REDUCTION OF BRAZILIAN PORTUGUESE VOWELS IN SEMANTICALLY PREDICTABLE CONTEXTS

Caleb Everett, Zachary Miller, Kayla Nelson, Vlad Soare & Jacqueline Vinson

University of Miami, USA
caleb@miami.edu

ABSTRACT

Ten adult Brazilian Portuguese speakers were recorded producing the same words in contexts of relatively high and low semantic predictability. Significant vowel reduction in the former context was uncovered in the case of two of the three vowel types examined. The reduction of these vowels, /e/ and /a/, was both spectral and temporal. We describe some subtle parallels and differences between the semantically-oriented vowel reduction patterns in Portuguese and those in the other two languages in which such patterns are documented. Our results demonstrate that semantically based vowel reduction exists in Portuguese, and that interesting patterns in this type of reduction can be uncovered via cross-linguistic analysis of the phenomenon.

Keywords: vowels, formants, Portuguese, semantics, stress

1. INTRODUCTION

Several studies [2, 7, 10] have demonstrated that vowels in English are often reduced spectrally and/or temporally when they are embedded in words occurring in contexts of relatively high semantic predictability (HP), when contrasted with contexts of relatively low semantic predictability (LP). This sort of reduction is similar to that observed in faster speech [5], in unstressed contexts [8], and in words of high lexical density [9]. Clopper and Pierrehumbert [2] suggest that HP oriented reduction is motivated by the decreased need for vowel clarity in such contexts, given that word intelligibility can be maintained with slightly obfuscated vowel qualities in cases in which the word is relatively predictable.

In the most comprehensive study on the subject to date [2], the vowels of speakers of three American English dialects were analyzed. Significant temporal reduction of HP vowels was demonstrated for all dialects, however spectral reduction of HP vowels was only observed in two of the three dialects tested (and not for all vowels).

Given that spectral reduction in HP contexts is not even common to all English vowels or dialects, and given how modest the literature on this subject is, it remains an open question whether spectral and temporal reduction in HP contexts is a common cross-linguistic phenomenon. This seems especially true when one considers the general prevalence of vowel reduction in English [6, 8]. Only one study we are aware of has provided evidence for HP oriented reduction in a language outside English. [4]

To better understand this phenomenon, especially its cross-linguistic nature (or lack thereof), we tested for HP vowel reduction in Brazilian Portuguese (BP). While post-tonic vowels in BP are reduced spectrally, spectral vocalic reduction in the language is less ubiquitous than in English or even European Portuguese. [3] This study focuses on the duration and F1-F2 vowel space locations of three phonemic BP vowels, /i/, /e/, and /a/. The three vowel types were selected for analysis since there are findings in the modest literature on HP reduction for each of them [2, 4]. They were also selected since, as non-nasal monophthongs, their formant structures in HP contexts could be definitively and facilely contrasted with those in LP contexts.

2. METHODS

2.1. Speakers

Ten native BP speakers (5 female) volunteered to participate in the study, for modest remuneration. All speakers were adults between 20 and 45 years of age. Task participation lasted approximately twenty minutes per speaker.

2.2. Materials

A list of 24 clauses was generated. Each clause contained one vowel of interest, which in all cases occurred in the stressed first syllable of a disyllabic word located in clause-final position. In half the clauses the clause-final words were characterized by HP contexts, and in the remainder LP contexts.

The same vowel of the same word was contrasted across contexts. Place of articulation (POA) of the preceding consonants was controlled for. One third of the clauses were dedicated to /i/ analysis, one-third to /e/ and one-third to /a/. The clauses were written by a fluent BP speaker. HP/LP status of clause-final words was confirmed via third-party BP speakers' judgments. The clauses used as stimuli are presented in the Appendix.

2.3. Procedure

Each speaker produced three exemplars of all 24 clauses, by reading them in randomized order. A total of 720 clauses (24 clauses x 3 tokens x 10 speakers) were recorded, and the final word was excised digitally in each case. Speakers were recorded in a sound-treated room near their residences in Brazil. Only one BP dialect was represented so as to prevent cross-dialectal effects of the sort observed in [2]. Speakers were recorded via a Mac Powerbook laptop, with a sampling rate of 44 kHz and a 16-bit quantization. Spectral and temporal analysis was conducted via PRAAT. [1]

2.4. Analysis

Waveforms and FFT-based spectrograms were generated for all of the analyzed words. Wide-band spectrograms were utilized for duration measurements, and PRAAT's formant analysis tool was employed for F1 and F2 derivations. F1 and F2 values were gathered from steady state portions of the vowel, beginning approximately 30 ms after vowel onset. Formant values were based on means of 20 ms segments of the steady state portions. Duration values (in ms) and F1 and F2 values (in Hz) were obtained for each of the 720 analyzed vowels. Formant values were converted into Barks. Mean values of duration, F1 and F2 were obtained for all speakers, and for all three vowel types in both HP and LP conditions. To prevent researcher bias in the acoustic analysis, all values were tabulated by researchers (the four second authors) unaware of the hypothesis being tested.

