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PROBING RHYTHMIC PATTERNS IN ENGLISH-L2: A PRELIMINARY STUDY ON VOWEL REDUCTION BY BRAZILIAN LEARNERS AT DIFFERENT AGES

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Abstract: *Languages are traditionally classified as mora-timed, syllable-timed or stress-timed in relation to their rhythmic patterns. The distinction between syllable-timed and stress-timed languages, however, lacks solid evidence in the literature. Syllable-timed languages typically have similar duration across unstressed and stressed syllables, whereas stress-timed languages tend to have similar inter-stress intervals, and unstressed syllables are shorter than stressed syllables. According to this categorical classification, English is a stress-timed language, thus having more reduction in unstressed vowels. Brazilian Portuguese, on the other hand, is typically classified as syllable-timed, and thus has little reduction of unstressed vowels. If these categorical rhythmic differences are correct, then acquiring the rhythmic patterns of English should be a challenging task to Brazilian learners, who are not expected to produce unstressed vowels with as much reduction as English native speakers. However, recent studies have found that the typology of rhythm is best understood as not categorical, but rather gradient, and that Brazilian Portuguese has a mixed classification, with more stress timing than would be expected from a traditional and categorical perspective. We therefore hypothesize that Brazilian learners of English should not have major difficulties reducing unstressed vowels, even when exposed to the second language later in life. To test this hypothesis, we analyze production data of native speakers of English (control group) and two groups of Brazilian advanced learners of English who differ in their age of initial exposure to formal instruction. The results show that neither group of learners is credibly different from the control group, which is consistent with the hypothesis that the mixed rhythm present in Brazilian Portuguese in fact facilitates the acquisition of the rhythmic patterns of English, a stress-timed language, at least in terms of unstressed vowel reduction.*

Keywords: *prosody; rhythm; acoustics; ESL; vowel reduction*

1 Introduction

There is not much consensus among scholars regarding the existence of a critical period for second language (L2) acquisition, especially if taking into account a biological view of critical periods, i.e., a period after which a certain behavior cannot be acquired at all (see (1–3) for review). Even so, the literature shows that there are a few trends in the relation between age of first exposure to the second language and success in acquiring it. The first trend is that most scholars agree that the phonological domain is the most affected by maturational constraints (e. g. 1,4–17). A second trend is that the difficulty to acquire the sound patterns in the L2 is positively correlated with the age of exposure to the L2. This correlation, however, is not necessarily linear, and ultimate attainment may vary considerably vis-à-vis learners' age (1,10,18–23).

The lack of linearity and determinism between age and acquisition is aligned with the view of language acquisition as a complex dynamic system (24–26). In such systems, processes are more important than products, since their dynamic nature prevents them from reaching a final state, which, in turn, challenges the notion of *ultimate attainment* and even of *acquisition*. In this case, *(Second) Language Development* would be a more suitable term.

Complex Dynamic Systems are also non-linear in nature, meaning that effects are disproportionate to causes. A lot of snow, for instance, might not cause any change to a mountain, whereas a small pebble or even the steps of a skier might unchain an avalanche with unpredicted

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effects. Likewise, numerous language classes or considerable exposure to the L2 might not cause any progress at a certain stage, whereas some small interference with the interlanguage at a different stage might lead to significant progress. This nonlinear relation between cause and effect is, to a certain extent, due to the movement of the system toward attractor states, which bring temporary stability to the system.

One of the attractor states in second language development is the learner's own L1. The challenge when learning a new language is not that people lose their ability to learn how to produce new sounds, but that they have learned their L1 so well. As we acquire our native language, our brains need to learn to accommodate phonetic variation into the same phonological category so that every little phonetic variation does not get in the way of communication. As a result, we create some prototypical sound categories where we accommodate sounds we hear according to our experience with the language (21,27–32).

As we grow older, it becomes more challenging to perceive L2 sounds that are different yet very close to our L1 prototypical sounds, since the L1 categories function as attractor states of the system. That is why Brazilian learners of English tend to hear both /i/ and /ɪ/ as /i/, /ɛ/ and /æ/ as /ɛ/, /θ/ and /f/ as /f/, for instance. The entire phonology of the L1 exerts attracting force over the L2 developing system, including its prosodic level. Therefore, the expectation is that Brazilian learners of English-L2 use Brazilian Portuguese (BP) rhythm when speaking the L2. From a traditional rhythmic classification of languages, then, Brazilian learners, especially older ones, would use *syllable timing* when speaking English, a *stress-timed* language.

