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O DESENVOLVIMENTO DA LEITURA E ESCRITA (A)TÍPICA EM MONOLÍNGUES E BILÍNGUES À LUZ DA PSICOLINGUÍSTICA

Reading Effects Over The Production of Brazilian Portuguese (BP) Mid-vowels by Speakers of Spanish

Efeitos de leitura sobre a produção de vogais médias do Português Brasileiro (PB) por falantes de Espanhol

Efectos de lectura sobre la producción de vocales medias del Portugués Brasileño (PB) por hablantes de Español

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Abstract: This study investigates the impact of task type on vowel dispersion and Mahalanobis distance in the production of Brazilian Portuguese mid vowels by 10 native speakers of Spanish (5 males and 5 females) residing in Brazil. The participants completed two tasks: a card task and a list task, with the latter requiring more focused speech monitoring due to the reading effects. The selection of target words was based on acoustic parameters to avoid phonological context interference in F1 and F2 values. The words were pairs of morpheme alternates in Brazilian Portuguese, triggered by the following morphophonological processes: verbal inflection, metaphonic plural formation, gender inflection, suffixation, and abbreviation/truncation. Multiple linear mixed-effects regression models were applied to examine how vowel dispersion varied according to task type. The results showed that, contrary to the research hypothesis, vowels exhibited greater dispersion in the list task. This increased variability is attributed to hyperarticulation, which tends to occur in tasks that require greater attention to speech production. In contrast, the low-mid front vowel /ɛ/ showed reduced dispersion in the list task, suggesting that more controlled tasks may lead to more stable vowel productions. The findings highlight the phonetic monitoring effects induced by reading tasks on vowel dispersion and the distance between mid vowels and the centroids of the high-mid vowels /e/ and /o/ in the productions of Spanish speakers, as low-mid vowels are not part of the Spanish phonological system. This study contributes to the understanding of how tasks and reading-induced monitoring impact L2 vowel production, offering insights for the development of effective L2 pronunciation training.

Keywords: second language acquisition; morpheme alternants; reading and monitoring effects; vowel dispersion; Mahalanobis distance.

Resumo: Este estudo investiga o impacto do tipo de tarefa na dispersão das vogais e na distância de Mahalanobis na produção das vogais médias do Português Brasileiro por 10 falantes nativos de Espanhol (5 homens e 5 mulheres) residentes no Brasil. Os participantes realizaram duas tarefas: uma tarefa de cartas e uma tarefa de lista, sendo que a segunda exigiu maior monitoramento da fala devido aos efeitos da leitura. A seleção das palavras-alvo foi baseada em parâmetros acústicos para evitar interferência do contexto fonológico nos valores de F1 e F2. As palavras foram pares de morfemas alternativos no Português Brasileiro, que têm como gatilhos os seguintes processos morfofonológicos: flexão verbal, flexão de gênero, derivação sufixal, abreviação/truncamento e plural metafônico. Modelos de regressão linear de efeitos mistos foram aplicados para examinar como a dispersão das vogais variou em função do tipo de tarefa. Os resultados mostraram que, ao contrário do que sugeria a hipótese de pesquisa, as vogais apresentaram maior dispersão na tarefa de lista. Essa maior variabilidade é atribuída à hiperarticulação, que tende a ocorrer em tarefas que exigem maior

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atenção à produção da fala. Em contraste, a vogal média baixa anterior /ɛ/ apresentou menor dispersão na tarefa de lista, sugerindo que tarefas mais controladas podem levar a produções vocálicas mais estáveis. Os resultados destacam os efeitos de monitoramento fonético induzido por tarefas de leitura na dispersão vocálica e nos valores de distância entre vogais médias e os centroides das vogais médias altas /e, o/ nas produções de hispanofalantes, uma vez que as vogais médias baixas não compõem o sistema fonológico do Espanhol. O estudo contribui para a compreensão de como as tarefas e o monitoramento ocasionado pela leitura impactam a produção das vogais em L2, oferecendo *insights* para o desenvolvimento de treinamentos eficazes de pronúncia em L2.

Palavras-chave: aquisição de segunda língua; morfemas alternativos; efeitos de leitura e monitoramento; dispersão vocálica; distância de Mahalanóbis.

Resumen: Este estudio investiga el impacto del tipo de tarea en la dispersión de las vocales y en la distancia de Mahalanobis en la producción de las vocales medias del portugués brasileño por 10 hablantes nativos de español (5 hombres y 5 mujeres) residentes en Brasil. Los participantes realizaron dos tareas: una tarea de cartas y una tarea de lista, siendo que esta última requirió un mayor monitoreo de la producción del habla debido a los efectos de la lectura. La selección de las palabras se basó en parámetros acústicos para evitar la interferencia del contexto fonológico en los valores de F1 y F2. Las palabras fueron pares de morfemas alternantes morfológicamente en portugués brasileño, activados por los siguientes procesos morfofonológicos: conjugación verbal, flexión de género, derivación sufijal, truncamiento/abreviación y plural metafónico. Se aplicaron modelos de regresión lineales de efectos mixtos para examinar cómo la dispersión de las vocales variaba según el tipo de tarea. Los resultados mostraron que, contrariamente a lo que sugería la hipótesis de investigación, las vocales presentaron una mayor dispersión en la tarea de lista. Esta mayor variabilidad se atribuye a la hiperarticulación, que tiende a ocurrir en tareas que requieren una mayor atención a la producción del habla. En contraste, la vocal media baja anterior /ɛ/ mostró una menor dispersión en la tarea de lista, lo que sugiere que las tareas más controladas pueden llevar a producciones vocálicas más estables. Los resultados destacan los efectos de monitoreo fonético inducidos por tareas de lectura en la dispersión vocálica y en los valores de distancia entre las vocales medias y los centroides de las vocales medias altas /e/ y /o/ en las producciones de hablantes hispanohablantes, dado que las vocales medias bajas no forman parte del sistema fonológico del español. Este estudio contribuye a la comprensión de cómo las tareas y el monitoreo inducido por la lectura impactan la producción de vocales en L2, ofreciendo ideas para el desarrollo de entrenamientos efectivos de pronunciación en L2.

