STATE UNIVERSITY OF CAMPINAS
LANGUAGE STUDIES INSTITUTE

MAGNUN ROCHEL MADRUGA

# THE PHONETICS AND PHONOLOGY OF BRAZILIAN PORTUGUESE [ATR] HARMONY

CAMPINAS
2017

# THE PHONETICS AND PHONOLOGY OF BRAZILIAN PORTUGUESE [ATR] HARMONY

Dissertation presented to the Language Studies Institute of the University of Campinas in partial fulfillment of the requirements for the degree of Doctor in Linguistics.

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**Este exemplar corresponde à versão final da Tese defendida pelo aluno Magnun Rochel Madruga e orientada pelas Profas. Dras. Maria Bernadete Marques Abaurre e Silke Hamann.**

**CAMPINAS**
**2017**

**Agência(s) de fomento e nº(s) de processo(s):** CNPq, 140280/2012-0; CAPES, 6344/13-5 **ORCID:** https://orcid.org/0000-0001-8913-9639

Ficha Catalográfica
Universidade Estadual de Campinas
Biblioteca do Instituto de Estudos da Linguagem
Crisllene Queiroz Custódio - CRB 8/8624

M267p Madruga, Magnun Rochel, 1987-
The phonetics and phonology of Brazilian Portuguese [ATR] harmony / Magnun Rochel Madruga. – Campinas, SP : [s.n.], 2017.

Orientadores: Maria Bernadete Marques Abaurre e Silke Hamann.
Coorientador: Silke Hamann.
Tese (doutorado) – Universidade Estadual de Campinas, Instituto de Estudos da Linguagem.
Em cotutela com: University of Amsterdam.

1. Língua portuguesa - Brasil - Fonologia. 2. Língua portuguesa - Fonética. 3. Língua portuguesa - Vogais. 4. Língua portuguesa - Dialetos - Brasil. 5. Língua portuguesa - Português falado - Rio Grande do Sul. 6. Língua portuguesa - Português falado - Bahia. I. Abaurre, Maria Bernadete Marques, 1946-. II. Hamann, Silke, 1971-. III. Universidade Estadual de Campinas. Instituto de Estudos da Linguagem. IV. Título.

Informações para Biblioteca Digital

**Título em outro idioma:** A fonética e a fonologia da harmonia de [ATR] do português brasileiro
**Palavras-chave em inglês:**
Portuguese language - Brazil - Phonology
Portuguese language - Phonetics
Portuguese language - Vowels
Portuguese language - Dialects - Brazil
Portuguese language - Portuguese spoken - Rio Grande do Sul (Brazil)
Portuguese language - Portuguese spoken - Bahia (Brazil)
**Área de concentração:** Linguística
**Titulação:** Doutor em Linguística
**Banca examinadora:**
Maria Bernadete Marques Abaurre [Orientador]
Maria Filomena Spatti Sandalo
Plínio Almeida Barbosa
Luiz Carlos da Silva Schwindt
Raquel Santana Santos
**Data de defesa:** 27-11-2017
**Programa de Pós-Graduação:** Linguística

UNICAMP

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**IEL/UNICAMP**
**2017**

**Ata da defesa, com as respectivas assinaturas dos membros da banca, encontra-se no SIGA - Sistema de Gestão Acadêmica.**

This work was funded by CNPq (the National Council for Scientific and Technological Development), grant number 140280/2012-0. During a visiting scholar period at University of Amsterdam, this work was sponsored by the Capes Foundation within the Ministry of Education, Brazil, grant number 6344/13-5.

This research received approval from the Research Ethics Committee of the State University of Campinas (UNICAMP), protocol number 49001015.4.0000.5404.

*In memoriam of my dearest friend Ana Laura da Luz Ávila, 1987-2016.*

# ACKNOWLEDGMENTS[1]

First and foremost, I would like to mention that the goal of this acknowledgment section is twofold. In addition to being a part of my work, where I will acknowledge everyone who has contributed to the work itself and been present in my life, this text is also a manifest. Considering that this is the place where I can freely express my ideas, it is the right place for me to state what most academics think about the exceptional political scenario we have been experiencing in Brazil since last year.

Originally, this work used resources from scientific programs that are now terminated or almost terminated by the political austerity orchestrated by an illegitimate president who froze the government budget for the next 20 years. The lives of workers, academics and society in its entirety have been affected by those people who frauded an impeachment to take the political power and govern our country without one single Brazilian vote. The result is an attack against our democracy to impose a neoliberal agenda without the endorsement of general elections. This is crystal clear. As result, the budget of the main scientific agency, namely the National Council for Scientific and Technological Development (CNPq), is now lower than it was 16 years ago back in 2001.

Regarding this serious situation, I have to thank the left governments which have pulled 36 million people from extreme poverty by creating social programs to offer work, education and life-changing opportunities. I am one of the beneficiaries, whose undergraduate studies were funded by the *University for All Program* (PROUNI) at the Catholic University of Pelotas. This was just the beginning of my academic career, but it allowed me to continue my studies, complete my Master's degree and now this doctoral work, all of which were completely public-funded.

Any attempt to thank the people who have helped me in my journey in the doctorate (which started in 2012) would be unfair if I were to disregard these political matters. I feel obliged to thank the Presidents Lula and Dilma, who were responsible for providing the poorest people in this country with better life opportunities. Also, living at the time of this coup has made me realize that social setbacks can always take place. That is why I am grateful to have had the opportunity of changing my life, while still fighting for the return of a former president directly elected by my people. In a democracy, it does not matter whether or not you personally like the government: you have to accept the decision of the majority. However, this decision was not respected when Dilma was ousted as Brazil's President. Although I had some concerns over Dilma's government policies, I strongly believe that deposing a president cannot be the solution for a political and economical crisis - especially her, who was in charge of manipulating the federal budget.

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[1]If you are a linguist, but still do not realize how powerful the so-called meaningless parts of a language are and how they can be encode messages linearly and non-linearly combined I suggest you look at the capital letters in each paragraph.

This doctoral research would not be possible without public funding which allowed me to move from my hometown to Campinas, where I have had countless opportunities ever since. At the State University of Campinas (UNICAMP), I have met incredible professors who I deeply thank for all the lessons and advice. I am extremely grateful to Bernadete Abaurre, who accepted to supervise my work, even when I decided to write it in English. I am indebted to her for being so patient and providing me with accurate feedback and constant encouragement; in short, for being such an incredible collaborator. Her honesty and courage to speak her mind will be always an example for me. I also owe special thanks to Filomena Sandalo and Plínio Barbosa, who were always interested in contributing to my professional growth and to my work, for their valuable comments in the previous version of my Dissertation on the occasion of my qualifying examination. I am grateful to Wilmar D'Angelis for his incredible and challenging classes, whose competence both as a linguist and an indigenous rights activist have changed the way I see myself as a linguist in a colonized third world country.

Even more, I have to thank my friends who I have made in Campinas. I could not finish this work without the lovely support of Ivana Ivo, whose friendship and loving care I am thankful for. I also would like to thank Dalson Eloy Almeida, Marcela Balbino and Tiago Balbino, Ana Amélia Calazans, Juliana and Francisco Meneses, Vinícius Castro, Aline Machado, Helder Cavalcanti and Priscila Tonelli who became my partners in life, Linguistics, politics and all other controversial subjects. I wish to thank Diego Jiquilin Ramirez, my first friend in Campinas, for having introduced me to UNICAMP and to life beyond it. I would particularly like to thank Jael Sânera Gonçalves, for her loyal friendship since we started our undergraduate studies, for being a partner in life and at work, for supporting me both in Pelotas and Campinas so many times.

My visit at the University of Amsterdam (UvA) was an incredible time of my journey as a doctoral student. It was the most challenging time of my life, because while living there I had to improve my language skills as quickly as possible to communicate and complete the work I was supposed to do. I am extremely grateful to Paul Boersma for accepting me as his visiting researcher and opening the doors to the university. I have learned a great deal from his suggestions to my work and his Statistics classes, which opened a new world to me that I want to explore further in the future. I am forever indebted to Silke Hamann for her kindness and patience, for accepting to co-supervise my work and for being such an incredible person to me. This work would not be possible without her encouragement and invaluable comments on the countless drafts I sent her. Silke's ability as a phonologist will always impact my career. I owe special thanks to my linguist friends in Amsterdam who made my stay so much happier: Amanda Post da Silveira, Ana Vogeley, George Nagamura and David Wang-Li. I had an unforgettable time with you, guys! Thank you for everything.

Eternally grateful for my friends and colleagues from São Paulo: Amanda Rassi, Armando Silveiro, Fernanda Reis, Guilherme Antônio Silva, Larissa Rinaldi, Luana Campos, Melanie Campilongo, Renata Camargo and Tatiane Macedo Costa. I would like to thank their support since we started working together. Yet, I cannot forget to mention Carina Fragozo and Andreia Rauber for being amazing friends, co-workers and supporters. During the doctoral journey, I was also inspired by former professors to whom I dedicate special thanks:

Ubiratã Kickhöfel Alves, Carmen Matzenauer, Aracy Ernst, Hilário Böhn, Glória Di Fanti, Susana Funk. I am ever so grateful to Armando Silveiro for supporting me in the last years of my doctorate, for encouraging me to complete this dissertation and helping me with his incredible ability as a proofreader.

