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Front Vowels of English as a Foreign Language Produced by Proficient Brazilian Speakers

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Abstract:
This research aims to investigate the production of front vowels in English as a foreign language by proficient Brazilian Portuguese speakers. The methods consisted of analyzing the production of English front vowels by two groups: native and foreign (proficient Brazilian) speakers of English. An acoustic-based analysis was performed based on the acoustic parameters of the first three vowel formants, other than vowel duration. A total of eleven acoustic features were computed. For the statistical procedures, a two-way analysis of variance (ANOVA) was carried out. Results pointed out to significant differences between groups for the third formant mean, slope of the first formant, and vowel duration. It was concluded, albeit on a preliminary basis, that, even for foreign language proficient speakers, the cognitive effort imputed when producing vowels in the target language is affected by the speaker's mother tongue in terms of labial protrusion, maintenance of mandibular excursion and intrinsic duration of vowel elements. Furthermore, it is possible to infer that the studied parameters can contribute to the teaching of foreign language pronunciation.

Keywords:
Front vowels; English as a foreign language; acoustic parameters.

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INTRODUCTION

Brazilian speakers who strive to learn English perform this task by being exposed to environments such as movies, music, series, streaming platforms and other media to maintain contact with the pronunciation of the language other linguistic and cultural aspects. In terms of pronunciation, aspects that compose the production of segments, such as vowels and consonants, depend on both the phonological awareness (perception) and phonetic training (production). Regarding the comparative aspect of front vowels existing between English and Portuguese, the vowel repertoire is different in the number of vowels and these vowels also have different acoustic qualities (Katz, 2013; Silva, 2003).

In recent decades, some studies, such as Baptista (2000), Rauber (2006), Gonçalves and Silveira (2014), Dias Júnior (2018), Lima (2022) among others, addressed the production of front vowels in English as a foreign language (L2) and the difficulties of L2 target speakers in producing (and perceiving) these vowel sounds. The aforementioned studies, which used American English vowels produced by Brazilian speakers of English as L2 in their experiments, observed that the participants tended not to distinguish between certain pairs, as in /ɛ, æ/, for example.

In the perception-production relationship of vowel pairs in American English, as in /i, ɪ/, in the words "b[i]t" (beat) and "b[ɪ]t" (bit), and /ɛ, æ/, in words such as b[ɛ]t (bet) and b[æ]t (bat), the acoustic properties of the first three formants and duration should be taken into account as proposed by Rauber (2006); however, not only in the domain of centrality, i.e., the formant and durational means but also of the variability (how these formants and duration vary between the different productions) and dynamics (how these formants tilt and change their trajectories throughout the productions).

Thus, the present article aims to investigate the production of front vowels of English-L2 by speakers (proficient in English) of Brazilian Portuguese (BP) as their mother tongue (L1) based on durational and spectral characteristics (vowel quality) of front vowels indicating interference in the interlinguistic domain during pronunciation of L2-target. This influence of BP was discerned from an acoustic analysis of the front vowels of L2 English based on acoustic-spectral and temporal parameters generated, respectively: a) by the formants (which determine the quality of the vowels from the concentration of harmonic energy in certain frequency bands) and b) by the duration of the target vocalic segment.

The present study is justified by the difficulties encountered in the production of English vowels by Brazilian speakers (see Baptista, 2000; Rauber, 2006; Silva Júnior, 2009 for details), both in conversational contexts and in word production containing each L2 vowel segment on screen. The front vowels of English are commonly confused by Brazilians with vowels present in the phonological inventory of BP due to a phenomenon referred to as Interlingua (Selinker, 1972), in which the L1 sounds of the speaker/listener influence the production of the L2 (Rauber et al., 2005). It is important that L2 speakers understand the interferences in their productions arising from BP and, thus, be able to perceive and identify such distinctions.

In due course, we corroborate what is indicated by the Brazilian curriculum (base nacional comum curricular - BNCC – (Brasil, 2018). The aforementioned document, which regulates foreign language teaching practices in basic education in Brazil, establishes that pronunciation practices during the acquisition of English as L2 should be strengthened to optimize the speaker's oral performance and intelligibility. The pronunciation should not necessarily be a "copy" of the native pronunciation of a target L2, but it should bring the speaker closer to his interlocutor in a communicative situation so that there is a mediation from the point of view of the speech comprehensibility and intelligibility of both (Jenkins, 2000, 2008).

As already mentioned in this section, the acoustic properties of (front) vowels of L2 English produced by Brazilian speakers are commonly analyzed from the point of view of vowel quality, i.e., from the formant values (with emphasis on the first and second formants, F1 and F2, respectively), as highlighted by Baptista (2000), Rauber (2006), Barboza (2007, 2008), Silva Júnior (2009), Gonçalves and Silveira, (2014), among others. In terms of L2-English vowel duration, the characteristics assumed by these vowels are similar to those of the BP vowel inventory (Barboza, 2007, 2008). With respect to vowel tension, the differences emerge in an attempt to in an attempt of adjustment at the starting point of the production of the high vowels of L2 English (Gonçalves; Silveira, 2014).

In this research, we present the following research question:

- Are the front vowels produced in L2 English by proficient speakers affected by their L1 phonetic categories?

This article is divided into: Introduction, in which we present the theme, rationale and objectives of the study; Theoretical Background, in which we present a brief description of front vowels in the broadest sense, as well as studies in Brazil that studied the front vowels of English through phonetic-acoustic analysis. Methodology, where we present the participants and the details of the experimental design; Results and discussions, in which we present the results from the acoustic and statistical analyses, as well as a discussion concerning such analyses; Conclusions, where we resumed the study design and the results found, in addition to its limitations and directions for future studies, and, finally, the references.

LITERATURE REVIEW

From studies such as those by Flege (1980) to more recent Brazilian studies such as Rabello and Silva Júnior (2022), the literature on L2 acquisition proposes that nonnative speakers normally produce and perceive the sounds of a L2 differently from native speakers. These phonetic deviations occur due to the influence of the speaker's L1 phonological system. Munro and Derwing (2008), for example, point out that deviations from phonetic categories, that is, the production of segments (by Brazilians in our study) due to the influence of phonetic categories of L1, are the factors that most dominate the phonetic production of L2 and act as one of the causes of greatest impact for foreign speaker unintelligibility.

