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THE PRODUCTION OF ENGLISH HIGH-FRONT VOWELS BY BRAZILIAN LEARNERS

A PRODUÇÃO DAS VOGAIS ALTAS ANTERIORES DO INGLÊS POR APRENDIZES BRASILEIROS

LA PRODUCCIÓN DE LAS VOCALES ALTAS ANTERIORES POR APRENDICES BRASILEÑOS

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ABSTRACT: The present study reports on the results of a small-scale study which looks at acoustic features of English high front vowels produced by Brazilian learners of English, who were enrolled at two level-one groups (beginners) from an extension course. Normalized and non-normalized plots were built to look at how vowels are organized in the participants' L2 vowel space regarding sex differences. Results suggest that the English high front vowels are produced as equivalent vowels and tend to overlap. The tense vowel was lowered and centered, whereas the lax vowel was raised and moved frontwards. Thus, learners' tendency, at least at the current stage of language acquisition, was to merge two different categories into one, supporting Flege's (1995) Speech Learning Model.
KEYWORDS: interlanguage; production; acoustic features; high front vowels.

RESUMO: O presente estudo reporta resultados preliminares de uma pesquisa de mestrado que lida com a produção das vogais altas anteriores do inglês por aprendizes brasileiros do idioma. Estes participantes estavam matriculados em cursos de extensão de inglês – nível um – na Universidade Federal de Santa Catarina quando a coleta de dados ocorreu. São apresentadas plotagens de dados em versão normalizada e não normalizada para se observar como as vogais altas anteriores estão organizadas na interlíngua dos participantes. Os resultados indicam que ambas vogais são produzidas como equivalentes e tendem a sobrepor-se. A vogal tensa foi rebaixada e centralizada, enquanto a vogal frouxa foi alçada e anteriorizada. Em conclusão, observa-se uma tendência para que estas duas categorias distintas fossem combinadas em uma, corroborando com o *Speech Learning Model* proposto por Flege (1995).
PALAVRAS-CHAVE: interlíngua; produção; características acústicas; vogais altas anteriores.

RESUMEN: El presente estudio se refiere a los resultados de una investigación de posgrado que trata sobre la producción de las vocales altas anteriores del inglés por aprendices brasileños del idioma. Esos participantes estaban matriculados en cursos de extensión de inglés - primer nivel - en la Universidad Federal de Santa Catarina en el momento de la recolección de datos. Son presentadas plotagens de datos en versión normalizada y no normalizada para observar como las vocales altas anteriores están dispuestas en la interlingua de los participantes. Los resultados indican que ambas vocales son producidas como equivalentes y tendien a sobreponerse. La vocal tensa fue rebajada y centralizada, mientras que la vocal floja fue levantada y anteriorizada. En conclusión, se observa una tendencia para que estas dos categorías distintas fueran combinadas en una, corroborando el *Speech Learning Model* propuesto por Flege (1995).
PALABRAS-CLAVE: interlengua; producción; características sonoras; vocales altas.

1 INTRODUÇÃO

Contrary to the Brazilian Portuguese (BP) vowel system, English includes the contrast between tense and lax vowels. Thus, English has minimal pairs such as "seat" [sit], and 'sit' [sɪt], 'fool' [ful], and 'full' [fʊl], whose distinction is based on the tense/lax contrast. A tense vowel has a higher tongue position, greater duration than its "lax" counterpart, and it requires a greater muscular effort in production than the lax vowel (YAVAS, 2011). In this study, the focus is on the production of the /i/ - /ɪ/ contrast, known as the high front vowels, by BP learners of English. Differently from previous studies (e.g., BAPTISTA, 2006; RAUBER, 2006), here[1] we focus on the production of beginners in order to gather information about whether the tense-lax vowel contrast is present in the initial stages of L2 vowel inventory acquisition.

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2 REVIEW OF LITERATURE

Empirical research has attested the major influence of one's L1 when learning any other additional languages (L2)[2]. As regards L2 speech, Flege (1995) claims that the mechanisms and processes used in the acquisition of the L1 are available for the acquisition of the sounds of an L2 at any age. The author's *Speech Learning Model* (SLM) proposes that similar L2 sounds may be merged with those of the L1, so that different acoustic realizations may be perceived as belonging to the same phonetic category. Thus, phonetic differences between the L1 and the L2, and even within the L2, may not be discerned by the speaker, leading to inaccurate L2 perception and production. As regards this process, Flege (1995) remarks:

> During L2 acquisition, speech perception becomes attuned to the contrastive phonic elements of the L1. Learners of an L2 may fail to discern the phonetic differences between pairs of sounds in the L2, or between L1 and L2 sounds, either because phonetically distinct sounds in the L2 are 'assimilated' to a single category, because the L1 phonology filters out features (or properties) of L2 sounds that are important phonetically but not phonologically, or both. (FLEGE, 1995, p. 238).

As to the acquisition of L2 vowels, Flege (1995) asserts that L1 and L2 categories exist in a common phonological space. New categories for vowels will then be established according to the dispersion of an L2 vowel from an L1 one. Therefore, learners need to adjust their acoustic space to accommodate new phonetic categories. Additionally, Baptista (2006) observes that "[...] these categories need to be linked in some fashion in the long-term memory, so that the representation for each vowel can include its position relative to the other vowels of the L2 system" (BAPTISTA, 2006, p. 20), showing that L2 vowels are acquired as a whole, with the accommodation of new phonetic categories in the vocal tract in relation to previously established categories.

