Foreign Accent and L2 Speech Rhythm of English

a pilot study based on metric and prosodic parameters

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Abstract: This research is under development and it aims to carry out a comparative study between L1-L2 English (American and Brazilian speakers respectively) speech rhythm, from the some of the classical rhythm metrics and prosodic-acoustic parameters measured during production, perception and factor discrimination, and then project which classes of parameters (metrics and prosodic-acoustic) best model foreign accent degree of English. As for the Methods, a group of L1 (four Americans) and L2 (ten Brazilians) speakers read a phonetically-adapted version of the Aesop's fable "The Lion and the Mouse". For the acoustic analysis, phonetic data were segmented and labeled into six different units; vowels, consonants, pauses, (phonetic) syllables, sentences and higher units. For the perceptual analysis, ten American raters listened to chunks of L1-L2 English and scored through a 7-point Likert scale the speakers' foreign accent degree (the higher the score, the higher foreign accent degree was). For the statistical analysis, we ran one-way ANCOVAs, cross-setting the classes of parameters, and for the perceptual scores. We also ran discriminant analysis statistics to check the most robust parameters in the classification of the groups. Preliminary results confirm our hypothesis and point out to significant acoustic and perceptual differences between groups, such as: i) lower speech rate, ii) lower consonantal, syllabic and melodic variability, dispersion, and modulation produced by the Brazilian speakers, as well as a normal distribution between the classes of parameters. Even preliminarily, this study comes to fill a gap on studies of L2 experimental prosody in Brazil.

Keywords: L2 prosody; foreign accent; speech rhythm; metric and prosodic parameters.

I.I NTRODUCTION

As stated by [1] defines one's accent as being "a salient aspect of communicative fluency" as well as being communicatively dynamic, in the foreign language (L2) as it is in the native language (L1). The author points out that one's accent shifts over time in response to one's experience, and orientation towards the target language. Furthermore, a person's accent also fluctuates as a function of the situational level, as seen in phenomena such as speaking-style shifting and speech accommodation. Accents may exist in-between dialects of the same language, and in the case of L2s. The latter is denominated *Foreign Accent*.

Since the early 1970s, L2 speech studies have pointed out to L1 transfer on the phonological and the phonetic levels establishing a new phonetic category which might be different from the original L1's and the target L2's as pointed out in [2]. [2] postulates empowered the latter statistical learning perceptual models since then ([3], as well as other models). Yet with regard to speech perception, [4] states that L2 speech is first perceived by an acoustic-phonetic processor, then undergoes linguistic decoding in the speech comprehension system (the parser), and is finally interpreted by a conceptualizing module influenced (or not) by the L1 system.

The aforementioned concepts give us an outline of the complexity of one's foreign accent, on both segmental and prosodic domain as addressed in [3], [5]. Phonetic literature has been controversial regarding on choosing segmental or prosodic

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approaches that best determine foreign accent degree. This research was conducted shedding light on the L2 prosodic domain. Herein, we aimed to analyze how English speech is produced by both Brazilian Portuguese (BP) and American English (AmE) speakers (L2 and L1 respectively), as well as perceived by American speakers, and how acoustic correlates such as duration, fundamental frequency (F0), and intensity influence the production and the perception of a speaker's foreign accent.

Our main hypothesis is that L2 English speech rhythm is performed by BP speakers in such configuration: i) lower speech rate, and lower variability, dispersion and modulation of F0 (due to lack of fluency and prosodic planning, as well as due to excessive attention to segmental aspects rather than prosodic ones (see [5], [6]), ii) lower segmental and syllabic variability due to regularity patterns on both syllabic and stress group levels (see [7], [8]).