*R*egarding the committee, I would like to thank Raquel Santos and Luiz Schwindt for the comments and valuable suggestions to my work. I owe special thanks to Luiz Schwindt for being a great phonologist interlocutor of mine, and for his ironic kindness which I appreciate. In addition to the committee, I wish to thank Márcia Zimmer, who believed in me since when I was an undergraduate student, for introducing me to Linguistics and especially for encouraging me to pursue my doctorate at UNICAMP. Last but not least, I would like to thank my parents Angela Madruga and Valdenir Madruga, my sister Lidiane and my newborn niece Sofia, who are the reason of my life. I must thank my old friends Delmar Mendes, Sabrina Costa, Joana Schneider, Bruno Kauss and Christian Hardtke, who were there for me in the best and worst moments and always listened to me when I needed them. Finally, I am thankful to Igor Henrique Gallo da Silva for his support and companionship in the last two years.

# ABSTRACT

This study analyzes pre-stressed vowels that undergo vowel harmony in Brazilian Portuguese. Based on the analysis of the *Gaucho* and *Baiano* dialects, this work provides an acoustic description of pre-stressed and stressed vowels involved in vowel harmony. This subject is relevant because of the limited amount of acoustic-phonetic studies of this phenomenon in the literature, particularly of the role of low vowels in triggering vowel harmony, as well as the role of adjacent consonants. This study investigates the harmony patterns found by Abaurre-Gnerre (1981), a phenomenon which is hypothesized in this research as a process of harmony governed by the feature [ATR]. For this purpose, we developed a reading experiment with six participants (3 men and 3 women) from each dialect. The acoustic-phonetic analysis of the vowels was based on the measurements of the first and second formants (F1 and F2) of the pre-vowel and stressed vowels. From the acoustic description of the whole set of Brazilian Portuguese vowels, we found that the pre-stressed vowel harmony targets /e/ and /o/ are affected primarily by the low vowels /ɛ, a, ɔ/, which can be considered the triggers. From the experimental results, we developed a method called Vowel Threshold, which is based on measurements of F1 and F2 to estimate thresholds of vowel categories in the acoustic space and therefore map the movements of raising, lowering, vowel-fronting and vowel-backing in vowel production. This method reduces the values of F1 and F2 to a scale that has zero as the reference point, which would be considered the expected value for the token of a vowel if there were no biases introduced by the V-to-V coarticulation, by the intervening consonants or other process related to speech. With this measurement, a critical value is stipulated to determine whether a vowel has undergone intra-category or inter-category movements. The results of the analysis of the Vowel Threshold measurements showed that the vowels /e, o/ of all subjects do not tend to be raised to [i, u], rather they are lowered to [ɛ, ɔ] by speakers of both the *Gaucho* and *Baiano* dialects. Moreover, the experimental results show that: (1) the preceding consonants have no effect of lowering or raising in the vowels /e, o/; (2) the intervening sounding consonants are transparent to the lowering in the two dialects, while the obstruents appear to be opaque in the *Gaucho* dialect; (3) there is a dissimilatory process in *Baiano* that does not seem to be a disharmony, but indicates a tendency for intra-category lowering, motivated by the disagreement in [back] of the target and the trigger. The work also presents a re-analysis of the Bisol (1981) and Barbosa da Silva (1989) corpora in order to examine the process of [+high] harmony verified by those authors to discuss the supremacy of this sort of harmony in Brazilian Portuguese in contrast with the experimental results found in this work. Finally, this study shows that the BP [ATR] harmony seems to be the active harmony in Brazilian Portuguese; and as evidence for this, arguments from phonology-morphology interaction, vowel contrastiveness, secondary stress assignment, and orthography biasing in the analysis of vowel harmony are brought into the discussion. It is argued that there is a consonantal blocking effect of [+high] harmony motivated by certain preceding consonants to the target vowels. Evidence of [+high] harmony avoidance is also found in the sociolinguistic literature that shows a decreasing application of such harmonization according to the age and education of the speakers.

**Keywords:** vowel harmony; [ATR] harmony; pre-stressed vowels; Brazilian Portuguese

# RESUMO

Este trabalho apresenta uma análise das vogais pretônicas alvos de harmonia vocálica no português brasileiro. A partir da análise dos dialetos Gaúcho e Baiano, o trabalho descreve acusticamente as vogais pretônicas e tônicas envolvidas no processo de harmonia. O interesse pelo tema decorre da limitada abordagem fonético-acústica do fenômeno na literatura da área, sobretudo para investigar o papel de vogais baixas no gatilho da harmonia, assim como o papel das consoantes adjacentes. O trabalho aprofunda a observação de harmonia com vogais baixas constatada por Abaurre-Gnerre (1981), fenômeno defendido como um processo de harmonia governado pelo traço [ATR]. Para isso, desenvolveu-se um experimento que contou com a participação de seis sujeitos (3 homens e 3 mulheres) de cada dialeto. A análise fonético-acústica das vogais partiu das medidas do primeiro e segundo formantes (F1 e F2) das vogais acentuadas e das pretônicas. A partir da descrição acústica das vogais do português brasileiro, investigou-se em específico o comportamento das vogais pretônicas /e/ e /o/, alvos do processo de harmonia, constatando-se experimentalmente que a influência coarticulatória principal advém das vogais tônicas baixas /ɛ, a, ɔ/ que agem como gatilho da harmonização. Partindo-se, então, dos resultados experimentais, o trabalho desenvolve uma metodologia chamada de Vowel Threshold baseada nas medidas dos parâmetros acústicos F1 e F2. Vowel Threshold tem como objetivo estimar limiares de categorias vocálicas no espaço acústico e desta forma mapear os movimentos de alçamento e abaixamento, anteriorização e posteriorização na produção de uma vogal. Esse método reduz os valores de F1 e F2 a uma escala que tem como ponto de referência o valor zero, que seria considerado o valor esperado para o token de uma vogal se não houvesse vieses introduzidos pela coarticulação V-V, pelas consoantes intervenientes ou outro processo relacionado à fala. Com essa medida, estipula-se um valor crítico que determina se uma vogal sofreu movimentos intra ou inter categoria. Os resultados da análise das medidas de Vowel Threshold evidenciaram que as vogais /e, o/ de todos os sujeitos não tendem ao alçamento para [i, u], mas são abaixadas para [ɛ, ɔ] pelos falantes tanto do dialeto Gaucho quando do dialeto Baiano, embora haja variação intra e inter-falantes. Os resultados experimentais evidenciam ainda: (1) consoantes precedentes não possuem efeito de abaixamento ou de alçamento nas vogais /e, o/; (2) as consoantes soantes intervenientes são transparentes ao abaixamento nos dois dialetos, enquanto as obstruintes parecem ser opacas no dialeto Gaucho; (3) há um processo dissimilátorio no dialeto Baiano que não se configura como desarmonia, mas indica uma tendência a abaixamento intra-categoria, motivado pelo desarmonia de posterioridade entre o alvo e o gatilho. O trabalho ainda apresenta uma re-análise dos corpora de Bisol (1981) e Barbosa da Silva (1989) de modo a verificar o processo de harmonia de [+alto] constatado por essas autoras para discutir a supremacia da harmonia de altura no português brasileiro, contrastando com os resultados experimentais encontrados. Por fim, o trabalho evidencia que a harmonia de [ATR] parece ser o processo ativo do português brasileiro; e como evidência para isso, são trazidos argumentos da interação fonologia-morfologia, da contrastividade de vogais, da atribuição do acento secundário e do enviesamento introduzido pela ortografia nas análises do processo harmonia vocálica. Argumenta-se também que há um bloqueio da harmonia de [+alto] cuja motivação parece estar nas presença das oclusivas coronais /t, d/ precedentes às vogais-alvo. Traz-se evidência da literatura de que a harmonia de [+alto] é evitada por razões linguísticas, mas também sociolinguísticas, com resultados indicando um uso decrescente da harmonia de altura considerandos-se a idade e a escolaridade dos falantes.



**Palavras-chave:** harmonia vocálica; harmonia de [ATR]; vogais pré-tônicas; português brasileiro

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# 1 INTRODUCTION

This dissertation addresses the behavior of pre-stressed vowels in Brazilian Portuguese (BP). The research objective is to determine the behavior of vowel harmony (VH) that reaches the upper-mid subset of pre-stressed vowels of the language. In order to understand the importance of phonetics–phonology interplay in this phenomenon, this chapter introduces the discussion of vowel coarticulation and VH. It also introduces the reader to the two BP VH systems: the first is based on the value of [High] and the second on the value of [ATR][2]. Recognizing that there is a strong relationship between these VH systems, this research focuses upon the behavior of the pre-stressed VH targets – which are the mid-high /e/ and /o/ – in order to understand the influence of the vowel triggers on the height of the targets, as well as the role of the target's surrounding consonants.