Flege's SLM is relevant to help us to analyze the acoustic features of the English high front vowels by informants of the present study. Our goal is to verify whether these learners produce a distinction for the tense and lax vowel pair, or whether they tend to produce both vowels as being equivalent to the BP high front vowel [i]. In order to better understand how these vowels are produced by the Brazilian speakers, we shall now review studies which dealt with acquisition, perception and production of English vowels by Brazilians.

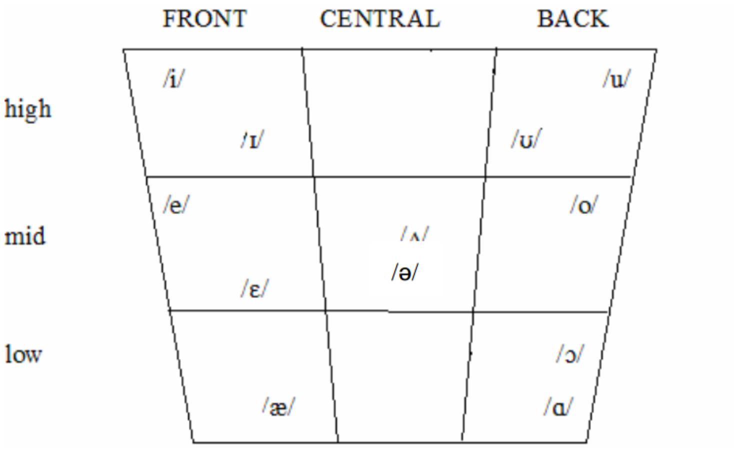
2.1 Vowel inventories and acoustic features

Vowels can be characterized according to the position of the tongue and the lips in their production. They are usually described according to two main categories: one is related to the part of the tongue involved, and the other is related to the height of the tongue. Hence, traditionally, vowels are classified as regards frontness, middleness, and backness; and, according to (four) height dimensions: high, mid (which is divided into high-mid, and low-mid), and low (YAVAS, 2011). Moreover, some vowels might be grouped as regards lip roundness. In American English (AE), and in BP, all back vowels present the rounding feature.

The AE vowel system has ten monophthongs[3] (/i/, /ɪ/, /ɛ/, /æ/, /ə/, /ʌ/, /ɑ/, /ɔ/, /ʊ/, /u/), two homogeneous[4] diphthongs or semi-diphthongs (/e/, /o/, also transcribed as /eɪ/ and /oʊ/), respectively, and three heterogeneous diphthongs (/aɪ/, /aʊ/, /ɔɪ/). Figure 1 displays the distribution of AE monophthongs and homogeneous diphthongs in the vocal tract (Rauber, 2006).

[2]See chapters 4 and 5 in Gass and Selinker (2008) for a discussion.
[3] In AE, all monophthongs and diphthongs are nasalized when they occur before a nasal consonant (YAVAS, 2011).
[4] Roca, and Johnson (1999) as cited in Rauber (2006), explain that /eɪ/ and /oʊ/ are called homogeneous diphthongs because both phases of the diphthongs are close in articulatory position and share the lip gesture; as for /aɪ/, /aʊ/, /ɔɪ/, the two phases of the vowels are not close in articulatory position and do not share lip gesture, thus being called heterogeneous diphthongs.

Figure 1 - Distribution of AE monophthongs and diphthongs in the vocal tract (Rauber, 2006, p. 23)



BP vowel system has seven oral monophthongs (/i/, /e/, /ɛ/, /a/, /u/, /o/, /ɔ/), five nasal monophthongs (/ĩ/, /ẽ/, /ã/, /ũ/, /õ/), and a number of ascending diphthongs (e.g., /eɪ/, /aʊ/) and descending diphthongs (e.g., /ɪa/, /ʊo/). Figures 2 displays BP oral monophthongs, whereas Figure 3 displays the nasal monophthongs (MARCHAL; REIS, 2011).

Figure 2 - Distribution of BP oral monophthongs in the vocal tract (MARCHAL; REIS, 2011, p. 165)

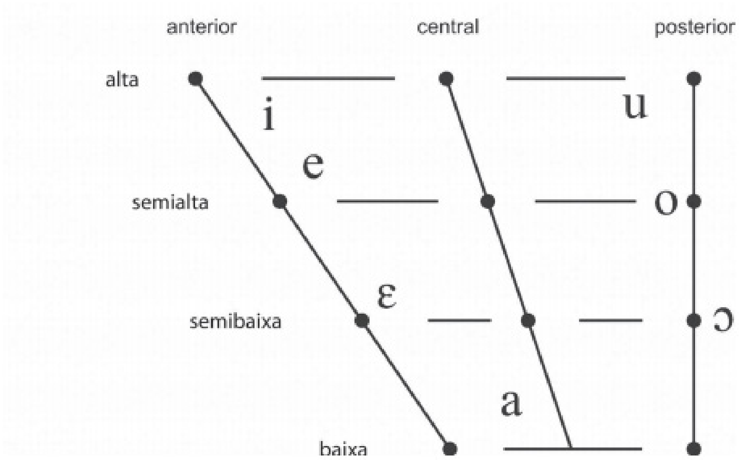
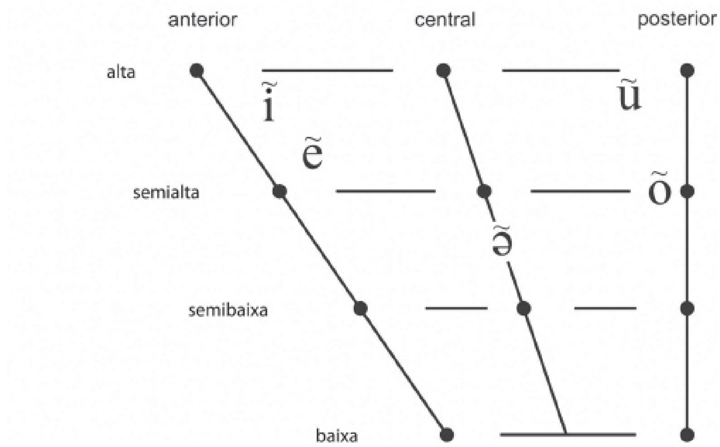


