Vowel deletion and reduction: acoustic cues of rhythmic organization in Brazilian and European Portuguese

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Abstract

In this paper we analyze vowel deletion in Brazilian and European Portuguese based on acoustic data. The observed differences in the application of deletion processes in both languages was the basis of the main hypothesis discussed: Brazilian Portuguese is a language that deletes vowels to avoid degenerate feet within lexical words. The hypothesis has been statistically tested by applying a random effects model.

1. Introduction

This paper presents an acoustic analysis of Brazilian Portuguese (BP) vowels. The data show that many words containing an odd number of syllables have undergone vowel deletion. The fact that /i/ and other non-low vowels can be deleted (or drastically reduced) in unstressed position between t_s has been observed by Bisol (1991), and the fact that non-low vowels can be deleted between homorganic (coronal) consonants has been noticed by Bisol & Hora (1993). The deletion discussed by these authors occurs regardless of the metrical structure of the word (cf. satisfatória ‘satisfactory’ and satisfeito ‘satisfied’, where /i/ can always be deleted). We note, however, that there are other contexts that allow vowel deletion. We refer to the latter case as rhythmic deletion in Sandalo, Abaurre, Mandel & Galves (2006).

1 This research was supported by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo, Brazil) and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico, Brazil).
The analyzed data show that, as noted by Bisol (1991) and Bisol & Hora (1993), vowel deletion is mandatory between homorganic coronals, even when the resulting word has an odd number of syllables. The data, moreover, show that BP exhibits a strong tendency to reduce vowels in order to generate words with an even number of syllables, avoiding degenerate feet. An acoustic comparison with European Portuguese (EP) suggests that vowel reduction in this language is much more frequent and not related to the number of syllables of a word. The facts suggest a different rhythmic organization in EP, supporting claims by Vigário (1998) and Frota (1998).

This paper claims that vowel reduction optimizes BP tendency towards binarity (related, among other things, to the number of lexical words with an even number of syllables). The analysis is based on an acoustic investigation of 426 sentences (2502 lexical words), read by BP and EP native speakers. The PRAAT software was used to study vowel behavior and to identify occurrences of deletion/draastic reduction. The hypothesis that BP and EP differ in the way they undergo reduction processes was tested statistically by application of a random effects model.

2. Vowel deletion and secondary stress

Brazilian Portuguese secondary stress follows a rarely violated binary (two-syllable) pattern. The exceptions to the binary system are mostly cases of the so-called initial dactyl (Prince 1983). The initial dactyl is not obligatory, however. For instance, a word like abacaxi ‘pineapple’ can be stressed as abacaxi, an example of the initial dactyl, or as abacaxi (where bold syllables bear primary stress and underlined syllables are secondarily stressed).
It is well known that Spanish presents the same phenomenon (Harris 1983, 1989, Roca 1986). Our data, however, show that Harris’s (1989) analysis is not adequate for the BP data. Harris, within Metrical Theory, has suggested an analysis for Spanish which states that the two variants represent alternative outcomes to the resolution of a stress clash. On Harris's analysis, secondary stress in Spanish is applied by building trochees from right to left on the syllables preceding the syllable bearing main stress. If we allow degenerate feet at an intermediate stage of the derivation, the sort of clash shown in (1) will result. Initial dactyls can then be derived by applying a rule of rightward destressing and reparsing, whose effects are shown in (2), where one syllable in the middle of the word (ti) is left unparsed. The other option is to resolve the clash with leftward destressing, as shown in (3).

\[
(1) \begin{array}{c}
(x) \\
(x) (x) (x) (x) (x) (x) \\
\sigma \sigma \sigma \sigma \sigma \sigma \sigma \\
\text{cons tan ti no po li ta nis mo}
\end{array}
\]

\[
(2) \begin{array}{c}
(x) \\
(x) (x) (x) (x) \\
\sigma \sigma \sigma \sigma \sigma \sigma \sigma \\
\text{cons tan ti no po li ta nis mo}
\end{array} \rightarrow \begin{array}{c}
(x) \\
(x) (x) (x) (x) (x) (x) \\
\sigma \sigma \sigma \sigma \sigma \sigma \sigma \\
\text{cons tan ti no po li ta nis mo}
\end{array}
\]

\[
(3) \begin{array}{c}
(x) \\
(x) (x) (x) (x) \\
\sigma \sigma \sigma \sigma \sigma \sigma \sigma \\
\text{cons tan ti no po li ta nis mo}
\end{array}
\]
Hayes (1995:97) points out that "the crucial point of Harris's analysis is that it relies on a temporary degenerate foot, set up in the middle of the derivation (1), that either is expanded into a proper foot by destressing and reparsing, or is itself deleted." In neither case does the degenerate foot surfaces and, according to Hayes, this fact shows that the crucial point of Spanish phonology is the presence of a constraint that bans degenerate feet.

