

THE STATUS OF UNSTRESSED LAX-MID VOWELS IN NORTHERN DIALECT OF BRAZILIAN PORTUGUESE^{1,2}

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ABSTRACT

This study experimentally analyses the claim that northern dialects of Brazilian Portuguese show a pattern of reduction via laxing. With an experiment of sentence reading that resulted in a corpus of 4800 tokens, the analysis showed that it is possible to predict the surfacing of tense-mid vowels. In the data, they either result from [+ATR] harmony or coarticulation. Lax-mid vowels, however, cannot be fully predicted as the result of harmony. It is also shown that the quality of unstressed lax-mid vowels is not different from their stressed counterpart, a further evidence that reduction via laxing in fact, exists.

Keywords: Neutralization; Lax-mid vowels; ATR. Brazilian Portuguese; Northern dialects.

RESUMO

Este estudo analisa experimentalmente a hipótese de que dialetos nordestinos do Português Brasileiro apresentam um padrão de redução que favorece a produção de médias-baixas. Com um experimento de leitura de palavras em frase veículo que resultou em um corpus de 4800 produções, a análise mostra que é possível prever a emergência de vogais médias-altas. Nos dados analisados,

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essas vogais são resultado de harmonia de [+ATR] ou coarticulação. Médias-baixas, entretanto, não se restringem a contextos de harmonia. Também se mostra que a qualidade das vogais médias-baixas quando na posição pretônica, não difere de quanto em posição tônica, outra evidência de que o padrão de neutralização favorecendo médias-baixas, de fato, existe.

Palavras-chave. Neutralização; Médias-baixas; ATR; Português Brasileiro; Dialetos nordestinos.

1. Introduction

This paper reports the results of an experimental study that targeted a long-standing problem in the phonology of Brazilian Portuguese, the claim that reduction via laxing exists in northern dialects. Brazilian Portuguese (henceforth, BP) has a vowel inventory of seven vowels in stressed syllables /a, ε, e, i, o, u/ (see (1))⁴. The contrast between lax /ε, o/ and tense mid-vowels /e, o/ is lost in unstressed contexts and, in southern dialects (SD), mid-vowel neutralization favors tense-mid vowels (see (2)) (Câmara Jr., 1970; Wetzels, 1992).

In general, vowel reduction (or vowel neutralization) is understood as the loss of an existing contrast in a specific context, as was defined as such by Trubetzkoy (1939). The contrast usually exists in stressed syllable and is neutralized in some unstressed syllable.

In optimality theoretical terms (Prince & Smolensky, 1993), it has been proposed that neutralization is the result of contrast enhancement requirement or as prominence alignment enforcement (cf. Flemming, 2004; Crosswhite, 2004). The pattern of reduction observed in SD (reduction via tensing) is well-attested and observed in other Romance languages such as Italian and Spanish. It is also predicted by the majority of theoretical accounts that have been proposed for vowel reduction.

However, lax-mid vowels are licensed outside stress position (pretonically and non-final posttonically) in northern dialects (ND) (see (3)), and previous sociolinguistic studies have claimed that reduction via laxing is the neutralization strategy used in those dialects, given that not always vowel harmony triggers their production (Silva, 2009; Bisol & Veloso, 2016).

⁴ Examples in this paper are transcribed phonetically. Stress is marked with an acute accent over the vowel and an underline indicates the relevant context being discussed.

| | | | | | | | | |
|-----|------|-------------|-----|--------|-------------|-----|---------|------------------|
| (1) | síku | ‘foort bug’ | (2) | bélu | ‘beautiful’ | (3) | peládu | ‘naked’ |
| | séku | ‘dry’ | | beléze | ‘beauty’ | | póláh | ‘polar’ |
| | séku | ‘I dry’ | | kóle | ‘glue’ | | pehfúmi | ‘perfume’ |
| | sáku | ‘bag’ | | koládu | ‘glued’ | | ólínde | ‘brazilian city’ |
| | sóku | ‘I punch’ | | | | | nádege | ‘buttock’ |
| | sóku | ‘punch’ | | | | | abóbore | ‘pumpkin’ |
| | súku | ‘juice’ | | | | | | |

Reduction via laxing has also been claimed to exist in Slovene. However, Lehiste (1961) argued that this is not the correct classification for the pattern that exists in that language. An experimental study was carried out and the results showed that stressed and unstressed lax-mid vowels did not have the same quality. That is, the reduced forms were not “true” lax-mid vowels, they were produced with a quality that was in-between lax and tense-mid and, therefore, should be better viewed as archiphonemes that are not specified for the feature [ATR].

The main aim of the present study is to verify experimentally the existence of reduction via laxing in ND, as claimed by previous sociolinguistic studies. The experiment, carried out with 20 native speakers of ND, resulted in a phonologically balanced corpus of 4800 tokens. The results show that reduction via laxing is, in fact, the neutralization strategy speakers of this dialect make use of.