In this paper, we first discuss the dichotomous rhythmic classification of languages into syllable-timed or stress-timed, showing that a categorical classification is not appropriate. We also review previous studies, which suggest that Brazilian Portuguese (BP) should have a mixed classification, given that it has characteristics of both stress and syllable timing. Therefore, we hypothesize that Brazilian learners of English should not have major difficulties reducing unstressed vowels as would be expected if BP were entirely syllable-timed — this is how most Romance languages were classified when the dichotomy was originally proposed. To test our hypothesis, we analyzed the patterns of unstressed vowel reduction in the semi-spontaneous speech of advanced Brazilian learners of English who had begun studying the language at different ages.

This paper is organized as follows: in section 2, we review the proposal of syllable-timed and stress-timed rhythmic patterns, looking at the traditional and current classification of English and BP. In section 3, we describe our methods, which is followed by a section on data analysis, where we present the results and the discussion. In the conclusion, we highlight the most important results and suggest future directions for the study of English-L2 rhythm.

2 Stress- vs Syllable-timing

The idea that languages have different rhythms was initially proposed by Lloyd James (33), whose impression was that some languages, such as Spanish, sounded like machine guns, while others, like English, resembled more the rhythm of Morse Code. Trying to systematize such impression, Pike (34) proposed what came to be known as *syllable-timed*, *stress-timed* and, later, *mora-timed* languages. For him, languages required isochrony (i.e. similar durational intervals) at different levels — syllable, inter-stress intervals, or mora, the last one proposed by Ladefoged (35) to account for Japanese.

However, research has shown that isochrony does not appear in the acoustic signal (36–39), which has led researchers to look for different acoustic cues that could justify the "machine gun versus Morse Code" impression. Dauer (40), for instance, observed that, among the characteristics that lead to this perception, two are the most important: a) so-called syllable-timed languages have fewer phonotactic options than so-called stress-timed ones, and b) languages usually classified as syllable-timed present less reduction of unstressed vowels than those which tend to be classified as stress-timed.

In this paper, we focus on differences in vowel reduction in English and in English-L2 spoken by Brazilian learners. Whereas English is usually classified as stress-timed, BP has been traditionally treated as syllable-timed (41–43). This classification entails that English stressed and unstressed syllables display greater variation vis-à-vis their duration relative to Portuguese syllables, whose length should be less variable across prominent and non-prominent positions in the word.

The durational differences between English stressed and unstressed syllables are clearly observed in words such as ***sé**cre**tà**ry*, ***cóm**fortable* and ***nà**tionali**zá**tion*, where the underlined vowels tend to be reduced to schwas. This tendency can be contrasted with syllable-timed languages such as Spanish, for example (44), where both stressed and unstressed syllables tend to have similar durations. BP, on the other hand, offers a less straightforward rhythmic pattern.

Traditionally, BP has been treated as a syllable-timed language. Recent studies, however, have questioned this classification. Athanasopoulou et al. (45), for example, show that foot-head syllables are significantly longer than foot-dependent syllables. In other words, unstressed syllables reduce a lot more than what one would expect from a syllable-timed language. If we assume a non-categorical rhythmic classification, this prosodic pattern approximates BP to English (as opposed to Spanish, which is truly syllable-timed), a conclusion that is consistent with the recent literature in BP (see below). As a result, a BP speaker learning English should not have as much difficulty reducing (i.e., shortening) unstressed syllables in the L2 as would be expected were BP truly syllable-timed.

In recent studies, the categorical classification into either syllable- or stress-timed has given place to a continuum, where languages might be classified, according to acoustic measurements, as more or less syllable- or stress-timed. A continuum-like result is what both Ramus et al's (46) and Grabe and Low's (47) proposals have achieved. Ramus et al (46) have plotted eight languages — four syllable-timed, three stress-timed and one mora-timed, according to the traditional dichotomous classification, according to their normalized vocalic duration (%V) in relation to the standard deviation of consonantal intervals (ΔC), and the languages occupied the plot in a continuum-like manner. Likewise, Grabe and Low (47), using their *Pairwise Variability Indices*, conclude that their data "show that languages can be more or less stress-timed or syllable-timed" and that "therefore, a strict categorical distinction between stress-timing and syllable-timing cannot be defended" (47).