3. RESULTS

3.1. Temporal reduction in HP contexts

The mean duration of all vowels in HP contexts was 159 ms, while the mean duration in LP contexts was 165 ms. This difference was significant (paired $t(359)=2.917$, $p =0.0038$). In the case of the /i/ vowel, HP tokens were marginally *longer* than LP tokens (144 ms vs. 140 ms), though

this difference did not approach significance (paired $t(119)=0.9667$, $p=0.336$). For /e/, HP tokens were shorter than LP tokens (159 ms vs. 173 ms), and this difference was significant (paired $t(119)=4.68$, $p=0<0.001$). For /a/, HP tokens were once again shorter than LP tokens (174 ms vs. 183 ms), and this difference was significant at the 0.05 level (paired $t(119)=2.07$, $p=0.041$). In short, significant disparities in duration were of the sort expected: HP vowels tended to be shorter.

Figure 1: Mean durations for the three vowel types, for HP and LP contexts. p values are based on paired t-tests contrasting LP and HP tokens, for each vowel.
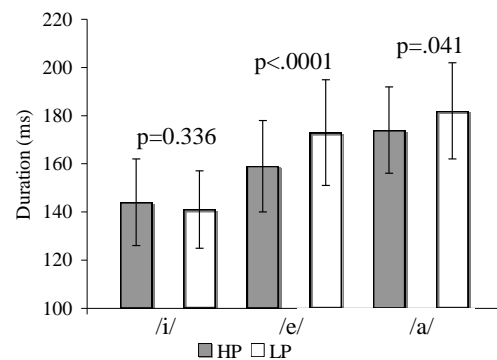
As can be seen in Fig.1, there are also clear disparities in duration across vowel types. A one-way ANOVA contrasting the durations of the three vowel categories (with HP and LP values collapsed for each category) revealed significant vowel-type disparities. ($F(2,717)=50.3$, $p=0.000$) Tukey post-hoc tests revealed significant disparities (at the 0.001 level) for each possible vowel-type pair (/i/ vs. /e/, /i/ vs. /a/, /e/ vs. /a/). As we see in Fig. 1, the /i/ vowels were noticeably shorter than /e/ vowels, which were in turn shorter than /a/ vowels. It is worth noting that spectral reduction, described in 3.2, was greatest for the vowel with the longest duration (/a/), and non-existent for the vowel with the shortest duration (/i/). In other words, for this data set at least longer vowel types were more susceptible to HP oriented spectral reduction.

3.2. Spectral reduction in HP contexts

Vowel loci in the F1-F2 plane are presented in Fig. 2. There is some overlap between the loci of the /i/ and /e/ vowels. This overlap is also evident in a more comprehensive study of BP vowels [3]. Paired t-tests were conducted contrasting F1 vs. F1 and F2 vs. F2, across HP and LP variants of each vowel type. The only significant disparities uncovered involved the F2 vs. F2 differences between HP and LP contexts, for both /e/ and /a/.

The disparity was somewhat weaker in the case of /e/ (paired $t(119)=2.49$, $p =0.013$) than in the case of /a/ (paired $t(119)=3.225$, $p =0.0016$). F2 values were significantly lower in HP contexts, for both vowel types. Mean loci are plotted in Fig. 3.

