinal study focused on two L3 speakers of BP: one participant was a successive English-Spanish bilingual and the other a simultaneous English-Spanish bilingual. The study measured various phonological features that differ between Spanish and BP, such as vowel nasalization, vowel reduction, (BP features) and spirantization of intervocalic stops (a Spanish feature). The results suggest that native and non-native phonological systems are inherently different: the study's successive bilingual showed greater negative regressive transfer from L3 to L2 as L3 proficiency improved, but the simultaneous bilingual showed no regressive transfer from L3 to L1s[7]. The researchers then predict that the simultaneous bilingual would show evidence of progressive

[7] This study assumes that the simultaneous bilingual has two native language systems.

negative transfer from L1 (Spanish) to L3 that did not improve as quickly as it would with the successive bilingual, a developmental trajectory predicted by the authors' Phonological Permeability Hypothesis (PPH), which assumes different phonological developments which depend on the stability of previously acquired languages.

The methodologies, variables, language groupings, and results of these studies all indicate various sources and combinations for transfer in the L3. Additional research that expands, replicates, and addresses various unanswered questions from previous L3 phonological acquisition studies may further develop and provide evidence for these possible transfer sources. Several limitations in the studies discussed that could also be addressed in future studies include using reference values from monolinguals instead of the participants' own L1/L2 production (in the case of Llama et al 2010, Wunder 2010 and Blank and Zimmer 2009), the relatively small sample sizes (due to various difficulties in finding participants with the same language acquisition order), and the vast differences between languages used in the studies, which make generalizations about L3 transfer difficult.

Keeping in mind the observations and limitations of these previous studies, the current study is motivated by the following research questions:

1. How do Spanish-English bilinguals produce BP vowels in comparison with L1 BP speakers[8]?
2. Do these L3 BP speakers produce nasal vowels in BP similarly to nasalized vowels in Spanish?
3. What theoretical implications, if any, about transfer and the acquisition of typologically similar languages can be made in reference to the L3 BP speakers' production of BP?

4. Method

4.1. Participants

There were ten participants in this study: six native speakers of BP and four Spanish-English bilinguals who learned BP as an L3 in a university setting. All participants were between 18-26 years old and university students at the time of data collection. The L1 BP participants represent three regions of Brazil: Amazonas, in the Northwest; Minas Gerais and São Paulo, in the Southeast; and Rio Grande do Sul, in the South. The Spanish-English bilinguals (henceforth L1 Spanish) represent Latin American, Caribbean and Peninsular varieties of Spanish and all reported studying Portuguese for at least two semesters in a university setting. All participants besides Participant 8[9] acquired English during adolescence and received higher education in English as well. Participant 7 was the only participant who reported studying abroad in Brazil for nine months at the time of the study. Table 1 includes more demographic information about the participants.

Participant	L1	Age	Gender	Place of origin	Other languages
1	BP	22	Male	Amazonas	--------------------
2	BP	20	Female	Amazonas	Spanish
3	BP	21	Male	São Paulo	English, Spanish, Italian[10]

[8] The current study does not anticipate that the L1 Spanish group will produce monolingual-like values in their vowel production. Rather, these values, along with their production of Spanish will serve as two points of reference at which to situate their interlanguage values.

[9] Participant 8 is the study's only heritage speaker of Spanish, which Valdés (2000) defines as a person who acquires a minority language (in the case of the United States, any language other than English) in the informal setting of their home in addition to the relevant majority language.

[10] The current study acknowledges that knowledge of Italian (Participant 3) and French (Participant 10) may have influenced the BP production by these participants. However, both participants reported using these languages less than once a month and the small sample size made it difficult to determine whether there were differences in these participants' production when compared to the others.