Barbosa (48) and Frota et al (42,49) have studied the rhythmic pattern of (Brazilian and European) Portuguese and agree that the rhythmic differences among languages is gradient. They also agree that both European and Brazilian Portuguese have mixed rhythms, with the former closer to a stress-timed classification, and the latter closer to a syllable-timed one. Frota et al (49) used Ramus et al's model to plot EP and BP, and their data revealed that EP is more stress-timed in ΔC and more syllable-timed in %V, whereas BP is more syllable-timed in ΔC and mora-timed in %V (the mora-timed classification in Ramus et al's model has more extreme values than syllable-timing).

Barbosa (48) uses a coupled-oscillator model in which the strength of the coupling between the syllable oscillator and the stress group oscillator is used to infer if languages have more tendency towards syllable-timing or stress-timing. To calculate the strength of the coupling, he used O'Dell and Nieminem's (50) technique, in which the duration of stress groups and the number of syllables in that stress group are used in a linear regression model, and the correlation coefficient is used to determine which oscillator dominates over the other. If $r < 1$, the syllable oscillator is dominant (more tendency towards syllable-timing); if $r > 1$ the stress group oscillator is dominant (more tendency towards stress-timing); and if r is close to 1, the influence of one oscillator over the other is neutral.

Barbosa (48) proposes the use of two parameters to characterize the rhythm of a language: the strength of the coupling, as described above, and speech rate, as he has attested that as speech rate increases, so does the strength of the coupling, since speech rate might (de)accelerate the syllable oscillator. Using controlled data of 36 sentences in BP read by a professional radio broadcaster in three different speech rates, he concludes that BP has a great amount of syllable-timing, yet should be characterized as a language with mixed rhythm. When compared to the data of other languages, BP presented more stress-timing than Greek and Italian, but less than British English, for instance.

As we can see, different studies suggest that BP is not a prototypical syllable-timed language. Rather, the rhythmic patterns in Portuguese may not be as different from English as previously thought. If that is the case, then BP speakers learning English should not face major problems shortening unstressed vowels. In the present paper, we test this hypothesis with preliminary production data. As we will see, BP speakers' patterns of reduction are indeed quite similar to the patterns found in the English control data. Furthermore, this seems to be the case even when we consider two different groups of BP speakers that differ in the age they started learning the L2.

3 Method

The data used in this paper were collected for other studies, and were chosen to be used in this preliminary analysis on rhythm in order to answer the initial question and also to guide the design of a more comprehensive future study, with data collection specifically tailored to rhythm analysis. In the original study, advanced students of English-L2 as well as native speakers of American English were recorded reading tokens in a carrier sentence and reading a paragraph. The tokens were used to analyze their vowels in terms of spectral quality and duration (51,52) and also their VOTs (53). The paragraph was originally used to assess learners' level of intelligibility and rate of foreign accent by a panel of judges (54), and has now been used for this pilot study.

3.1 Participants

The participants were 20 Brazilian learners of English-L2, who were all at the last (eighth) semester of their English course when they were recorded and who had all studied the L2 exclusively and uninterruptedly in Brazilian classrooms, with limited, if any, contact with native speakers and/or experience in English-speaking countries. They were divided into two groups: G1 and G2, with ten participants (5 male and 5 female) in each. Learners in G1 started studying the L2 before they were 12 years old, and those in G2 started studying the L2 after they were 16. The chart below summarizes participants' characteristics.

Table 1: Research participants by group

Group	**G1**	**G2**
Number of participants	10 (5 male, 5 female)	10 (5 male, 5 female)
Age at the beginning of studies	8-111 $\bar{x}$=9.3, s=0.9	17-55 $\bar{x}$=36, s=13
Age at recording	$\bar{x}$=16.4, s=1	$\bar{x}$=44.5, s=13

In addition to the learners, 10 native speakers of American English, five male and five female, were also recorded as our control group. They were between 18 and 74 years of age ($\bar{x}$=38.7, s=20) and came from different regions of the US. American English speakers were selected because this is the variety the participants were taught in Brazil.

3.2 Data

The paragraph used in the experiment was retrieved from Time Magazine's website[1], and consisted of an authentic piece of news. Since the original purpose of this recording was to run it through a panel of judges to assess speakers' intelligibility and rate of foreign accent, it was crucial that the paragraph be authentic. Participants were recorded in a silent room with a supercardioid AKG-P5S microphone attached to a computer through a Roland Tri-Capture interface. Recordings were done in mono, with a sampling rate of 44KHz, bit rate of 16 bits, and saved in .wav. Participants could read the paragraph in silence before recording it. Once they were ready to proceed, they were asked to read as naturally as possible, as if reading the news to a friend.