This paper is organized as follows: in section 2, I present some relevant facts regarding mid-vowel alternation in BP as well as a general overview of the observations made by previous studies; in section 3, I present the methodology that was used in the experiment; in section 4, the results are detailed and analyzed and I argue in favor of reduction via laxing; section 5 summarizes the main findings of this study and points out remaining questions and future research directions.

2. Unstressed mid-vowels in northern dialects

As the distinction between /e, o/ and /ɛ, ɔ/ is lost in unstressed syllables, mid-vowel alternation is highly productive in pretonic syllables. However, this alternation is more frequent in northern than in southern dialects. In SD, [ɛ, ɔ] may occur in unstressed syllables, however, in much more restricted cases if compared to ND, and this might also depend on the variety of SD⁵.

⁵ Recent experimental work has argued that unstressed [ɛ, ɔ] result from [-ATR] harmony in certain varieties of SD, but this kind of harmony is not observed in other varieties. (cf. Abaurre & Sândalo, 2009; Kenstowicz

This difference has been used as a property to distinguish northern from southern dialects in seminal work by Nascentes (1953). Therefore, I assume in this paper that the pattern under discussion, as well as the results of the experiment that was carried out, show the tendency of northern dialects in general, and not of only a particular variety.

It is also assumed in this paper that [ATR] is the feature that distinguishes [ɛ, ɔ] from [e, o]. Therefore, [ɛ, ɔ] will be treated as lax and [e, o] as tense mid vowels. It is a long-stand debate in the literature what feature specification should be adopted in this case, i.e., if these vowels are specified for [ATR] or [open] features. However, the pattern under discussion does not seem to provide any further evidence of what the answer might be. Given that the line of work that this analysis builds on has made use of [ATR] as the feature that differentiates the vowels, this specification will also be adopted here.

The majority of work that has analyzed vowel alternation in pretonic syllables argues that it results from vowel harmony. Height harmony was first analyzed by Bisol (1981) for SD and was defined as a variable regressive assimilatory rule that targeted the height of the pretonic vowel (eg. pepíno ~ pipíno ‘cucumber’). Regarding ND, Barbosa da Silva (1988) was one of the first authors that attempted to provide a formal account for mid-vowel alternation in pretonic syllables in ND (Salvador variety, to be more precise). Interviews with 24 speakers resulted in a corpus of around 3000 tokens. The general distribution showed more cases of lax-mid vowels [ɛ, ɔ] in pretonic syllables than of tense-mid [e, o] or high vowels [i, u]. In order to account for mid vowel alternation, Barbosa da Silva (1988) proposed four categorical SPE-style rules. The rules capture the following tendency observed in the data: (i) front-mid vowel in absolute word-initial position was produced as [i] when followed by an alveolar fricative [s] (eg. iskóle ‘school’, iskúro ‘dark’); (ii) when in verbs and nominalized forms, the front-mid vowel was produced as [e] if followed by a palatal fricative (eg. plãnezáh ‘to plan’; fejáh ‘to close’; fejadúre ‘door lock’); (iii) [e, o] were produced pretonically when followed by stressed tense-mid vowels (eg. schvéza ‘beer’, koxéju ‘mail’) and (iv) whenever those more specific rules did not apply, lax-mid vowels were produced, i.e., a type of elsewhere condition.

Even though the formalization lacks an explanatory character, the rules proposed by Barbosa da Silva (1988) serve an important descriptive role. First, they show that adjacent consonants, especially coronal fricatives, are a relevant factor in determining the form of the pretonic vowel. Secondly, they show that tense-mid vowels may be predicted. Finally, and most importantly, even though not stated

& Sândalo, 2016; Madruga, 2017).

in these terms by the author, the way the rules are proposed indicate the view that lax-mid vowels are the result of neutralization, as they are the more general forms, the elsewhere case, and tense-mid vowels are restricted to specific contexts, the ones that are motivated and predictable.

It is important to highlight that Barbolsa da Silva's (1988) description has an important phonological implication: BP has not only height harmony but also [ATR] harmony. Assuming the feature specification for BP vowels as presented in (4), if pretonic tense-mid vowels are conditioned by subsequent tense-mid or high vowels, this must be the result of [+ATR] harmony⁶.