Palabras clave: adquisición de segunda lengua; morfemas alternativos; efectos de lectura y monitoreo; dispersión vocálica; distancia de Mahalanóbis.

Introduction

Speech production is a complex human ability that requires different skills. With the intention of better understanding the factors involved in speech production, Levelt (1983) identifies conceptualization, formulation, articulation, and self-monitoring as the stages through which one goes from the intention of an utterance to its actual production. According to the author (Levelt, 1983), conceptualization involves the speaker's intention—a message that is created first, even before the selection of the words that will compose the speech.

Secondly, formulation includes the mental lexicon and language-specific knowledge, which help the speaker develop a phonological representation of what is planned to be said. These steps lead to articulation, that is, the audible production of the message. The self-monitoring stage can occur both before and during the production itself and serves as a way to identify possible mistakes related to grammar, semantics, or phonology, for example.

Labov (1990) suggests the use of the term *monitoring* in relation to speech as a way to discuss issues of social prestige, style, and variation. In this sense, monitored speech would stem from an intentional construction of identity rather than from linguistic error correction, and is often even more conscious than the type of monitoring proposed by Levelt (1983). Still, both perspectives can be connected: in a formal event, for example, one might monitor their language use to avoid grammatical mistakes in order to better align stylistically with the social setting.

During reading tasks, researchers suggest that the level of speech production monitoring tends to be higher compared to non-reading tasks. One argument supporting this claim is that more conscious activities, such as reading, are likely to enhance the activation of the monitoring system (Levelt, 1983). Similarly, tasks that allow more time, involve less communicative pressure, and demand greater attention to speech are also expected to increase monitoring (Ellis, 2005; Kormos, 2014).

Seymour (1997) proposes a scale of the orthographic systems that stablishes the grapheme--phoneme relation of the languages according to their transparency or opacity. This increased level of monitoring during reading tasks is particularly relevant when considering the grapheme-phoneme relationship and the degree of orthographic transparency of a language. In languages with more transparent orthographies — where there is a more consistent correspondence between graphemes and phonemes — readers may rely more directly on the written form to guide pronunciation, potentially reinforcing accurate phonological representations. In contrast, in languages with opaque orthographies, where this correspondence is less predictable, readers may require more cognitive effort to decode pronunciation, which can further activate the speech monitoring system. Therefore, the effects observed in reading tasks may be modulated by the transparency or opacity of the language's orthography, influencing both the ease of phonological processing and the degree of monitoring required (Ellis, 2005; Kormos, 2014).

Considering the increasing migration to Brazil by speakers of Spanish, specially from South America, and, thus, the raising number of native speakers of Spanish that have learned Portuguese language, this paper focuses on the relation between the phonological systems of Spanish and Portuguese. Within this context, Spanish is characterized as the more transparent language, whereas Portuguese is considered more opaque.

Given this contrast in orthographic transparency between Spanish and Portuguese, the Dual Route Cascaded (or DRC) model, proposed by Coltheart *et al.* (2001), offers insights into how speakers of Spanish approach the acquisition of Portuguese phonology. The DRC model suggests that readers utilize two distinct routes: a lexical route, which is fast and relies on stored word representations, and a non-lexical route, which is slow and involves decoding via letter-sound rules. For speakers of Spanish learning Portuguese, the opacity of Portuguese orthography may challenge the efficiency of the non-lexical route, requiring greater reliance on the lexical route, especially when encountering irregular spelling-to-sound correspondences.

One of the most significant differences between the phonological systems of Portuguese and Spanish lies in the vowel phonemes: while Spanish has five phonological vowels (/i, e, a, o, u/), Portuguese features two additional mid vowels, resulting in a total of seven phonological vowels (/i, e, ɛ, a, ɔ, o, u/).

Although the mid vowels of Portuguese may have their phonetic relationships established through accentuation in some cases (with ô and ê corresponding to [o] and [e], respectively, while ó and é correspond to [ɔ] and [ɛ]), in most instances, Portuguese speakers must identify the phoneme in a word without any clear indication. This means that the grapheme "o" can correspond to either the phonemes [o] or [ɔ], and the same applies to the grapheme "e," which can represent either [e] or [ɛ].

In this sense, this study aims to investigate whether the monitoring provided by reading can influence the production of mid vowels in Brazilian Portuguese, specifically in word pairs that display mid vowel alternations triggered by specific morphophonological processes, in the speech of Spanish-speaking learners of BP, even when explicit graphemic markers are absent.

The hypothesis of this study is that, by providing more monitoring through reading, participants will produce the mid vowels of Brazilian Portuguese with greater evidence of dissimilation between low and mid-high vowels, which can be observed through acoustic characteristics such as the Mahalanobis distance between the centroids of [o, e] and vowel dispersion. If this dissimilation pattern is identified, it would suggest that the participants likely followed the lexical route, recognizing the words and thus producing the vowels according to their lexical representations, or that they followed the phonological route. In the latter case, they may have consciously or unconsciously perceived the behavior of mid vowels in specific morphophonological processes that trigger alternate morphemes, adjusting their

production based on these variations.

Phonological Vowel Systems of Portuguese and Spanish

As previously mentioned, the vowel systems of Brazilian Portuguese and Spanish differ phonologically. Spanish features only two mid vowels — /e/ and /o/ — while Brazilian Portuguese distinguishes between mid-high vowels (/e/, /o/) and low-mid vowels (/ɛ/, /ɔ/).

Due to phonological differences between languages, the acquisition of the low-mid vowels in the Brazilian Portuguese vowel system has proven challenging for speakers of Spanish (Allegro, 2010; Alves; Santana, 2020; Buske, 2021; Machry da Silva, 2014, 2015; Pereyron; Alves, 2019; Santana, 2021; Santos Filho, 2019).

In Brazilian Portuguese, mid vowels can appear, among other cases, as alternate morphemes due to morphophonological processes such as verbal inflection, metaphonic plural formation, gender inflection, suffixation, and abbreviation or truncation (which are not differentiated for the purposes of this paper). It is worth noticing that morphophonologically conditioned alternations of mid vowels within morphemes provide a greater contrast between low-mid and mid-high vowels.