Pre-stressed mid-vowel shifts were first observed by Silveira (1939, cited by Camara Jr., 1977; Silva Neto, 1977), although more consistent and frequent studies of VH only started consistently in the 1980s. Silveira pointed out that /e/ and /o/ tend to become [i] and [u], followed by the high vowel, in a contiguous syllable. The author claimed that the height VH rule is a remnant of an earlier rule that could be tracked from the 15th and 16th centuries (Silveira 1939 apud Naro 1971). This observation led Bisol (1981) to conduct a study of BP vowel harmonization within a generative and Variation Theory approach. In a sociolinguistic framework, she claims that BP is a height harmony language triggered by feature [+high] of the nearest vowel, as in the examples below:

(1) Bisol (1981):

| | | | |
|---|---|---|---|
| a. | /peɾigo/ | p**i**ˈɾ**i**gʊ | danger |
| b. | /foɾmiga/ | f**u**ɾˈm**i**gɐ | ant |
| c. | /peɾuka/ | p**i**ˈɾ**u**kɐ | wig |

Nascentes (1953) divides the dialects spoken in Brazil into two main groups according to the realization of the pre-stressed vowels. The author argues that southern dialects can be characterized by the realization of the pre-stress vowels as the mid-high vowels [e, o], whereas northern dialects, which include northeastern dialects, tend to produce these vowels

[2] The [ATR] feature (Advanced Tongue Root) is used to describe VH systems, especially in many West African languages. This feature was also used to describe distinctions between tense and lax vowels in Romance languages (for discussion, see Calabrese, 2008).

as mid-low [ɛ, ɔ]. Further investigations into this revealed that the behavior of such realizations, both in southern and northern dialects, could be explained by VH. In the same year as Bisol, Abaurre-Gnerre (1981) attested the existence of a low VH in one of the southeastern Brazilian dialects, namely Capixaba, spoken in the state of Espírito Santo. She pointed out that pre-stressed vowels undergo a lowering process when a low vowel is in a stressed position. She showed that pre-stressed /e, o/ undergo a cyclic low-vowel harmonization.

(2) Abaurre-Gnerre (1981, p. 27):

| | | | |
|---|---|---|---|
| a. | /peɾeɾɛka/ | pɛɾɛˈɾɛkɐ | tree frog |
| b. | /poɾoɾɔka/ | pɔɾɔˈɾɔkɐ | pororoca |
| c. | /robɛɾto/ | ɦɔˈbɛɾtʊ | Robert.PR |
| d. | /kolɛga/ | kɔˈlɛgɐ | colleague |

Similar to the studies of the northeastern dialects, Barbosa da Silva (1989) studied the presence of a low vowel in a pre-stressed position within the Variation Theory approach (Labov, 1972). Unlike Bisol, this author observed a ternary variation of /e/ and /o/ and proposed for this a series of rules to account for the alternations, such as [i ~ e ~ ɛ] and [u ~ o ~ ɔ]. She pointed out that the vowels are sensitive to the phonological height of the following vowel, but the alternation is considered highly sociolinguistically motivated. The literature on VH considers then that the northeastern region uses both low and high harmony (e.g., ***tɔmate*** 'tomato' and ***pirigo*** 'danger'), whereas southern dialects present only high-vowel agreement (e.g., ***piruca*** 'wig'). In other words, it could be said that those dialects would have two sorts of harmonization that display opposite behaviors: whereas one raises vowels, the other lowers vowels.

This work proposes that pre-stressed vowel targets of harmony present only a lowering tendency, which is interpreted as a result of [ATR] assimilation of the right adjacent vowel. For such purposes, this work analyses two varieties of BP: the first is the Gaucho dialect (henceforth GA), spoken in the state of Rio Grande do Sul, which has a population of approximately 11 million people and is the fifth-most populous state in Brazil; the second dialectal variety is Baiano (henceforth BA), spoken in Bahia, which is a state with approximately 15 million people (IBGE, 2010). The choice of the dialects was guided by the phonological literature on VH, which was the most representative study of VH with data collected from a specific dialect. Hence, Bisol (1981) and Barbosa da Silva (1989) represent the two main studies dedicated to determining the behavior of pre-stressed vowels in BP.

## 1.1 Motivation

Most of the studies of BP/VH have claimed the existence of high-to-high agreement in southern dialects (Alves, 2008; Battisti, 1993; Bisol 1981, 1989; Bortoni et al., 1992; Callou et al., 2003; Casagrande, 2004; Freitas, 2009; Oliveira, 1991; Schwindt, 1995, 1997, 2002; Silva, 2012; Viegas, 1987). For northeastern and southern dialects there is no consensus: some authors claim the existence of a general pervasive pre-stressed lowering, that is, harmony is not on the basis of lowering (Guimarães, 2007; Lee & Oliveira, 2003; Nascentes, 1953), others assert that there is, in fact, a low vowel harmonization for such dialects (Abaurre & Sandalo, 2009; Araújo, 2007; Bohn, 2014; Hora & Vogeley, 2013; Kenstowicz & Sandalo, 2016; Lee, 2006). Schwindt (2002) and Schwindt and Collischon (2004) make a distinction between categorical harmony, applied to verbs (e.g., f**e**rir > f**i**ro) versus variable harmony (e.g., b**o**nito ~ bonito), which occurs in nouns in most cases. The behavior of verbs will not be the main focus in this work, but it is worth noting the existence of verb harmony.

The main claim about pre-stressed /ɛ/ and /ɔ/ in many Northern and Northeastern dialects is related to a lowering process (Lee & Oliveira, 2003; Lee, 2006) that is not always triggered by harmony. Pacheco et al. (2013) assert that pre-stressed low vowels are dialect-characteristic, which cannot be explained by VH. It should be noted, however, that arguing that pre-stressed low vowels are characteristic of one dialect does not provide any explanations about that dialect, although it has certain observational value. Six main reasons to conduct this doctoral research are as follows:

(3)

a. unattested agreement of low-to-low vowels in southern dialects;
b. height harmony supremacy in the language;
c. lack of experimental studies on VH;
d. the role of morphology in triggering or blocking harmony;
e. the effect of adjacent consonants on the VH targets; and
f. the phonetic grounds of vowel-to-vowel assimilation.

The unattested low-low vowel patterns triggered by VH have led us to conduct an experiment to inquire how V-to-V coarticulation interacts with VH. Since there are low vowels in pre-stressed syllables in the language that go to the surface governed by the word-formation process, I designed an experiment to investigate whether VH targets would be affected in their phonetic height triggered exclusively by coarticulation with the next vowel. This issue, then, had led me to the second motivation of the work: to challenge the supremacy of height harmony.

Height harmony has been attested to in all dialects spoken in Brazil, but there are sociolinguistic studies showing that this phenomenon has been decreasing in the language. The main problem of conceiving such harmony (among others discussed in Chapter 7), is that dialects considered to be [ATR]-oriented also are described as having height harmony triggered by [+high]. This is controversial since the BP subset of triggers for one or another harmony is opposite in terms of the value of the feature [High]. Logically, it would be impossible for a language to present opposite vowel harmonization processes within the same set of targets and triggers. These controversial assumptions made by the literature motivated us to investigate different dialects attested to be harmonic systems based on [ATR] or [High]. This work argues that BP is [ATR]-oriented, regardless of the dialect (discussed in Chapter 7).

Due to the lack of experimental studies on VH, the first part of this work presents results of the experiment designed to investigate pre-stressed vowel behavior. The experiment is influenced by Sandalo (2012) and Kenstowicz and Sandalo (2016), whose work focused on vowel reduction and VH. The experiment (described in Chapter 3) was conducted to determine the production of the pre-stressed vowels of the language, in order to investigate how the behavior of targets can be predicted by the following vowel and the consonantal environment. Further, the pre-stressed vowels, and their relationship with the immediately following stressed ones, will be described acoustically. Therefore, our interest is to enquire how speakers from different dialect backgrounds reproduce VH in novel words. To an extent, the goal is to look at the applicability of VH, expecting to find that speakers show the patterns of VH characteristic of their dialects.

The second part of this work discusses the phonological behavior of the height harmony, defended by the literature, and presents arguments in the defense of an active [ATR] VH in BP. For such purposes, a reanalysis of the corpora of Bisol and Barbosa da Silva is made in order to track the authors' steps with new statistical analysis to check whether the same or new patterns can be found in the data. Analysis of the corpora will shed light on the discussion about the role of height harmony in both dialects, as well as its role in the phonology of the language.

These two parts of the analysis are crucial to delimiting the empirical phenomenon that this study aims to cover. Firstly, I assume that VH is not only a product of coarticulation[3], but also a phonological phenomenon with phonetic grounds. According to Ohala (1994), VH is essentially a product of an earlier phonetic process involving vowel-to-vowel assimilation; a fossilized phenomenon of coarticulation. I depart from this concept, assuming its phonetic basis, but also assuming that VH may be independent, triggered and delimited by a phonological grammar. Its relative independence from phonetics can be seen in many languages in which VH is completely governed by word-formation rules. According to Nevins (2005), these languages are characterized by the following: (1) affixes undergo the harmonization process (i.e., affixes have harmonic allomorph); and (2) the combination of a lexical word plus affixes is a consistent grammatical cue for speakers to perceive harmonic alternations, which are not supposed to be perceived when harmony occurs root-internally. The author asserts that speakers do not seem to store contrasts of non-alternating roots, even though they are subject to coarticulation (Nevins, 2005, p. 14). Considering that BP VH in nouns seems to occur root-internally (arguments for that are presented in Chapter 7), the process is supposed to be influenced by vowel adjacency within the root and this is one of the reasons for investigating BP/VH experimentally.