(4) Feature specification for BP vowels

| | i, u | e, o | ɛ, ɔ | a |
|--------|------|------|------|---|
| [low] | - | - | - | + |
| [high] | + | - | - | - |
| [ATR] | + | + | - | - |

If the opposite was true, that lax-mid vowels are the result of [-ATR] harmony, one would expect [ɛ, ɔ] to be produced exclusively in harmonic contexts, which according to Barbosa da Silva's (1988) results does not occur. The studies that followed and targeted mid-vowel alternation in ND made use of similar methodologies and, overall, found similar results. Pereira (1997), Araújo (2007) and Silva (2009) carried out sociolinguistics analyses with speakers of three different cities, João Pessoa, Fortaleza and Teresina, respectively, all of which are representative of ND. The general distribution of their results shows that lax-mid vowels are produced more frequently in pretonic syllables than their tense and high counterparts⁷. Their results have also indicated correlation between the height of the pretonic vowel and adjacent consonants. A similar observation throughout the studies is that tense-mid vowels are always predicted when followed by other tense-mid vowels and even though lax-mid vowels are also expected to be produced if followed by other lax-mid vowels, they are not restricted to these contexts.

6 A full account regarding [ATR] harmony in BP is developed by Madruga (2017).

7 João Pessoa: [ɛ]- 46,3%, [e]- 20,3%, [i]- 31,7%; [ɔ]-44,5%, [o]- 21,7%, [u] 34% (Pereira, 1997)
Fortaleza: [ɛ] 58%, [e] 32%, [i] 10%; [ɔ]64%, [o] 24%, [u] 12% (Araújo, 2007)
Teresina: [ɛ] 65%, [e] 21%, [i] 14%; [ɔ] 52%, [o] 16%, [u] 32% (Silva, 2009)

Even though these studies were developed within a sociolinguistics framework, the analyses indicate that extralinguistic factors such as gender or level of education are not the factors that seem to condition these alternations. That is, extra-linguistic factors, by themselves, cannot account for the pattern under discussion, which indicate that the character of the phenomenon is purely phonological.

This overview seems to clearly indicate that reduction via laxing is the neutralization strategy existent in ND. However, this hypothesis is not confirmed in another unstressed context that also licenses lax-mid vowels: non-final postonic syllables (σσσ).

In an experimental study that analyzed mid-vowel alternation in non-final postonic syllables, Santana (2016, 2018) proposed that lax-mid vowels are predictable and are produced when followed by a low-vowel in word-final position (eg. *agríkōla* ‘agricultural’; *kámara* ‘camera’), i.e., lax-mid vowels are the result of harmony. Santana (2018) argues that the vowel subsystem non-final postonic context is /i, e, a, o, u/, or, in other words, that neutralization favors tense-mid vowels in non-final postonic syllables.

The difference observed in Santana’s (2016, 2018) studies regarding non-final postonic context and the ones that targeted pretonic syllables might either be due to prosodic reasons (reduction via laxing occurs pretonically, but not postonically), or to the methodology used by the studies (sociolinguistics interview vs. controlled experiment). Recall that the analysis targeting mid-vowel alternation in pretonic syllables all have a sociolinguistic character and, given the methodology that was adopted, the large number of tokens in the corpus not always correspond to a similar number of lexical types. That is, the corpora are not always phonologically balanced, and this might be what is causing the difference in the results found by these two types of studies.

Experimental studies have already shown that, for ND, lax-mid vowels are licensed in pretonic syllables (Kenstowicz & Sandalo, 2016; Madruga, 2017). These studies have also shown that when followed by another lax-mid or low vowel (i.e., when there is a context for potential [-ATR] harmony), unstressed lax-mid vowels have the same quality as stressed lax-mid vowels. What remains unanswered is if the quality of lax-mid vowel in pretonic context is any different from the quality of stressed tense-mid vowels when there is no context for potential [-ATR] harmony, i.e, when [ε, ɔ] are produced pretonically and followed by [i, u, e, o].

Based on what has been exposed, two questions are going to be addressed in this study: first, *are the results obtained with sociolinguistic studies also obtained with an experimental set?* Second, *is the quality of pretonic lax-mid vowels any different from the quality of stressed lax-mid vowels in contexts where [-ATR] harmony is not possible?* The answer of these two questions will serve as evidence to answer a more general and important question: *is there really reduction via laxing in northern dialects of Brazilian Portuguese?*

3. Methods and Experiment

The data was obtained with an experiment of sentence reading. 20 participants, 10 men and 10 women, produced 80 words in a carrier sentence. These 80 trisyllabic words with stress in the penultimate syllable (σσσ) were randomly repeated three times throughout the experiment, which resulted in a corpus of 4800 tokens.

Participants were born and raised in São Luís, capital of the State of Maranhão, located in the northeast area of the country, who had never been away from the city for longer than two years. Therefore, they were speakers of northern dialect of Brazilian Portuguese.

The words that composed the experiment were chosen in order to obtain a phonologically balanced corpus with respect to the controlled variables (see Table 1). Given our main hypothesis, that mid-vowel alternation is conditioned by harmony, the height of the stressed vowel was controlled.