Morpheme Alternants

The morphophonological processes discussed here — verbal inflection, metaphonic plural formation, gender inflection, suffixation, and abbreviation/truncation — are responsible for triggering mid vowel alternations within morphemes in Brazilian Portuguese.

In cases driven by verbal inflection, a consistent pattern emerges: third person singular verb forms exhibit low-mid vowels, while first person singular forms exchibit mid-high vowels. This alternation affects both front and back mid vowels. For example, in the verb *esquecer* ("to forget"), the third person singular form *esquece* is esqu/ɛ/ce, while the first person singular *esqueço* is esqu/e/ço. Similarly, in *sofrer* ("to suffer"), there is the low-mid vowel /ɔ/ in *sofre* (third person singular) and the mid-high vowel /o/ in *sofro* (first person singular).

The second process mentioned, metaphonic plural formation, affects only the back mid vowels. In contexts of vowel alternation, singular forms contain the mid-high vowel /o/, while plural forms show the low-mid vowel /ɔ/. For instance, the singular form *novo* ('new') contains the mid-high vowel /o/, and its plural form contains the low-mid vowel /ɔ/ (i.e., n/ɔ/vos).

In alternations triggered by gender inflection, masculine forms typically exhibit mid-high vowels, while their feminine counterparts present low-mid vowels. For instance, the masculine nouns *sogro* ('father-in-law') and *esse* ('this', referring to a masculine noun) are phonologically transcribed as s/o/gro and /e/sse. In contrast, their corresponding feminine forms *sogra* ("mother-in-law") and *essa* ("this", referring to a feminine noun), respectively, contain low-mid vowels, being phonologically transcribed as s/ɔ/gra and /ɛ/ssa.

In cases involving suffixation, alternations between mid vowels occur such that low-mid vowels are found before suffixation, and mid-high vowels appear after the addition of a suffix. For instance, in the pair *belo* – *beleza* ("beautiful" – "beauty"), *belo* contains a low-mid vowel (b/ɛ/lo), whereas *beleza*, with the suffix -eza, contains an mid-high vowel (b/e/leza). A similar pattern is found with back vowels, as in *pobre* – *pobreza* ("poor" – "poverty"), realized as p/ɔ/bre and p/o/breza, respectively.

Finally, in cases of abbreviation/truncation, non-abbreviated forms typically contain mid-high vowels, while abbreviated forms exhibit low-mid vowels. For example, *cerveja* ("beer") and *fotografia* ("photograph") are transcribed as c/e/rveja and f/o/tografia, respectively, while their abbreviated forms *ceva* and *foto* are realized with low-mid vowels (c/ɛ/va and f/ɔ/to).

Methods

The subjects of this study were ten Spanish-speaking adults who have moved to Porto Alegre/RS, Brazil, between 2017 and 2024. The female subgroup (n = 5) had a mean age of 52.4 years

(SD ≈ 10.71), while the male subgroup (n = 5) had a mean age of 45.0 years (SD ≈ 14.32). The overall mean age of the participants was 48.7 years (SD ≈ 13.18).

This study was approved by the Research Ethics Committee under protocol number CAAE 77621424.4.0000.5336 on March 2, 2024. Furthermore, all participants provided written informed consent prior to their participation.

Data collection was carried out through one--on-one interviews lasting approximately 45 minutes. All participants completed a social and linguistic background form (see Da Ros, 2025), providing information such as their age and length of residence in Brazil.

Participants completed two tasks: a card game and the reading of words in the carrier sentence *Digo ____ com cuidado* ("I say _____ carefully"). Both tasks involved the same target words: 20 pairs related to the morphophonological processes discussed (verbal inflection, metaphonic plural formation, gender inflection, suffixation, and abbreviation/truncation). Four pairs were selected for each process, with two involving front mid vowels and two involving back mid vowels. Since metaphonic plural formation affects only the back vowels, to maintain data parallelism, four pairs involving back mid vowel alternations were selected from this process.

In total, the stimuli comprised 40 target words containing mid vowels selected based on the morphophonological processes, along with 14 distractor words designed to map the participants' phonetic space across the seven phonological vowels of Brazilian Portuguese. Specifically, two distractor words were included for each vowel. The inclusion of the peripheral vowels /i/, /a/, and /u/ is particularly relevant, as these vowels serve as anchor points for analyzing the relative positioning of other vowels, as discussed in Baranowski (2013, p. 4).

According to Labov (1972), tasks with a higher degree of control — such as the reading of word lists embedded in carrier sentences, where reading is the primary activity — foster more careful and monitored speech production along a continuum of attention to speech. In contrast, card game tasks, although they also involve instances of reading, do not center on pronunciation monitoring. Instead, the focus is on task, which results in low levels of monitoring compared to list-reading tasks. Even when reading is required during the game — for example, when verbs must be read in their infinitive forms for subsequent conjugation, as detailed below — the primary cognitive load remains directed toward gameplay rather than the careful articulation of words.

Tasks

Word selection was carried out prior to the development of the data collection instruments. Given the frequency variations that can occur depending on the phonetic context of the target vowel in words, as well as the implications of these variations for acoustic analysis, the selection of target words considered not only the triggers of the morphophonological processes described, but also the influence of the phonological context on the formative values of vowels. This consideration is informed by the works of Baranowski (2013), Brown (1990), Labov (1994), Lima (1991), Ribeiro (2017), and West (1999).

Based on the acoustic patterns considered, clusters were avoided due to their effects on F1 and F2; approximants without codas, for their influence on F2; nasal consonants in the surrounding context, for their impact on vowel quality; alveolar tap, which affects F1 and F2, and *the realization of /R/,* which may be realized as a trill by participants in this study. Given the restriction that target word selection was limited to cases involving morpheme alternants within the morphophonological processes under investigation, it was necessary to assess the available acoustic contexts to determine which non-ideal phonological environments would least compromise vowel quality.

The word list consisted of 54 items — 40 target words and 14 distractor words. In the card game, participants were challenged to fill in the blanks within sentences. The number of characters in the target word was indicated by the length of

the blank. In addition to the sentence context, participants could also rely on visual cues. All cards were created using the Canva[2] platform, and the images were generated through artificial intelligence using specific prompts.