This research is therefore conducted while assuming the role of vowel-to-vowel coarticulatory effects, whose assimilation constraints are delimited by the internal organization of the word. In this way, the dissertation is a unification of phonetic effects and phonological organization. For this purpose, the experiment carried out in this research not only determined vowel-to-vowel effects but also investigated VH applicability for novel words. If speakers from different varieties of BP have their own knowledge of their VH, they are expected to reproduce the same pattern for novel words in the language.

### 1.2 Phonetics–Phonology Interplay

Phonetics and phonology have been considered to be different fields of study since the Prague School (Trubetzkoy, 1931[2001]), but it is often difficult to determine which one explains the origin of some phonological phenomena most clearly. Many phonological phenomena have been described as remnants of earlier phonetic processes, which is the case of VH (Ohala, 1994), seen as a product of vowel-to-vowel assimilation. Öhman (1966) pointed out that vowels and consonants have a certain degree of independence in language production, which allows them to influence each other discontinuously. In this view,

[3] For coarticulation, see Kozhevnikov and Chistovich, 1965; Öhman, 1966; Kent and Minifie, 1977

coarticulatory effects may occur where the articulatory requirements for an ongoing gesture do not conflict with those for adjacent gestures (Öhman, 1966; Recasens, 1985). In other words, in a CVCV sequence, for instance, there is more influence from C-to-C and V-to-V than from C-to-V and V-to-C patterns.

These findings were supportive of non-linear approaches to phonology, such as Autosegmental Phonology, which claimed independence between consonants and vowels in phonological strings, that is, such independence allows consonants and vowels to extend beyond individual segments (Goldsmith, 1976). These approaches were indeed successful in explaining VH systems (Archangeli & Pulleyblank, 1994; Clements, 1977, 1981; Halle & Vergnaud, 1978; Kiparsky, 1981), providing insights on notions of anchor, feature bearing unit, projections and harmonic vowels. Phonologists have pointed out that, as VH exists in a language, it cannot be considered a product of coarticulation, since it is governed by phonological rules; that is, it is part of the grammar. However, phonetic detail has been considered part of the grammar, since speakers usually apply patterns that are characteristics of their language, but are not considered strictly phonological (e.g., allophonic innovations). Researchers have claimed that speech is characterized by the fact that consonants are superimposed in a V-V cycle (Fowler, 1988), which justifies the usage of the term *coproduction* (instead of coarticulation). In the Articulatory Phonology (AP) model, Browman and Goldstein (1990) also propose that speech can be defined by a series of overlapping gestures given by the activation of what they call tract variables, such as tongue body location (TBL) and tongue body constriction degree (TBCD), for instance (Byrd, 1996; Fowler & Saltzman, 1993; Tjaden, 1999). Therefore, it is worth investigating VH, determining how one vowel can anticipate the next one in its spectral characteristics (anticipatory coarticulation), or how one vowel is affected by the previous one (perseveratory coarticulation)[4]. It is assumed that these phonetic details are used by the speakers in their speech production and perception. They are considered also as part of the grammar in which structural properties are responsible to delimit the phonetic knowledge.

[4]This is an open issue regarding how segments are **coproduced**. In the latter case, one might assume that vowels are autonomous, with no need to assume assimilation (for the notion of coproduction, see Barbosa & Madureira 2015; Browman & Goldstein 1989; Öhman 1966; Rodrigues 2010).

### 1.3 Aim and Objectives

As VH may be interpreted as highly influenced by coarticulation among the vowels of a certain domain, the aim of this work is:

(1) to examine and determine the behavior of Brazilian Portuguese pre-stressed vowels that undergo VH.

This research goal will be achieved through four specific objectives:

(1) describing acoustically the pre-stressed and stressed vowels involved in vowel harmony of Baiano and Gaucho dialects according to certain consonantal environments;

(2) developing a method of predicting vowel thresholds based on acoustic measurements to estimate articulatory movements of the tongue, such as fronting/backing and lowering/raising;

(3) reanalyzing the data of Bisol (1981) and Barbosa da Silva (1989) to investigate the pre-stressed vowel co-occurrence patterns with the preceding and following consonants and, particularly, with the immediately following vowel; and

(4) analyzing the phonology of the pre-stressed vowel targets in Brazilian Portuguese, providing arguments to delimit the extent of vowel harmony in the language.

### 1.4 Structure of the Dissertation

This dissertation will be structured in line with the four specific objectives previously outlined. Chapter 2 will introduce the main aspects of VH in the world's languages, including harmonic features, locality, directionality, domain, and recursivity. These notions will be important for the reader to understand how these typologically attested characteristics may be seen in BP VH, which will be introduced and discussed. The phonology of BP VH and the main approaches to the phenomenon will also be discussed.

Chapter 3 presents the results of an experiment designed to examine the acoustic characteristics of the pre-stressed vowel and their relationship with the stressed vowels in Baiano (BA) and Gaucho (GA) dialects. In this chapter, the role of the consonants on the acoustic parameters of the pre-stressed vowels (C-to-V and V-to-C patterns) as well the relationship between pre-stressed and the stressed vowel in V-to-V sequences are investigated. Guided by the hypothesis that obstruents or sonorants may be opaque or transparent to vowel-to-vowel assimilation (Kenstowicz & Sandalo, 2016; Sandalo et al., 2013; Schwindt, 2002; among others), the role of the intervenient consonantal class is also addressed.

Chapter 4 is dedicated to investigating the behavior of the VH targets /e/ and /o/. In this chapter, all the patterns investigated (i.e. V-to-V, C-to-V, and V-to-C) are discussed, with a focus on the targets. Such analysis is necessary as the influence of the consonants and vowels in the subset of pre-stressed vowels is not the same as in the target vowels. It was thereby possible to make predictions about the behavior of the targets, verifying that those vowels do not tend to be raised in any context, as the literature has claimed, but only lowered in context of the stressed /ɛ, a, ɔ/. These findings support our proposal that BP is an [ATR] harmony system, with seven vowels in the pre-stressed position, regardless of the dialect. The main finding was that northeastern and southern dialects show the same sort of harmony. A surprisingly dissimilatory pattern was also observed in BA. The target /e/ presented a trend of being lowered followed by a high vowel /u/, while the target /o/ tended to be lowered followed by the high vowel /i/. This is interesting for two reasons: (1) the dialect-specific dissimilatory effect and (2) the requirement of disagreement of [back] between the target and the trigger of the dissimilation.

In order to achieve the fourth objective, Chapter 5 develops a method to estimate vowel thresholds. The measure proposed aims at delimiting vowel boundaries based on their acoustic characteristics, estimating if a vowel target of the harmony process has changed its category in favor of the category of the trigger, or whether its spectral characteristics still reflect the variation within the same category to which the target belongs. The measure, *Vowel Threshold*, is presented to shed light on how vowels move themselves in the front-back axis as well in the close-open dimension influenced by surrounding vowels. The method assumes that all vowels have a prototypical value to what they attract if no bias is introduced. However, as speech is not a linear sequence of segments, vowels tend to be moved away from this point until crossing a critical value that defines a category shift influenced by other vowels. Based on this method, the results of the intra and inter-speakers analysis for the VH targets in both dialects are presented.

In Chapter 6, I reanalyze the two corpora yielded in the 1980s by Bisol and Barbosa da Silva in order to investigate the authors' findings with additional statistical methods. Basically, the datasets are analyzed considering the co-occurrence patterns that can be found in BA and GA dialects. The results revealed that the association between the preceding consonants and pre-stressed vowels reflects universal patterns found by MacNeilage (1998) and MacNeilage and Davis (1990, 2000)[5]. To the role of trigger vowels, that is, the V-to-V co-occurrence patterns may be explained by the [High] in GA and by [High] and [ATR] in BA, which suggests that the Bisol and Barbosa da Silva were partially correct with their generalizations. However, considering the role of the consonants that is supposed to explain height disagreement, some occurrences of high vowels followed by low vowels in both dialects were found, suggesting that height harmony is not as strong a characteristic of the language as claimed. This is confirmed by the frequency of non-high pre-stressed vowels, which are around four times more frequent than high vowels in both GA and BA.

Chapter 7 offers a discussion of the assumptions of VH in BP. In this chapter, a series of facts about BP phonology is discussed to defend an active [ATR] harmony instead of [+high] harmonization. The [ATR] VH is delimited and contrasted with the so-called [+high] harmony, whose avoidance may be found by the interaction between phonology–morphology, consonantal blocking effects and sociolinguistic motivations. The orthographic bias introduced to the analysis on the choice of an underlying form to which VH is imposed is also discussed. Finally, the examination of the behavior of [+high] and [ATR] harmony led me to conclude that there are more linguistic reasons to consider that BP speakers have an [ATR] harmony preference in their grammar over the height harmony system.