The preceding and following contexts were also targeted. Preceding consonants were categorized with respect to the main place classes, except coronal fricatives that were categorized separately due to the consistent observations of previously mentioned studies that these consonants have an effect on mid vowel alternation (cf. Bisol 1981; Barbosa da Silva, 1988, Silva, 2009 xxx). Regarding following consonants, rather than the onset of the stressed syllable, this study targeted syllable weight, i.e., the coda of the pretonic syllable. Coronal fricatives and nasals were given specific categories due to the specific way they might be correlated to vowel height.

Table 1: Controlled variables

| Variable | Factors | Examples ⁸ |
|--------------------------------|---|---------------------------|
| Stressed vowel height | high | tEhnúɾɐ ‘tenderness’ |
| | high-mid | zElóʒɐ ‘careful’ |
| | low-mid | kOlégɐ ‘colleague’ |
| | low | sOládu ‘sole’ |
| Preceding consonant (onset) | labial | vOlántʃɪ ‘steering wheel’ |
| | dorsal | gOʃtóʒɐ ‘tasty’ |
| | coronal | nEhvóʒɐ ‘nervous’ |
| | none | Exádu ‘wrong’ |
| Syllable weight | light | mE.ló.zɐ ‘mellow’ |
| | heavy | sEh.ví.sɐ ‘service’ |
| | heavy by nasal | kÕm.plé.tɐ ‘complete’ |
| | heavy by coronal fricative ⁹ | tEʃ.tú.rɐ ‘texture’ |

The target vowels were manually segmented in PRAAT (Boersma & Weenink, 2015). During segmentation, the investigator labeled the target vowel following auditory information and the value of the first formant (F1) frequency. Two statistical tests were run, a chi-square, assuming the category assigned as the dependent variable, and an Analysis of Variance, assuming the value of F1 as dependent variable. As the results of both tests were similar, only the first one will be reported in this study, given that the results are easier to display and serve the purpose of this paper. When necessary, reference to nuances observed with the ANOVA will be made.

⁸ Pretonic vowels are transcribed with a capital E, O to show they are the dependent variable of the study and their height is what was being observed.

⁹ In this dialect, phonemic /s/ in coda position is categorically palatalized and produced as a palatoalveolar fricative when followed by alveolar stops /t, d/ (eg. meʃ.trá.du ‘masters degree’)

4. Results and Analysis

One of the main indications that there may be reduction via laxing in ND is the overall preference for lax-mid vowels in pretonic syllables, as attested by previous studies. However, this overall preference was not observed in the results obtained by this study at first. See on Table 2 that both back and front tense-mid vowels were the most frequent vowels overall (54,7% and 53,4%, respectively).

Table 2: Overall distribution

| Front vowel | | | Back vowel | | |
|----------------|----------------|---------------|------------------|------------------|---------------|
| [ɛ] | [e] | [i] | [ɔ] | [o] | [u] |
| 926 (38,6%) | 1.314 54,7% | 160 (6,7%) | 1.003 (41,8%) | 1.283 (53,4%) | 114 (4,8%) |
| 2.400 tokens | | | 2.400 tokens | | |
| Total: 4.800 | | | | | |

But there is a point of discrepancy in this distribution. In BP, nasal consonants in coda position categorically trigger nasalization and there are not nasal lax-mid vowels in the language *[ɛ̃, ɔ̃]. Therefore, in the corpus, every time there was a nasal consonant in coda position, lax-mid vowels were blocked from being produced because they were nasalized and produced as [ɛ̃, ɔ̃]. As this bias the overall distribution of mid vowels, conclusions regarding the frequency of mid-vowel must be drawn from a distribution that does not include contexts that trigger nasal assimilation. Table 3 shows that without nasal context, both back and front lax-mid vowels were produced more frequently in pretonic context (59,8% and 55%, respectively). However, one must note that even with the exclusion of nasal context from the distribution, tense-mid vowels were still frequently produced (41,7% for [e] and 39,1% for [o]). This shows, as expected, that other factors besides nasalization must be correlated with mid-vowel alternation in the pretonic context.

Table 3: Overall distribution (without nasals)

| Front vowel | | | | Back vowel | |
|--------------|----------------|--------------|----------------|----------------|-------------|
| [ɛ] | [e] | [i] | [ɔ] | [o] | [u] |
| 926 (55%) | 700 (41,7%) | 55 (3,3%) | 1.002 (62%) | 609 (37,5%) | 9 (0,5%) |
| 1.680 tokens | | | 1.620 tokens | | |
| Total: 3.300 | | | | | |

This study controlled three variables, namely, height of the stressed syllable, syllable weight and preceding context. Only the first two showed straightforward patterns that could phonologically indicate the conditioning for any of the vowel heights.