4	BP	18	Female	Minas Gerais	--------------------
5	BP	21	Male	Rio Grande do Sul	English
6	BP	22	Female	Rio Grande do Sul	English
7	Spanish	26	Male	Canary Islands	English, Portuguese
8	Spanish	20	Female	US/ Dominican Republic	English, Portuguese
9	Spanish	23	Male	Bolivia	English, Portuguese
10	Spanish	27	Female	Spain	English, Portuguese, French

Table 1. Participant demographics

4.2. Data collection

Participants were recorded in a quiet, carpeted environment for acoustic clarity. The L1 Spanish participants (except Participant 7) were recorded in a phonetics laboratory. Participant 7 and the L1 BP participants were recorded in quiet rooms in the cities of Itajubá, Manaus, and Passo Fundo, Brazil. Only the participant and the researcher were present at the time of the recording. The participants were recorded using an Olympus LS-11 recorder with an internal microphone at a sampling rate of 44.1 kHz.

4.3. Tokens and tasks

Token words from both Spanish (n = 10) and BP (n = 12) were analyzed in the current study. The tokens chosen were disyllabic real words[11] with the target vowel in the tonic syllable. Both oral[12] and nasal(ized) contexts were chosen for each language to allow for within and between-group comparisons of oral and nasal(ized) vowel production. The full list of tokens analyzed in the present study is shown below in Table 2.

Spanish tokens		**Portuguese tokens**	
Orthography	**Transcription**	**Orthography**	**Transcription**
faro ‘lighthouse’	[ˈfa.ɾo]	*fado* (music genre)	[ˈfa.dʊ]
velo ‘veil’	[ˈbe.lo]	*vejo* ‘I see’	[ˈve.ʒʊ]
fila ‘line’	[ˈfi.la]	*fica* ‘s/he stays’	[ˈfi.kɐ̃]
foro ‘forum’	[ˈfo.ɾo]	*fofo* ‘cute’	[ˈfo.fʊ]
fuga ‘escape’	[ˈfu.ga]	*fuga* ‘escape’	[ˈfu.gɐ̃]
panda ‘panda’	[ˈpãn.da]	*santo* ‘holy’	[ˈsɐ̃.tʊ]
pento nonce word	[ˈpẽn.to]	*vento* ‘wind’	[ˈvẽ.tʊ]
pinta ‘pint’	[ˈpĩn.ta]	*vindo* ‘came’	[ˈvĩ.dʊ]
pongo ‘I put’	[ˈpõŋ.go]	*fonte* ‘fountain’	[ˈfõ.tʃɪ]
punto ‘point’	[ˈpũn.to]	*fundo* ‘bottom’	[ˈfũ.dʊ]

Table 2. Spanish and Portuguese tokens analyzed

[11] The Spanish nasalized token *pento* is the exception to this. This is a nonce word that was used as a name in the Spanish task in order to conform with the phonological environment and syllable structure of the other tokens.
[12] The BP mid-open vowels /ɛ/ and /ɔ/ were not included in the present analysis due to their lack of corresponding nasal counterparts.

Three tasks were used in the current study, which were completed twice by each participant. Task 1 was completed by L1 Spanish speakers only and consisted of reading a paragraph that included the Spanish tokens. Before continuing the Tasks 2 and 3, L1 Spanish participants completed a short distractor task in English as a means to change language mode and to clear their short term memory from the Spanish task.

Tasks 2 and 3 were completed by all participants and contained the BP tokens. Task 2 consisted of 27 Portuguese sentences formed around the content of the token words. Critical sentences were pseudo-randomized with filler sentences of approximately the same length. An example sentence from Tasks 1 and 2 are provided below in Figure 5ab, with token words underlined.

(5a) *Example from Task 1:* Érase una vez, un oso <u>panda</u> que se llamaba <u>Pento</u> vivía en un <u>faro.</u> (Once upon a time, a <u>panda</u> bear named <u>Pento</u> lived in a <u>lighthouse</u>).

(5b) *Example from Task 2:* Nunca <u>vejo</u> ninguém quando tem <u>vento</u> forte lá fora. (I never <u>see anyone</u> when there is strong <u>wind</u> outside).