II. Theoretical Backgruond

A. *L2 Prosody*

For [9], [10], Prosody is defined as variations in suprasegmental parameters (stress, rhythm, lexical tone and intonation, and voice quality) in the prosodic domain such as duration, F0 and intensity. [11] poses that L2 prosody has been based on a possible connection of prosodic cues in L2 speech production and perception. Both, production and perception, organize prosodic planning and are crucial for the determination of one's degree of foreign accent. As far as foreign accent is concerned, [12] highlight the relevance of voice quality and its interaction with rhythmic and intonational aspects, in the recognition of a foreign accent (up to five times more robust than vocalic and consonantal parameters). [13], [14] point out several of the classical metrics and acoustic parameters more readily interpretable, and restate their importance for L2 prosody research. These metrics and prosodic-acoustic parameters are referred to as local and global mathematical parameters that are calculated into segmental- and higher-level units. They inform rhythmic characteristics of centrality, variability and modulation of produced speech.

L2 prosody has emerged in strength since 1990s with the prioritization of L2 prosodic aspects, such as the account for rhythmic and intonational aspects to the determination and smoothness of foreign accent (see [15], [16]).

B. *L2 speech rhythm*

[17] described L2 rhythm as a rule, which cause it to be apprehended in different ways from a dynamic point of view. It happens according to one's sensory perception, production or both. The literature has conceptualized speech rhythm as a given movement marked by successions of strong and weak beats ([8]). According to [18], [19], [20] and so, speech rhythm would be characterized by regular time intervals of linguistic units just like (stressed) syllables.

In the interaction between L2 speech rhythm and foreign accent, [21] states that a L2 global accent remains as a function of the phonological and phonetic productions of a target-L2 in three levels: segmental (individual sounds), syllables (onset and coda complexity, and architecture) and prosody (rhythm and intonation). The global accent concerns to whether or not one can sound more or less native/non-native in a specific target-L2.

III. METHODS

A. *Participants*

For the speech production experiment, we collected data from a group of L1 (four Americans) and L2 (ten Brazilians) speakers. Participants read a phonetically-balanced and adapted version of the Aesop's fable "The Lion and the Mouse". For the perceptual experiment, ten American speakers participated. The American participants from the speech production experiment were not included as part of the perceptual experiment.

For the L1-English groups (both production, and perceptual experiments), participants were 50% male/50% female, and in between 26 and 50 years old (mean = 38.1; standard deviation (SD) = 13.2), and for the L2-English group (also 50% male/50% female), they ranged between 22 and 44 years old (mean = 27.6; SD = 7.6). All of the participants from the L1-English group were BP-L2 speakers. Brazilian participants were submitted to the Oxford Online Placement Test for proficiency level assessment. The group qualified as "Advanced" (C2-C1 level) speakers (see [22] for proficiency level detailing). All of the participants were communicated about the experiments by e-mail or WhatsApp text and audio messages. It is also worth mentioning that 100% of the participants – L1- and L2-English groups - are acquaintances from the first author of this research, and when they were contacted, they immediately and freely volunteered to participate.

B. *Acoustic analysis*

Data segmentation was performed according to [13][1], [14] studies on L2-English speech rhythm, so that data were segmented into the following units: i) vowels (V); ii) consonants (C); iii) onset-to-onset units of vowels (VV); iv) pauses (#); v) syntactic-based sentences (S), and vi) higher units (chunks - CH) as showed in Figure 1. The software Praat was used for the acoustic and perceptual analysis ([23]).

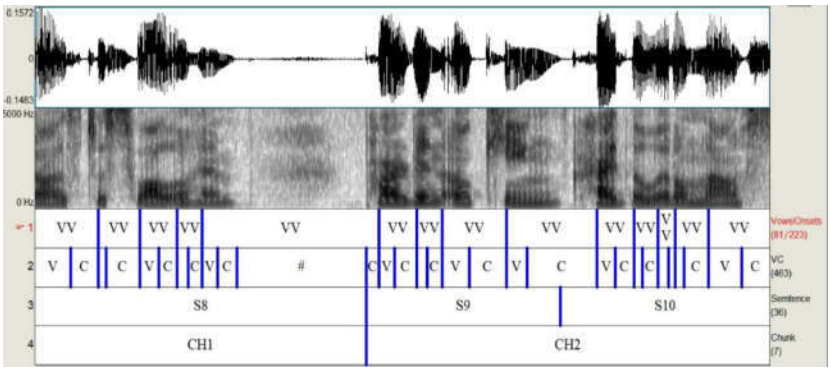

Figure 1: *Partial waveform, broadband spectrogram and four tiers respectively segmented and labeled as: 1) phonetic syllable units (VV); 2) vowel and/or consonant phonemic-sized units (V/C); 3) syntactic-based sentence units (S); 4) utterance (chunk-based) units (CH) produced by a native speaker of English. [13], [14].*

[1] For a further-detailed analysis of the protocol adopted for data segmentation, see [13], section 3.3., p. 7-8. Available in: <https://econtents.bc.unicamp.br/inpec/index.php/joss/article/view/14996>.