For the present study, a few words from the paragraph were selected for this preliminary analysis. Since the main question concerns the reduction of unstressed syllables, the first criterion for selection of words was having more than one syllable. Among the multiple-syllable words in the paragraph, 1 has four syllables, 8 have three syllables, and 36 have two syllables, so the choice was to work with two-syllable words. Among those, only two have the unstressed vowel in the first syllable, and all the others have the unstressed vowel in the final syllable, which led us into selecting those. Finally, in order to maintain prosodic consistency and to isolate other variables that might interfere with vowel duration, we selected, from the two-syllable words with initial stress, the ones that were content words, monomorphemic, and not occupying the boundary of an utterance. All these criteria left us with 13 items, being the 5 unique words *music* (4x), *apple* (3x), *google* (3x), *major* (1x) and *record* (the noun - 2x). However, we later decided not to consider the proper name "Google", though we kept "Apple" because, even though it was used as a proper name in the text, it is also a common noun, which does not impose extra difficulty to its rendition. Therefore, in this study we analyzed the recordings of the words *music* (4x), *apple* (3x), *major* (1x) and *record* (the noun - 2x). The 10 items that composed the corpus recorded by 30 speakers (10 from each group) generated a total of 300 stressed vowels and 300 unstressed vowels to analyze.

[1] http://techland.time.com/2011/05/27/apples-online-music-locker-a-great-idea-thats-10-years-old/

These words were segmented in PRAAT (55), and their vowels were also segmented and labeled *stressed* and *unstressed*. We considered as the beginning and end of each vowel the first and last valley in the periodic pulse with considerable amplitude in the waveform to resemble the vocalic pulse, and that presented steady formants in the spectrogram. The duration of the words and their vowels were extracted using Arantes' script (56), and the values used for analysis were the relative durations of the vowels in relation to the words.

4 Data Analysis

We begin the data analysis presenting some descriptive statistics. In table 2 we present the medians and standard deviations of the relative durations the stressed and unstressed vowels.

Table 2: Median (M) and standard (s) deviation of the relative duration of stressed and unstressed vowels by group

	Control	G1	G2
Stressed	M=0.32, s=0.07	M=0.35, s=0.08	M=0.33, s=0.1
Unstressed	M=0.18, s=0.06	M=0.2, s=0.09	M=0.2, s=0.8
Difference in means	0.14	0.15	0.13

The descriptive data show that the medians of relative durations were very similar across groups. As was expected, every group had longer stressed vowels compared to the unstressed vowels. Learners had vowels occupying slightly larger proportions of the words and also had slightly greater variation. Because of this variation, in the boxplots below the native speakers seem to have a greater contrast between stressed and unstressed values; however, the difference in means (and medians) was very small.

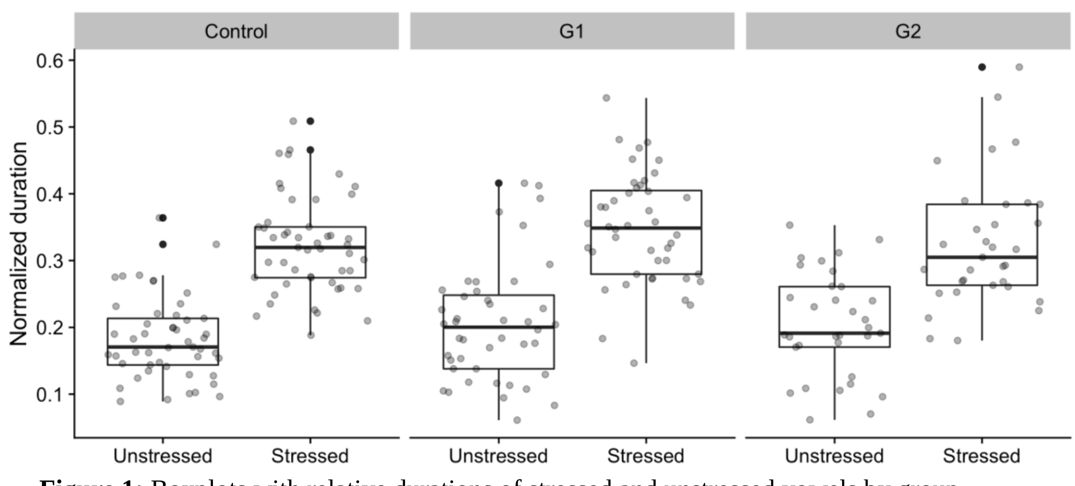

Figure 1: Boxplots with relative durations of stressed and unstressed vowels by group

Next, we collapse unstressed and stressed vowels and plot the absolute differences between them by group, presented in Figure 2.