Task 3 contained the Portuguese tokens as well as filler words (n = 29) in the carrier sentence "Diga ____ também" ("Say ____ as well"). The purpose of this task was to place the tokens in a more controlled phonetic environment than that of the sentences of Task 2. The filler words were random nouns taken from the sentences in Task 2, so that familiarity with the words from Task 2 would not reveal the tokens. Each L1 Spanish participant produced 60 tokens and Each L1 BP participant produced 40 tokens for a total of 480 analyzable tokens.

4.4. Data analysis

The current study's data was acoustically analyzed using *Praat* (Boersma and Weenink 2012). Statistical analyses were performed in SPSS Version 20 and included mixed linear models with a random effect for speaker in order to compare L1 groups and a paired-samples t-test to compare the L1 Spanish group's production of Spanish and BP. The following dependent variables were measured in this experiment:

1. Vowel duration: Using spectrograms and waveforms, duration was measured from the beginning of formant structure and periodicity to the end of periodicity (or the beginning of the next segment, in the case of adjacent periodic segments) in milliseconds (ms). For nasal vowels, this value includes the nasal murmur, following the precedent of Gigliotti de Sousa (1994). An example of this is shown below in Figure 6.

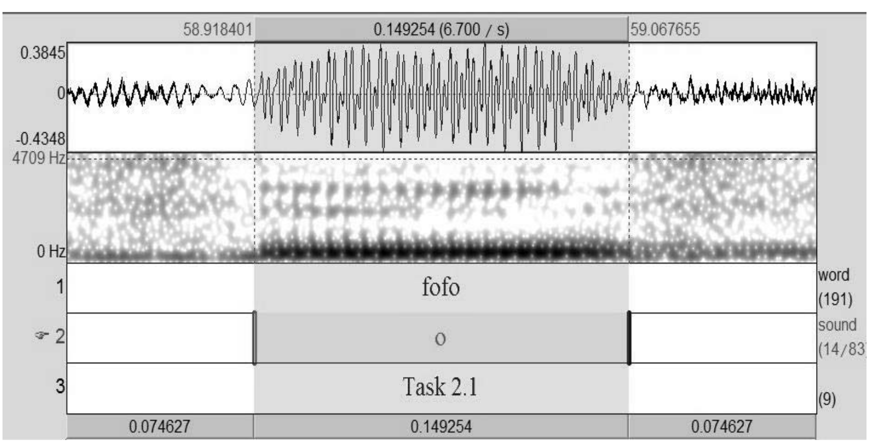


Figure 6. Duration measurement example

2. Formant values: The first two formants (F1 and F2) were measured in Hz using a 20-30 ms spectral slice[14] taken from the middle (most stable portion) of the vowel. An example of this is shown below in Figure 7 (segment also taken from the word *fofo*), in which the first two formant areas are circled.

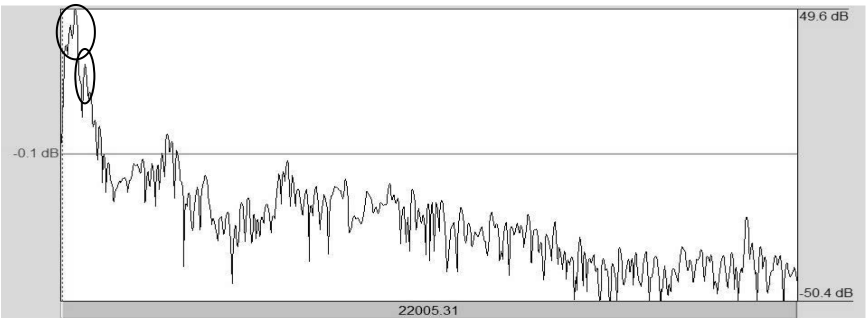


Figure 7. Formant measurement example

The following independent variables were considered for this experiment:

1. Native language (L1): Spanish or BP
2. Type of vowel:
   a. Nasal: Defined for the purposes of the current study as a BP vowel in an (orthographic) tautosyllabic VN context (e.g. *vento*)
   b. Nasalized: similar to the nasal vowel context above, in which the target vowel is in a tautosyllabic VN context, but refers to allophonic nasalization, or Spanish words for the purposes of the current study (e.g. *pinta*)
   c. Oral: BP or Spanish vowels that are not followed by a tautosyllabic nasal consonant (e.g. *fuga*)

The data from the experiment were analyzed according to the variables and measurement thresholds clarified in section 4.1. The following section will discuss the results of the experiment, both within and between L1 groups with respect to the variables defined.