Automatic extraction of parameters was carried out by a script for Praat: *SpeechRhythmExtractor*[2], ([24]) in order to extract the classic rhythm metrics, and local and global prosodic parameters (see section II.A for a definition of the classic rhythm metrics and prosodic-acoustic parameters), from V, C, VV, S and CH for the determination of the rhythmic, intonational, and vocal effort differences between L1-L2 productions. In TABLE I, we described the parameters extracted for the analysis:

TABLE I. CLASSES OF PARAMETERS EXTRACTED FOR THE ACOUSTIC ANALYSIS.

METRICS		PROSODIC-ACOUSTIC PARAMETERS	
Measure	**Segment of application**	**Parameter**	**Segment of application**
Percentual (%)	V, C	F0 median (F0med)	S, CH
Standard deviation (delta)	V, C, (V or C), VV	F0 peak (F0peak)	S, CH
Variation coefficient (Varco)	V, C, (V or C), VV	F0 minimum (F0min)	S, CH
Raw pairwise variability index (r-PVI)	V, C, (V or C), VV	F0 standard deviation (F0sd)	S, CH
Normalized pairwise variability index (n-PVI)	V, C, (V or C), VV	F0 skewness (F0sk)	S, CH
Rhythm ratio (RR)	V, C, (V or C), VV	Mean of F0 first derivative (dF0mean)	S, CH
Variability index (VI)	V, C, (V or C), VV	Standard deviation of F0 first derivative (sdF0)	S, CH
Yet another rhythm determination (*z-score duration*) (YARD)	V, C, (V or C), VV	Skewness of F0 first derivative (dF0sk)	S, CH
		Speech rate (SR)	VV, S, CH
		F0 rate (F0-R)	S, CH
		Spectral emphasis (SE)	S, CH
		Mean of normalized syllable-peak duration (MeandurSil)	VV, S, CH
		Mean duration of pauses (Meandur-#)	S, CH

C. *Perceptual analysis*

For the perceptual analysis, we ran a Multiple Forced Choice listening experiment (*ExperimentMFC* Praat object – [23]) that was held under the following criteria: i) ten American raters/listeners, who lived in Brazil during the time of the experiment, and were BP-L2 speakers, as well as having different job positions, were asked to listen to 60 chunks extracted from our data (30 chunks produced by each group) of 20 seconds approximately each). After listening, their task was to rank the foreign accent degree from the chunks in a 7-point Likert scale (the higher the ranking values, the stronger the foreign accent) as showed on Figure 2.

The raters of the perceptual experiment were not the same participants of the speech production participants.

Yet it is noteworthy mentioning that the participants' data collection of both groups for speech production, and the American raters for the perceptual experiment, occurred before the lockdown determined by the Brazilian health authorities due to the sanitary protocols established because of the Covid-19 pandemic.

[2] For a stepwise calculation of each metric and prosodic parameter, access *SpeechRhythmExtractor*'s documentation, available in: <https://github.com/leonidasjr/SpeechRhythmCode>.