The data collection was conducted in private rooms of the Brother José Otão Library at the Pontifical Catholic University of Rio Grande do Sul (PUCRS), Brazil, using a Zoom H4N Pro recorder to capture the participants' speech production.

Participants were instructed to read each sentence and produce out loud, twice, their hypotheses regarding the word that would complete the blank. The correct answer was concealed beneath a black stripe at the bottom of each card and was revealed upon a correct guess. All target words were selected from among the high-frequency items of the Portuguese lexicon, as identified in the LexPorBr[3] and AC/DC Project[4] corpora.

Figure 1 illustrates the card game using the distractor word *suco* ("juice") in the sentence *Este é um copo de _ _ _ _ de laranja* (equivalent to "This is a glass of orange _ _ _ _ _"). Participants completed a brief pilot session prior to the official data collection.

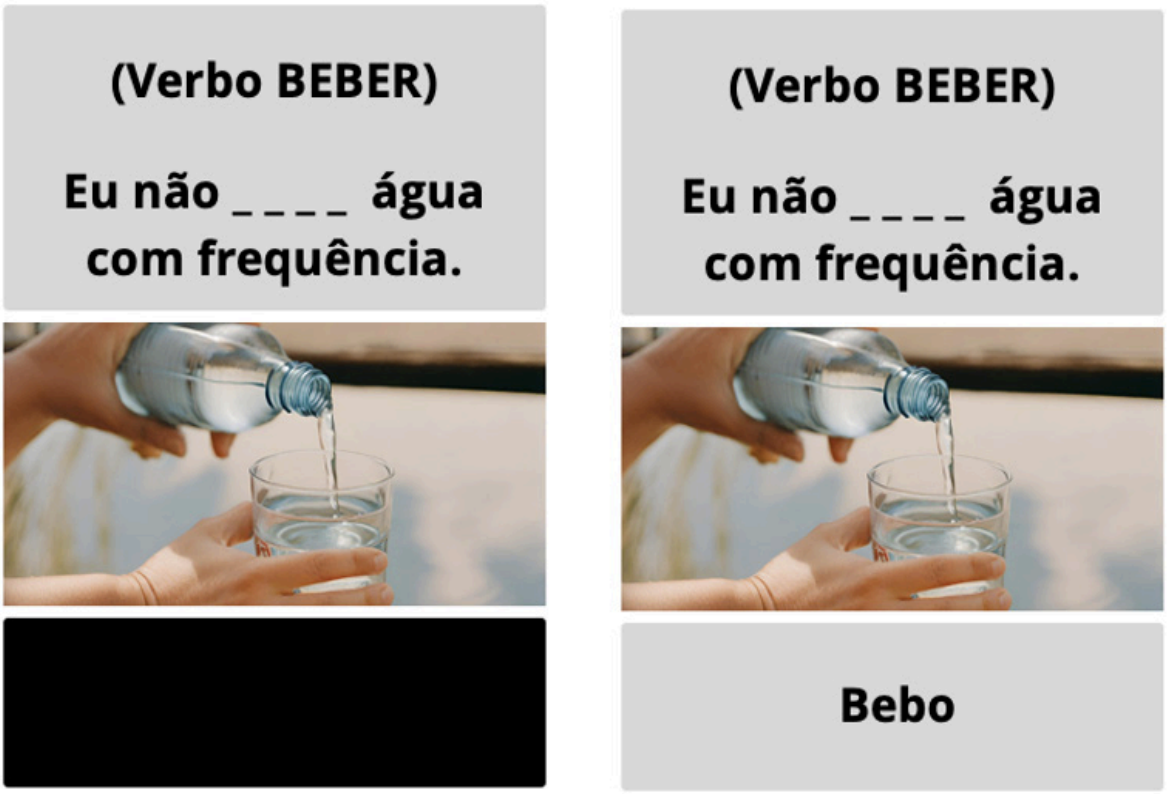
Figure 1 — Example of a card used in the game, featuring the distractor word *suco* ("juice")

Source: Da Ros (2025, p. 101).

All target words were presented to participants following this card format, except for those involving verbal inflection. In such cases, the infinitive form of the verb was displayed above the sentence containing the blank, as illustrated in Figure 2 below, with the verb *beber* ("to drink"), in the sentence *Eu não _ _ _ _* água *com frequência* (equivalent to "I don't _ _ _ _ _ water frequently").

[2] Available on http://www.canva.com/
[3] Available on https://www.lexicodoportugues.com/index.php/
[4] Available on https://www.linguateca.pt/acesso/corpus.php?corpus=CBRAS

Figure 2 — Example of a card designed for verbal inflection, displaying the infinitive form *beber* ("to drink") above the sentence



Source: Da Ros (2025, p. 102).

For the following task, which consisted of reading the target words in a carrier sentence, good visibility was ensured by using a neutral font (Aptos Display, similar to Times New Roman but with fewer embellishments), appropriate for the screen size to avoid being either too large or too small (size 60), in black on a white background, as shown in Figure 3 below.

Figure 3 — Example of target word in a carrier sentence in the reading instrument

Digo poço com cuidado.