One could argue that Harris’s analysis could be proposed for BP. Our data, however, show that this analysis faces empirical problems, as discussed below.

An acoustic analysis of the BP facts shows that many words containing an odd number of syllables have undergone vowel deletion. The fact that /i/ and other non-low vowels can be deleted in unstressed position between t_s has been observed by Bisol (1991), and the fact that non-low vowels can be deleted between homorganic (coronal) consonants has been noticed by Bisol & Hora (1993). The deletion discussed by these authors occurs regardless of the metrical structure (cf. *satisfatória* ‘satisfactory’ and *satisfeito* ‘satisfied’, where the /i/ can always be deleted). We note, however, that there are other contexts that allow vowel deletion only if the number of syllables of the word is odd, like in *modernização* ‘modernization’ and *modernizaria* ‘conditional form of to modernize’, where the deletion of /i/ can only occur in the first case.

In other words, the syllable that Harris claims to be left unparsed is a syllable that, in some contexts in BP, is not realized because it can undergo vowel deletion. Thus, one of the possible realizations of a word like *constantinopolitanismo* is *constant(Ø)nopolitanismo*, where the vowel /i/ has been deleted, resulting in a perfect binary structure ((constant) (nopo) (líta) (nismo)). One could argue that the strategy
employed by Brazilian Portuguese to avoid degenerate feet is vowel deletion (instead of simply reparsing). Thus, an analysis along the lines of Harris's proposal could be offered, provided that a rule of /i/ deletion is added.

The phenomenon of vowel deletion in Brazilian Portuguese, however, shows that the facts are more complex. The words containing an odd number of syllables can be the target for rhythmic vowel deletion, which suggests that we are indeed looking at a language that prefers to avoid degenerate feet, as claimed by Hayes. The realizations in (4), however, are problematic for Metrical Theory because, if secondary stress results from an alternation of stressed and non-stressed syllables from right to left on the syllables preceding the syllable bearing main stress, there would be no reason for vowel deletion since there are four syllables preceding the syllable with main stress in \textit{modernização}, and therefore a perfectly binary alternation would result, in a metrical parsing. The prosodically-induced vowel deletion of (4) only makes sense if we assume that there is a constraint that forces binary feet in the word as a whole (i.e. \textit{(mo dern)Ü (za çã)Ü}), and that there is no need to introduce directionality (i.e. right to left counting from main stress) in order to achieve binarity via perfect alternation between strong and weak syllables, as predicted by a Metrical Theory analysis. Note that words that have an even number of syllables do not undergo rhythmic deletion in BP and we interpret this fact by saying that they already have a binary structure (e.g. \textit{(mo der)Ü (ni za)Ü (ri a)Ü}).

(4) A modernização foi satisfatória

[a mo dern za ção foi sats fa tô ria]

In Sandalo, Abaurre, Mandel & Galves (2006), we offer an OT alternative analysis for secondary stressing in BP, arguing for the relevance of a binarity constraint
in this language. In this paper, we look at vowel deletion/drastic reduction as another possible evidence for the importance of such constraint in this language.\(^2\)

European Portuguese differs from Brazilian Portuguese in that it is not a binary system. In European Portuguese the beginning of a sentence tends to be prominent, as already noticed by Frota (1998) and Vigário (1998). This fact can be seen in the example below:

\[
\begin{align*}
(5) & & \text{O investigador já me ofereceu dinheiro} ~ \\
& & \text{O investigador já me ofereceu dinheiro}.
\end{align*}
\]

‘The investigator already to-me offered money.’

But we find in our corpus other prominences at the beginning of smaller domains (cf. \textit{A catalogadora compreendeu o trabalho da pesquisadora} ‘the-fem cataloguer-fem understood the work of-the-fem researcher-fem’). Here, we argue that such domain is the phonological word.\(^3\) Evidence comes from the sentences below:

\[
\begin{align*}
(6) & & \text{A abelha rainha oferece frequentemente frutas.} \\
& & \text{A abelha rainha frequentemente oferece frutas.}
\end{align*}
\]

‘The-fem bee queen often offers fruits.’