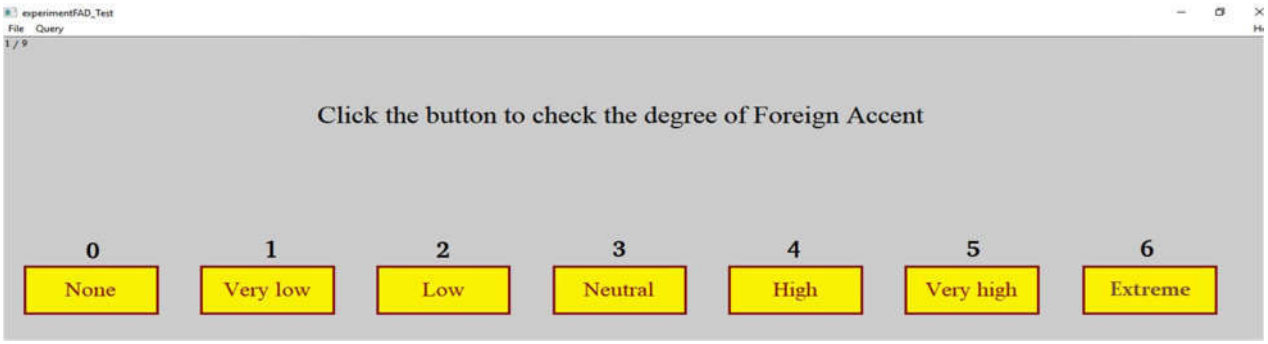

Figure 2: *Command to start the perception test: "Click the button to check the degree of Foreign Accent"; 7-point Likert scale to assess the degree of foreign accent. Buttons correspond to the ranking: None = 0; Very low = 1; Low = 2; Neutral = 3; High = 4; Very high = 5 and Extreme = 6. (Personal source).*

D. *Statistical analysis*

The statistical analyses were partitioned into three distinct moments:

- Speech production statistics: where we ran one-way Analysis of Covariance (ANCOVA) in order to assess the effect of the language group (L1-/L2-English) on each class of parameters, that is, the metric class and the prosodic-acoustic class controlled for the covariate parameter(s) of the cross-set class, i.e., a metric dependent variable was accounted for prosodic-acoustic covariates and vice-versa.
- Speech perception statistics: where we ran one-way ANCOVA in order to assess the effect of the language groups on the scores rated by the raters controlled for the covariate parameter(s) per class of parameters.
- Factor discriminant statistics: where we ran a linear discriminant analysis (LDA) in order to classify the speakers into one of the two clearly defined language groups (L1- and L2-English speakers). According to [25], LDA is a machine-learning technique used in order to perform dimensionality reduction of data features (in our case, the quantity of parameters in both classes) and pattern classification application. For the sake of our research, LDA is used to associate the classes of parameters with the research's factorial categories (language groups).

IV. PRELIMINARY RESULTS

For the results, we present herein only the significant metric and prosodic-acoustic parameters extracted from the participants' productions (see TABLE II, and Figure 3), as well as the perceptually-based scores attributed by the American raters (see Figure 4). Yet as proposed in the Methods section, we also provide (preliminary) LDA models that best discriminated both groups (see TABLE III, and Figure 4).

TABLE II. MEANS FOR THE METRIC AND PROSODIC-ACOUSTIC PARAMETERS PRODUCED BY BOTH L1- AND L2-ENGLISH; ANCOVAS' DEGREES OF FREEDOM (D.F.), F- AND P-VALUES, AND; THE EFFECTI SIZE OF THE RELATED MEASURES AND PARAMETERS.

Class	*Measure/Parameter*	*English production*		*D.F.*	*F-value*	*P-value*	*Effect size (R^2)*
		L1	L2				
Metric	*%C*	0.58	0.47	91	15.83	<0.0001	0.52
	Delta-S	226.0	238.0	93	43.84	<0.0001	0.49
	Varco-S	0.90	0.81	89	13.33	<0.0001	0.54
	YARD-S	0.81	0.94	92	16.33	<0.0001	0.53
Prosodic-acoustic	*F0sd*	5.12	3.56	88	11.86	<0.0001	0.59
	SR	3.70	2.36	89	25.51	<0.0001	0.67