As previously mentioned, one of the main hypothesis of this study is that mid vowel alternation in pretonic syllables is conditioned by harmony. The correlation between the height of the pretonic vowel and the height of the stressed vowel was statistically attested, as shown on Table 4. See that front and back tense-mid vowels were significantly more produced when a tense-mid or high vowels were in stressed position. Similarly, lax-mid vowels were significantly more frequent when followed by stressed lax-mid vowel or low vowels.

Table 4: Pretonic height x stressed height

| Pretonic Stressed | [ɛ] | [e] | [i] | Pretonic Stressed | [ɔ] | [o] | [u] |
|--------------------|-------------|-------------|----------|-------------------|-------------|-------------|----------|
| high (480) | 173 (36%) | 306 (63,8%) | 1 (0,2%) | high (360) | 165 (45,8%) | 192 (53,3%) | 3 (0,9%) |
| tense-mid (420) | 120 (28,6%) | 300 (71,4%) | 0 (0%) | tense-mid (420) | 55 (13%) | 362 (86,2%) | 3 (0,8%) |
| lax-mid (480) | 458 (95,4%) | 22 (4,6%) | 0 (0%) | lax-mid (360) | 342 (95%) | 18 (5%) | 0 (0%) |
| low (300) | 175 (58,3%) | 71 (23,7%) | 54 (18%) | low (480) | 440 (91,7%) | 37 (7,7%) | 3 (0,6%) |
| Total: 3300 tokens | | | | | | | |
| p-value < 0.001 | | | | | | | |

Two main points follows from the results presented on Table 4. Firstly, high vowels do not seem to be conditioned by height harmony. Notice that, besides speaker's disfavor for this form (given the overall rate of production, much smaller than what was attested for the mid vowels), high vowels were not produced more frequently in harmony context, i.e., when followed by high vowels. Rather, the back high vowel was almost never produced and showed no real correlation to any vowel height, while the front high vowel was more frequently produced when followed by a low vowel /a/, but as

will be argued later in this section, the correlation does not come from the height of the vowel, but the following consonant (specifically, [ʃ] in coda position). This result corroborates the hypothesis that height harmony is no longer productive in BP.¹⁰

Secondly, based exclusively on the results presented above, it is not possible to determine if tense-mid vowels result from [+ATR] harmony or if lax-mid vowels are the ones that result from [-ATR] harmony. This is fundamental in order to define if neutralization favors a particular vowel (either lax or tense-mid) and, consequently, if there is really reduction via laxing in this dialect. In order to clarify this, it is important to look at the exceptional cases, that is, the cases that cannot be accounted for through [ATR] harmony.

Table 5 shows the number of cases of lax-mid vowels that were produced when there was a high or tense-mid vowel in stressed position and the number of cases of tense-mid vowels that were produced when followed by stressed lax or low vowels. As one can see, overall, there are more cases of disharmonic lax-mid vowels than cases of disharmonic tense-mid.

Table 5: Non-harmonic cases

| Pretonic Stressed | [ɛ] | [o] | Pretonic Stressed | [e] | [o] |
|-------------------|-----|-----|-------------------|-----|-----|
| high | 173 | 165 | lax-mid | 22 | 18 |
| tense-mid | 120 | 55 | low | 71 | 37 |

This number is further sharpened by observing the correlation between vowel height and syllable weight. As shown in Table 6, no real effect was found regarding syllable weight per se. There were more cases of both tense and lax-mid vowels when the syllable was light. But a significant correlation was found with respect to coronal fricatives in coda position. Notice that front tense-mid vowels were more frequently produced when followed by a palatoalveolar fricative (eg. eʃtáke ‘stake’) The same effect was not observed for the back vowel, as both lax and tense-mid vowels were produced exactly the same number of times.

¹⁰ See Madrugá (2017) for full analysis.

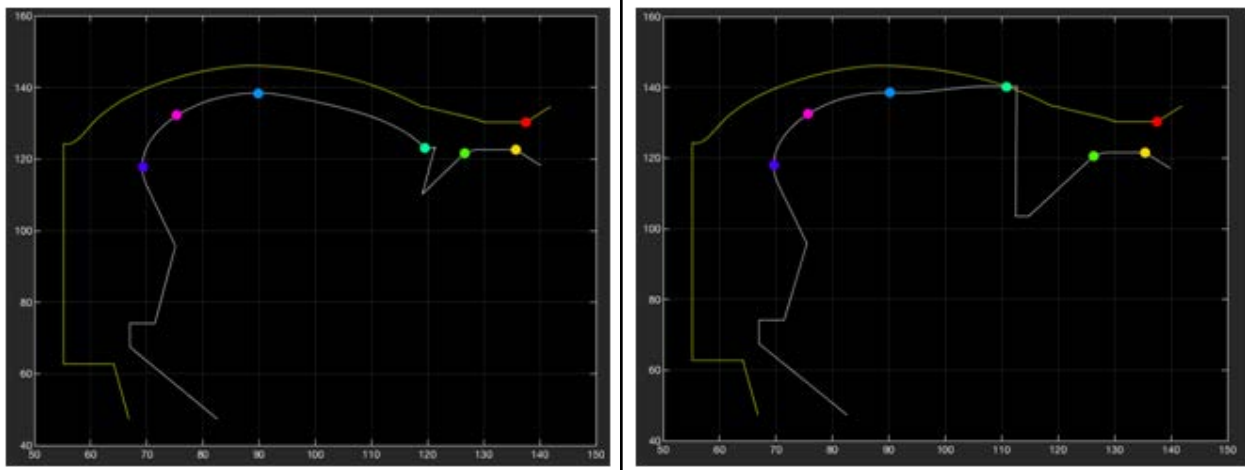
Table 6: Pretonic height x Syllable weight