Figure 3 - Distribution of BP nasal monophthongs in the vocal tract (MARCHAL; REIS, 2011, p. 169)



English has minimal pairs such as 'seat' [sit], and 'sit' [sɪt], 'fool' [ful], and 'full' [fʊl], whose distinction is based on the tense/lax contrast. In BP, tense/lax is not a distinctive feature used to characterize vowels

(CRISTÓFARO-SILVA, 2012). Moreover, English vowels are greatly influenced by surrounding consonants. Yavas (2011) remarks that this effect is much more noticeable with liquids /ɹ/ and /l/ in AE. If the retroflex is in the same syllable as the vowel, the contrast among various vowels tends to disappear, e.g., in words such as 'ear' /ɪɹ/, 'pier' /pɪɹ/ for the contrast of /i/ and /ɪ/, attesting for what is commonly known as "r-coloring". For the effect of the velar /l/ on vowels, Yavas (2011) demonstrates that postvocalic /l/ has a retracting effect on front vowels, resulting in more centralized vowels, in cases such as 'meat' and 'meal'; and, 'Mick' and 'milk'.

Acoustically, vowels can be characterized according to their formant frequencies (F1, F2, and F3), and duration values. Formant frequencies relate to the vocal tract configuration. F1 relates to vowel height (how high or how low the tongue position is), whereas F2 usually relates to frontness and backness (i.e., if the tongue is pushed forward or backward) (YAVAS, 2011). Ladefoged states that "the acoustic vowel space can be considered to be an area bounded by the possible ranges for the frequencies of the first two formants" (2001, p. 39). F3 relates to lip rounding, and thus is not investigated in the present research, as this feature is not relevant to describe English high front vowels.

In regard to duration, Ladefoged (2007) posits that, in English, length is not a distinctive feature used to distinguish vowels or consonants. However, it is a significant cue to the devoicing in the final consonant pairs of words, such as in *"beat"* and *"bead"*, for vowels are shorter before voiceless consonants. Similarly, Lisker (1999) argues that information about the place of articulation of a consonantal segment can be provided with the formant frequency modifications of the vowel that precedes such segment. Nonetheless, for some L2 speakers of English, vowel duration is used to differentiate vowel contrasts, such as /i/-/ɪ/ (BION, 2007; ESCUDERO, 2002, 2006), as this feature seems to be perceived as more salient than tongue height or backness/frontness.

Having described how vowels can be characterized, we now review studies investigating the acquisition, perception and production of English high-front vowels by Brazilians.

2.2 Vowel studies in Brazil: acquisition, perception and production

From the many studies carried out so far dealing with vowel acquisition, perception, and production by Brazilians (e.g., BAPTISTA, 2006; BION et al., 2006; RAUBER, 2006; RAUBER et al., 2005; NOBRE-OLIVEIRA, 2007), we shall report findings of two of them (BAPTISTA, 2006; RAUBER, 2006) given their relevance to the present study.

Baptista (2006) developed a longitudinal study which investigated the acquisition of the English language vowel system by eleven native Brazilian-Portuguese speakers. Participants were five men and six women, who were residing in Los Angeles at the time the study was carried out, and, according to the researcher, "they had had varying amounts of English instruction in Brazil, but none [...] was able to utter complete sentences in English without considerable hesitation, frequent pauses and backtracking" (BAPTISTA, 2006, p. 22).

Over a period ranging from four to eight months, participants were asked to read and retell a story in English which had many of the words used in the production test. The researcher, then, evaluated the participants' communicative competence level according to the level at which they were able to retell the story in the first session. Also, participants were recorded in different moments reading forty-two monosyllabic English words containing the seven vowels /i/, /ɪ/, /ei/, /ɛ/, /æ/, /ɑ/, and, /ʌ/ along with 13 distractors.

In regard to the pair of high front vowels, Baptista (2006) reports that nine of the 11 participants failed to acquire the distinction between them, as "the emergence of an /ɪ/ appeared to have been literally blocked by the proximity of the inappropriately high IL [interlanguage] /eɪ/ (modeled after Portuguese /e/) to the IL /ɪ/" (BAPTISTA, 2006, p. 26). Additionally, the two participants who acquired the /ɪ/ during the study "lowered their IL /eɪ/ at approximately the same time as they gradually lowered and separated /ɪ/ from /i/" (BAPTISTA, 2006, p. 27), attesting that one's L2 phonology categories need to be adjusted so that new categories can be formed.