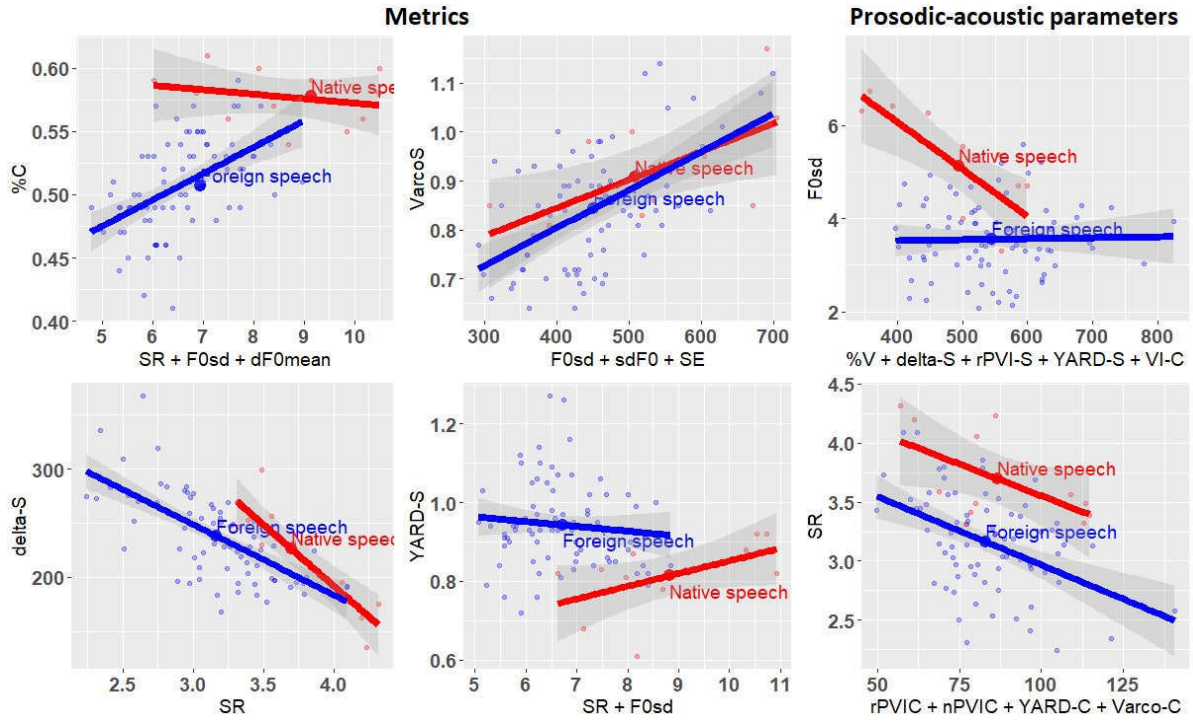

Figure 3: ANCOVA results for the significant metrics and prosodic-acoustic parameters for the *native speech* (red) and *foreign speech* (blue) of English. Measures and parameters' captions used in each panel are detailed in TABLE I, section III.B.

As we mentioned previously, this is on-going research. So, what we will present here are preliminary results treated so far:

- Durational, melodic, and intensive parameters have showed significant main effect as covariate predictors of the response metrics: consonantal proportion (%C), syllabic variation coefficient (Varco-S), syllabic z-scored duration (YARD-S), and syllabic standard deviation (Delta-S);
- Three out of four of the most robust metrics are syllabic. This can preliminarily indicate that phonetic syllable-based metrics emerges to be a consistent class of features to determine prosodic differences in L1-L2 context. The metrics presented in most part of the literature on L2 speech rhythm take extensively vocalic and consonantal intervals to iterate along the utterances. In fact, the structural interdependence of syllabic and consonantal criteria could be thought over at this point, since syllable structure of BP influence Brazilian speakers' productions of English, in terms of consonantal proportion, voicing, and consequently, duration. Our results point out to a possibility of revisiting the experimental designs in order to invoke syllabic metrics onto analyses, and then, observe how C-metrics covary with the S-metrics;
- Syllabic-based and consonantal-based metrics have showed significant main effect as covariate predictors of the response prosodic-acoustic parameters F0 standard deviation (F0sd) and Speech rate (SR);
- As for the SR, C-metric covariates played a very important role since just this class of metrics discriminated L1-L2 prosody consistently. An interesting aspect is the non-significance of vocalic and syllabic metrics that we initially hypothesized to be discriminative at SR level. One reason that we imagine what would have happened could be connected to the *speaking style* for the task (READING). Reading style demands a considerably more expressive prosody since it claims for role playing characters (a lion and a little mouse for our data). [26] points out that in L2 prosodic-based contexts, expressivity is revealed early in the syllabic level, and at least for this preliminary analysis,

we found no significant expressivity in syllables for none of the groups. We conclude that even the native speakers could have felt somewhat introspective during the reading, since the analyzed data constitute the first data we have collected with the participants;