In the search for a systematization of L2 speech production and perception, statistical learning models (or L2 perceptual models - cf. Best, 1995; Best et al. 2007, Flege, 1995) play an important role in the phonetic scenario by proposing probabilistic models in which the oral aspects are perceived from a dynamic system as pointed out by Rabello and Silva Júnior (2022). Roughly speaking, it is as if every time we hear and practice L2 pronunciation, we move toward a finer pronunciation. With regard to the front vowels of L2 English produced by Brazilian speakers, acoustic parameters such as formant values (among others) may be able to illustrate in practice how the learning models would work.

Formants are presented as (harmonic) concentration of acoustic energy represented by the

natural resonance frequencies of the vocal tract. In regard to the characterization of vowels, the first three formants (F1, F2, F3) are necessary to define such elements. F1 is related to tongue height; F2 is related to the advancement/retraction of the tongue; and F3 is related to the protrusion (rounding/stretching) of the lips (Barbosa; Madureira, 2015, Silva et al., 2019). Languages will present distinct acoustic properties as phonological inventor differs from each other. Taking into account the articulatory parameters generated from the movement of the tongue and protrusion of the lips, as well as parameters such as duration and mandibular tension (Silva, 2003), we can observe that although some vowels are relatively similar between Brazilian Portuguese and English, the configuration of the articulatory organs will lead to differences in vowel quality. (Barboza, 2008; Callou; Leite, 2009).

Regarding the vowel space configuration of BP and English, Callou and Leite (2009), and Silva (2003) show that Portuguese vowels assume a more closed triangular configuration while English vowels assume configurations relatively similar to a quadrilateral. However, it is from acoustic-experimental studies, which address analyses of F1 and F2, duration, that reference values are assigned between languages.

In Tables 1, 2 and 3, respectively, we may see the reference values of F1, F2, F3 and duration for the stressed front vowels of BP, L1 English (United States) and L2 English produced by Brazilians speakers from Natal, in the State of Rio Grande do Norte (RN). In Table 1, formantic values were extracted from Silva et al. (2019) and durational values were extracted from Escudero et al. (2009). In Table 2, the values were extracted by Hillenbrand et al. (1995). In Table 3, the values were extracted from Barboza (2008).

Table 1 - Geometric means between female and male productions of the formant (F1, F2, and F3 – Silva et al., 2019) and durational (Escudero et al., 2009) reference values of the stressed front vowels of BP.

FRONT VOWELS	F1 (Hz)	F2 (Hz)	F3 (Hz)	DURATION (ms)
/i/	300	2428	3099	97
/e/	391	2233	2871	116
/ɛ/	577	2045	2732	132

Source: Adapted from Escudero et al. (2009, p. 8) and Silva et al. (2019, p. 92).

Table 2 - Geometric means between male and female productions of formant (F1, F2, and F3) and durational reference values of stressed front oral vowels in L1 English.

FRONT VOWELS	F1 (Hz)	F2 (Hz)	F3 (Hz)	DURATION (ms)
/i/	389	2541	3186	275
/ɪ/	495	2301	2869	214
/ɛ/	685	1999	2752	222
/æ/	828	2150	2787	179

Source: Adapted from Hillenbrand et al. (1995, p. 3103).

Table 3 - Geometric means between male and female productions of formant (F1, F2, and F3) and durational reference values of stressed front oral vowels in L2 English produced by Brazilian (Natal-RN) speakers.

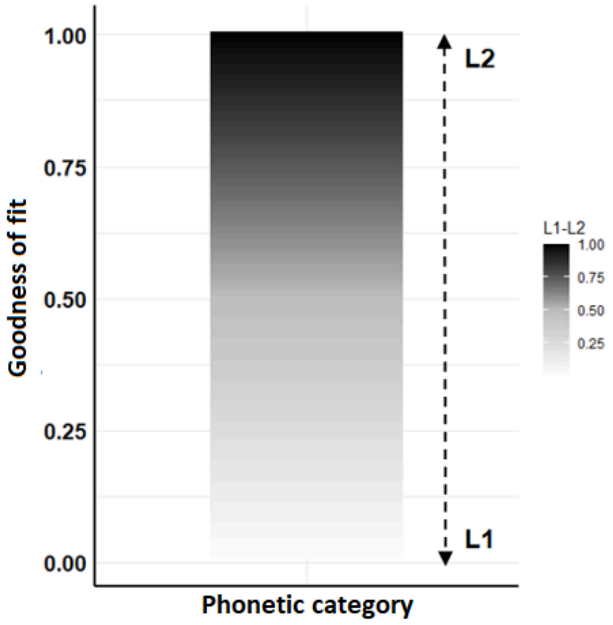
FRONT VOWELS	F1 (Hz)	F2 (Hz)	F3 (Hz)	DURATION (ms)
/i/	311	2274	2892	104
/ɪ/	412	1976	2658	85
/ɛ/	617	1730	2550	133
/æ/	626	1786	2469	126

Source: Adapted from Barboza (2008).

Comparing the data in Tables 1, 2 and 3, we can observe that the formant (F1, F2 and F3) and durational values of L1 English (Table 2) are higher than the BP values (Table 1). In turn, L2-English (Table 3) exhibits intermediate values in between L1 English and BP regarding F1 (linguomandibular height) and lower F2 values (linguomandibular advancement/retraction).

From Tables 1, 2 and 3, we can observe that, despite sharing somewhat similar vowels of the phonological inventory, these vowels, in English and BP, have distinct acoustic-articulatory characteristics. These sounds are perceptible to the ears of a native speaker however, they are often not perceptible to the ears of the L2 speaker as pointed out by Seara, Nunes e Lazzarotto-Volcão (2015), Ladefoged and Disner (2012), and Flege (1995). Sometimes, the influence of the speaker's L1 perception can degrade the intelligibility of their productions. For speech comprehensibility to occur in L2, it is necessary to find a "middle ground", i.e., a space common to L2 speakers that occurs gradually and dynamically during the pronunciation of target segments (front vowels in this article) as shown in the transition space of phonetic categories in Figure 1, which is based on the L2 speech perceptual models mentioned earlier in this section.

Image 1 - Y-axis: Gradual and dynamic representation of the goodness of fit of phonetic categories of L2 (= 0) and L1 (= 1), as well as multiple interlinguistic possibilities (between 0 and 1). X-axis: L2 phonetic categories.