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[5] According to these authors, languages express phylogenetic CV patterns that can be found ontogenetically in the babbling. The "content" is placed into syllable structures "frames", which follow certain combinatorial regularities. The *Frame-then-Content Theory* of speech evolution makes this assumption.

# 2 THE PHONOLOGY OF VOWEL HARMONY IN THE WORLD'S LANGUAGES

## 2.1 Introduction

This chapter presents a general discussion about VH in the world's languages. It describes how VH is characterized, based on the languages traditionally studied. It also discusses the behavior of BP/VH, the dialectal differences of the features involved, the relationship between target and trigger vowels, domain, locality, directionality and recursion. This discussion is necessary because BP/VH shows a special behavior in terms of harmonizing features, target-trigger asymmetry and morphological sensitivity between the two dialects under study here. As is well known in canonical harmonic languages (such as Turkish, Hungarian, and Swedish), VH is triggered by the addition of a morpheme to the root, while BP/VH is driven by the quality of the next vowel of the trigger subset. This raises a number of questions about the phenomenon, such as the triggering aspect of harmony, the non-occurrence of harmony in its phonological context, and the role of surrounding consonants.

In order to discuss these issues, the following are presented: a characterization of VH in both dialects; the subset of target and trigger vowels and the phonological processes that occur in the same context reached by VH; the interaction between vowels and consonants; and the interaction of morphology and VH. The chapter begins by presenting the characteristics of VH, using particular languages where relevant.

## 2.2 Vowel Harmony

Many researchers have given definitions for VH, supported both by phonetic and phonological claims. It is only one process of a large number of assimilation phenomena – such as nasal harmony, consonant-to-vowel assimilation, and tone assimilation – where some characteristics of one segment are spread to others.

As it was discussed in the Introduction, VH might be seen as a fossilized process of a phonetic vowel-to-vowel assimilation (Ohala, 1994) or an agreement requirement of some phonetic features, such as backness, height or rounding in a specific domain (Benus et al., 2003). It is, in fact, a process grounded on phonetics, in which some phonetic property of the participants in the harmonization process must agree and then they have to be converted to phonological abstract values. Krämer (2003, p. 3) defines VH as the phenomenon where potentially all vowels in adjacent moras or syllables within a domain systematically agree with one or more articulatory features.

The fact that VH is defined by having a domain, generally a prosodic word, might indicate that this phenomenon is phonologically defined. It rarely crosses word boundaries and, in many languages, VH is expressed in affixes that bear a harmonic vowel presented in the root in which they will be attached (Krämer, 2003; Nevins, 2005, 2010).

### 2.3 Vowel Harmony in the Word's Languages

### 2.4 Harmonic Features

In the world's languages, harmony can affect vowel systems in a phonetic dimension, such as posteriority (or palatality, as assumed by the literature on VH), height, or rounding. In terms of distinctive features, this means the dimension affected refers to the features [back], [high], or [round]. Krämer (2003, p. 17) presents a set of languages in which he attested that VH systems are triggered by one or more features.

(4)

Table 1. Vowel Harmony Systems and Feature Combinations

| Types Of Vowel Harmony | Feature Combinations | Language |
|---|---|---|
| Palatal or backness harmony | [back] | Finish |
| Labial or rounding harmony | [round] | Warlpiri |
| Height harmony | [high] | Shona |
| Tongue root harmony | [ATR] or [RTR] | Yoruba, Brazilian Portuguese |
| Backness and roundness | [back]&[round] | Turkish, Eastern Cheremis |
| Backness and height | [back]&[high] | Yucatec Maya |
| Backness and ATR/RTR | [back]&[ATR/RTR] | Kalabari |
| Height harmony and ATR/RTR | [high]&[ATR/RTR] | Kimatuumbi |

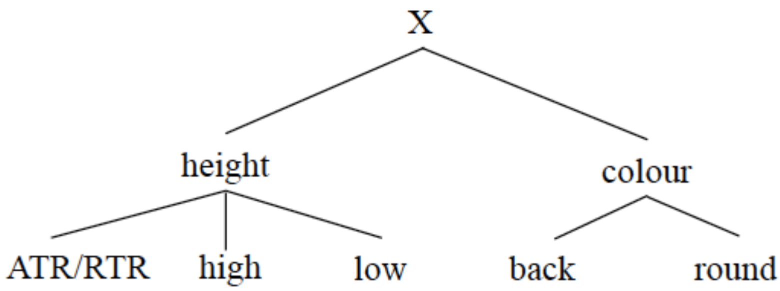
Adapted from Krämer (2003, p. 17).

The trend in languages whose harmony is consistent with more than one distinctive feature is to present combinations between [back]&[round] and [height]&[ATR/RTR]. Krämer (2003) asserts that the co-occurrence of height and ATR/RTR is more natural, since it is more natural for high vowels to present advanced tongue root, while low vowels have retracted tongue root. The articulatory gestures involved in these cases are not opposite, as has been the case for low-vowel combinations plus advanced tongue root and high vowels plus retracted tongue root. The interaction between these gestures is easier, since vowels [+ATR] are easily [+high] because it seems more natural to combine the advancement of the root with jaw raising. Therefore, it is extremely likely that harmonic systems can provide the combination of these two features.

In order to explain why some harmony systems present combinations of only some features and not others, that is, why languages avoid opposite features, Goad (1993) and

Odden (1996), within Feature Geometry, propose that vowels may be grouped into two main categories of height and color, in which specific features of these properties are terminal nodes. This relationship between vowel features is seen below.

(5)




From the representation above, it can be concluded that phonological processes are more frequently expected to reach features dominated by the same node. Thus, a system may be affected by phonological processes that involve the whole node or only one feature attached to it. There is a problem with this representation when trying to explain harmonic systems that involve a combination of features, but the harmony of a feature blocks or does not affect the harmony of others. As noted by Krämer (2003), in Turkish, a language with backness and rounding harmony, backness harmony applies even if rounding is blocked.

Harmonic features are important to an understanding of how harmony works in natural languages and what phonetic properties can be used in categorical phonological processes. Moreover, it can be seen that most vowel inventories have back plus round combinations, and front plus non-rounded vowels; thus, one might infer that the combinations of features used in harmonic languages tend to preserve the unmarked characteristic of vowel inventories. In other words, it should be noted that languages tend to respect features that occur distinctively in their vowel inventories.

### 2.4.1 Domain

The VH domain is usually the prosodic word (van der Hulst & van Weijer, 1995). Harmonic systems tend to adhere to word boundaries, but not always to morphological limits. However, there are cases in which harmony domains may be morphological or syntactic. In BP, the failure of harmony to occur across words allows us to assume the prosodic word as the domain of BP VH. The word concept is much discussed in the literature, since there are various processes that affect word boundaries by modifying their internal structures, such as liaison and nasal harmony.

The height harmony in BP seem also sensitive to morphology and there are cases where some morphological limits seem to block harmony. In general, only unstressed vowels within the root seem to undergo height harmony; affixes do not trigger harmony even when they bear high vowels, but the trigger behavior is defined by the morphological structure of the word. Thus, if an affix is adjoined to the root, harmony may occur, but if it is attached to the word, VH is then blocked. This fact suggests that BP height harmony would be root-controlled, a system in which the target vowels are controlled by the stressed vowel within the root (see discussion in Chapter 7).

The two dialects under study here have distinctive behaviors for prefixes. While in GA, prefixes tend to remain unchanged, affixes in BA are strongly affected by the quality of the root vowel. For the same word structure, the harmonic form *[ɦitʃiɾa] is rare and ungrammatical for GA; however, in BA, this form is highly acceptable and productive. Furthermore, in BA, the prefix *re-* alternates its vowel to [ɛ] when it is followed by a low or mid-low vowel. This difference fosters the discussion about the role of morphological structure in harmony.

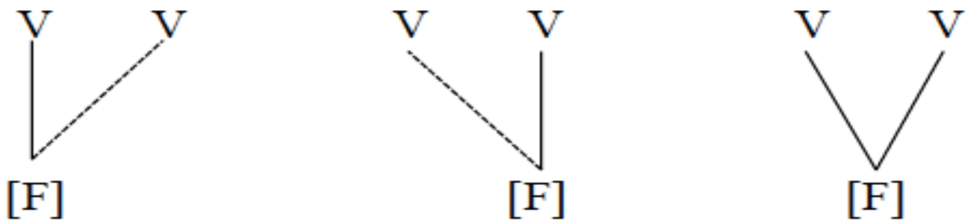
Considering the prosodic word as the harmonic domain, it follows that the process applies to stems forming a prosodic word with the base, and do not apply to affixes which are prosodic words themselves (van der Hulst & van Weijer, 1995). The existence of disharmonic affixes within prosodic words seems to indicate that prosodic words *per se* are not the domain of harmony. The question of the domain of harmony is open, but it is known that there are rare cases in which it exceeds the limits of the prosodic word. This indicates that harmony is a process sensitive to word structure. What is subject to debate is the status of affixes that block harmony and those that allow it to occur.