As respects vowel acquisition, Baptista (2006) discusses that research examining the acquisition of L2 vowels should take into account the L2 vowel inventory as a whole (or large portions of the L2 vowel inventory), not only sounds in isolation, as learners do not acquire one vowel at a time, but rather build a whole system of interlanguage vowels simultaneously.

Rauber (2006) investigated the perception and production of three American English (AE) vowel pairs, /i/-/ɪ/, /ɛ/-/æ/, and /u/-/ʊ/, since they tend to be mispronounced and misperceived by Brazilians. The participants who took part in her study were eighteen highly proficient Brazilian speakers of English, M.A. and doctoral students from the Graduate Program in English (PGI) of the *Universidade Federal de Santa Catarina*. The research corpus consisted of sixty-six words, six for each of the eleven AE vowels, comprising the following six phonological structures: bVt pVt sVt tVt tVk kVp. They were produced by three different groups of speakers: AE monolinguals, BP monolinguals and Brazilian speakers of English (L2 learners). The perception test is explained by the author as "a forced-choice labeling test which consisted of the participants' listening to one synthetic vowel and clicking on the label which most resembled the vowel heard" (RAUBER, 2006, p. 90).

Tables 1 summarizes the findings of Rauber's study for both the production and perception tests for the female and male participants. Table 1 contains information regarding the distance between the two vowels (Euclidean Distance), the percentage of similarity between the Euclidean distances obtained for the AE monolinguals and the L2 speakers, the duration of keach vowel for the AE monolinguals and the L2 speakers, and the percentage of overlap between the F1 and the F2 values for each group of informant.

Table 1 - Rauber's (2006) production test results for female and male participants

	Females	Males
Euclidean Distance (AE mon.)	678 Hz	440 Hz
Euclidean Distance (L2 speakers)	184 Hz	262 Hz
Similarity (%)[a]	27.1	59.5%
Duration (AE mon.)	/i/: 130 /ɪ/: 103	/i/: 140 /ɪ/: 118
Duration (L2 speakers)	/i/: 129 /ɪ/: 123	/i/: 126 /ɪ/: 102
Overlap (AE)	F1: 0% F2: 0%	F1: 0% F2: 0%
Overlap (L2)	F1: 42% F2: 37%	F1: 0% F2: 22%

[a] This percentage was obtained by subtracting the L2 speakers' ED from the AE monolinguals ED, and multiplying the result times 100.

Regarding the production test results, we can see that the Euclidean distances of both male and female AE speakers are much larger than the distances observed for the L2 learners. Nonetheless, we can see that the L2 learners are producing a distinction between the two high front vowels, despite not reaching the valued obtained by the AE speakers. The results in Table 1 also show that clearly the AE speakers present longer duration for the tense vowel than for the lax vowel. Yet, for the L2 female speakers, the two vowels have similar duration (both pretty close to the duration of the tense vowels produced by female English monolinguals), and, for the male speakers, the results are similar to those obtained by the male English monolinguals. Note, also, that there is no overlapping between F1 and F2 values for the English monolinguals, which indicates that these vowels belong to separate categories in the Brazilian informants' vowel inventory. However, considerable overlapping is observed for the BP female speakers for both F1 and F2 values and for the BP males' F2 values. Clearly, the female BP speakers showed greater difficulty to distinguish between the two vowels.

Turning to the perception test results, Rauber found that both female and male L2 speakers obtained near native-like performance, thus showing that they tend to distinguish between the two high front vowels at the perception level. Apparently, the L2 leaners use both acoustic cues (F1, F2 values) and duration to make this distinction in terms of perception, but the good performance at the perception level does not carry over to the production level, especially for the BP females.

In general lines, Baptista (2006), by dealing with vowel acquisition, shows that the formation of new interlanguage categories can be delayed due to the influence of one's L1, whereas Rauber (2006), as regards vowel perception and production, attests that L2 speakers tend to accurately perceive L2 vowels, and yet are not as successful at distinguishing them at the production level. In sum, both studies show that English high front vowels pose a challenge to Brazilians.

Having presented the relevant findings of previous research dealing with English high front vowels by Brazilians, we shall now present information about the present study method.

3 METHOD

3.1 Participants

Reading aloud data from 20 participants, 13 women and 7 men, were recorded[5]. They all spoke BP as their L1, and were learners of English. They had been taking the English course in Brazil for approximately four months, and had received absolutely no focused instruction on vowels by the time data collection occurred. The participants were receiving 3 hours per week of classroom instruction. The women's ages ranged from 18 to 46 (mean = 24 years), and the men's ages ranged from 18 to 25 (mean = 20 years). All speakers volunteered to take part in the study.

3.2 Sentence-reading test: gathering vowel tokens

Vowel data were supplied through a sentence reading test. The speakers were required to read aloud sentences containing words with the target English vowels /i/ and /ɪ/, along with distractors. Schadech (2013) states that reading-aloud tasks have several limitations, but they also give the researcher the advantage of providing control over the studied phonemic categories and facilitate control over the phonological context in which these occur.

The target vowels were inserted in consonant-vowel-consonant (CVC) monosyllabic words which comprise the following phonological structures: bVt, kVk, pVk, pVt, sVt. Table 2 demonstrates the controlled phonological environment along with the tested words.