5. Results

5.1. Formant values

5.1.2. BP vowels

The findings for the first formant (F1), which corresponds to vowel height, will be discussed first. F1 frequencies have an inverse relationship to tongue height, in which a higher F1 frequency corresponds to a lower tongue height and a lower F1 corresponds to greater tongue height. A linear mixed model with random effect for speaker and fixed effects of L1, vowel, and vowel type (nasal or oral) revealed a significant main effect for vowel, $F(4, 349) = 113.83$, $p < .001$ and type of vowel, $F(1, 349) = 11.54$, $p = .001$; significant interactions were found between the variables vowel and type of vowel, $F(4, 349) = 24.68$, $p < .001$ and L1 and vowel, $F(4, 349)= 3.36$, $p = .010$. An analysis of simple main effects (Bonferroni adjustment) revealed that for both L1 groups, /ɐ̃/ was produced with a significantly lower F1 (higher tongue height) when compared to /a/ ($p < .001$), and that the L1 Spanish group produced /ɐ̃/ with a higher F1 (lower tongue height) than the L1 BP group, and this difference approached significance ($p = .056$). These values are displayed in Table 3. The vowel plot below visually illustrates both L1 groups' mean production of BP nasal vowels. The y-axis represents tongue height, with the higher frequencies representing higher tongue height and the lower frequencies

[14] The decision to measure (oral) formants with a spectral slice was made after attempts to measure formants with formant trackers on the spectrogram yielded inconsistent results and follows the practice of Chen (1997). Measuring formants using linear predictive coding (LPC) was is an option, but the presence of all poles (oral and nasal) in the LPC makes determining formants difficult.

representing lower tongue height. The tongue height difference between /ɐ̃/ and /a/ is circled. There were no significant differences found for F2, or tongue advancement (frontness/backness).

L1 Portuguese					L1 Spanish				
Vowel	F1 (Hz)	S.E.	F2 (Hz)	S.E.	Vowel	F1 (Hz)	S.E.	F2 (Hz)	S.E.
/ɐ̃/	549	15	1431	37	/ɐ̃/	638	15	1488	35
/ẽ/	499	15	2144	37	/ẽ/	478	15	2032	35
/ĩ/	460	16	2401	38	/ĩ/	439	15	2468	35
/õ/	478	15	924	37	/õ/	508	15	938	35
/ũ/	449	15	952	37	/ũ/	456	16	887	39
/a/	781	15	1392	37	/a/	809	15	1373	35
/e/	442	15	2156	37	/e/	467	15	2052	35
/i/	456	16	2392	38	/i/	452	15	2521	35
/o/	440	15	897	37	/o/	524	15	885	35
/u/	455	15	843	37	/u/	417	16	826	39