\textit{A catalogadora compreendeu repentinamente o trabalho da pesquisadora.} \(^4\)

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\(^2\) A process of vowel deletion that forces a binary system has been noticed before for primary stress (Bisol 2000). For instance, it is well known that words like \textit{abóbora} ‘pumpkin’ are often realized as \textit{abobra}.

\(^3\) See Vigário (2003) for presentation of the algorithm for phonological (prosodic) word formation in EP and for a discussion of the importance of this domain in the language. Note also that, as far we know, Vigário (2003) is the first to point out that the phonological word initial position bears stress in EP.

\(^4\) Note that the determiner \textit{o} ‘the-masc’ does not bear secondary stress in \textit{a catalogadora repentinamente compreendeu o trabalho da pesquisadora}, since it would generate a stress clash because the verb \textit{compreendeu} bears main stress on the last syllable.
'The cataloguer-fem suddenly understood the work of the researcher-fem.'

As can be noticed above, there is no difference in secondary stressing if an adverb precedes or follows a verb (the adverb and the verb are in boldface). If the phonological phrase, rather than the phonological word, were the relevant domain, a prominence in the adverb should not be allowed when the verb precedes the adverb, since in this case the verb and the adverb are in the same phonological phrase. We explain below.

The fact that an adverb can intervene between the verb and its object suggests that the verb has moved from its base-position next to the object to a higher functional projection (Costa 1998: 19-36). The adverb might then be left-adjoined to VP, where it follows the moved verb. We follow Selkirk’s (1986/1995) theory of phonological phrasing, according to which phonological and syntactic phrases are right- or left-aligned; in Portuguese they are right-aligned (Sandalo & Truckenbrodt 2002). The right edge of a verb itself in the sequence verb-adverb, not being phrasal in nature, does not trigger a phonological phrase boundary and the verb and the adverb are grouped into a single phonological phrase. Therefore no stress on the adverb would be expected in the case of verb-adverb sequences if the relevant domain were the phonological phrase because the adverb would be in the middle of the phonological phrase in this case. Since the initial position of an adverb can bear a prominence in the sequence verb-adverb, we have evidence that the relevant prosodic domain is shorter than a phonological phrase, namely the phonological word.

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5 Selkirk (1986) proposed a universal theory of the syntax-phonology mapping, with special attention to phrasal right-edge alignment in Chi Mwi:ni. The theory was later formulated in Optimality Theory in Selkirk (1995), where the notion of edge-alignment from Selkirk (1986) has been expanded on the basis of the theory of Generalized Alignment (McCarthy and Prince 1993).
The important fact is that EP shows unbounded secondary footing. The transcription of our EP data does not indicate either binary or ternary alternations.

3. **The Hypothesis**

For the acoustic analysis, the PRAAT software was used to study vowel behavior and to identify occurrences of deletion/dramatic reduction.

In our investigation, any deletion/reduction was considered, regardless of the position of the syllable within the word. Only lexical words were considered (2502).

Our BP data contain minimal pairs of same roots, but the number of syllables (odd and even) is the variable under analysis. Given our discussion above (section 3), we have considered the entire lexical words, rather than pretonic syllables, to count number of syllables before and after deletion. Table 1 shows some results of BP. Each sentence was read three times by a given speaker. The segmental environment for deletion is indicated, as well as the resulting number of syllables when deletion applied. Note that, as pointed out by Bisol and Hora (1993), deletion always occurs between t_s. Notice, however, that, as pointed out by Sandalo, Abaurre, Mandel & Galves (2006), vowel deletion does not occur in other contexts when the number of syllables is even.

<table>
<thead>
<tr>
<th>Speaker 1</th>
<th>Environment</th>
<th># syllables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st reading</td>
<td>A modernização foi satisfatória</td>
<td>i/ n_z</td>
</tr>
<tr>
<td></td>
<td>A falta de modernização é catastrófica</td>
<td>i/ n_z</td>
</tr>
<tr>
<td></td>
<td>O governador aceitou a modernização</td>
<td>___</td>
</tr>
<tr>
<td>2nd</td>
<td>A modernização foi satisfatória</td>
<td>___</td>
</tr>
<tr>
<td></td>
<td>A falta de modernização é catastrófica</td>
<td>i/ n_z</td>
</tr>
<tr>
<td></td>
<td>O governador aceitou a modernização</td>
<td>___</td>
</tr>
<tr>
<td>3rd</td>
<td>A modernização foi satisfatória</td>
<td>i/ n_z</td>
</tr>
<tr>
<td></td>
<td>A falta de modernização é catastrófica</td>
<td>i/ n_z</td>
</tr>
</tbody>
</table>
O governador aceitou a *modernização* i/ n_z 5 → 4