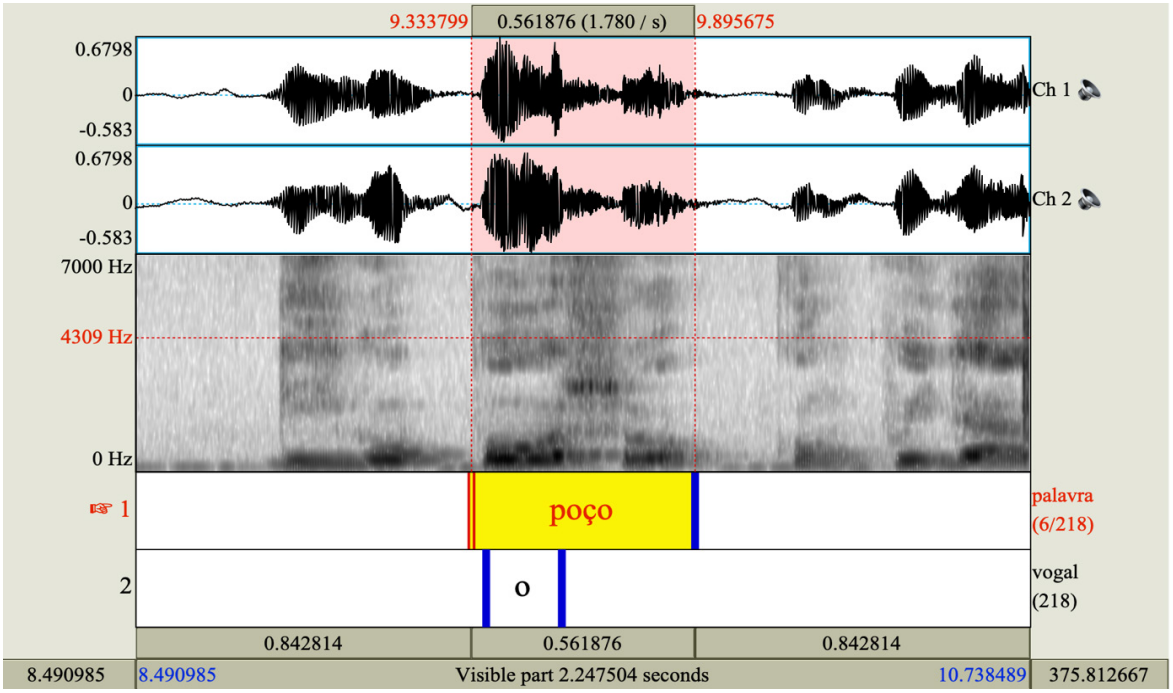
Source: Da Ros (2025, p. 103).

A total of 54 target words, each produced twice by each of the ten participants, resulted in 2,160 tokens for analysis.

Acoustic and Statistical Approaches

The acoustic analysis was conducted using version 6.1.26 of the Praat software (Boersma; Weenink, 2012), with the default configuration of five formants in a frequency range up to 5500 Hz for women and 5000 Hz for men. The words and target vowels from the .wav audio files were segmented and identified in the word and vowel tiers. The target vowels were segmented based on the start and end of the periodic voice signal curve with considerable amplitude and regularity, with the markings made at the point closest to the zero line. Figure 4 illustrates the segmentation of the target words and mid vowels using *Praat Software*.

Figure 4 — Illustration of the word and vowel segmentation performed using Praat software



Source: Da Ros (2025, p. 106).

Formant frequency values (F1 and F2, in Hertz) were extracted from the segmented intervals using the *CreateTable5600.praat* and *AddFormantes.praat* scripts. The automatically generated table was manually reviewed to identify and correct any outlier values. To minimize potential measurement errors inherent to the exclusive use of Linear Predictive Coding (LPC), the data were also cross-checked using a Fast Fourier Transform (FFT).

Given the acoustic differences between male and female speech, formant values were normalized following Lobanov's (1971) method. This normalization process was carried out through the *VisibleVowels* platform (Heeringa; Van de Velde, 2018), which plots productions and normalizes data upon overlap.

Vowel distance measures were calculated using the Mahalanobis Distance (Mahalanobis, 1936), which computes the centroids of vowel categories and measures the distance of individual productions from these centroids. Specifically, the distances calculated were between the mid vowels /e, ɛ, ɔ, o/ and the centroids of the mid-high vowels /e/ and /o/: that is, the distances between /e/ and /ɛ/ to the /e/ centroid, and between /o/ and /ɔ/ to the /o/ centroid. Less distance between the mid-high vowels and their respective centroids, such as greater distance between the low-mid vowels and the centroids of /e, o/ would indicate better dissimilation of the phonological categories related to the mid vowels of Brazilian Portuguese.

To assess vowel dispersion, the full production dataset was filtered by participant and task. For each resulting subset, 95% confidence ellipses were generated for each vowel. The ellipses were constructed by manually adjusting the data through the calculation of a custom covariance matrix for each vowel category. This matrix was then used to compute the ellipse points, yielding confidence ellipses equivalent to those produced by the *VisibleVowels* platform (Heeringa; Van de Velde, 2018).

Subsequently, using the RStudio interface (RStudio Team, 2021), version 2024.09.0+375, each ellipse was converted into a dataframe based on formant values, and the area of each ellipse was calculated. In this study, inter-vowel dispersion is operationalized as the area of the vowel

production ellipses, with larger areas indicating greater dispersion. Ellipse areas were computed using the standard mathematical formula ($\pi \times a \times b$), where *a* and *b* correspond to the semi-axes of the ellipse.

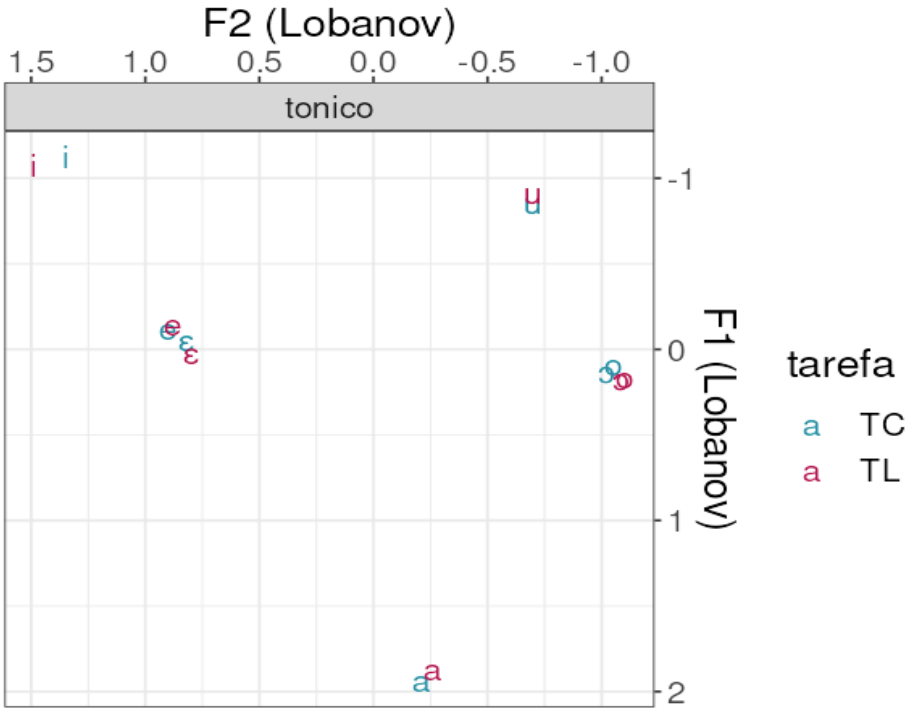
In addition to visualizing mean distances and dispersion through plots, a linear regression analysis was conducted using the RStudio platform (RStudio Team, 2021) to examine the statistical significance of the task effect on vowel productions.