Table 3. F1 and F2 frequencies for BP vowels

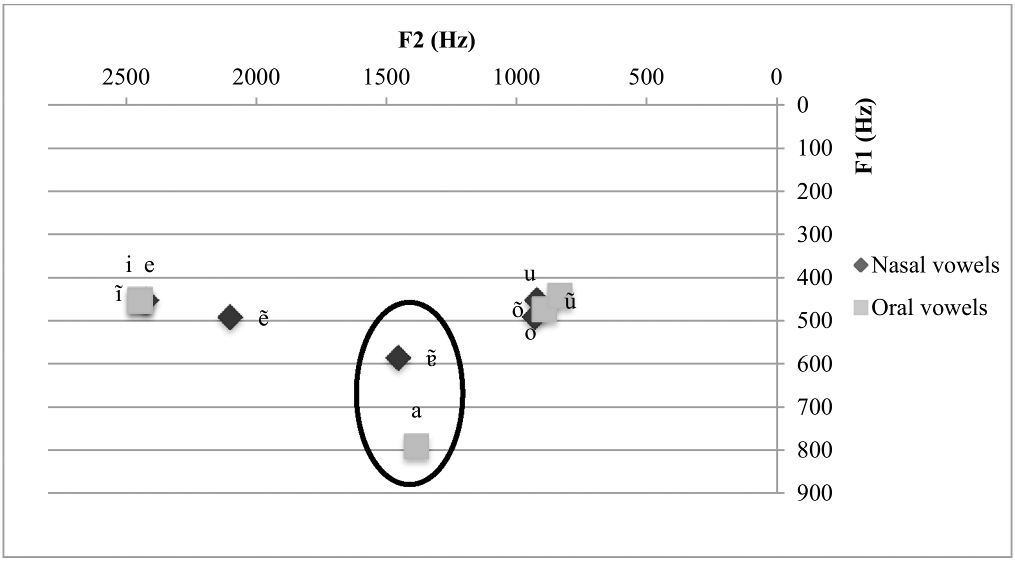


Figure 8. BP vowels (mean values), all participants

5.1.3. Comparison of Spanish and BP vowel formants

The L1 Spanish group's production of Spanish and BP vowels was analyzed to test for any differences between nasalized and nasal vowels by these speakers. Although the lexical items measured in both Spanish and Portuguese were different, the target vowels and syllabic environments (VN) were similar and a within group analysis was completed with a paired samples t-test, in which corresponding Spanish and Portuguese vowels were compared in terms of duration and formant frequencies (F1 and F2). The analysis revealed no significant differences in F1 frequency between Spanish nasalized vowels and Portuguese nasal vowels, and one F2 difference for /e/, in which the nasal (BP) vowel had a significantly lower F2 (tongue further back) than its nasalized (Spanish) counterpart, $t(6) = 2.67$, $p = .037$. These values are provided in Table 4. Figure 9 shows a scatterplot of the L1 Spanish group's production of Spanish and Portuguese vowels and the F2 difference between (BP) /ẽ/ (empty square) and (Spanish) [ẽ] is circled.

Portuguese nasal vowels					Spanish nasalized vowels				
Vowel	F1 (Hz)	S.E.	F2 (Hz)	S.E.	Vowel	F1 (Hz)	S.E.	F2 (Hz)	S.E.
/ɐ̃/	617	45	1431	37	[ã]	730	30	1488	80
/ẽ/	502	19	2144	56	[ẽ]	467	27	2032	177
/ĩ/	454	24	2401	156	[ĩ]	478	37	2468	273
/õ/	505	28	924	39	[õ]	511	38	938	55
/ũ/	472	38	952	43	[ũ]	406	52	887	31

Table 4. F1 and F2 frequencies (Hz) for nasal and nasalized vowels, L1 Spanish group