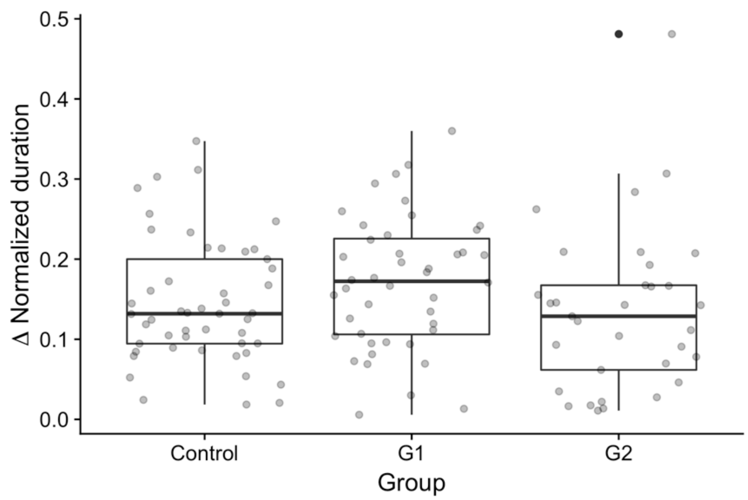

Figure 2: Absolute differences in relative duration between stressed and unstressed vowels by group

The absolute differences slightly increased from control (0.145) to G1 (0.169), and slightly decreased from control (0.145) to G2 (0.134). To estimate the differences between the three groups, we use Markov Chain Monte Carlo (MCMC) simulations (40,000 samples). Unlike frequentist methods (Null Hypothesis Significance Testing, NHST), which provide the probability of the data given a parameter, a Bayesian approach provides the probability of a *parameter* given the data, *p* (Parameter|Data) — which is exactly what we wish to know.

In the present study, the parameter to be estimated is the mean of each group, which will in turn allow us to estimate the *difference* in means between the groups of interest. In other words, we wish to know the probability of mean values for each group given the data (and not the probability of the data given a mean value under the null hypothesis). Another important difference between frequentist approaches and Bayesian estimation is that the latter provides an entire *distribution* of credible parameter values given the data (as opposed to a single point estimate)—this is referred to as the *posterior distribution*. This distribution has a straightforward interpretation: more frequent parameter values are more likely *given the data*. Indeed, this is yet another advantage of Bayesian approaches: the interpretation of the results of any model is considerably easier and more intuitive, since *p*-values and Confidence Intervals play no role in Bayesian estimation (see Credible Interval below).

One crucial difference between Frequentist methods and Bayesian estimation is the presence of a *prior*. Simply put, a prior allows the researcher to design informed models which take into account what is known about a given phenomenon of interest. The intuition behind priors is as follows: if there is consensus in the literature that a particular effect is real, the prior should encode such a consensus into the model. As a result, it is considerably harder for a new single study to falsify an entire body of knowledge, given that the posterior distribution depends not only on the data, but also on the prior. This is a desirable feature, since extraordinary claims require extraordinary evidence — and not only a *p*-value below an arbitrary threshold. Priors can be informative, mildly informative, or non-informative (also known as *non-committal*). In our study, we assume non-informative priors, which are normally distributed with mean 0 and standard deviation 1: $\mathcal{N}(0, 1)$. This means that our estimation is guided by the data alone.[2]

The model used here is hierarchical, and takes into account by-speaker variation within each group. The simulations were performed using JAGS in R (57). In the case in question, we are interested in the credible differences in means between the groups, as mentioned above. Consequently, three posterior distributions will be provided, namely, Control-G1, Control-G2, G1-G2, each of which is merely the difference of two posterior distributions. Finally, the model reported below was checked for chain ($n = 4$) convergence and effective sample size (> 10,000).