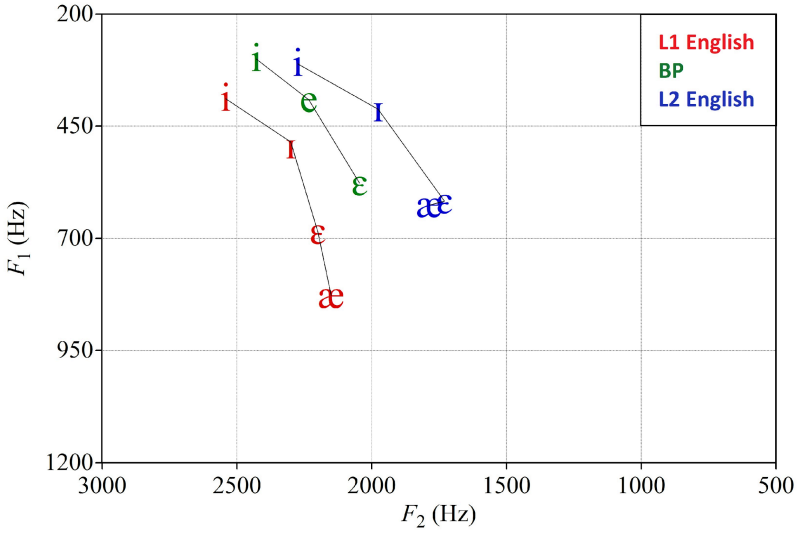
Source: Adapted from Rabello and Silva Júnior (2022).

In terms of front vowels of English produced by Brazilian speakers, the

acoustic-experimental studies involving some of the aforementioned acoustic correlates, to the best of our knowledge, seem to have started with the study conducted by Baptista (2000). The research focused on the production of L2 English sounds: [i, ɪ, ɛ, æ] (which will also be our object of analysis) in addition to the diphthong [ej] compared to its analogs in BP in a phonetically controlled context. The results of the present study reveal the need for reconfiguration of the L2 acoustic-vocalic space from the new L2 phonetic categories. According to Barboza (2007), the L2 space reconfiguration is important, especially when we take into account that the front vowels of English occur in greater numbers than in BP.

Figure 2 shows the acoustic space with values of F1 and F2 of the vowels of L1 English (Hillenbrand et al., 1995), BP (Silva et al., 2019) and English-L2 (Barboza, 2008) in which we performed a reconfiguration of the acoustic space involving the new phonetic categories acquired in the target L2.

Image 2 - Acoustic space containing the geometric means of F1 and F2 of the front vowels of L1 English (in red), BP (in green) and L2 English (in blue).



Source: Personal collection.

METHODOLOGY

The methodology of the present study was qualitative (when analyzing the data in order to determine, from a phonetic-acoustic point of view, how the production of L2 English front vowels by Brazilian speakers occurred) and quantitative (when analyzing statistical analysis of the data to determine the effect of the groups (Brazilian speakers and native English speakers) on the acoustic parameters of L1-L2 production. The section includes the participants, the constitution of the corpus, the data collection and the experiment, in addition to the acoustic and statistical analyses.

PARTICIPANTS

The participants were divided into two groups: a control group (CG) consisting of four L1-English speakers from the United States (50% female/male) and an experimental group (EG), consisting of twelve speakers of L1 Portuguese native from the state of Paraíba (50% female/male).

During data collection, participants in the CG were aged between 25 and 35 years (mean, m = 29.7; standard deviation, SD = 10.4). All CG participants were monolingual English

speakers in addition to being professionals from diverse areas of the trade sector. All participants also resided in the United States. The participants in the EG were aged between 20 and 25 years (m = 23.1; SD = 4.2). In addition, all participants in the EG were undergraduate students of the English Language and Literature at the State University of Paraíba (UEPB). These students had already coursed subjects, such as: "Fonética da língua inglesa I and II" (English phonetics).

We performed the Oxford Online Placement Test to determine the level of English proficiency of the participants in the EG. After application of the test, the subjects of the EG were classified into proficiency category B2 (High Intermediate Independent User - Vantage) with an average score = 75. According to Pollitt (2019, p. 9), a score of 71 or more indicates that the speaker is comfortable at Level B2 and well on the way to Level C1 (Advanced). Thus, the speakers of the EG were considered proficient.

Similar to the Brazilian speakers in the study by Rauber (2006), in addition to proficiency in L2 English, the choice of participants for the EG was because they had already taken the aforementioned subjects (phonetics of the English language). It is noteworthy that during the English Phonetics II course, the students performed, albeit in an introductory and conceptual manner, acoustic-experimental activities involving the production of vowels. All data used throughout the study were authorized and freely and voluntarily provided by participants of both groups, i.e., CG and EG.

DATA COLLECTION, CORPUS AND EXPERIMENT

Data were recorded in the room of the Phonetics Study Group/UEPB. The room has – to some extent – soundproofing (wooden and anti-noise boards). We used a Zoom H1 Handy Recorder with a unidirectional on-board microphone already attached as a standard to the equipment at a sampling frequency of 44.1 kHz and quantization rate of 16 bits. In addition, the signal-to-noise ratio was higher than 30 dB.

The corpus of the recording consisted of a total of ten words distributed as follows:

- Four target words (b[i:]t, <beet>; b[ɪ]t, <bit>: b[ɛ]t, <bet> and, b[æ]t, <bat> containing the front vowels of the English /i, ɪ, ɛ, æ/ and;
- Six distracting words: "break", "bicycle", "proud", "park", "cross" and "crowd" so that participants would not understand the purpose of the investigation.

The experiment was conducted as follows:

- The participants read the ten words (4targets + 6distractors) three times (three rounds) in random order. Ten slides were used in Microsoft PwoerPoint (one per word) so that the data could be computed. Thus, each participant read a total of 30 words (10words * 3 rounds);
- The reading material on the slides was the carrier phrase: "I say WORD boldly", with 'WORD' being the target word or a distracting word;
- Only sentences containing the target words were used for acoustic analysis, i.e., 12 words per participant (4target words * 3rounds).