### 2.4.2 Directionality

The understanding of VH as an assimilation process requires a definition of the direction of the assimilatory movement – leftward or rightward. The question that arises from the directionality is whether a vowel must spread a harmonic feature [F] to another vowel or whether they only need to share the respective feature [F], without any direction requirement. Feature Geometry can formalize these two directions. The representation below captures both progressive and regressive assimilations (6a–b, respectively) as well as the sharing feature approach (6c).

(6)

(a) (b) (c)




A non-directional view is also a possible interpretation of harmony. Finley and Badecker (2008) argue that Turkish – a well-known left-to-right harmonic language – may be described in terms of a non-directional stem-outward system because Turkish is a suffixing-only language. According to the authors, this interpretation of Turkish VH is adequate because in this system the trigger vowel is always within the suffix. In non-directional systems, vowel features spread outward from the trigger vowel, regardless of the direction of spreading. However, it seems that there is a bias towards right-to-left harmony (Hyman, 2002). In a language with affixes that trigger VH, the suffixes spreading to the roots do not necessarily involve harmony from prefixes to roots; on the contrary, it is more common for languages to spread only from suffixes to roots (right to left). The spreading from prefixes to roots implies suffix triggers (Finley & Badecker, 2008).

In psycholinguistic terms, a regressive process (right to left) is preferable because it anticipates the linguistic information in the phonological string. Regressive assimilations can be seen in many languages in different sorts of process, such as nasal harmony, consonant harmony, consonant-to-vowel assimilation. As an anticipatory cognitive process, it is expected that languages show right-to-left VH more frequently than non-directional or left-to-right assimilations, as anticipatory segmental assimilations are unmarked. In that case, one might consider right-to-left harmony as a default of directionality in harmonic language systems.

### 2.4.3 Locality and Recursivity

Locality is a distance measurement that determines the possible distance between triggers and targets. According to van der Hulst and van de Weijer (1995), it is a constraint that governs all linguistic representations. Assuming the notion of locality implies that vowels between the trigger and the target may be opaque or transparent to harmony. If they are opaque, harmony will not apply, and if transparent, harmony will apply regardless of the intervening vowel. However, many researchers have assumed that harmony skips transparent vowels (Anderson, 1980; Kiparsky, 1981; Steriade, 1987; Vago, 1988) and locality is not a relevant concept for VH. Krämer (2003, p. 29) points out that this type of analysis does not take into account that many phonological feature assimilations are strictly local (e.g., consonantal assimilation), and VH respects some restrictions on phonological distance.

Nevins (2010) suggests that VH is just one example of how humans calculate locality. Taking this into account, the author proposes the minimal search principle. This principle refers to VH as an emergent computational operation whose purpose is to provide a solution to the target vowels needs, which start a search for the closest feature-source. According to Nevins' view, VH is target-centric and not the traditional trigger-centric as traditionally stated. Despite the debate in the literature about the concept of "locality", one might consider that VH can be described as local or strict and non-local or non-strict. In non-local relations, what must be understood is how vowels participate in harmonic systems and what features are borne by vowels that allow them to participate in harmony or to block assimilation.

The problem imposed by locality is to determine how far VH can be spread. Thus, the question is: can VH occur only once or can the harmonic feature be spread up to a critical phonological edge? Many harmonic languages show that recursivity is productive and that it is strongly sensitive to morphology. Regarding this point, van der Hulst and van der Weijer (1995) suggest that VH can interact in two ways: (a) cyclically, by interacting with word-formation rules; and (b) post-cyclically, after word-formation rules, therefore non-cyclically. The issue that arises is whether cyclic harmony applies only when harmony establishes local relations – in case it affects all local vowels iteratively – or if it can skip transparent vowels through the harmonic domain in order to affect all the target vowels within the prosodic word. Cyclic harmony could be represented as follows: in (7a) all vowels participate in harmonization and in (7b) one of the vowels is transparent, but the leftmost ones undergo VH cyclically.

(7)

(a) (b)


The question involving non-harmonized vowels is the status of their transparency or opacity. Calabrese (1995), and Halle, Vaux, and Wolfe (2000) assume that VH applies only to segments that are contrastively specified for the harmonic feature within the harmonic domain. In such cases, any transparent vowel could be placed between triggers and targets because they are the only ones specified contrastively, and the transparent vowel does not bear the harmonic feature. The issue about transparent and opaque vowels is important because it preserves, in a certain way, the notion of locality.

It seems that cyclic harmony is more common in strict VH systems than in non-strict ones. A possible explanation is the fact that assimilations reach all the possible targets, as can be seen, for instance, in nasal harmony, which reaches all the vowels in some languages, and all the vowels and consonants in others, even across boundaries. This claim supports the view of VH as an assimilation process. As an assimilative process, VH has some of the same requirements as other assimilations, such as locality, sensitivity to boundaries, and directionality bias.

In the next section, I discuss VH in BP by considering these typological characteristics of VH in the world's languages and drawing on arguments from the phonology–morphology interaction and from sociolinguistics.

## 2.5 Brazilian Portuguese Vowel Harmony

BP can be considered an example of a language where VH affects only the height of its set of vowels, just like Swahili (Tuker, 1942), and many languages throughout East and West Africa, such as Igbo, Mande, Kalenkin, Acholi, Dinko, Luo, Somali, Ife Yoruba, and Standard Yoruba (Antell et al., 1973; Denning, 1989). The vowel system of BP is organized into three degrees of phonological height, for example: high /i, u/, mid-high /e,o/, and low vowels /ɛ, a, ɔ/. As in many languages, back vowels are redundantly rounded, and [+round] is only contrastive with /a/ within the back subset of vowels.

## 2.6 Phonology of the BP Vowel System

The BP inventory is a seven-vowel system organized in terms of front, back/round and height. According to Camara Jr. (1977, p. 44), the BP vowel system is sensitive to stress, reducing its inventory from seven vowels in stressed position to five in the pre-stressed position, four in non-final unstressed, and three in final unstressed positions of the word. This distribution is shown below.

(8)

Table 2. Inventory of Brazilian Portuguese vowel system according to Camara Jr. (1977)

| | **Stressed** | | | **Pre-Stressed** | | | **Non-Final Unstressed** | | | **Unstressed Final** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | front | | back | front | | back | front | | back | front | | back |
| high | i | | u | i | | u | i | | u | i | | u |
| mid-high | e | | o | e | | o | e | | | | | |
| mid-low | ɛ | | ɔ | | | | | | | | | |
| low | | a | | | a | | | a | | | a | |

The distinction between /e, ɛ/ and /o, ɔ/ is neutralized in unstressed positions (Camara Jr., 1977). Since neutralization reaches vowels in the height paradigm, it also interacts with VH in the same way. Because BP VH is a height-harmonic system, it is expected that harmony can reach the same subset of neutralized vowels. Wetzels (1992), within the Feature Geometry theory, proposes four degrees of opening for BP using three [open-*x*] features. Within this theory, one might propose that BP neutralization can be understood as [open 3] delinking when mid-low vowels go to unstressed position through the derivation cycle (Wetzels, 1991, 1992, 1995).

In contradiction to Camara Jr., Bisol (2010) proposes that the unstressed vowel system is organized in two ways: (a) five vowels in non-final unstressed syllables, regardless of the position of the word, and (b) three vowels in final unstressed position. Thus, the vowel organization proposed by Bisol (2010) can be expressed as follows.

(9)

Table 3. The BP vowel system according to Bisol (2010)

| | Stressed | | Unstressed | | Final Unstressed | |
|---|---|---|---|---|---|---|
| | front | back | front | back | front | back |
| high | i | u | i | u | i | u |
| mid-high | e | o | e | o | | |
| mid-low | ɛ | ɔ | | | | |
| low | a | | a | | a | |

The authors make these assumptions because they claim that /ɛ, ɔ/ disappear from unstressed positions, and are in complementary distribution with /e, o/. However, in many northeastern dialects, the seven-vowel system remains the same in pre-stressed position, although the opposition between mid-high and mid-low vowels is neutralized. One might point out that, in many dialects, especially in mid-west and southern Brazil, the /e, o/ counterpart of the midwestern system has overtaken the mid-low vowels. The opposite trend is seen in the northeastern system, where the mid-low and mid-high vowels can freely replace one another in unstressed position.

(10)

Table 4. Northeastern Vowel System

| | Stress | | | Unstressed Non-Final | | | Final Unstressed | | |
|---|---|---|---|---|---|---|---|---|---|
| | front | | back | front | | back | front | | back |
| high | i | | u | i | | u | i | | u |
| mid | e | | o | e | | o | | | |
| low | ɛ | a | ɔ | [ɛ] | a | [ɔ] | | a | |

In a northeastern system, such as in BA, the pairs /e, ɛ/ and /o, ɔ/ are not found in complementary distribution, but the choice for one or the other is made systematically by VH (see Chapters 4 & 5), which is the reason to use [ɛ, ɔ] with square brackets. The harmonic behavior will be discussed in the next sections.