Results

To conduct the statistical analysis, two plots were created based on the variable *type of task*. The first plot (Figure 5) displays the mean vowel values in stressed syllables, while the second plot (Figure 6) presents the mean values in unstressed syllables. These data were separated into distinct plots due to the acoustic differences in vowel production based on syllable stress. Among the target words selected for the tasks, most vowels occur in stressed syllables. However, in cases involving abbreviations/truncation or suffixation, one of the paired words contains the target vowel in an unstressed syllable. For example, in the pair *cerveja – ceva* ("beer" and its abbreviation in Brazilian Portuguese), the target vowel in the full form occurs in an unstressed syllable. Similarly, in *belo – beleza* ("beautiful" and "beauty"), the target vowel in the derived form occurs in an unstressed syllable.

Figure 5 illustrates the average formant values of the target vowels when produced in stressed syllables, across the different task types. The vowels in blue correspond to the cards task (TC), while the vowels in pink correspond to the list task (TL).

Figure 5 — Mean values of stressed vowels in the cards (TC) and list (TL) tasks



Source: Da Ros (2025, p. 115).

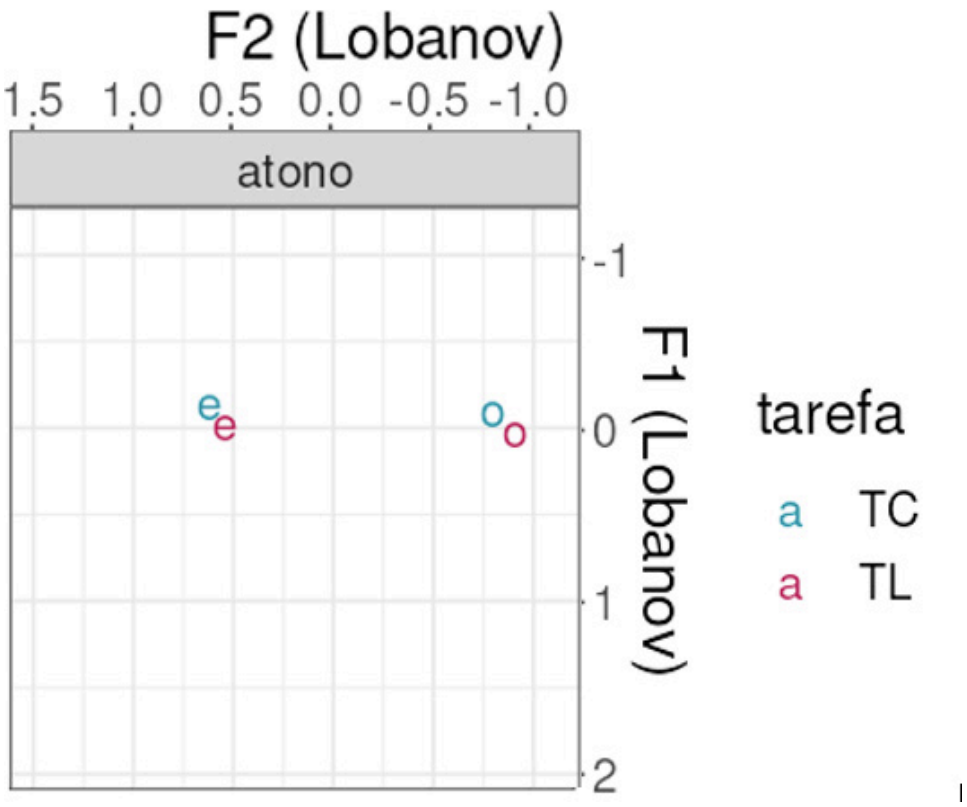
According to Figure 5, the production of the vowel /u/ exhibits a tendency toward centralization when compared to that of the mid-high back vowel /o/. On average, the low vowel /a/ is produced at a higher and slightly more retracted position in the list task than in the cards task.

It can be observed that the front mid vowels exhibited greater distance from one another in

the list task; however, this was not the case for the back vowels, which showed larger distances between each other in the cards task.

As mentioned, in Brazilian Portuguese, only the mid-high vowels /e/ and /o/ occur in pretonic position. Among the morphophonological processes examined in this study, pretonic mid vowels appear only in cases of abbreviation/truncation (e.g., *c/e/rveja – c/ɛ/va*) and suffixal derivation (e.g., *b/ɛ/lo – b/e/leza*). The figure below (Figure 6) was designed to display the mean formant values of participants' productions of pretonic vowels across both tasks (TC and TL). The vowels in blue correspond to the cards task (TC), while the vowels in pink correspond to the list task (TL).

Figure 6 — Mean values of the pretonic vowels produced in the cards task (TC) and the list task (TL)



Source: Da Ros (2025, p. 116).

Figure 6 illustrates the tendency toward anteriority and height of the mid-high vowels /e, o/ in the card task. Further information would require values such as those from the centroid. In light of this, Table 1 below presents the calculated and rounded Mahalanobis distance values between the mid-front vowels /e, ɛ/ and the centroid of /e/, as well as between the mid-back vowels /o, ɔ/ and the centroid of /o/ in both the card task (TC) and the list task (TL).