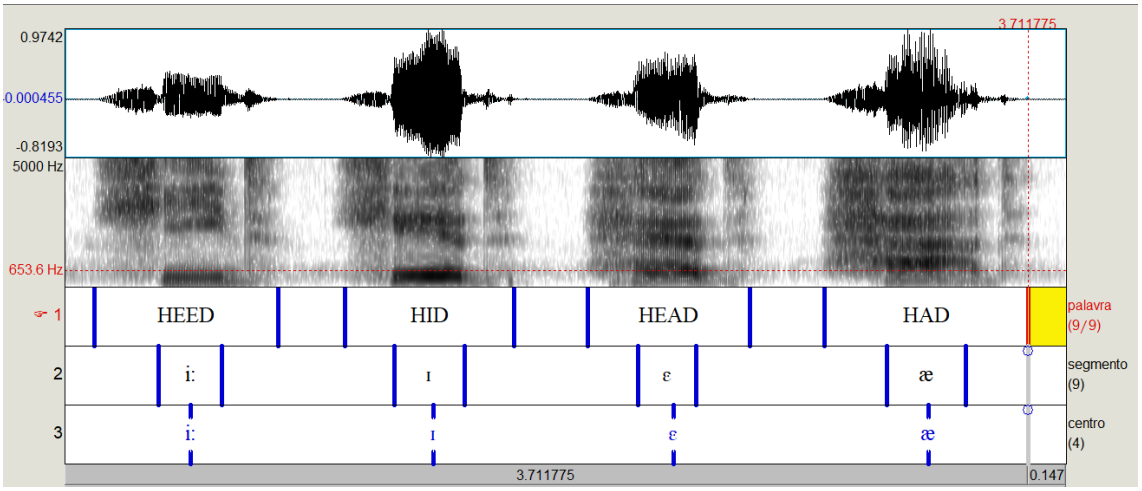
A total of 192 occurrences of target words (16participants * 12occurrences per participant = 192 occurrences) composed the phonetic material for later acoustic analysis.

ACOUSTIC ANALYSIS

The corpus containing the carrier phrases with 192 occurrences was uploaded to the 'webMAUS' forced-aligner, v. 3.1 (Kisler; Reichel; Schiel, 2017), which performed a semiautomatic segmentation of the target vowels. The acoustic analysis was performed in Praat (Boersma; Weenink, 2021). After MAUS' segmentation, the boundaries returned from the aligner were reviewed and manually corrected, as recommended by Barbosa and Madureira (2015).

Next, the vowels were realigned according to the examples in Figure 3 for further extraction of acoustic parameters.

Image 3 - Waveform, broadband spectrogram and layers with segmentation of the English front vowels in the words:"heed", "hid", "head" and "had" (tier 1), vowel segment for investigation (tier 2) and stable region of the vowels (tier 3) produced by an American speaker.



Source: Personal collection.

A total of eleven acoustic parameters, shown in Table 4, were used in this study. For automatic extraction of acoustic parameters, we used the script for Praat referred to as 'VowelParameterExtractor' (VPE - Silva Júnior, 2022).

Table 4 - Acoustic correlates, acoustic parameters extracted from the VowelParameterExtractor script, name of the parameter returned in text file, description of each parameter and its unit of measurement.

ACOUSTIC CORRELATE	PARAMETER	RETURNED NAME BY VPE	DESCRIPTION	UNIT
FORMANTS	Mean values of F1, F2, F3	*F1, F2, F3*	Absolute formant values (mandibular height, mandibular setback/advance and lip protrusion)	Hz
	Values normalized by the *z score* method (Lobanov, 1971) of F1, F2, F3	*F1norm, F2norm, F3norm,*	Formant values that minimize differences between vocal tracts	Standard deviation
	Mean values of the slope (1st discrete derivative) of the trajectory of F1, F2, F3 and F4	*d1F1, d1F2, d1F3*	Stability and maintenance of height, mandibular setback/advancement and lip protrusion	Peaks per second
DURATION	Mean duration values (in milliseconds - ms) of the target vowel	*Dur*	Absolute duration	month
	Values normalized by the *z score* method (Lobanov, 1971) of the duration of the target vowel	*Dur_norm*	Relative duration that minimizes the effects of perception	Standard deviation

Source: Personal collection.

STATISTICAL ANALYSIS

For the statistical treatment of the data, we used a two-factor Analysis of Variance (ANOVA) in which the dependent variables (DV) were the acoustic parameters of Table 4, and the independent variables (IV) were the following factors according to a protocol proposed by Brown (1988), Rietveld and Van Hout (2005), Garcia (2021) among others for statistical treatment of research in L2 phonetics and phonology:

- Group factor (stratified into two levels: L1/L2 English;
- Target vowel factor (stratified into four levels: [i, ɪ, ɛ, æ];

A significance value (alpha) of 5% was used for determining significant/non-significant variance for the Gorup and Target vowel performance. The test statistics were performed in R language (R Core Team, 2021) and the figures that describe the behavior of the data from a statistical point of view were generated using the "ggplot" R library (Wickham, 2016).

RESULTS AND DISCUSSIONS

This section presents the results of each acoustic parameter of the production of front vowels ([i, ɪ, ɛ, æ]) of both groups (L1 and L2 English). Table 5 shows the means between groups

returned from the ANOVA. In Table 6, F-Welch's values (representing the difference between the means) and p values (representing the probability of occurrence of differences). In Figure 4, we present the parameters that showed significant differences between the groups and the vowels

Table 5 - Formantic values of F1, F2 and F3; normalized values in units of standard deviation (F1norm, F2norm and F3norm), slope of the trajectory of the first three formants (d1F1, d1F2 and d1F3), duration in milliseconds (ms) and normalized duration (dur_norm) in units of standard deviation of front vowels of English from the productions of Brazilian speakers (English-L2) and North American speakers (English-L1).