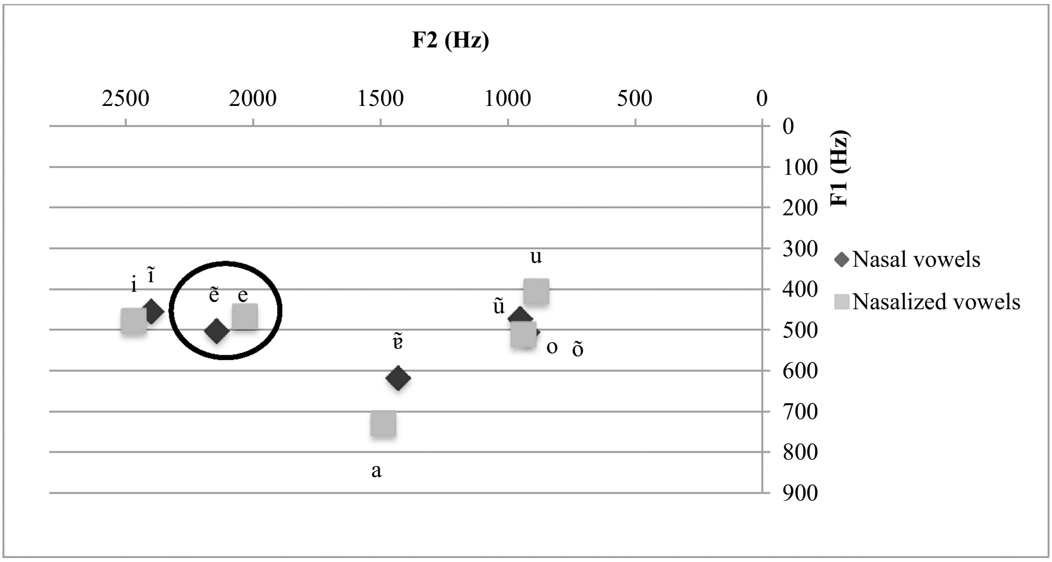


Figure 9. BP and Spanish nasal(ized) vowels (mean values), L1 Spanish participants

5.2. Vowel Duration
5.2.1. BP vowels

The mixed model analysis outlined in 5.1.2 was also performed for vowel duration and this analysis revealed significant main effects for vowel, $F(4, 349) = 8.95$, $p < .001$; type of vowel, $F(1,349) = 135.36$, $p < .001$; and a significant interaction between these two variables, $F(4, 349) = 9.39$, $p < .001$. To further explore this interaction, an analysis of simple main effects (Bonferroni adjustment) was administered and revealed that both L1 groups produced BP nasal vowels with a longer duration than oral vowels in all cases except /a/ and its counterpart /ɐ̃/. Figure 10 below shows a graph which visually displays the duration difference between BP nasal and oral vowels; the nasal murmur portion of the nasal vowels is represented by the solid portion of the nasal vowel bars on the graph in order to illustrate its proportion of the total vowel duration. There were no differences between groups for nasal murmur (the consonant-like phase at the end of a nasal vowel as shown in Figure 4b) duration.

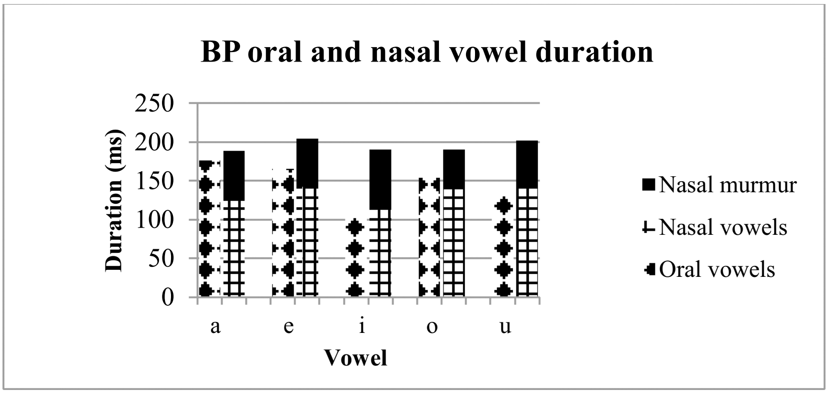


Figure 10. BP vowel duration, all participants

5.2.2. Comparison of Spanish and BP vowel duration

The paired-samples t-test outlined in section 5.1.3. was also performed with respect to Spanish and BP vowel duration, as produced by the L1 Spanish group. The results of this analysis revealed that for L1 Spanish participants, all Portuguese nasal vowels were significantly longer than the respective Spanish nasalized vowel except for /o/: /a/, $t(6) = 7.4$, $p < .001$; /e/, $t\ (6) = 11.74$, $p < .001$; /i/, $t(6) = 20.15$, $p < .001$; and /u/, $t(6) = 3.84$, $p = .008$. These differences are displayed in Figure 11, in which Spanish and BP vowels are compared and the portion of the vowels corresponding to the nasal consonant (Spanish vowels) and nasal murmur (BP vowels) is represented by the patterned portion of the bar[15].