Table 2 - Tested words within the controlled phonological environment

Phonological context	[i]	[ɪ]
b_t	beat	Bit
k_k	keak	Kick
p_k	peak	Pick
p_t	Pete	Pit
s_t	seat	Sit

The need for controlling the phonological context is explained by the fact that the sounds surrounding the vowels affect their quality, especially the sounds in coda position (LADEFOGED, 2007; YAVAS, 2011). For instance, vowels followed by voiced consonants (e.g., 'tab') are longer than when followed by voiceless consonants ("tap"). Also, voiceless consonantal contexts allow a more precise identification of the first and last constant periodic pulses of the vowel sound wave displayed in a software, so, it becomes easier to identify the whole vowel for the acoustic analysis (RAUBER, 2006). Furthermore, all the target words were inserted at the end of the sentences so that there would be a pause after them, which also facilitates the identification of the segment for analysis.

[5] Refer to Gonçalves (2014) for a complete description on the experiments that were carried out.

The sentence-reading test contained sentences where the target words were included in different co-texts[6] ("Do you always keak?", "Do not kick"), and sentences which were the same for each minimal pair used ("Don't keak", "Don't kick"). Both declarative and interrogative sentences were included in each set. As the pitch decreased at the end of some declarative sentences, some of the tokens in this type of sentence could not be used as the target words were unintentionally whispered by the speaker, which causes the segments to be devoiced.

The sentences (APPENDIX 1) included the words "beat", "keak", "peak", "Pete", and "seat", which contain the tense vowel - [i]; and "bit", "kick", "pick", "pit", and "sit", which contain its lax counterpart - [ɪ]. Ten distractors containing the English low-front vowels ([e] and [ɛ]) were inserted in the test, but they were not analyzed. In addition to working as distractors, other vowels can be used when performing normalization procedures, as normalization methods that use information across multiple vowels usually perform better. These methods preserve phonemic information, information on the talkers' regional background, and sociolinguistic information best. Moreover, by having F1 and F2 values of vowels such as /a/ and /u/ in the data set (as done by Rauber, 2006), the vowel chart gets easier to read.

To have vowel production elicited, speakers were taken to the language lab individually to meet with the researcher. All the production data were digitally recorded by using Praat version 5.3.32 (BOERSMA; WEENINK, 2012), at a sampling frequency of 22050 Hz, and a dynamic, multilateral SM 58 Plus "Le som" microphone. The computer used was a Toshiba Satellite C655. At the lab, they received a hardcopy version of the sentence-reading test, but were not allowed to read or rehearse the sentences before reading them aloud for recording. All speakers were instructed to hold the microphone up close to their mouths (around 5 centimeters away), and were told to repeat the entire sentence in case anything interrupted the reading.

3.3 Comparing female and male data

Previous studies have consistently analyzed vowel tokens separately (BION et al., 2006; NOBRE-OLIVEIRA, 2007; RAUBER, 2006; RAUBER et al., 2010) due to the physiological differences that lead to different acoustic features in the vowels produced by speakers from different sexes. The present study relies on statistical procedures to decide whether the differences between female and male speakers are considerable. Furthermore, both normalized and non-normalized versions of vowel plotting are demonstrated and discussed.

The statistical analysis reported reported here was guided by the hypothesis that there are significant differences between the means of the high front vowels produced by female and male speakers. The first step was to create spreadsheets in SPSS software[7] with data regarding F1, F2, and duration of each vowel token separated by sex. Descriptive statistics and normality tests (LARSON-HALL, 2010) were run to check the data for normal distribution. The results indicated that the data were not normally distributed ($p < 0.05$). Thus, non-parametric tests (Mann-Whitney U) were run to compare the F1, F2, and duration values for female and male speakers, which showed that the differences between the groups (female and male) were significant ($p = .000$).

Having established that the differences in vowel production between groups are significant, and therefore vowels produced by female and male informants should be analyzed separately, we shall now explore how vowel plotting was carried out.

3.4 Vowel plotting: comparing English high front vowels

After having gathered all rough acoustic vowel data by making use of scripts, the next step was to carry out vowel plotting. In order to do so, F1 and F2 values for vowels which were clearly mispronounced in

[6] Catford (1965) defines "co-text" as the "items in the text that accompany the item under discussion" (CATFORD, 1965, p. 31).
[7]Statistical Package for Social Sciences (Version 16).

the production reading tests (for example, when "ea" in "beat", was pronounced [ɛ], resulting in [ˈbɛt][8]) were excluded from the data spreadsheets. Two different methods of vowel plotting were carried out: normalized and non-normalized vowel plotting, as data presented in these two ways usually differ.

To have non-normalized vowel data stratified, the procedures for building vowel graphs were conducted through the script "*Plotar vogais*", written by Bion (2006). To obtain vowel dispersion (vowel *loci*), the script used was "*Plot from table*", also written by Bion (2006). Both scripts were run on Praat; the input for both of them were Excel data charts (in txt. extension) displaying the speakers, the high front vowel feature (tense or lax), and F1 and F2 values. The plotting with non-normalized data compared sex (female versus male production) in the sentence-reading test.

Normalizing vowel tokens is necessary in order to reduce the existing differences among female and male tokens. To have normalized[9] vowel data, the LOBANOV procedure was used. This is a vowel extrinsic normalization procedure which requires information distributed across more than one vowel of a talker. It takes formant frequencies as input and generates output in normalized versions of those formant frequencies (ADANK et al., 2004). This procedure is easily done through the website "Norm: vowel normalization suite 1.1"[10] (THOMAS; KENDALL, 2013).