VOWEL	GROUP	FORMANT AND DURATIONAL ACOUSTIC PARAMETERS										
		F 1	**F2**	**F3**	**F1 norm**	**F2 norm**	**F3 norm**	**d1 F1**	**d1 F2**	**d1 F3**	**DURATION (ms)**	**DURATION (dur_ norm)**
[i]	English-L1	329	2731	3355	-0.03	0.04	0.32	0.72	13.1	4.78	148	1.47
	English-L2	412	2585	3278	0.31	0.30	0.52	1.31	15.5	29.7	260	1.46
[ɪ]	English-L1	515	2074	3077	-0.29	-0.19	0.06	-5.9	-2.6	18.5	117	0.93
	English-L2	474	2367	3066	0.24	0.24	0.19	1.71	-15.3	4.37	217	1.02
[ɛ]	English-L1	735	2032	2982	0.03	0.30	0.07	4.09	0.28	4.56	127	1.08
	English-L2	806	1794	2464	0.57	0.20	-0.16	9.21	0.76	8.03	239	1.27
[æ]	English-L1	875	1929	2060	0.21	0.17	-0.07	6.13	2.24	7.54	173	1.88
	English-L2	871	1774	2393	0.43	0.44	-0.26	14.8	6.77	-1.5	266	1.58

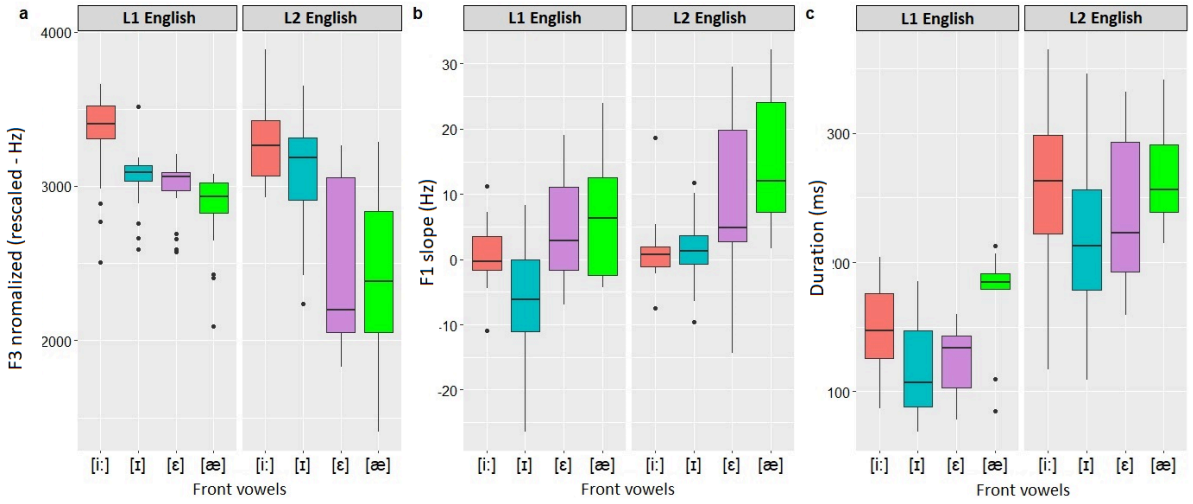
Source: Personal collection.

Table 6 - Statistical values of F-Welch and p-values returned from the ANOVA in the comparison of vowels between groups (L1-L2 English); degrees of freedom (df) of the total number of observations. and coefficient of determination (R2) to explain the variation between groups.

PARAMETER	VOWELS' COMPARISON: FOR ENGLISH-L1 -L2 GROUPS									
	[i]		**[ɪ]**		**[ɛ]**		**[æ]**			
	F-value	**P-value**	**F-value**	**P-value**	**F-value**	**P-value**	**F-value**	**P-value**	**df**	**EFFECT SIZE (R2)**
F1	1.86	=0.15	1.53	=0.89	-0.80	=0.44	-0.10	=1.00	188	.78
F2	0.05	=0.92	2.56	=0.20	0.48	=0.59	-1.20	=0.92	188	.42
F3	2.70	=0.99	3.19	=1.00	-0.34	**=0.004**	-4.41	**=0.004**	188	.48
F1 *norm*	1.47	=0.15	1.13	=0.89	0.18	=0.44	1.47	=1.00	188	.11
F2 *norm*	-0.06	=0.93	-0.48	=0.21	-0.75	=0.59	-0.78	=0.93	188	.10
F3 *norm*	1.02	=0.99	0.99	=1.00	0.11	=0.98	0.99	=0.99	188	.08
d1F1	-2.36	=1.00	-0.31	=**0.02**	-1.00	=0.46	3.45	=**0.002**	188	.34
d1F2	2.23	=1.00	-0.33	=0.81	0.79	=1.00	1.00	=1.00	188	.02
d1F3	0.12	=0.24	1.53	=0.86	-2.36	=1.00	0.18	=0.99	188	.02
Duration (*ms*)	6.60	**=0.001**	0.41	**=0.001**	0.96	**=0.001**	6.32	**<0.001**	188	.64
Duration (*north)*	1.24	=1.00	1.71	=1.00	2.06	=0.94	-1.77	=0.64	188	.27

Source: Personal collection.

Image 4 - Boxplots with data distribution and dispersion for the third formant – F3 (4a), F1 slope (4b) and duration in milliseconds (4c) for the production of L1 and L2 English front vowels. Whiskers indicate a 95% confidence interval.



Source: Personal collection.

The statistical data help in the investigation of which of the analyzed parameters were significant in the production of these vowels and which may thus help in the understanding of the influence of L1 BP on L2 English. The parameters F3 (for the vowels [ɛ, æ], *d*1F1 for the vowel [ɪ] and vowel duration for all vowels (see Table 5 and Figure 4) showed significant differences.

Based on the results described here, it is possible to make inferences from the acoustic parameters used in this study:

I. The 'F3' parameter is related to the protrusion (stretching/rounding) of the lips. The higher the F3 value, the more stretched the lips are. In Table 6 and Figure 4a, the low vowels [ɛ, æ] presented significant differences [F(3,188 = -4.41, p = .004) between groups. The results reveal that although the opening and lingual advancement/retraction are assimilated more quickly (even as a function of the proficiency of the speakers), the degree of lip protrusion is not easily produced.