| Pretonic Syll. Weight | [ɛ] | [e] | [i] | Pretonic Syll. Weight | [ɔ] | [o] | [u] |
|------------------------------|----------------|----------------|-------------|------------------------------|----------------|----------------|-------------|
| light (840) | 518 (61,6%) | 322 (38,4%) | 0 (0%) | light (780) | 474 (60,8%) | 303 (38,8%) | 3 (0,4%) |
| heavy (660) | 396 (60%) | 263 (39,8%) | 1 (0,2%) | heavy (720) | 468 (65%) | 246 (34,1%) | 6 (0,9%) |
| heavy by nasal (0) | 0 (0%) | 0 (0%) | 0 (0%) | heavy by nasal (0) | 0 (0%) | 0 (0%) | 0 (0%) |
| heavy by cor. fric. (180) | 12 (6,7%) | 114 (63,3%) | 54 (30%) | heavy by cor. fric. (120) | 60 (50%) | 60 (50%) | 0 (%) |
| Total: 3300 | | | | | | | |
| p-value < 0.001 | | | | | | | |

As mentioned earlier, the observation that coronal fricatives might somehow play a role in the production of [e] was first made by Barbosa da Silva (1988), who proposed a SPE-style rule to account for this pattern. I, however, assume here that the effect is due to coarticulation. To illustrate this claim, let's adopt the Task dynamics model proposed by Saltzman & Munhall (1989). According to this theory, phonological primitives are gestures, which can be defined as abstract constriction tasks and are modeled as dynamical systems that have an intrinsic temporal aspect. In this model, units of contrast are not a sequence of items, rather, they are transmitted in parallel and may overlap. This can be modeled through the Task Dynamics Application, TaDA (Nam et al, 2004).

The sequence of front tense mid-vowel and palatoalveolar fricative was modeled through TaDA and is shown on Figure 1 below. The light blue dot indicates that both sounds are produced with the same tongue body constriction location (TBCL) and tongue body position degree (TBCD). Notice also that the lack of effect that the palatoalveolar fricative had on back vowel is also captured in terms of coarticulation, as back vowels will substantially differ from the palatal fricative especially with respect to TBCL.

Figure 1: Modeling of [e] followed by [ʃ] by TaDA



In other words, the front vowel is produced as [e] when followed by a palatoalveolar fricative because both sounds ([e] and [ʃ]) are produced with the same tongue TBCD and TBCL configuration, facilitating their coarticulation.

One could argue that following this rationale, [ɛ] and [i] could also result from coarticulation, as they are also produced with the same TBCL used to articulate [e] and [ʃ]. However, they differ with respect to TBCD. That is, only [e] and [ʃ] have the same tongue body configuration (TBCL and TBCD) for their production.

If it is true that coarticulation can only explain the production of [e] when followed by the palatoalveolar fricative, then the production of [i] still needs to be addressed. See on Table 6 that [i] was produced 54 times when followed by [ʃ], which is almost all of the 55 times that the high front vowel was produced in the distribution that excluded nasal consonants.

Instead of coarticulation, this might be better captured on aerodynamics grounds, following previous observation regarding vowel devoicing in the context of coronal fricatives (Meneses, 2016). In this case, devouring would cause the vowel to be produced as an [i]-like sound, explaining their occurrence.

In face of what has been shown, it is possible to affirm that the front lax-mid vowel is disfavored when followed by the coronal fricative. Notice that we are showing that coarticulatory effects (and, possibly, even aerodynamics reasons) can be used to predict tense-mid and high vowels, but not to predict lax-mid vowels. This lack of a straightforward motivation is further evidenced when we

look at the last variable that was controlled, the preceding context. As one can see in Table 7, a significant difference was found for the production of lax-mid vowel when there was no preceding consonant, that is, when the vowel was in absolute word-initial position. It is not clear, however, what phonological motivation this might have for the production of this particular form.