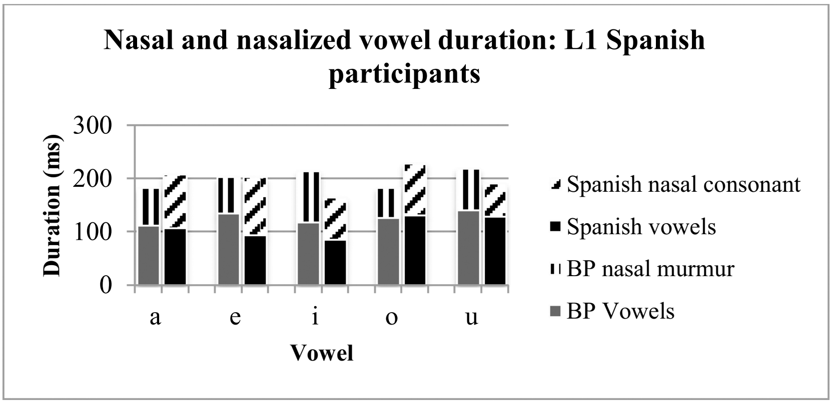


Figure 11. Nasal and nasalized vowel duration, L1 Spanish participants

6. Discussion and implications of results

6.1. Formants

The overall results regarding formant frequencies partially corroborate those of Kelm (1989), who also reported higher tongue height for /ɐ̃/ when compared to /a/. However, the present study did not find evidence of F2 differences between these two vowels. The difference in tongue height between these low vowels is often attributed to the lowering of the velum, which affects the tongue's positioning during articulation (Silverman 2006).

[15] Following the precedent of Gigliotti de Sousa (1994), the nasal mumur was considered as part of the nasal vowel and therefore part of the total vowel duration. However, the nasal consonant following the (Spanish) nasalized vowels was considered an independent segment and its duration is not included in the total vowel duration.

The comparisons between L1 groups did not reveal any significant differences with regards to formant values of BP vowels. This could be due to the overlap in the vowel inventory between Spanish and Portuguese, as the vowels examined could share similar acoustic spaces in both languages. A comparison between the L1 Spanish participants' production of Spanish and Portuguese vowels revealed differences only for the advancement of nasal and nasalized /ẽ/. These results suggest that the differences in formant frequencies between Portuguese and Spanish nasal(ized) vowels are minimal, which results in similar formant frequencies for these vowels in both L1 groups. The observed similarities between the acoustic properties of vowels in Spanish and Portuguese and their typologically related status could be a potential source for positive transfer, as predicted for morphosyntactic structures by the Typological Primacy Model (Rothman 2011) and by Best and Tyler's (2007) Perceptual Assimilation Model-L2 (PAM-L2), which predicts that sounds that are easily matched/assimilated with previously learned categories will be easier to acquire. Therefore, it is possible that the current study's L3 BP speakers were able to associate BP vowels with their similar Spanish counterparts and produce these similarly to BP speakers. However, without an analysis of the L3 BP speakers' English or a mirror-image L3 group (L1 English/L2 Spanish/L3 BP), it is difficult to determine whether the typological similarities between the languages is the main factor (or factors) of transfer, or if L2 status, or L3 proficiency also play a role.

6.2. Vowel and nasal segment duration

Similar to Gigliotti de Sousa (1994), the present study also found that nasal vowels had a longer duration than oral vowels. This durational difference between vowel types could be attributed to the nasal murmur portion of the vowel or an articulatory source. Costa (2004) found that nasal vowels in European Portuguese had durations similar to long vowels and attributes this length to the additional movements involved in velic lowering. Ouellet and Tardif (1996) also found parallel results between nasal and long vowels in Canadian French. This seemingly cross-linguistic property of long nasal duration could have multiple sources (articulatory or segmental, i.e. the murmur portion) and could possibly affect the lack of intrinsic vowel duration typically correlated with tongue height found in the current study's data.