- For the F0sd, we had more syllabic metrics controlling for this parameter as we expected. We yet had one vocalic and consonantal metric. It is plausible that these syllabic metrics covary because variability and dispersion of F0 is intrinsically melodic and, thus prosodic boundaries can make a difference over syllabic configuration by means of melodic variation, especially over native speech. On the other hand, foreign speech appeared to be monotonical when controlled for the metrical units. These aspects have been pointed out in [5] study where the authors analyzed variability in F0 and duration of both native and Brazilian speakers of English;
- The effect size presented in TABLE II through the determination coefficient (R^2), brings up consistent models designed from the ANCOVAs, since, at least to a preliminary analysis, gives an account at explaining the variation between the groups (except for the *Delta-S* – $R^2 = 0.49$).

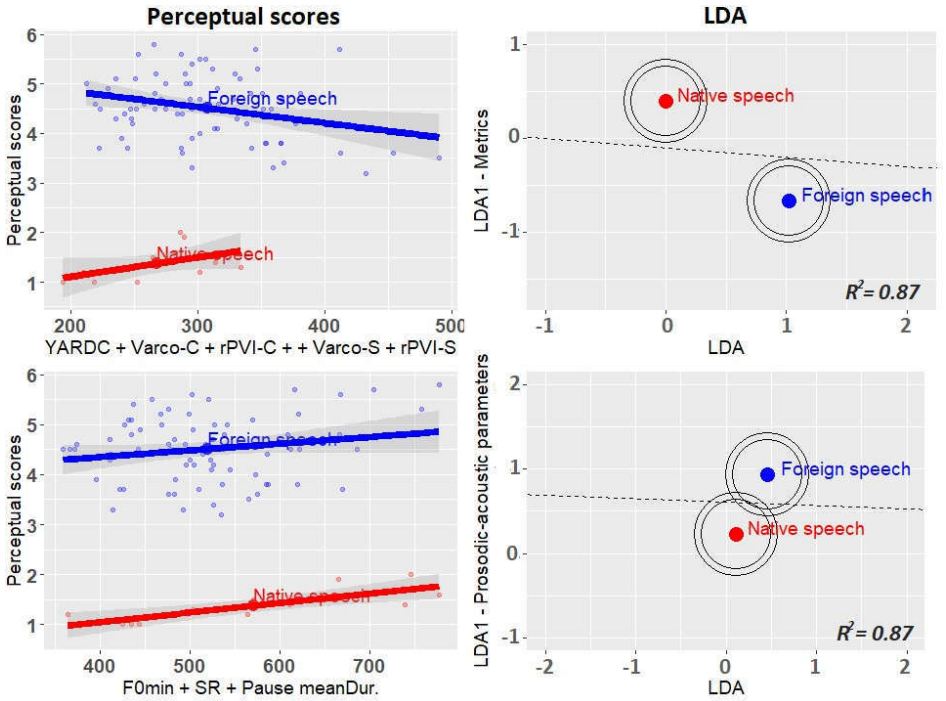

Figure 4: ANCOVA results for the significant perceptual scores from native speech (red) and foreign speech (blue) of English and LDA for both factors. Measures and parameters' captions used in each panel are detailed in TABLE I, section III.B.

In Figure 4, we present results of a perceptual task held by native raters, as well as a LDA, in order to group the subjects into L1 or L2-English.