## 2.7 Phonology of BP Vowel Harmony

### 2.7.1 Gaucho Dialect: Bisol (1981)

According to Bisol, in BP, VH reaches the pre-stressed vowels /e/ and /o/ that are immediately followed by a high vowel in an adjacent syllable, generally stressed. The vowel /o/ is raised to [u], regardless of whether the trigger is /i/ or /u/. However, it is not the same for /e/, which rises more often when the following vowel is /i/, but not /u/. Bisol's explanation for this fact has a phonetic basis. She points out that:

> a high back vowel is less high than a high front vowel. Being less high, naturally, it does not exert as great an attractive force on e, because changing the latter to i would mean causing a higher articulation than that of u itself. (Bisol, 1989, p. 186)

This explanation is problematic because, in principle, there is no reason for /u/ to block harmony, since /u/ is phonologically [+high].

Bisol (1989, p. 186) points out that the main linguistic factors for applying VH are: quality of the following high vowel, distance from the stressed vowel, nasalization, place of articulation of adjacent consonants, and underlying stress. According to Bisol's findings, palatal consonants favor VH for both target vowels because they are also [+high]. The argument whereby consonants play a role in raising vowels is important to the author in explaining why some words do not raise even with a high vowel in the second position. As we can see, in such cases, regardless of the quality of the stressed vowel ($V_2$), the target vowel does not change. The words in (11) exemplify this case.

(11)

| | | | | |
|---|---|---|---|---|
| a./zebu/ | [zeˈbu] | | *z**i**'b**u** | zebu |
| b. /temido/ | [teˈmidʊ] | *t**i'**m**i**dʊ | *tʃ**i**ˈm**i**dʊ | frighten |

In the examples in (11a–b), we can see that if VH has been applied, it will result in non-acceptable forms in GA. This aspect shows that there is not an implicational relationship, at least in principle, between the presence of a high vowel in the stressed syllable and VH itself; that is, more than one aspect has to be conjoined to raise vowels. In order to discuss this issue, the role of trigger vowels, place and consonantal class are in this dissertation analyzed based on Bisol's dataset.

The goal of this section is to present the proposal made by Bisol (1981) for BP VH, as I present the phonological rule and discuss the role of the surrounding consonants of the target[6]. This point is important as I also investigate the interaction between consonants and vowels in VH patterns in BP.

[6]I will not present Bisol's statistical results here, because I will analyze her data in Chapter 6. For now, only Bisol's findings will be discussed in order to clarify her proposal for BP/VH, which takes into account the relationship between target and trigger vowels and between consonants and arget vowels.

Silveira (1939, cited by Camara Jr, 1977, p. 44) noticed harmonic vowel behavior in BP, in which the tendency for sequences of mid and high vowels is harmonizing in height in colloquial speech. Camara Jr. points out that pre-stressed /e/ and /o/, followed by stressed /i/ and /u/, only appear in a few and very formal words, as disharmonic roots are avoided in the language. Bisol (1981), within the Variation Theory (Labov, 1972) and Generative Grammar approaches (Chomsky & Halle, 1968) proposes a variable rule to take into account the variable nature of this phenomenon. BP [+High] VH can be exemplified as follows:

(12) Bisol (1989, p.185):

| | | |
|---|---|---|
| a. /pepino/ | p**i**'p**i**nʊ | cucumber |
| b. /koɾuʒa/ | k**u**'ɾ**u**ʒɐ | owl |
| c. /foɾmiga/ | f**u**ɾ'm**i**gɐ | ant |

The literature after Bisol has argued that VH is a current phenomenon in almost all Brazilian dialects, described as a regressive assimilation in which the mid-high vowels /e/ and /o/ are the targets, the high vowels /i/ and /u/ are the triggers, and feature [+high] is the harmonic feature (Bisol, 1981, 1989). According to the author, BP VH can be formalized by the following general rule:

(13) General Rule:

$$\begin{bmatrix} V \\ -low \end{bmatrix} \rightarrow [+high] \,/\, \_\_ C_1 \begin{bmatrix} V \\ +high \end{bmatrix}$$

However, this rule does not account for the behavior of the triggers. According to Bisol, a possible solution would be to formalize the different behaviors of /i/ and /u/ as triggers separately. To capture the asymmetry of the target-trigger vowel, in which /i/ can spread [+high] to both mid vowels and /u/ for the back mid-vowel, she proposes these two separated rules (Bisol, 1989, p. 197), which I present here in a simplified version:

(14) Specific Rule 1: /e/ → [i] $/\_\_$ /i/

$$\begin{bmatrix} V \\ -low \\ -back \end{bmatrix} \rightarrow [+high] \,/\, \_\_ C_1 \begin{bmatrix} V \\ < +high > \\ -back \end{bmatrix}$$

(15) Specific Rule 2: /o/ → [u] /___/i, u/

$$\begin{bmatrix} V \\ -low \\ +back \end{bmatrix} \rightarrow [+high] \ /\_\_\_C_1 \begin{bmatrix} V \\ < +high > \end{bmatrix}$$

These rules tend to capture the fact that /e/ changes to [i] only when /i/ is a trigger, but /o/ changes to [u] before both /i/ and /u/ as trigger vowels. This target-trigger asymmetry has been confirmed in the literature, but its explanation remains unclear[7]. In order to explain this asymmetry, Bisol proposes a hierarchy that formalizes the role of the surrounding consonants, in which place of articulation of the Cs plays a conjoined role with the trigger vowels. In this hierarchy, the target vowels are affected by the following Cs, organized from the most triggering place of articulation to the least important one.

(16) Target /e/: velar > palatal > alveolar > labial

(17) Target /o/: *palatal > labial > velar > alveolar*

The main problem with this scale is that it is based on phonetic categories instead of phonological features. One might generalize that only [+high] consonants, such as velars and palatals, may trigger harmony, but the order on the scale consistently changes after the first position, what makes it impossible to generalize the role of consonants for other V-to-C possibilities.

Another important point concerning BP/VH is that it is strictly local, and it applies mainly when the trigger vowels immediately follow the targets. It may also be cyclic if there are more target vowels adjacent to the vowel closest to the trigger, but there are only a few words that can be harmonized cyclically, as in (18). For cyclic harmony, the target vowels must satisfy two conditions: (a) to be within the root, and (b) to take place in adjacent syllables.

(18) a. /peregrino/ p**i**ɾ**i**'gɾinu peregrine

b. /meʃerika/ m**i**ʃ**i**'ɾika tangerine

---

[7] In Bisol's words: "a separate treatment of *i* and *u* in the variable rule does not adequately capture the generalization" (1989, p. 197).

Traditionally, one considers that BP VH does not skip vowels, that is, there are no neutral or opaque vowels. In general, this claim is widely assumed by phonologists (Abaurre-Gnerre, 1981; Abaurre & Sandalo, 2009; Bisol, 1981, 1989; Lee & Oliveira, 2003; Schwindt, 1995, 1997; Schwindt & Collischonn, 2004; Wetzels, 1995). Bohn (2014) proposes that height VH is strictly local, and even when targets are spaced by only one syllable from the trigger they cannot be harmonized. Bohn's work not only confirms the locality condition of harmony but also proposes that [–ATR] spreading has the opposite trend of [+High] harmony, since [–ATR] vowels may skip vowels[8].

Considering the role of morphology, Hancin (1991) and File-Muriel (2014) propose that BP VH is triggered by suffixation. According to the authors, there should be a height agreement between root and the initial suffix vowel. Their claim, however, is based on some words where transcription and acceptability can be challenged by native speakers. In the next section, I discuss the difference between GA and BA dialects concerning VH by presenting the analysis of Barbosa da Silva (1989).

### 2.7.2 Baiano Dialect: Barbosa da Silva (1989)

Barbosa da Silva (1989) follows Bisol's steps in her research on pre-stressed vowels of the BA dialect by using the same methodology and theoretical approaches. This section presents the Barbosa da Silva's analysis. The main difference between the two dialects is their pre-stressed vowel systems: in the GA dialect there are only five vowels while the BA dialect has seven. However, as mentioned before, the distinction between /e, o/ and /ɛ, ɔ/ remains neutralized.

(19)

Table 5. Gaucho and Baiano vowel system in unstressed non-final position.

| | *Gaucho Dialect Unstressed* | | | *Baiano Dialect Unstressed* | | |
|---|---|---|---|---|---|---|
| | front | | back | front | | back |
| high | i | | u | i | | u |
| mid | e | | o | e | | o |
| low | | a | | ɛ | a | ɔ |

[8] I address locality condition on BP [ATR] harmony in Chapter 7. In my point of view, [–ATR] surfaced vowels that are more than one syllable far from the trigger may be explained by secondary stress assignment.