TABLE 1 — Rounded Mahalanobis distance values between mid vowels and the centroids of /e, o/ in the card (TC) and in the list (TL) tasks

/e/		/ɛ/		/ɔ/		/o/	
TC	**TL**	**TC**	**TL**	**TC**	**TL**	**TC**	**TL**
2,0	1,98	1,98	2,03	1,61	1,74	2,10	1,88

Source: Da Ros (2025, p. 117).

Based on the data presented in Table 1, it is evident that the mid-high vowels /e, o/ were closer to their respective centroids in the list task, which allows for greater monitoring. The mid-high

front vowel /e/ exhibited a Mahalanobis distance of 2.0 in the card task (TC) and 1.98 in the list task (TL), while the mid-high back vowel /o/ showed a distance of 2.10 in the TC and 1.88 in the TL.

In contrast, the low-mid vowels /ɛ, ɔ/ were more distanced from the centroids of /e, o/ in the list task. The low-mid front vowel /ɛ/ displayed a distance of 2.0 in the TC and 1.98 in the TL, whereas the low-mid back vowel /ɔ/ exhibited a distance of 1.61 in the TC and 1.74 in the TL.

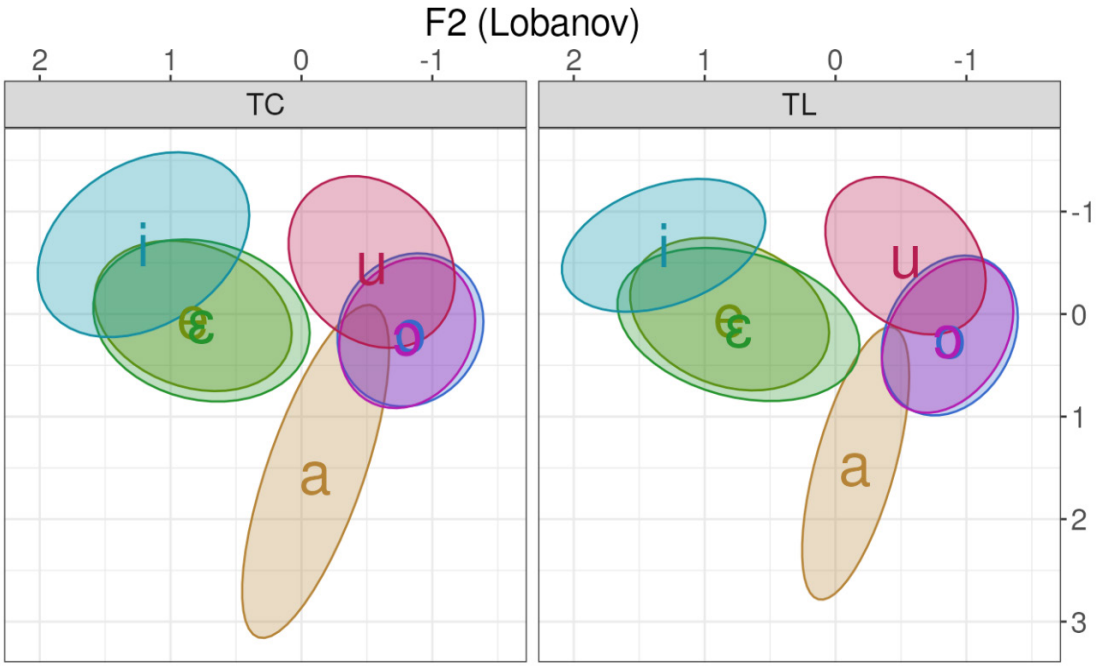
The greater distance between the posterior vowels and the centroid of /o/ in the TL supports the hypothesis that tasks involving higher levels of monitoring lead to greater phonological category dissimilation.

In addition to the Mahalanobis distance between mid vowels and their centroids, another response variable relevant to the objectives of this study is vowel dispersion, defined here as intravocalic dispersion — that is, the elliptical area representing the spread of productions for each vowel individually.

The working hypothesis proposes that target vowels produced in tasks that afford greater articulatory monitoring will be confined to smaller dispersion areas, whereas tasks involving reduced monitoring will result in larger dispersion ellipses.

Figure 7 illustrates the dispersion ellipses of stressed vowels in both the card task (TC) and the list task (TL).

Figure 7 — Dispersion of stressed vowels produced in the card task (TC) and in the list task (TL)

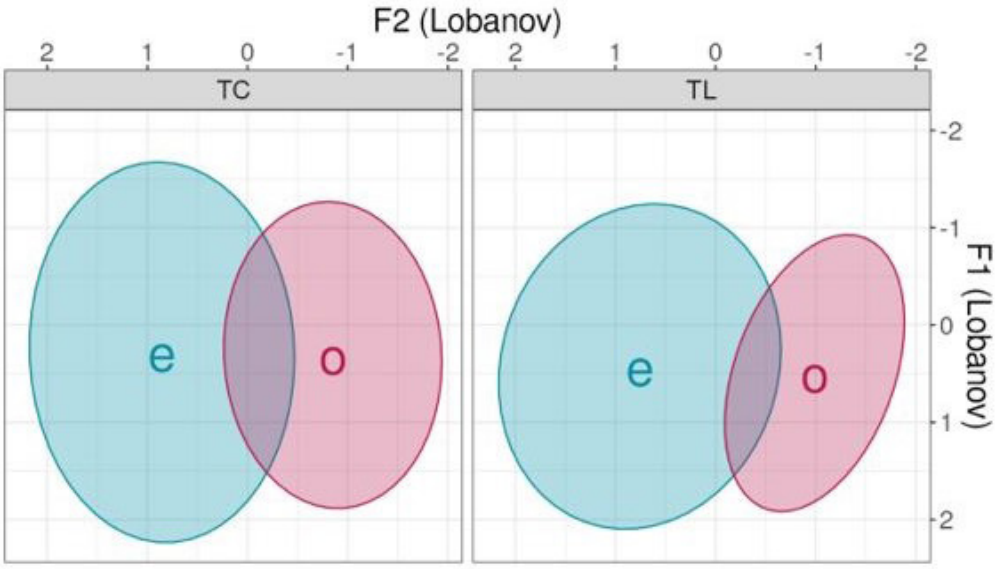


Source: Da Ros (2025, p. 118).