- As for the metrics, syllabic-based and consonantal-based parameters have showed significant main effect as covariate predictors of the perceptual scores attributed by the raters in determining foreign accent degree. This estimates that raters lied down consistently on durational parameters as far as foreign accent is concerned. A determination coefficient of 84% ($R^2 = 0.84$) explains the variation between the factor group controlled for the metrics.
- Three out of five of the most robust metrics are syllabic metrics. This can previously indicate that phonetic syllable-based metrics emerges to be a consistent class of metrics to determine prosodic differences in L1-L2 context from a

perceptual point of view. As we mentioned in earlier section, classical metrics take extensively vocalic and consonantal intervals and the previous results herein presented shed light towards a great consistency of syllabic units besides consonantal intervals. We reiterate the possibility of revisitation of the experimental designs in order to invoke syllabic metrics onto acoustic analyses;

- As for the prosodic-acoustic parameters, F0 minimum, SR, and Mean duration of pause parameters have showed significant main effect as covariate predictors of the perceptual scores attributed by the raters in determining foreign accent degree. A determination coefficient of 78% ($R^2 = 0.78$) explains the variation between the factor group controlled for the prosodic-acoustic parameters.
- These results corroborate [27], [13], [14] and [5] studies where F0 minimum is significantly higher for foreign speakers rather than for native ones. SR has also presented as significantly different between the groups. Traditionally, SR (speech rate, calculated in syllables per second) has been showed to be quite different when comparing L1-L2 prosody. Literature has attributed that there is a high computational cost of cognitive effort at producing aspects such as L2 rhythm, intonation and emphasis for reasons that go, since the foreign speaker context-and-language experience until one's emotional-expressive state ([26], [28]). The acoustic characteristics established for SR are either extended to Pause duration especially in prosodic boundary detection (see [1], [6], [26], [28] for details);
- As for the LDAs, we performed class-isolated analyses that accounted for the metric and prosodic parameters in order to check if there would be a more robust class of parameters for group classification. Both classes have performed robustly similar parameters to explain the variation between groups. Both models had determination coefficients of 87% ($R^2 = 0.87$, for both classes). From the LDAs, we obtained the models in TABLE II. For the LDA model for the metrics, syllabic and consonantal metrics showed the best performances. For the prosodic-acoustic parameters, the melodic and durational ones.

TABLE III. LDA MODELS FOR BOTH CLASSES OF PARAMETERS.

Parameter class	***LDA models***	***Effect size (R^2)***
Prosodic-acoustic parameterss	$LDA_{Languages}$ = (*f0min*srate*) + (*f0med*f0sd*) + (*meandf0*sdf0*)	0.87
Metrics	$LDA_{Languages}$ = *Varco-C + rPVI-C + YARD-C + delta-S + Varco-S + rPVI-S + VI-S*	0.87

V. SOME REMARKS

This study preliminarily presented the performance of metrics and prosodic-acoustic parameters performed in the production and perceptual domains through ANCOVA statistics as well as through LDA technique. We primarily infer that both classes of parameters are robust for the determination of foreign accent (degree). Differently from a great deal of the literature on L2 speech rhythm (see [29], chapters 2 and 3), the classical metrics were not performed into a 2-dimensional model, but rather as ANCOVA and LDA models to check the influence of the main effect and /or interaction of several parameters simultaneously in order to find the best ones to classify the groups from the foreign accent degree. With the use of LDA, we intended to best classify between groups with a simplification of the number of modeled parameters.

The findings herein presented so far show, at least to some extent, consistent potential of how rhythm metrics and prosodic parameters may influence and model L2 production. Further results provided from the continuation of this study are likely to be applied in different L2 scientific areas such as: L2 pronunciation teaching, where prosody could play a role in conversational situations as attested by [6], [26]; L2 forensic phonetics, where prosodic-acoustic features are likely to be detected from voice disguise in instances such as those of raising or lowering pitch, whispering (which is the most frequently used voice disguise type by criminals), increasing or decreasing of speech rate, among others, in the task of speaker's identification as confirmed by [30].

Since this research is under development, we have been working on the following steps: i) extending the analysis for Brazilian Portuguese (BP) L1 group and BP-L2 group performed by American speakers of BP, ii) using more prosodic parameters of centrality, dispersion and modulation domains related to duration, F0, intensity as well as adding voice quality ones, iii) Collecting data from a different speaking style rather the reading (spontaneous talk, for example), and iv) check the forensic implications of foreign accent degree of the possible alignments between production, perception and LDA classification herein observed.

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