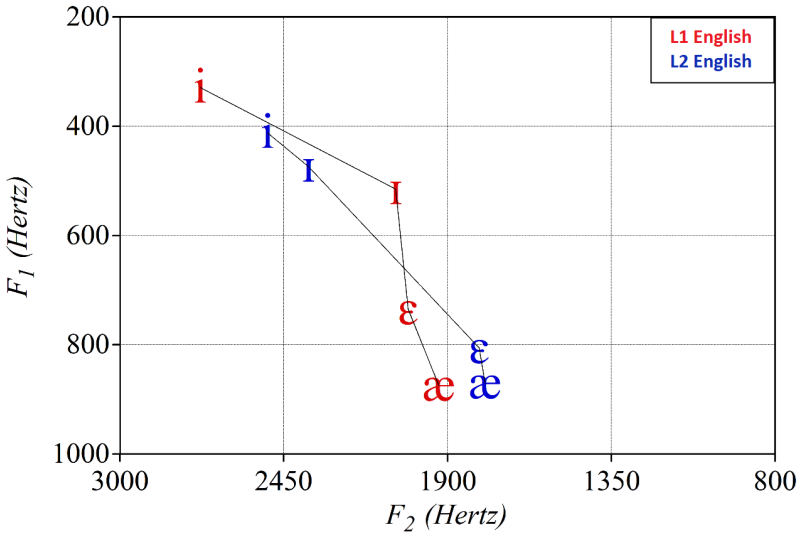
II. The formant slope 'd1F1' also presented significant differences between groups [F(3,188 = 3.45, p = .020)]. This parameter is related to the variation in the trajectory of the formants of the entire vowel production, as indicated by Xu *et al.* (2022). The slope of F1 provides information on the speaker's mandibular excursion, i.e., the jaw's excursion and linguomandibular oscillation in terms of height during vowel production (if the tongue and jaw are tenser due to vowel maintenance, there will be greater variability). The high vowels [ɪ] [F(3.188 = -0.31, p = .020)] and low vowels [æ] [F(3,188 = -0.31, p = .040)] showed significant differences. The vowels [ɪ, æ] do not belong to the BP phonological inventory, so the variations in the F1 trajectory, which is related to lingual closure/opening, may be an indication that speakers are trying to find a stable point for the production of these vowels.

III. The duration parameter in milliseconds (ms) showed significant differences

[F(3.188 = 6.32, p < .001) for all analyzed vowels [i, ɪ, ɛ, æ]. Vowels in L2 English are significantly longer than in L1 English even with phonetic training. This fact occurs due to the considerable difficulty in reproducing L2 target durational aspects**.**

In Figure 5, we can see the acoustic space of the English L1 and L2 vowels regarding the results from F1 and F2 (normalized and rescaled in *Hertz*).

Image 5 - Acoustic space for the means of the normalized and rescaled first and second formants (in Hz) of the front vowels of L1 English (in red) and L2 English (in blue).



Source: Personal collection.

Considering that Brazilian group went through phonetic training in the vowel categories shown in Figure 5, speakers were able to minimize the differences between vowels as shown in Table 6. The study by Baptista (2000) indicates that the speaker, in any L2, stores vowels in a prototype formed by formant and spectral structures inherent to these prototypes. The author highlights that the speaker, of any L2, seems to have the notion of the limits of the vowel system and of the position of each vowel (of the L2) within this limit. The prototypes of acoustic characteristics, as predicted in the perceptual models, work in a gradual and dynamic way. As reported in the data of Baptista (2000), who recorded eight recordings per month, our speakers of the EG, in addition to being proficient, had classes with phonetic training and recognition of acoustic characteristics (F1 and F2) of English and BP vowels. Furthermore, our data are in line with those of Barboza (2008 – cf. Figure 2) regarding the lowest values of F2 for the vowels [i, ɛ, æ] of L2 English compared to L1 English.

GENERAL DISCUSSION

In this section, we analyze and discuss the F3 values, the F1 slope values and the vowel duration, in addition to pointing out the influence of F2xF1 relation on English production.

With regards to F3, a formant related to the stretching or protrusion of the lips, Table 6 shows that the low vowels [ɛ, æ] showed significant differences (p < .001) in their production. The behavior of these vowels is illustrated in Figure 4a, where we can observe, through the arrangement of the boxplots (purple and green), the variation in the realization of these vowels in

the L1-L2 comparison. The findings for the two vowels in question indicate, at least to a certain extent that, no matter how much mandibular opening and mandibular advancement/retraction are inferred, Brazilian speakers did not change the position of stretching or even protrusion of the lips.

This characteristic may come from BP, since the vowel [ɛ] is not performed with the same spread in English, nor does the vowel [æ] belong to the phonological inventory of BP. The lip position is, it seems to us, transferred to L2 English, even in situations where there is phonetic training, which is the case of the speakers in the present study. Moreover, these speakers are proficient in English and are able to perform phonetic categories that do not differ significantly for the first two formants; however, the productions show that there is a distance to be considered when it is a case of lip protrusion. Thus, vowels may even be produced with similar heights and frontness-backness relation in the L1-L2 comparison, but the opening or closing of the speaker's lips, at the time of producing vowels, is a more difficult parameter to (perceived) produce.

In respect to the slope of F1 (first derivative - d1), it is an acoustic parameter capable of helping us to understand the variation in the formant trajectory throughout the entire length of vowel production (Xu et al., 2022). In other words, the fomant slope reflects how much the speaker displaces and maintains the jaw at a certain position at the time of production. In this study, we analyzed the slopes of F1, F2 and F3 (Tables 5 and 6). The slope of F1 showed significantly-different results between groups, especially in the high vowels [ɪ] ($p = .002$) and low vowels [æ] ($p < .001$). Figure 4b shows the dispersion of speakers producing English as L1 and L2 and the large variation that occurs in these vowels (orange and green boxplots). The vowels [ɪ, æ] do not compose the stress vowel structure of BP, so the variations that occur in the trajectory of F1 may be an indication that the speakers are trying to find a stable point during the production of these vowels.

Regarding the aspects of duration, we used here two parameters for its description, i.e., duration in milliseconds and Lobanov-normalized duration (which correlates the duration of segments to speech perception). In comparing the English-L1-L2 produced by American and Brazilian speakers, the study by Silva Júnior and Barbosa (2021) - showed consistent results in its application. The present study did not show significant differences based on this parameter.

As for the production of L2 vowels, Adank, Smits Van Houte (2004) suggest that this choice for the normalized duration is not always the most reliable. Disner (1980) compared data from several languages - L1 and L2 - and found that Lobanov's method, as well as the extrinsic methods of measuring vowel duration, obtained an unsatisfactory performance regarding the linguistic validation for each L1, i.e., in preserving subtle and L1-specific differences during the production of (new) phonetic categories generated in the interlanguage and/or in vowels analogous to the L2 target. For example, the prestressed vowel [i] in BP in the word "[i]tu", (a city from São Paulo State, Brazil) when measured using Lobanov, has duration values similar to the stressed [i] in English "[i:]taly" (Italy).