**Speaker 2**

1º
A *modernização* foi satisfatória __
A falta de *modernização* é catastrófica __
O governador aceitou a *modernização* __

2º
A *modernização* foi satisfatória __
A falta de *modernização* é catastrófica __
O governador aceitou a *modernização* __

3º
A *modernização* foi satisfatória __
A falta de *modernização* é catastrófica __
O governador aceitou a *modernização* __

**Speaker 2**

1º
A modernização foi *satisfatória* i/t_s 5 → 4

2º
A modernização foi *satisfatória* __

3º
A modernização foi *satisfatória* i/t_s 5 → 4

**Speaker 1**

1º
A modernização foi *satisfatória* i/t_s 5 → 4

2º
A modernização foi *satisfatória* i/t_s 5 → 4

3º
A modernização foi *satisfatória* i/t_s 5 → 4

**Speaker 3**

1º
A *satisfação* e autoridade diminuíram i/ t_s 4 → 3
A pesquisadora *modernizaria* com *satisfação* i/ t_s 4 → 3
A *insatisfação* e autoridade diminuíram i/ t_s 5 → 4
A pesquisadora *modernizou* com *insatisfação* i/ t_s 5 → 4

2º
A *satisfação* e autoridade diminuíram i/ t_s 4 → 3
A pesquisadora *modernizaria* com *satisfação* i/ t_s 4 → 3
A *insatisfação* e autoridade diminuíram i/ t_s 5 → 4
The data suggest the following metrical footings for BP for the words *modernizaria* ‘would modernize’ (even number of syllables) and *modernização* ‘modernization’ (odd number of syllables):

\[
(7) \ \text{(mo der)} \Sigma \ (ni za) \ \Sigma \ (ri a) \Sigma
\]
\[
(mo \ der) \Sigma \ (ni za) \ \Sigma \ (c\ddot{a}o) \Sigma
\]
\[
(mo \ dern) \ \Sigma \ (za\tilde{c}ao) \Sigma
\]

The hypothesis to be tested is the following. Vowel reduction optimizes BP tendency towards binarity. EP shows a different behavior. Our data show that vowel reduction is much more frequent in EP and it does not seem to be related to the number of syllables of a word. In order to test the hypothesis, we have run a statistical test that compares vowel deletion in BP and EP.

4. **Discriminating BP and EP: some statistics**

2502 lexical words were acoustically analyzed. 220 BP words have undergone deletion. 132 words with an odd number of syllables turned to an even number of syllables, and 88 with an even number of syllables turned to odd. Considering the

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6 The statistical analysis was conducted by Verónica Gonzalez-Lopez (IME/UNICAMP/BRAZIL), whom we thank.
percentage of deletions from odd to even over the total number of deletions, we get the value of 0.6 for BP.

A much greater number of EP words (622) have undergone deletion. 356 words with an odd number of syllables turned to even, and 266 with an even number of syllables turned to odd. Considering the percentage of deletions from odd to even over the total number of deletions, we get the value of 0.57 for EP.

Three confidence levels ($\gamma = 0.9, 0.95, \text{and } 0.99$) have been considered in order to test the possibility of discriminating BP and EP on the basis of the $q\square$ values (0.6/0.57) obtained for both languages. Table 2 presents the obtained confidence intervals.

<table>
<thead>
<tr>
<th>$\gamma$</th>
<th>$z_\gamma$</th>
<th>language</th>
<th>$q\square$</th>
<th>BL</th>
<th>UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
<td>1.64</td>
<td>PB</td>
<td>0.6</td>
<td>0.55</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PE</td>
<td>0.57</td>
<td>0.54</td>
<td>0.60</td>
</tr>
<tr>
<td>0.95</td>
<td>1.96</td>
<td>PB</td>
<td>0.6</td>
<td>0.54</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PE</td>
<td>0.57</td>
<td>0.53</td>
<td>0.61</td>
</tr>
<tr>
<td>0.99</td>
<td>2.58</td>
<td>PB</td>
<td>0.6</td>
<td>0.51</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PE</td>
<td>0.57</td>
<td>0.52</td>
<td>0.62</td>
</tr>
</tbody>
</table>

Table 2: Confidence Intervals

Given a fixed value for $\gamma$, the obtained confidence intervals show overlapping confidence regions for both languages, which leads to the conclusion that it is not possible to discriminate EP and BP only on the basis of the confidence intervals of odd to even reduction proportions relative to the total of deletions.
If we look at the data (partially shown in Tables 3 and 4 below), however, we notice that the behavior of reductions seems to be different in EP and in BP. Whereas in EP words seem to randomly go from an odd to an even number of syllables, and vice-versa; in BP, turning to an odd number of syllables is rare, and words frequently go to an even number of syllables if deletion applies.