To look at the distribution of vowels in the acoustic space, we assembled normalized data separated according to the participants' sex. The normalization was carried out twice, firstly for *individual vowels* in order to look at vowel dispersion, and secondly for *speaker means* to look at group differences. In order to have results plotted in Hz, the scale results processing was chosen, whereas plot standard deviation was chosen to be one. Moreover, F1 and F2 values of [ɑ] and [u] from Rauber's 2006 study were inserted along with F1 and F2 values of the high front vowels from the present study so that the graph resembles the vowel distribution in the vocal tract. This procedure is important because if vowels from different heights and backness are not used, the normalization centralizes the vowels and F1 and F2 values are modified. The present study analyzes a total of 184 high front vowels tokens.

Having presented the procedures for data collection and analysis, we shall turn the discussion now to the results obtained in the present study.

4 RESULTS AND DISCUSSION

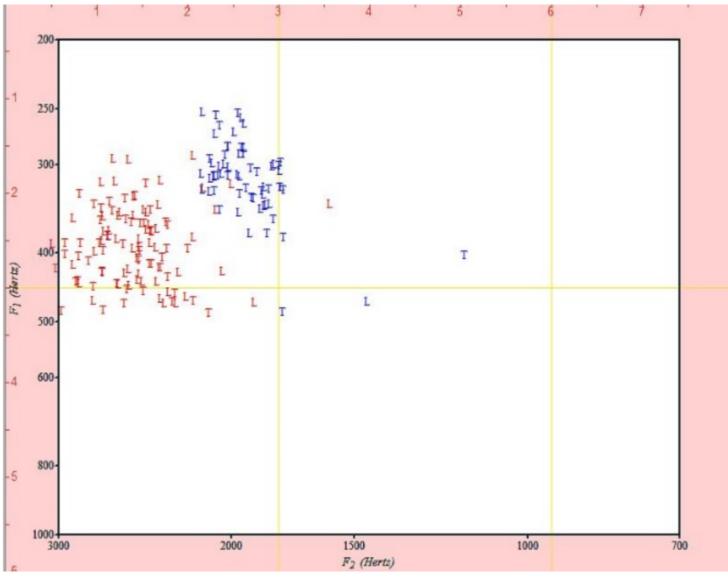
As previously mentioned, the present study investigates whether Brazilian learners of English, with an elementary proficiency level, produce a distinction between / i / and /ɪ/, or whether they tend to produce both vowels as being equivalent to the BP high front vowel /i/. Figures 4 and 5 were built using the BP speakers' data, and they display vowel dispersion for sex differences at the first set of sentences, in non-normalized and normalized versions.

[8] F1 values for a vowel such as /ɛ/ are usually around 550 Hz, which are higher than F1 values for the high front vowel pair (YAVAS, 2011). In the data spreadsheets, they are easily identifiable. However, the researchers also checked if the vowel was in fact mispronounced by conducting an auditory analysis.

[9] Fn[V]N = (Fn[V] - MEANn)/Sn, where Fn[V]N is the normalized value for Fn[V] (this is the formant frequency of the vowel (V)); MEANn is the mean value for formant *n* of the speaker who supplied the token; and SN is the standard deviation for the formant *n*; (JUNGES, 2013).

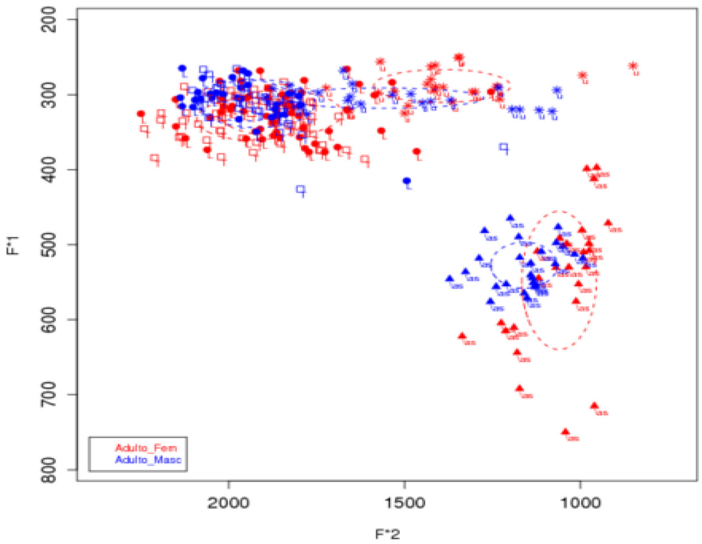
[10] http://ncslaap.lib.ncsu.edu/tools/norm/norm1.php

Figure 4 - BP speakers' vowel dispersion in the acoustic space within non-normalized values, separated by sex



Observation: Female production is displayed in red, and male production in blue. The vowels are represented by their tense (T) and lax (L) distinction.