Figure 2: Mean HP and LP vowel locations in the F1-F2 plane, for all ten speakers. Ellipses circumscribe all of the speakers' means for a particular vowel type.
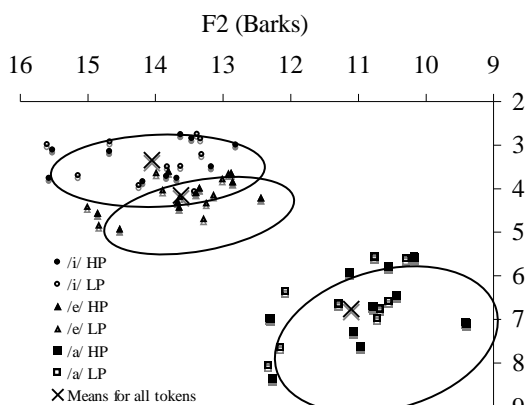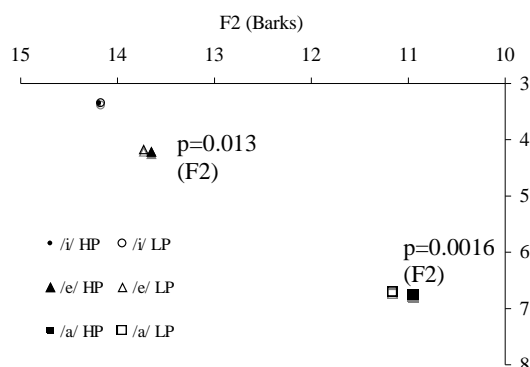
F2 (Barks)

Figure 3: Mean placement of vowels in F1-F2 plane. *p* values index significant HP vs. LP disparities.

F2 (Barks)

For /e/ and /a/, HP F2 values were generally lower than LP F2 values, i.e. HP variants were typically produced in a more retracted portion of the vowel space. This tendency was evident at an individual-speaker level, as we see in Table 1.

Table 1: (LP minus HP) values (in Barks) for F2 of /e/ and /a/ vowels, across ten speakers.

Speaker	/e/	/a/
Male 1	0.7	0.2
Male 2	0.04	0.12
Male 3	0.15	0.11
Male 4	-0.36	-.07
Male 5	-0.15	1.27
Female 1	0.31	1.18
Female 2	0.18	0.94
Female 3	-.03	0.06
Female 4	0.15	-.02
Female 5	0.54	0.21

Only one speaker (Male 4) did not produce HP variants of /e/ or /a/ with lower F2 values. All remaining speakers exhibited at least some HP F2 reduction for either /e/ or /a/, and in the case of seven speakers, for both. It should be noted that the F2 reduction observed is in most cases modest. One possible motivation for this is the repetitive nature of the task. Since each clause was repeated 3 times (though not sequentially), the 2nd and 3rd productions of words in LP contexts may not have actually seemed as unpredictable to the speakers. Nevertheless, significant spectral disparities between LP and HP contexts did surface for the /e/ and /a/ vowels.

4. CONTRAST WITH PREVIOUS STUDIES

To date, semantically oriented vowel reduction has been demonstrated for two languages, English [2] and Kariti âna (K) [4]. It is well known that vowels in English are spectrally and temporally reduced for a variety of reasons, and vowel reduction is apparently common in K as well [4]. Vowel reduction is less pervasive in BP, especially outside post-tonic positions [3]. This study demonstrates that, even in a language such as BP with generally less prevalent vowel reduction, HP oriented vowel reduction occurs.

We uncovered significant durational differences between LP and HP contexts, for both /e/ and /a/. Significant spectral differences also surfaced for these vowels. In English and K, HP reduction of front vowels, when present, was characterized by a lower F2 in most cases [2, 4], a finding we have replicated here. In English and K, however, HP reduction of /a/ was largely along the F1 dimension, with HP variants occurring higher in the vowel space. [2, 4] While we have uncovered spectral reduction for BP /a/, it is surprisingly along the F2 dimension, with HP variants exhibiting lower F2 values. Interestingly, the LP /a/ variants are located closer to the center of the vowel space, and closer to the prototypical values for /a/ described in previous work on BP [3]. In short, HP /a/ appears to deviate further from the expected vowel target. The fact that it does so along the F2 axis may be due in part to the particular stimuli employed here. Since for the /a/ stimuli the vowel of the next syllable was rounded in each case (see Appendix), it is plausible that there was some modest anticipatory labialization, but crucially only in the case of HP variants.

As in the case of English [2], the most obvious spectral differences between HP and LP contexts surfaced for /a/. Conversely, no effects of HP status were observed here for /i/, either for temporal or spectral reduction. Interestingly, no spectral or durational HP reduction was observed for this vowel in K [4], and no significant spectral reduction was observed for /i/ in English either [2].