Figure 7 presents vowel dispersion plots for both experimental tasks. The peripheral vowels /i, a, u/ exhibited greater dispersion in the card task (TC) compared to the list task (TL), suggesting a possible effect of reduced articulatory monitoring. Additionally, for the front mid vowels, /ɛ/ consistently showed greater intravocalic dispersion than /e/, a pattern that was more pronounced in the list task. As for the back mid vowels, there was substantial overlap between /o/ and /ɔ/ in both tasks; however, a slightly greater dispersion was observed for the mid-high vowel /o/ relative to the low-mid vowel /ɔ/.

Figure 8 displays the dispersion plots of unstressed vowels in the card (TC) and list (TL) tasks.

Figure 8 — Dispersion of unstressed vowels in the card task (TC) and the list task (TL)



Source: Da Ros (2025, p. 119).

As shown in Figure 8, the mid-high posterior vowel /o/ in a pretonic context exhibited less variability in the list task (LT). In contrast, the mid-high front vowel /e/ in the same context displayed a different pattern: the elliptical distribution was less vertically extended in the list task compared to the card task, but more extended along the horizontal axis. However, it is challenging to determine in which task the dispersion of /e/ is greater.

In order to assess the area values of the ellipses for measuring intra-vocalic dispersion, Table 2 has been developed, as presented below.

Table 2 — Dispersion values rounded by vowel and stress type in the card task (CT) and list task (LT).

vowel	stress type	TC	TL
/e/	stressed	11,57	12,08
/ɛ/	stressed	11,63	10,46
/ɔ/	stressed	9,79	10,86
/o/	stressed	9,89	11,59
/e/	unstressed	10,50	12,41
/o/	unstressed	10,02	11,53

Source: Adapted from Da Ros (2025, p. 120).

Table 2 displays the (rounded) dispersion values for each vowel, categorized by stress type (stressed vs. unstressed), across both the card task (TC) and the list task (TL). In the TC, dispersion values ranged from 9.79 for /ɔ/ to 11,63 for /ɛ/. In contrast, in the TL, values ranged from 10,46 for /ɛ/ to 12,41 for unstressed /e/.

Overall, most vowels exhibited greater dispersion in the TL compared to the TC. Specifically, this pattern was observed for stressed /e/ (from 11,57 in TC to 12,08 in TL), /ɔ/ (from 9,79 to 10,86), stressed /o/ (from 9,89 to 11,59), unstressed /e/ (from 10,50 to 12,41), and unstressed /o/ (from 10.02 to 11,53). The only exception to this trend was /ɛ/, which showed reduced dispersion in the TL (10,46), relative to the TC (11,63). The greater vowel

dispersion observed in the list task contradicts the assumption that increased monitoring would result in less dispersed vowel productions.

Multiple linear mixed-effects regression models were developed to assess whether the variation in Mahalanobis distance and vowel dispersion was statistically significant as a function of task type (card vs. list). Separate models were constructed for each vowel, given that differences in Mahalanobis distance required distinct inferential approaches for mid-high and low-mid vowels.

The variability in the dispersion of the mid-high front vowel /e/ as a function of task type was statistically significant ($\beta \approx 1.07$, $p < .001$), with greater dispersion observed in the list task. This result may be related to the increased monitoring encouraged by this task, which can lead speakers to produce more carefully articulated vowels. Such hyperarticulated productions tend to be more extreme in the vowel space, and while this may increase the distance between vowel categories, it can also lead to more variation within a category due to less automatic and more effortful articulation.

A similar pattern was found for the mid-high back vowel /o/, which also showed significantly higher dispersion in the list task ($\beta \approx 1.64$, $p < .001$). This suggests that mid-high vowels, in particular, may be more sensitive to task-induced changes in speech monitoring. Since both /e/ and /o/ have close counterparts in the speakers' L1 (Spanish), increased attention to articulation in L2 speech may lead to variability in how these vowels are realized, possibly reflecting attempts to adjust their productions to fit the L2 phonological space more precisely.

In contrast, the low-mid front vowel /ɛ/ showed reduced dispersion in the list task compared to the card task ($\beta \approx -1.18$), supporting the initial expectation that increased monitoring would result in less variable vowel productions. As /ɛ/ is not present in Spanish, speakers may rely on more consistent, learned strategies when producing this vowel in Portuguese, especially under conditions that require more careful speech.

Finally, the low-mid back vowel /ɔ/ showed a significant increase in dispersion in the list task ($\beta \approx 1.07$, $p < .001$), again consistent with the pattern observed for /e/ and /o/. As with these vowels, the increased dispersion may be due to hyperarticulation in a more monitored speech context. Given that /ɔ/ is also absent from the Spanish vowel inventory, speakers may show more variability when attempting to produce this unfamiliar vowel under greater cognitive control.

Conclusion

This study investigated the effects of task type on vowel dispersion and Mahalanobis distance in the production of Brazilian Portuguese mid vowels by Spanish-speaking learners. The results revealed that, contrary to initial expectations, the list task — which involves greater monitoring — often led to *greater* vowel dispersion, particularly for the mid-high vowels /e/ and /o/ and the low-mid back vowel /ɔ/. These findings suggest that increased cognitive control may trigger hyperarticulated productions, resulting in expanded vowel spaces and higher intra-category variability. In contrast, the low-mid front vowel /ɛ/ showed reduced dispersion in the more monitored task, aligning with predictions that careful speech would lead to more consistent productions.

These findings highlight the need to consider both L1–L2 phonological relationships and task characteristics when analyzing speech production in a second language. The observed variability suggests that tasks requiring greater monitoring may not always enhance phonetic precision, particularly when learners are producing vowels that do not exist in their native language phonological inventory. This points to the complex role that language-specific vowel systems play in the regulation of second language speech production.

Given these insights, future studies could further explore how different types of tasks or levels of monitoring impact the accuracy of vowel production, particularly for sounds that do not directly correspond between languages. Such investigations may inform teaching practices, particularly in L2 pronunciation training, where understanding the interaction between cogni-

tive load and phonological transfer could help optimize learning strategies.

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