Table 7: Pretonic height x Preceding context

| Pretonic Prec. Context | [ɛ] | [e] | [i] | Pretonic Prec. Context | [ɔ] | [o] | [u] |
|---------------------------|----------------|----------------|-------------|---------------------------|----------------|----------------|-------------|
| coronal (420) | 174 (41,4%) | 245 (58,3%) | 1 (0,3%) | coronal (360) | 228 (63,3%) | 129 (35,8%) | 3 (0,9%) |
| dorsal (300) | 172 (57,3%) | 128 (42,7%) | 0 (0%) | dorsal (360) | 212 (58,9%) | 148 (41,1%) | 0 (%) |
| labial (360) | 234 (65%) | 126 (35%) | 0 (0%) | labial (300) | 170 (56,7%) | 130 (43,3%) | 0 (0%) |
| s/z (300) | 194 (64,7%) | 106 (35,3%) | 0 (0%) | s/z (300) | 141 (47%) | 153 (51%) | 6 (2%) |
| empty (300) | 152 (50,7%) | 94 (31,3%) | 54 (18%) | empty (300) | 251 (83,7%) | 49 (16,3%) | 0 (0%) |
| Total: 3000 | | | | | | | |
| <i>p-value</i> < 0.001 | | | | | | | |

A possible explanation could be that having no preceding consonant guarantees no coarticulation coming from the right edge of the word and with this, lax-mid vowels could be produced without any kind of interference. However, this hypothesis needs to be further elaborated and tested, but even if it is shown to be true, it would not mean that lax-mid vowels were predicted, rather, it would imply that coarticulatory effects can only be used to predict tense and high vowels.

Now if we now look back at the cases of disharmonic productions assuming that coarticulatory effects can predict [e] (i.e., that [e] followed by [ʃ] is expected), the number of unexpected cases of tense mid-vowels being produced in disharmonic context is further reduced (see Table 8).

Table 8: Non-harmonic cases (updated without palatoalveolar fricative)

| Pretonic Stressed | [ɛ] | [ɔ] | Pretonic Stressed | [e] | [o] |
|----------------------|-----|-----|----------------------|-----|-----|
| high | 173 | 165 | lax-mid | 22 | 18 |
| tense-mid | 120 | 55 | low | 10 | 37 |

This number was reduced (from 71 in Table 5, to 10 in Table 7), because there were 51 cases of [e] being produced in disharmonic context when followed by palatoalveolar fricative (eg. *estado* ‘state’). These 51 cases were excluded from Table 7 because we are interested in the cases that cannot be predicted, i.e., that are unexpected, and as it has been shown, coarticulatory effects resulting from [ʃ] following the front mid vowel predicts [e].

By looking at the distribution in Table 7, it is even more evident now that the cases of disharmony involving tense-mid vowel are much smaller than the ones involving lax-mid vowels. This has an important implication, it shows that tense-mid vowels are, in general, predictable, they either result from harmony or are produced as the effect of coarticulation. Lax-mid vowels, however, were produced a total of 513 times even with no context for harmony or no apparent coarticulatory motivation, showing that lax-mid vowels cannot be fully predicted.

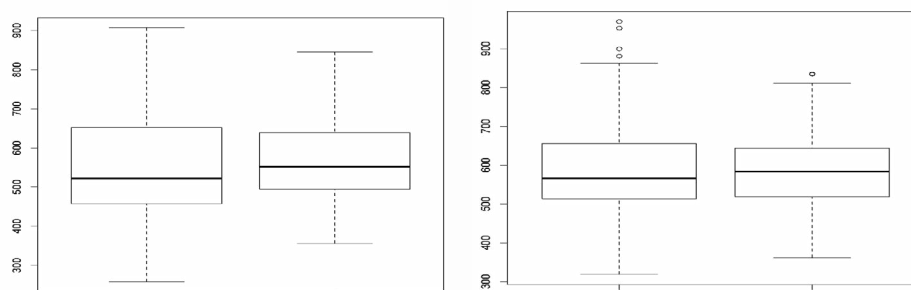
Earlier in this section, a question that was left unanswered was related to the kind of [ATR] harmony that existed in ND. The results presented corroborate the hypothesis that tense-mid vowels are the result of [+ATR] harmony, given that they are predictable, expected to be produced when followed by stressed tense-mid or high vowels. However, there is no evidence that lax-mid vowels are the result of [-ATR] harmony, as [ɛ, ɔ] are productively produced in disharmonic contexts. Therefore, the hypothesis of reduction via laxing in northern dialects of Brazilian Portuguese has found further evidence with experimental method

When experimentally analyzing the phonemes of Slovene, Lehiste (1968) argued that previous claims of reduction via laxing in the language should be disregarded, because reduced lax-mid vowels did not have the same quality of stressed lax-mid vowels, they actually had a quality between tense and lax-mid vowels. Because of this, the author proposed that what had been categorized as unstressed lax vowels, should, in fact, be categorized as an archiphoneme with no specification for [ATR]. One could wonder if this is also the case for unstressed lax-mid vowels in Brazilian Portuguese.