Table 2: PB speaker 1, third reading

<table>
<thead>
<tr>
<th>Sentence</th>
<th>i</th>
<th>t</th>
<th>s</th>
<th>g</th>
<th>d</th>
<th>5</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A modernização foi satisfatória</td>
<td>i</td>
<td>t</td>
<td>s</td>
<td></td>
<td></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>O professor também o descreveu aos alunos</td>
<td>o</td>
<td>n</td>
<td>s</td>
<td></td>
<td></td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>O governador aceitou a modernização</td>
<td>i</td>
<td>n</td>
<td>z</td>
<td></td>
<td></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>A falta de autoridade foi alarmante</td>
<td>c</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>O investigador já lhe devolveu o dinheiro</td>
<td>i</td>
<td>d</td>
<td>nh</td>
<td></td>
<td></td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>A professora discutiu a gramaticalidade</td>
<td>i</td>
<td>t</td>
<td>k</td>
<td></td>
<td></td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>A procura da gramaticalidade é nosso objetivo</td>
<td>i</td>
<td>t</td>
<td>k</td>
<td></td>
<td></td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>O professor também descreveu os alunos</td>
<td>c</td>
<td>d</td>
<td>s</td>
<td>o</td>
<td>n</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>A autoridade cabe ao governador</td>
<td>c</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>A gramaticalidade das frases foi conseguida</td>
<td>i</td>
<td>t</td>
<td>k</td>
<td>i</td>
<td>g</td>
<td>d</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 3: EP speaker 2, second reading

<table>
<thead>
<tr>
<th>Sentence</th>
<th>i</th>
<th>t</th>
<th>s</th>
<th>g</th>
<th>d</th>
<th>5</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A modernização foi satisfatória</td>
<td>i</td>
<td>t</td>
<td>s</td>
<td></td>
<td></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>A autoridade do governador diminuiu</td>
<td>c</td>
<td>d</td>
<td>#</td>
<td></td>
<td></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>O investigador já devolveu o dinheiro</td>
<td>c</td>
<td>v</td>
<td>s</td>
<td></td>
<td></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>O organizador apresentou a catalogadora</td>
<td>c</td>
<td>r</td>
<td>z</td>
<td>o</td>
<td>l</td>
<td>g</td>
<td>4</td>
</tr>
<tr>
<td>O trabalho da pesquisadora foi publicado</td>
<td>o</td>
<td>l</td>
<td>h</td>
<td>#</td>
<td>e</td>
<td>p</td>
<td>s</td>
</tr>
<tr>
<td>O professor também o descreveu aos alunos</td>
<td>c</td>
<td>f</td>
<td>s</td>
<td>c</td>
<td>d</td>
<td>s</td>
<td>3</td>
</tr>
<tr>
<td>O governador aceitou a modernização</td>
<td>c</td>
<td>v</td>
<td>r</td>
<td>o</td>
<td>m</td>
<td>d</td>
<td>4</td>
</tr>
<tr>
<td>A falta de autoridade foi alarmante</td>
<td>o</td>
<td>t</td>
<td>r</td>
<td>c</td>
<td>d</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>O investigador já lhe devolveu o dinheiro</td>
<td>c</td>
<td>v</td>
<td>s</td>
<td>c</td>
<td>d</td>
<td>v</td>
<td>i</td>
</tr>
<tr>
<td>A catalogadora compreendeu o trabalho da pesquisadora</td>
<td>o</td>
<td>l</td>
<td>g</td>
<td>o</td>
<td>l</td>
<td>h</td>
<td>#</td>
</tr>
<tr>
<td>A professora discutiu a gramaticalidade</td>
<td>o</td>
<td>r</td>
<td>f</td>
<td>c</td>
<td>f</td>
<td>s</td>
<td>i</td>
</tr>
<tr>
<td>A inteligência da catalogadora foi determinante</td>
<td>c</td>
<td>t</td>
<td>l</td>
<td>c</td>
<td>d</td>
<td>t</td>
<td>c</td>
</tr>
<tr>
<td>O investigador já ofereceu dinheiro</td>
<td>c</td>
<td>v</td>
<td>s</td>
<td>c</td>
<td>f</td>
<td>r</td>
<td>c</td>
</tr>
<tr>
<td>A procura da gramaticalidade é o nosso objetivo</td>
<td>o</td>
<td>s</td>
<td>#</td>
<td>o</td>
<td>v</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>O pesquisadora perdeu a autoridade</td>
<td>o</td>
<td>p</td>
<td>s</td>
<td>c</td>
<td>d</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>O professor também descreveu os alunos</td>
<td>c</td>
<td>f</td>
<td>s</td>
<td>c</td>
<td>d</td>
<td>s</td>
<td>o</td>
</tr>
<tr>
<td>A autoridade cabe ao governador</td>
<td>o</td>
<td>t</td>
<td>r</td>
<td>c</td>
<td>d</td>
<td>#</td>
<td>c</td>
</tr>
<tr>
<td>O investigador já me ofereceu dinheiro</td>
<td>c</td>
<td>v</td>
<td>s</td>
<td>c</td>
<td>f</td>
<td>r</td>
<td>c</td>
</tr>
<tr>
<td>A gramaticalidade das frases foi conseguida</td>
<td>c</td>
<td>d</td>
<td>#</td>
<td>c</td>
<td>z</td>
<td>s</td>
<td>c</td>
</tr>
</tbody>
</table>