Figure 5 - BP speakers' vowel dispersion in the acoustic space within normalized values, separated by sex



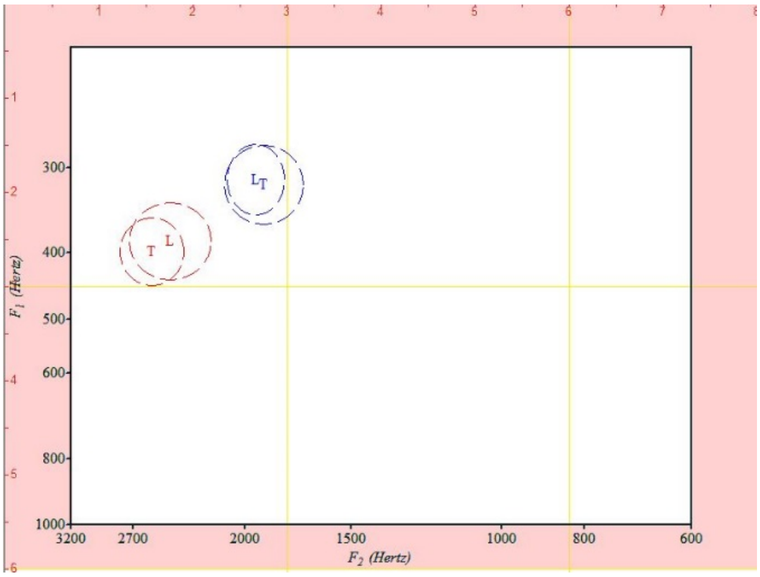
Observation: Female production is displayed in red, and male production in blue. The vowels are represented by their tense (T – squares) and lax (L – full circles) distinction. Data for [ɑ] and [u] are also displayed (see section 2.4).

As can be seen in Figure 4, female token distribution is more disperse, presenting an F1 range which varies from 300 Hz to 500 Hz, indicating the variation of the constriction of the pharynx. F2 values are presented within a range from 2000 Hz to 3000 Hz, demonstrating how the female participants high front vowel production varies regarding vowel frontness. There appears to be a greater number of tokens concentrated in an area where F2 reaches 2500 Hz, showing a tendency on /i/-/ɪ/ to be produced both frontwards. Male F1 values vary from 250 Hz to 360 Hz, showing a tendency for male front vowels to be higher than female vowels. F2 is more compact than women's, ranging from 1800 Hz to 2100 Hz, and indicating a tendency on the tongue to move backwards.

As Figure 5 indicates, there is considerable variation in the normalized vowel plotting of the high front vowels. Both male and female productions are asymmetric and disperse through the acoustic space. As regards female production, there is a bigger concentration of tokens in an area where F1 ranges from 300 Hz to 400 Hz, showing how BP learners vary on vowel height for the front vowel pair. F2 for female production appears to be concentrated mostly from 1800 Hz to 2200 Hz, giving evidence that these vowels also vary considerably regarding frontness and backness. F1 for male production ranges mostly on an area of 300 Hz, being lower and more fronted than female production. Male F2 goes from 1800 Hz to 2200 Hz, similarly to the results of female F2. Most importantly, Figure 5 shows that, if physiological differences are excluded, female and male speakers tend to produce the same vowels indistinctively.

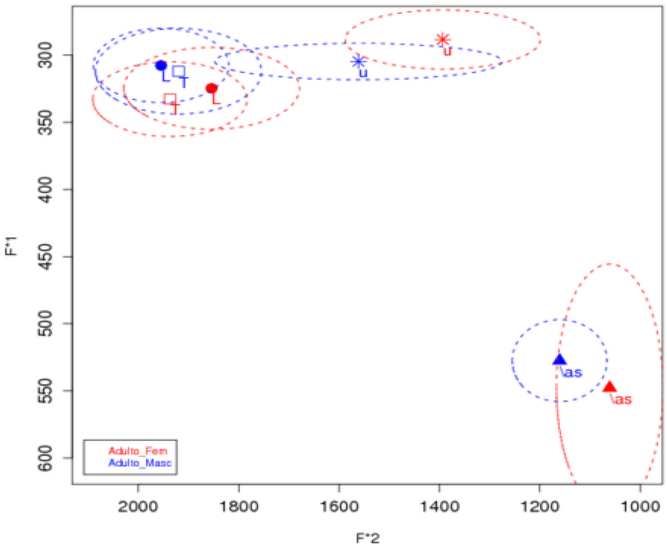
Figures 6 and 7 were built using the BP speakers' data, and they display vowel dispersion for group means, in non-normalized and normalized versions.

Figures 6 - BP speakers' vowel means in the acoustic space within non-normalized values, separated by sex



Observation: Red dots represent female tokens, while the blue ones represent male tokens. The vowels are represented by their tense (T) and lax (L) distinction.

Figures 7 - BP speakers' vowel means in the acoustic space within normalized values, separated by sex



Observation: Red dots represent female tokens, while the blue ones represent male tokens. The vowels are represented by their tense (T – squares) and lax (L – full circles) distinction. Note that tokens of [ɑ] and [u] (represented by triangles and asterisks, respectively) were included (see section 2.4).

As can be seen in Figure 6, female tense and lax vowels are very close and more fronted than male. The female tense vowel was lowered, and the female lax vowel raised and moved back. Male lax vowel is slightly higher than its tense counterpart. However, they are quite close and appear to be produced with little distinction in the male vocal tract.

In Figure 7, male and female tokens are quite close. Men's production appears to be slightly higher than women's. Regarding frontness, there appears to be some variation, but the vowels are very close. Women's tense vowel is more fronted than its lax counterpart, whilst for men, the opposite is seen - the lax vowel is slightly more fronted than its tense counterpart.