Kenstowicz & Sandalo (2016) and Madruga (2017) have shown that the quality of unstressed lax-mid vowels in ND is no different from the quality of stressed lax-mid vowels. These studies, however, only analyzed cases of unstressed lax-mid vowels when in harmony contexts. If one is arguing that reduction via laxing in fact is the neutralization strategy that speakers of this dialect are making use of, then there should be no difference between unstressed and stressed lax-mid vowels even with no context for harmony (eg. *tõhmẽto* ‘torment’).

A paired t-test was run to verify if there was significant difference between lax-mid vowels in stressed and pretonic position. As the boxplots on Figure 2 show, no significant difference was found ($p\text{-value} = 0.9$).

Figure 2: Stressed X unstressed lax-mid vowels



Therefore, the reasoning used by Lehiste (1968) to disclaim the hypothesis of reduction via laxing in Slovene, cannot be used for the pattern observed in BP. The non-difference between unstressed and stress lax-mid vowels, the predictability of [e, o], the non-predictability of [ɛ, ɔ], the overall preference for lax-mid vowels in pretonic contexts and the similarity of results observed in experimental as well as sociolinguistic studies, all point towards the same conclusion, that there is reduction via laxing in northern dialects of Brazilian Portuguese.

Conclusion

Sociolinguistic studies have previously claimed that simply harmony cannot fully account for the production of lax-mid vowels in pretonic syllables in ND. Because of this, a hypothesis that has been put forward is that reduction via laxing is the neutralization strategy used in those dialects (Silva, 2009; Bisol & Veloso, 2016). Therefore, the vowel subsystem for pretonic context instead of /i, e, a, o, u/, as proposed for SD by Câmara Jr. (1970), should be /i, ɛ, a, ɔ, u/ in ND. It is important to highlight, however, that this is the case only for pretonic contexts, as this cannot be extended for non-final postonic syllables, which also licenses lax-mid vowels. This is because [ɛ, ɔ] result from harmony in non-final postonic syllables in ND, and, therefore, the vowel subsystem should be /i, e, a, o, u/ (cf. “author”, 2016, 2018).

This study aimed to experimentally test the hypothesis of reduction via laxing in pretonic syllables for two reasons: (i) to analyze the pattern from a phonologically balanced corpus and (ii) to verify if the results found by “author” (2016) for non-final postonic syllable is different from the overall pattern found in pretonic syllable due to the use of experimental methods.

The corpus analyzed in this study, which resulted from an experimental test of sentence reading, showed that tense-mid vowels are predictable and result in the majority of cases from [+ATR] harmony. Coarticulatory effects can also play a role in the production of these vowels, specifically, for the production of the front tense-mid [e] when followed by a palatoalveolar fricative [ʃ]. Pretonic lax-mid vowels, however, cannot be fully predicted by harmony, as they are not restricted to contexts with a following [-ATR] vowel.

A possible alternative would be to assume that reduction in this dialect underspecifies [ATR] and that what has been classified as unstressed lax-mid vowels are, in fact, a form that is in between lax and tense-mid vowels, as what was proposed for Slovene by Lehiste (1961). However, a paired t-test showed that the quality of unstressed lax-mid vowels is no different from the quality of stressed lax-mid vowels in ND. So, if we assume that stressed [ɛ, ɔ] are specified for [-ATR], they should also be in unstressed context.

Circling back to the questions that were raised in Section 2, it is possible now to answer them directly: *are the results obtained with sociolinguistic studies also obtained with an experimental set?* Yes, the overall pattern is similar in both experimental and sociolinguistic studies. *Is the quality of pretonic lax-mid vowels any different from the quality of stressed lax-mid vowels in contexts where [-ATR] harmony is not possible?* No, no significant difference was found between their qualities.

The final question had a more broad and important character: *is there really reduction via laxing in northern dialects of Brazilian Portuguese?* Given the results of this study and what has been observed by previous investigations, the answer must be affirmative, as it is only by assuming that neutralization favors lax-mid vowels in ND that one can fully account for all the nuances observed in mid-vowel alternation in pretonic syllable.

It remains to be answered how this pattern can be formalized. As far as I can tell, no formal account has ever been provided to fully capture this. Reduction via laxing, by itself, is unexpected, given the way vowel reduction theories have been formalized (cf. Crosswhite, 1999; Flemming, 2004, among others). Besides reduction via laxing, a formal account should also be able to capture the fact that this pattern is observed pretonically, but not posttonically. So a simple assumption that feature specification is different when comparing SD and ND is not able to capture this nuance. Therefore, more analysis in this front are still required.

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