Table 3: EP speaker 2, second reading
Given that the confidence intervals (Table 2) did not discriminate BP and EP, we have tested the hypothesis that the behavior of deletion processes is significantly different in both languages by applying a random effects model.

We have defined:

\[ q'_{ij} = \text{odd words, that speaker } l \text{ turns into even, in sentence } j, \text{ language } i \]
\[ \text{number of reduced words in sentence } j, \text{ language } i \]

In the numerator of the proportion above, we used the mean value of the three readings of each sentence from a corpus of 20 sentences.\(^7\)

Thus we have, for our corpus of 20 sentences, considering two speakers for the sake of illustration:

\[^7\text{ The corpus of 20 sentences used in this test was elaborated by Sónia Frota, Marina Vigário, and Charlotte Galves. The sentences are the following:}\
1. A modernização foi satisfatória
2. A autoridade do governador diminuiu
3. O investigador já devolveu o dinheiro
4. O organizador apresentou a catalogadora
5. A falta de modernização é catastrófica
6. O trabalho da pesquisadora foi publicado
7. O professor também o descreveu aos alunos
8. O governador aceitou a modernização
9. A falta de autoridade foi alarmante
10. O investigador já lhe devolveu o dinheiro
11. A catalogadora compreendeu o trabalho da pesquisadora
12. A professora discutiu a gramaticalidade
13. A inteligência da catalogadora foi determinante
14. O investigador já ofereceu dinheiro
15. A procura da gramaticalidade é o nosso objectivo
16. A pesquisadora perdeu autoridade
17. O professor também descreveu os alunos
18. A autoridade cabe ao governador
19. O investigador já me ofereceu dinheiro
20. A gramaticalidade das frases foi conseguida\]
The box plot below indicates that BP has a more significant tendency to reduce odd numbered words to even numbered.

Table 5: Reduction proportions (odd to even relative to the total of reductions by language and speaker (corpus of 20 sentences)

In order to test the hypothesis using a random effects model, we have fixed $l_1$ for BP and $l_2$ for EP.\(^8\) We have the following results referring to variability estimates:

<table>
<thead>
<tr>
<th>Estimates</th>
<th>$\sigma^2_{\alpha}$</th>
<th>$\sigma^2_e$</th>
<th>$\rho$</th>
</tr>
</thead>
</table>

\(^{8}\) The letter \(l\) stands for Portuguese ‘locutor’ (speaker).
According to this results, it is possible to say that:

(i) there is evidence to discriminate BP and EP considering speakers 1/BP and 2/EP, and speakers 2/BP and 2/EP.

(ii) if we compare speakers 1/BP and 1/EP, it is not possible to discriminate the languages.

(iii) The random effects model was not adequate to compare speakers 2/BP and 1/EP.

5. **Final Remarks**

We have hypothetized that BP undergoes vowel deletion in order to optimize binarity in terms of the total number of syllables per word. A random effects model indicates that this hypothesis is worth pursuing in further research.

References