5. DISCUSSION

This study is the first to demonstrate the presence of HP vowel reduction in BP. Perhaps more significantly, the results presented here, when contrasted with those in previous work on HP reduction, are suggestive of some cross-linguistic patterns meriting further attention. While the greater tendency towards HP reduction of /a/ and non-reduction of /i/ must be corroborated via studies of other languages, we offer an initial hypothesis for these similarities in the studies so far undertaken. As a high front vowel, /i/ is immediately abutted in the vowel space by another vowel in all three of the languages in which HP reduction has so far been attested. The adjacency of /i/ and /e/ in BP is particularly evident in Fig. 2. We suspect that, since spectral reduction of /i/ would result in greater confusability with /e/, its reduction is disfavored. This analysis is also consistent with the greater HP reduction observed for /a/ in BP and English. Since this vowel has fewer immediate neighbors in the F1-F2 vowel space (in both languages), it can be produced with more reduction/less precision in HP contexts without significantly increasing confusability, i.e. it has more 'room to roam.' This account is of course tentative, and we hope that future work will allow it to be tested. Perhaps such work will also result in the discovery of other cross-linguistic patterns in semantically oriented vowel reduction.

6. APPENDIX

The following 24 clauses were employed. The analyzed vowel in each clause is highlighted. HP/LP status is designated parenthetically. Preceding POA was varied systematically.

/i/

Paulo começou a ler o livro. (HP)
Ela está feliz que Paulo ligou sobre o livro. (LP)
O atleta enorme pesa mais de cem kilos. (HP)
Você já considerou os kilos. (LP)
Durante o roubo a mulher deu um grito. (HP)
Nós consideramos a possibilidade de um grito. (LP)
Ontém a noite em casa assistimos um vídeo. (HP)
Ela está discutindo sobre o vídeo. (LP)

/e/

O menino gosta de balançar na rede. (HP)
A menina já considerou a rede. (LP)
Depois de jogar bola, eu estava com sede. (HP)
Antônio vai ligar sobre a sua sede. (LP)
O cachorro tem pulgas no seu pelo. (HP)
Eles discutiram sobre o pelo. (LP)
O cavalo listrado parece uma zebra. (HP)
Rodrigo espera que ela vai ligar sobre a zebra. (LP)

/a/

Uma ave branca que gosta de nadar é o pato. (HP)
Luiz considerou o pato. (LP)
Roberto apostou dinheiro num jogo de dados. (HP)
Ele já ligou sobre os dados. (LP)
Ford é uma marca de carro. (HP)
Josué discutiu com eles sobre o carro. (LP)
O cachorro correu atrás do gato. (HP)
Marcia está feliz que ele ligou sobre o gato. (LP)

7. REFERENCES

[1] Boersma, P., Weenink, D. 2008. Praat: Doing phonetics by computer. (Version 5.0.43) [Computer program], retrieved 15 December 2008 from *http://www.praat.org/*

[2] Clopper, C., Pierrehumbert, J. 2008. Effects of semantic predictability and regional dialect on vowel space reduction. *J. Acoust. Soc. Am.* 24, 175-184.

[3] Escudero, P., Boersma, P., Rauber, A., Bion, R. 2009. A cross-dialect acoustic description of vowels: Brazilian and European Portuguese. *J. Acoust. Soc. Am.* 126, 175-184, 1379-1393.

[4] Everett, C. 2010. Semantically-oriented vowel reduction in an Amazonian language. *Proc. Berkeley Ling. Soc.* 36.

[5] Fourakis, M. 1991. Tempo, stress, and vowel reduction in American English. *J. Acoust. Soc. Am.* 90, 1816-1827.

[6] Jurafsky, D., Bell, A., Gregory, M., Raymond, W. 2001. Probabilistic relations between words: Evidence from reduction in lexical production. In Bybee, J., Hopper, P. (eds.), *Frequency and the Emergence of Linguistic Structure*. Amsterdam: John Benjamins. 229-254.

[7] Lieberman, P. 1963. Some effects of semantic and grammatical context on the production and perception of speech. *Language and Speech* 6, 172-187.

[8] Lindblom, B. 1963. Spectrographic study of vowel reduction. *J. Acoust. Soc. Am.* 35, 1773-1781.

[9] Munson, B., Solomon, N. 2004. The effect of phonological neighborhood density on vowel articulation. *J. Speech, Lang, and Hearing Research* 47, 1048-1058.

[10] Scarborough, R. 2006. Lexical and Contextual Predictability: Confluent Effects on the Production of Vowels. Paper presented at the *10th Laboratory Phonology Conference*. Paris, France.