However, the differences in duration – in ms – between the groups were significant. In all front vowels [i, ɪ, ɛ, æ] ($p < .001$). Figure 4c shows significantly longer vowels in L2 English. Our results corroborate studies such as those by Barboza (2007, 2008) and Gonçalves and Silveira (2014), who found that vowels in L2 English will generally be longer than those in L1 English. Additionally, according to Gonçalves and Silveira (2014), the initial stages of learning L2 English show this lack of accuracy in the duration of vowel segments. Considering the results mentioned above and the fact that our EG produced vowels after classes on vowel production, we can see that speech production in L2 requires continuous training.

CONCLUSIONS

We concluded that the results confirm the hypothesis that the front vowels produced in L2 English are affected by phonetic categories of L1-BP during the production of Brazilian speakers, causing dynamic productions of occurrences and, consequently, new phonetic categories in an interlinguistic space, that is, between BP and English as target L2.

As previously presented in the Introduction, we return to our research question.

- Are the front vowels produced in L2 English by proficient speakers affected by L1 phonetic categories?

Yes. Although there were no significant changes in F2, the acoustic parameters related to F1 (slope) and F3 (lip rounding/spreading) of phonetic categories that exist (as in /ɛ/) and that there are not (as in /æ/) in the phonological inventory of BP influence the production of Brazilians. Although F1 (related to vowel height) did not show significant differences regarding its location in the acoustic space, F1 modulation, i.e., maintenance of linguomandibular opening toward the target vowel height, showed significant differences between groups. of speakers, which indicates the influence of L1 phonetic categories. The slope of F1 was found to be a parameter consistent with the differences between the groups (Brazilians and North Americans). A greater shift was observed in the mid-low and low vowels than in the higher vowels. It is concluded, albeit in a preliminary way, that F1 slope provides evidence that the speakers, when producing the lowest vowels, did so in an oscillatory way in the search, probably for a point of stability during the opening and closing of the jaw.

Regarding F3, it was also found that, even in the case of proficient individuals, the F3 parameter showed significant differences, especially for the mid and low vowels, which showed that when producing L2, the speaker maintains characteristics of stretching and tensioning of the lips inherent to one's L1.

Furthermore, all vowels in L2 had a longer duration (in ms) compared to L1, showing that even with phonetic training there is greater difficulty in maintaining L2 vowels with a duration similar to L1 due to the intrinsic duration of the segments, thus, requiring greater cognitive effort and greater constancy of training of prosodic elements (such as duration) by the speaker.

LIMITATIONS AND FUTURE DIRECTIONS

The present study concluded by pointing out some limitations, such as a relatively small number of samples (only three occurrences per subject based on the reading of isolated sentences. It is believed that with a larger corpus and other speech styles it is possible to determine with greater accuracy the effect of the groups analyzed here (L1-L2-English regarding the production of front vowels) on the extracted acoustic parameters was accurate. correlated with duration, and tongue and jaws tension.

An important point to be covered in the continuation of this study is to investigate to what extent there is a degree of acceptability of deviant pronunciation (since it does not affect communication). A perception test, for example, could give cues about reliability, and in this case, it can be suggested that the F3, F1 slope and formant duration weigh on understanding or discrimination between natives and foreigners.

For future studies, we intend to perform i) a comparison between L1-L2 English and BP (see Figure 2 in section 1) so that we can materialize and understand points that are related to the formation of new phonetic categories and thus observe the influence of BP on the production of L2 English. It is also intended to direct the studies ii) to increase the number of samples; iii) increasing the number of parameters extracted by the VPE script to test two or more classes of acoustic correlates by means of Analysis of Covariance and Discriminant Analysis in order to train robust acoustic models and, thus, iv) apply the more consistent acoustic models in tools

(applications) for teaching L2 English pronunciation.

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REFERENCES

ADANK, Patti; SMITS, Roel; VAN HOUT, Roeland. A comparison of vowel normalization procedures for language variation research. Journal of the Acoustical Society of America, Melville, NY, v. 116, n. 5, p. 3099-3107, 2004.

BAPTISTA, Bárbara O. The acquisition of English vowels by Brazilian-Portuguese speakers. Florianópolis: EDUUFSC, 2000.

BARBOSA, Plínio A.; MADUREIRA, Sandra. Manual de fonética acústica experimental: aplicações a dados do português. São Paulo: Cortez, 2015.

BARBOZA, Clerton Luiz F. Descrição acústica dos sons vocálicos anteriores do Inglês e do Português realizados por professores de língua estrangeira no oeste Potiguar. 2008. 183 f. Dissertação (Mestrado em Linguística Aplicada) - Universidade Estadual do Ceará, Fortaleza, CE, 2008.

BARBOZA, Clerton Luiz F. Production of English front vowels by Brazilian EFL teachers in western Rio Grande do Norte. In: NEW SOUNDS: International Symposium on the Acquisition of Second Language Speech, 5th, 2007, Florianópolis, SC. Proceedings […]. Florianópolis: Federal University of Santa Catarina, 2007. p. 28-37.

BEST, Catherine T. A direct realist view of cross-language speech perception. In: STRANGE, Winifred (ed.). Speech perception and linguistic experience: theoretical and methodological issues. Timonium: York Press, 1995. p. 171-204.

BEST, Catherine T.; TYLER, Michael D.; BOHN, Ocke-Schwen; MUNRO, Murray J. Nonnative and second-language speech perception: commonalities and complementarities. In: MUNRO, Murray J.; BOHN, Ocke-Schwen (ed.). Second language speech learning: The role of language experience in speech perception and production. Amsterdam: John Benjamins, 2007. p. 13–34.

BOERSMA, Paul; WEENINK, David. Praat: doing phonetics by computer. Version 6.1. Disponível em: www.praat.org. Acesso em: 2 dez. 2021.

BRASIL. Ministério da Educação. Base Nacional Comum Curricular - BNCC. Brasília: MEC, 2018.

BROWN, James D. Understanding research in second language learning. Cambridge: Cambridge University Press, 1988.

CALLOU, Dinah; LEITE, Yonne. Iniciação à fonética e à fonologia. 11. ed. Rio de Janeiro: Jorge Zahar Ed., 2009. (Coleção Letras).

DIAS JR, Antônio F. Um panorama inicial da produção das vogais alta e média anteriores /i/-/ɪ/ por falantes brasileiros de inglês como L2. 2018. 53 f. Monografia (Graduação em Letras) - Universidade Estadual da Paraíba, Guarabira, PB, 2018.