Both non-normalized and normalized data sets show that high front vowels production is asymmetric. A great number of the lax vowels tokens range in an area of a higher F1 (300-400 Hz), showing that this vowel was raised; whilst with the tense vowel, the F1 values are concentrated in the same area, indicating that this vowel was lowered. Thus, both vowels overlap and are produced in the same fashion by the BP learners of English. F2 values for both vowels are very high, confirming that these vowels are produced with the enlarging of the back cavity and the body of the tongue raised frontwards.

Turning now to the duration data, duration means of the present study were compared (1) to the means of monolingual speakers of English (RAUBER, 2006) and (2) to the means of BP /i/ produced by monolingual speakers of Brazilian-Portuguese (RAUBER, 2006). Table 3 displays the duration values used for comparison from Rauber (2006), and Table 4 displays the duration values obtained in the present study.

Table 3 - Duration values in milliseconds of monolingual speakers of English (RAUBER, 2006) and monolingual speakers of Brazilian-Portuguese (RAUBER, 2006)

	Monolingual English female		Monolingual English male		Monolingual BP /i/ female	male
	/i/	/ɪ/	/i/	/ɪ/		
Dur. Mean	130	103	140	118	92	95
Dur. Median	125	105	134	115	94	95
Dur. SD	28	22	24	20	19	17

Table 4 - Duration values in milliseconds of BP speakers of English from the present study

	BP speakers of English - female		BP speakers of English – male	
	/i/	/ɪ/	/i/	/ɪ/
Dur. Mean	98	82	96	92
Dur. Median	95	81	100	94
Dur. SD	39	28	26	24

Table 4 shows that the BP female and the male tense vowel had very similar duration means (98-ms, and 96-ms). As for the lax vowel, the BP female participants had the shortest vowel (82-ms), whereas the BP male participants had a mean similar to the one obtained for their tense vowel (92-ms).

The duration values of the present study also differ considerably from the native means obtained by Rauber (2006) displayed in Table 4. If compared, the lax vowel, as produced by the BP and the AE female participants, had the closest mean (BPSE: 82-ms – AE: 103-ms), and even so there was a considerable difference. If different vowels are compared, the means for the L2 longest vowel [i], as produced by the BP informants (females = 98-ms and males = 96-ms) approach the means for the English monolingual shorter vowel [I] (females = 103-ms and males = 118-ms), having the closest means in duration.

When the duration values for the two L2 vowels produced by the BP spearkers are compared to the duration values of the Brazilian-Portuguese /i/, it is clear that the means have very similar values. These results show that the English high front vowels were produced by the BP speakers with temporal cues similar to the BP /i/ category. For BP /i/, female and male participants had close means – 92-ms and 95-ms, respectively. These numbers approach the means obtained by the BPSE when producing the English high front vowel pair – for the tense vowel, 98-ms and 96-ms; as for the lax vowel, 82-ms and 92-ms. Thus the duration results, as well as the F1 and F2 values result indicate that at the initial stages of L2 acquisition, BP learners of English tend to produce the English high front vowels with the acoustic features of the L1 high front vowel.

5 CONCLUSION

This study investigated the production of English high front vowels by 20 speakers of Brazilian Portuguese at initial stages of L2 vowel acquisition. The preliminary results in this study revealed that, besides varying considerably, English high front vowels, as regards F1, F2 and duration values, are produced indistinctively.

The results corroborate Flege's (1995) Speech Learning Model (SLM), which hypothesizes that the establishment of phonetic categories for L1 may impede subsequent L2 category formation as L1 phonology causes L2 learners to filter perceptual acoustic differences. As Rauber (2010) mentions, equivalent classification is a cognitive mechanism which hinders the formation of new (L2) categories, so that "L2 learners may perceive an L2 and L1 category as similar enough to be considered equivalent" (RAUBER, 2010, p. 147). As the Brazilian Portuguese vowel inventory does not have analogs for English /i/-/ɪ/, speakers' tendency was to merge two different categories into one.

Production results from previous studies (Baptista, 2006; Rauber, 2006) have shown that the acquisition of the English high front vowels remains a challenge for more experienced and proficient learners. Possibly these learners could benefit from instruction that would make the phonetic features of both tense and lax vowels more salient, which should help these leaners develop distinct categories for the two vowels.

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Appendix 1

Sentence reading test

1. Do you always keak?
2. This is a beautiful kitchen set.
3. Can you see the mountain peak?
4. Watch the bat!
5. Give it to Pete.
6. The boy is sad.
7. Take a bet!
8. The doctor sat.
9. Watch out for the pit!
10. Hear the beat.
11. Do not kick!
12. "I love you", she said.
13. Do you like your pet?
14. Can you wait a bit?
15. The food is bad.
16. Give it a pat.
17. Take a seat.
18. It's in your bed.
19. Can you take your pick?
20. And now, can you sit?

Appendix 2

Means, median and standard deviation from the present study.

	F1 mean	F1 median	F1 SD	F2 mean	F2 median	F2 SD	Duration mean	Duration median	Duration SD
/i/ - female	400	397	45	2579	2566	223	98	95	39
/i/ - male	320	311	46	1909	1932	176	96	100	26
/ɪ/ - female	398	385	82	2442	2451	267	82	81	28
/ɪ/ - male	314	309	40	1942	1958	144	92	94	24

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