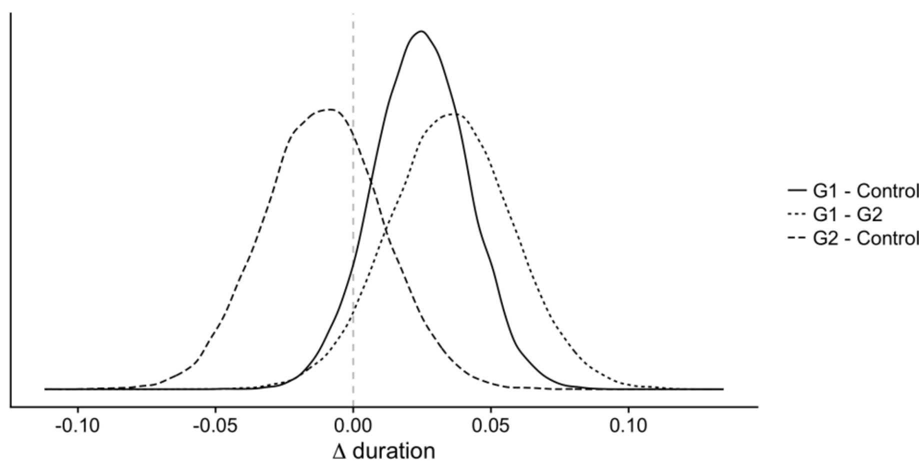

Figure 3: Posterior distributions using MCMC simulations

The plot above provides histograms of the most credible differences in means given the data. All three posterior distributions clearly include zero as a (highly) credible value. Once we have the posterior distributions in Fig. 3, we can define a Highest Density Interval (HDI), which typically includes the 90-95% most probable values in the posterior distribution. Unlike Confidence Intervals, which are *not* a distribution, HDIs are straightforward: values which are closer to the peak of the distribution are more likely given the data.[3] The HDIs of all three distributions unambiguously include zero. As a result, given our data, we can conclude that no credible statistical difference was found between the groups under consideration.

The fact that neither group of learners is credibly different from the control group is consistent with the hypothesis that the mixed rhythm present in Portuguese facilitates the acquisition of the rhythmic patterns in English, a stress-timed language, at least in the reduction of the unstressed vowel of two-syllable monomorphemic content words. Even when we compare controls and G2, which consists of late learners, we can see that the posterior distribution of the difference in means is around zero. This indicates that even with more data the posterior would likely still include zero in its HDI. If Portuguese were a prototypical syllable-timed language, then G2 should certainly be less similar to the control group than it actually is.

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[2] Our priors, in this case, approximate a more traditional approach, which also assumes a naïve initial hypothesis regarding the parameters to be estimated.

[3] Indeed, confidence intervals are often misinterpreted as a probability distribution.

Finally, to compare our results to a traditional frequentist approach (e.g., ANOVA), the single point estimate of the difference in means provided in an ANOVA would be similar to the peaks of the posterior distributions in Fig. 3, given that the prior used in our estimation was non-informative.

It should be mentioned that in all other analyses carried out with these data, i.e. spectral quality and duration of vowels, VOTs and intelligibility and rate of foreign accent (51–54), the learners in G2 were statistically different from those in G1, who were closer (yet statistically different as well) to the control group.

5 Conclusions

In this paper, we presented a preliminary analysis of the rhythm of English-L2 of advanced Brazilian learners. Coming from the traditional premise that English is a stress-timed language and BP a syllable-timed language, one would expect Brazilian learners not to reduce unstressed vowels as much as English native speakers, especially older learners. However, based on more recent studies that argue that BP is a language of mixed rhythm, with more stress-timing traits than its traditional categorical classification would account for, the hypothesis of this paper was that Brazilian learners would not present major difficulties in reducing unstressed vowels.

We showed that no statistically credible difference was found between our control data and BP speakers' data. In other words, if there is a difference, it is subtle enough to have gone undetected in our preliminary study. If BP were indeed a syllable-timed language, however, the prosodic differences in question, i.e. reduction of the unstressed vowel of two-syllable monomorphemic content words, should not be subtle. Our results therefore support what the more recent literature presented in section 2 has found, i.e., that BP has a mixed rhythm, with more stress-timing traits (thus, more unstressed vowel reduction) than would be expected if it were a prototypical syllable-timed language.

Due to its preliminary nature, this study used semi-spontaneous data that had already been collected for other purposes and, thus, were not controlled for type of word, number or frequency of words, number of syllables and number stress groups. Therefore, the next step in this investigation will be to conduct a more controlled analysis, with laboratory data collection specifically designed for rhythm analyses. It will include the data from learners' production of BP, for a rigorous comparison of the rhythmic patterns that Brazilian learners of English use when speaking the L1 and the L2. It will also look into other aspects of rhythm, such as the ones proposed by Ramus et al (46), Grabe and Snow (47) and Barbosa (58).

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