DISNER, Sandra Ferrari. Evaluation of vowel normalization procedures. Journal of the Acoustical Society of America, Melville, NY, n. 67, p. 253-261, 1980.

ESCUDERO, Paola; BOERSMA, Paul; RAUBER, Andréia; BION, Ricardo. A cross-dialect acoustic description of vowels: Brazilian and European Portuguese. Journal of the Acoustical Society of America, Melville, NY, v. 126, n. 3, p. 1379-1393, 2009.

FLEGE, James E. Phonetic approximation in second language acquisition. Language Learning, Ann Arbor, Mich., v. 30, n. 1, p. 117-134, 1980.

FLEGE, James E. Second language speech learning theory, findings and problems. In: STRANGE, Winifred (org.). Speech perception and linguistics experience: issues in cross language research. Timonium: York Press, 1995. p. 233-271.

GARCIA, Guilherme. Data visualization analysis in second language research. New York: Routledge, 2021.

GONÇALVES, Alison Roberto; SILVEIRA, Rosane. The production of English high-front vowels by Brazilian learners. Fórum Linguístico, Florianópolis, v. 11, n. 1, p. 9-22, 2014.

HILLENBRAND, James; GETTY, Laura A.; CLARK, Michael J.; WHEELER, Kimberlee. Acoustic characteristics of American English vowels. Journal of the Acoustical Society of America, Melville, NY, v. 97, n. 5, p. 3099-3111, 1995.

JENKINS, Jennifer. English as a lingua franca: attitude and identity. Oxford: Oxford University Press, 2008.

JENKINS, Jennifer. The phonology of English as an international language. Oxford: Oxford University Press, 2000.

KATZ, William F. Phonetics for Dummies. Hoboken, NJ: John Willey & Sons, 2013.

KISLER, Thomas; REICHEL, Uwe D., SCHIEL, Florian. Multilingual processing of speech via web services. Computer Speech & Language, Sheffield, v. 45, p. 326-347, 2017.

LADEFOGED, Peter; DISNER, Sandra Ferrari. Vowels and consonants. 3. ed. West Sussex: Wiley-Blackwell, 2012.

LIMA, Crislaynne. Análise da produção das vogais anteriores do inglês como L2 por falantes brasileiros. 2022. 50 f. Monografia (Graduação em Letras) - Universidade Estadual da Paraíba, Guarabira, PB, 2022.

LOBANOV, Boris. Classification of Russian Vowels Spoken by Different Speakers. The Journal of the Acoustical Society of America, Melville, NY, v. 2, n. 49, p. 606-608, 1971.

MUNRO, Murray J.; DERWING, Tracey M. Segmental acquisition in adult ESL learners. A longitudinal study of vowel production. Language Learning, Ann Arbor, Mich., v. 58, p. 479-502, 2008.

POLLITT, Alistair. The oxford placement test: the meaning of Oxford Placement Test Scores. Oxford: Oxford University Press, 2019. URL: oxfordenglishtesting.com.

R CORE TEAM. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing, 2021. Disponível em: https://www.R-project.org/. Acesso em: 22 jul. 2022.

RABELLO, Maria Guadelupe Dourado; SILVA JR, Leônidas J. Procedimentos estatísticos aplicados à fala do inglês como língua estrangeira. Revista Campo do Saber, João Pessoa, PB, v. 8, n. 2, p. 97-116, 2022.

RAUBER, Andréia. Perception and production of English vowels by Brazilian EFL speakers. 2006. 218 p. Tese (Doutorado em Letras) - Universidade Federal de Santa Catarina, Florianópolis, SC, 2006.

RAUBER, Andréia; ESCUDERO, Paola; BION, Ricardo; BAPTISTA, Bárbara O. The Interrelation Between the Perception and Production of English Vowels by Native Speakers of Brazilian Portuguese. In: INTERSPEECH - INTERNATIONAL SPEECH COMMUNICATION ASSOCIATION, 2005, Lisbon, Portugal. Proceedings […]. Lisbon: ISCA, 2005. p. 2913-2916.

RIETVELD, Toni; VAN HOUT, Roeland. Statistics in language research: analysis of variance. Berlin: Mouton de Gruyter, 2005.

SEARA, Izabel C.; NUNES, Vanessa G.; LAZZAROTTO-VOLCÃO, Cristiane. Para conhecer: Fonética e fonologia do português brasileiro. 2. ed. São Paulo: Contexto, 2015.

SELINKER, Larry. Interlanguage. International Review of Applied Linguistics, Berlin, v. 10, n. 3, p. 209-231, 1972.

SILVA JR, Leônidas. Erro de leitura das vogais do inglês americano como língua estrangeira pelos falantes do português do Brasil. 2009. 70 f. Dissertação (Mestrado em Linguística) – Universidadde Federal da Paraíba, João Pessoa, PB, 2009.

SILVA JR, Leônidas. VowelParameterExtractor, version 1.0. [Computer program for Praat]. 2022. Disponível em: https://github.com/leonidasjr/VowelCode.

SILVA JR, Leônidas; BARBOSA, Plínio A. Efeitos da prosódia de l2 no ensino de pronúncia e na comunicação oral. Prolíngua, João Pessoa, PB, v. 16, n. 1, p. 126-141, 2021.

SILVA, Thaïs C. Fonética e fonologia do português: roteiro de estudos e guia de exercícios. 7. ed. São Paulo: Contexto, 2003.

SILVA, Thaïs C.; SEARA, Izabel C.; SILVA, Adelaide H. P.; RAUBE, Andréia S. CANTONI, Maria M. Fonética acústica: os sons do português brasileiro. São Paulo: Contexto, 2019.

WICKHAM, Hadley. ggplot2: elegant graphics for data analysis. New York: Springer-Verlag, 2016.

XU, Anqi; GERAZOV, Branislav; VAN NIEKERK, Daniel; KRUG, Paul K.; PROM-ON, Santitham; BIRKHOLZ, Peter; XU, Yi. Modelling English diphthongs with dynamic articulatory targets. In: INTERSPEECH - INTERNATIONAL SPEECH COMMUNICATION ASSOCIATION, 2022, Incheon, KOR. Proceedings […]. Incheon: ISCA, 2022. p. 1-5.