Like the vowel formants, few statistical differences were found between L1 groups. The lack of statistically significant durational differences between L1 groups provides evidence that both groups produce nasal murmurs of similar lengths. These results may suggest that the L1 Spanish speakers in this study have developed a new phonetic category (Flege 1995). This new phonetic category could specify the differences between a nasalized vowel followed by a nasal consonant (like in Spanish) and a nasal vowel followed by a nasal murmur (like in BP). The comparison between the L1 Spanish group's production of nasal murmurs in Portuguese and nasal consonants in Spanish also suggests that this group has developed a new category for nasal murmurs. When compared, nasal consonants occupied a greater proportion of the VC sequence than the nasal murmurs did in three out of five vowels measured, which could show a phase in a developmental trajectory for positive transfer in this context. The differences between nasal consonants and murmurs have implications outside of duration; Sampson (1999) questions the underlying representation of the VN sequence in Portuguese, claiming that many speakers are not (perceptually) aware of a the N in a VN sequence, stating the 'psychological reality' (177), as opposed to phonetic reality, of phonemic nasality in BP. Nasal airflow differences (as discussed in section 2.2.1) found between nasal and nasalized vowels were also found in Medeiros (2011), suggesting separate articulatory targets for these vowel types. Additional evidence from perceptual and articulatory data of L3 BP speakers is needed in order to further solidify the claim that the nasal murmur category has become a mental and phonetic reality for these speakers.

6.3. Issues with multilingual phonological systems

There are several factors that may have influenced the production and developing systems of the current study's participants related to their multilingual status. All of the L1 Spanish participants are multilingual and have lived in an English-speaking environment for at least a year as university students. The linguistic environment of the university may require these participants to use English with more frequency than Spanish or Portuguese, and their language mode may have also been affected during the experiment. Previous works (e.g. Grosjean 1998; Zampini 2008) have suggested that bilingual (or multilingual, in this case) speakers are more likely to produce monolingual-like speech in contexts which require production of only one language. This mixed language context of the experiment may have affected the L1 Spanish group's production in both languages as a result of having all three languages activated within a short period of time. Conversely, the L1 BP participants were only addressed in BP by the researcher and only required to produce BP for the experiment, activating a monolingual-like mode for these participants that was not possible for the L1 Spanish group.

Although the current study's primary focus is the influence that (L1) Spanish may have on the production of (L3) Portuguese, the role and possible influence of the L2 (English) may also provide insights into the effects of multiple non-native phonological systems. English, a language with high levels of allophonic (regressive and progressive) nasalization across all dialects (Ladefoged and Disner 2012), may have positively affected the level of difficulty predicted in acquiring or producing these sounds. Yet without a comparison group of successive English-Spanish bilinguals who have learned Portuguese as an L3, or any English data from the current participants, the current study can make no claims concerning the role of the L2 and any possible progressive or regressive transfer.

7. Conclusion

The current study sought to analyze and describe the vowels of BP as produced by six native speakers and also to compare these values with the production of four Spanish-English bilinguals who acquired BP as a third language. The samples were analyzed acoustically, measuring and comparing vowel and nasal murmur duration and formant frequencies. The results revealed few differences in production between L1 groups, suggesting cross-linguistic similarity and the possibility for positive transfer for language learners of typologically similar languages.

There are several avenues for future research on this topic. A larger, more diverse (in both dialect and proficiency level) population of participants could be studied in order to test the applicability of the present study's results to other groups of Portuguese speakers. Additionally, proficiency could be measured independently of course completion in order to avoid variation in competence amongst participants. A comparison of trilinguals with different orders of language acquisition (e.g. a mirror-image pairing of the current study or learners of unrelated languages) could help further determine the source(s) of transfer for different types of L3 learners. Concerning the type of stimuli analyzed, oral and nasal diphthongs and triphthongs could also be investigated to see how these complex vocalic segments differ and overlap with monophthongs. Additionally, other acoustic correlates of nasality, such as nasal airflow or measurements of nasal poles and harmonics (i.e. the A1-P0/P1 method seen in Chen 1997) could be measured to achieve a more detailed understanding of how these types of segments are produced by different types of language speakers and learners.

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