The alternation among unstressed vowels remains unclear. The literature has argued for different interpretations, as mentioned in the Introduction. Barbosa da Silva (1989) proposes four rules to take into account the quality of vowel alternations in the pre-stressed position. Her aim was to formalize the variation of vowels in this context, and she does not particularly see it as VH. For the author, the behavior of pre-stressed vowels may be summarized in one categorical raising rule, three categorical quality rules and three variable rules. The first rule applies to the close-mid vowel /e/ in initial unstressed position when the vowel is followed by /s/, as in the words below:

(20)

| | | |
|---|---|---|
| a. /**e**skuɾo/ | **i**sˈkuɾʊ | dark |
| b. /**e**skɔla/ | **i**sˈkɔlɐ | school |
| c. /**e**star/ | **i**sˈtaɾ | be.INF |

Although one might make considerations about the nature of the rules proposed by the author, whether or not they are necessary, or even if it is simpler to consider the initial /e/ as an underlying /i/, I will not discuss this here, but present her formalization in the following paragraphs.

(21) Categorical Raising Rule:

$$\begin{bmatrix} V \\ -high \\ -low \\ -back \end{bmatrix} \rightarrow [+high] \; /\#\_\_\_\_ \begin{bmatrix} C \\ +continuant \\ +coronal \\ +anterior \end{bmatrix}$$

There are three rules that refer to alternation in vowel quality; the first one has as outputs the vowel [e] in verbal forms when the mid-low vowel precedes palatal consonants /ʃ/ and /ʒ/. The author considers that this vowel is underspecified[9] phonologically, and the rule is applied to ensure that this vowel will be produced as mid-high.

[9]Barbosa da Silva does not mention the Underspecification Theory (Archangeli 1988), but I assume that she is referring to that approach.

(22)

| | | |
|---|---|---|
| a. /f**E**ʃaɾ/[10] | f**e**ˈʃaɾ | close.INF |
| b. /dez**E**ʒaɾ/ | deze**e**ˈʒaɾ | desire.INF |
| c. /plan**E**ʒaɾ/ | plan**e**ˈʒaɾ | plan.INF |

(23) First Categorical Quality Rule:

$$\begin{bmatrix} V \\ -high \\ -back \\ -stress \end{bmatrix} \longrightarrow [-low] \ \ / \ \ \_\_\_ \begin{bmatrix} C \\ +continuant \\ +coronal \\ -anterior \end{bmatrix} \text{verb, 1}^{\text{st}} \text{ paradigm}$$

The problem with this rule is that it is very specific and does not interact with any other process in BP phonology, since there is no reported phenomenon in which vowels are categorically raised before palatals in BP. This issue on vowel behavior in verbs is revisited by Wetzels (1991, 1992). According to this author, mid-high vowels are underlying within the root, and they alternate between /e/ to /ɛ/ affected by categorical VH rules that verb forms undergo.

A similar rule is proposed in nouns. It refers to agreement in height among the pre-stressed and stressed vowels, as in shown in (24):

(24)

| | | |
|---|---|---|
| a. /sEɾeʒa/ | seˈɾ**e**ʒɐ | cherry |
| b. /sErveʒa/ | serˈv**e**ʒɐ | beer |
| c. /kOrejo/ | k**o**ˈɦ**e**jʊ | mail |

(25) Second Categorical Quality Rule:

$$\begin{bmatrix} V \\ -stress \\ -high \\ \alpha back \\ \beta round \end{bmatrix} \longrightarrow [-low] \ \ / \ X\, C_1^2 \_\_\_ C_1^2 \begin{bmatrix} V \\ -\,high \\ -low \\ -nasal \end{bmatrix}$$

Condition: *X* is not stressed

[10]Capital letter stands for archphonemic representation.

In other words, these rules indicate that the BA dialect seems to present [ATR] harmony, since the two categorical rules are applied to ensure agreement between the [+ATR] vowels. The latter refers to vowel context, in which stressed [+ATR] vowels are the phonological condition for surfaced [e]s.

The third and most *ad hoc* rule refers to consonant-triggered vowel lowering. The rule makes vowels [+low] motivated only by the surrounding [+consonant]. There is no mention about more specific features of the consonants involved. Examples are given in (26), followed by the formalization of the rule in (27):

(26)

| | | |
|---|---|---|
| a. /espoɾtivo/ | ispɔɾˈtʃivu | sporting |
| b. /korente/ | kɔˈɦentʃi | chain |
| c. /apelaɾ/ | apɛˈlaɾ | appeal.INF |

(27) Third Categorical Quality Rule:

$$\begin{bmatrix} V \\ -stress \\ -high \\ \alpha back \\ \beta round \end{bmatrix} \longrightarrow [+low] \;\; / \;\; X\, C_1^2 \_\_\_\_ \, C_1^2$$

This rule is a formalization of what the literature has claimed to be a lowering process: a rule that lowers vowels without any low vowel as a trigger. The main issue with such a rule is the fact that it attempts to take into account some special words with unstressed low vowels. However, this rule bleeds the context of the “Second Categorical Rule” and produces incorrect forms, as in the examples in (28), using the words *frequência* ‘frequence’ and *cereja* ‘cherry’.

(28) Rule Ordering 1:

| | /frEkuensia/ | /sEɾeʒa/ |
|---|---|---|
| | … | … |
| Third Categorical Rule | frɛkuencia | sɛɾeʒa |
| Second Categorical Rule | – | – |
| | … | … |
| **Output**: | [frɛˈkʷensja] | *[sɛˈɾeʒa] |

(29) Rule Ordering 2:

| | /frEkuensia/ | /sEɾeʒa/ |
|---|---|---|
| | … | … |
| Second Categorical Rule | frekuensia | seɾeʒa |
| Third Categorical Rule | frɛkuensia | sɛɾeʒa |
| | … | … |
| **Output:** | [frɛˈkʷensja] | *[sɛˈɾeʒa] |

The problem for these rules, as stated in this way, is that they produce incorrect forms regardless of the order in which they are postulated. The author points out that the word *frequência* is produced as [ɛ] and, in this case, the ordering of the rules would not pose any problem, but when one compares the application of this rule with a word that is not produced with an [ɛ], as in *cereja,* both orders produce wrong outputs.

To sum up, these rules were postulated by Barbosa da Silva to take account for the agreement between [+ATR] vowels, such as high-to-high and mid-to-mid. The third one, on the other hand, consists of an attempt to formalize the fact that this dialect presents low vowels in some contexts that are not explicitly satisfied by the others. However, the rules lack an explanation since they are very specific and ignore phonologically universal conditions typologically attested in the world's languages. It should be pointed out, however, that both attempts to study pre-stressed vowels made by Barbosa da Silva (1989) and Bisol (1981) seek to map phonological processes in terms of social conditions. For this reason, they are not exhaustive in analyzing structural conditions, and do not take into account typological information about the phenomena.

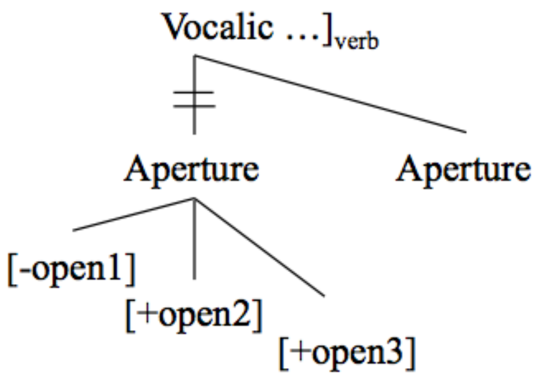
In the next section, I present arguments for considering BP harmony as an [ATR] system. The focus is the phonology–morphology interaction, in which structural descriptions for height harmony becomes available but harmony is blocked. Also, I discuss the factors "age" and "years of education" as indicative that [+high] harmony is an old rule that neither young people nor highly educated people use anymore.

## 2.8 Phonology–Morphology Interaction in BP Vowel Harmony

It could be postulated that BP has two VH rules if we analyze verbs and nouns separately. The first rule, known as categorical, is applied to verbs conjugated in the first-person indicative and all subjunctive forms (Harris, 1974; Mateus, 1975; Redenbarger, 1981; Wetzels, 1991, 1992, 1995) while the second rule is variable (Bisol, 1981; 1989). The categorical VH characteristic of the verbs proposed by Wetzels (1995) in the Feature Geometry (FG) approach may be summarized as the result of the intrinsic order between a truncation rule and VH, presented as follows:

(30) Truncation:


(31) Vowel Harmony:




The application of these rules may be seen in the first person of the indicative tense and all forms of the subjunctive paradigm. The author proposes a series of rules to take into account all the verb forms, assuming the lexicon is stratified as claimed by Lexical Phonology (Kiparsky, 1982; Mohanan & Mohanan, 1984). Wetzels states that the proposal of a floating node which triggers VH is based on Goldsmith's findings that tones are stable in tonal phonology languages, while vowels can be deleted (Goldsmith, 1976). Examples of the application of Wetzel's rules by deriving the 1st person of the present tense are:

(32)

| | /mov+e+o/ | /fer+i+o/ |
|---|---|---|
| *Truncation* | mov+Ø+o | fer+ Ø+o |
| *Vowel Harmony* | movo | firo |
| **Output**: | [ˈmovo] | [ˈfiro] |

VH applies immediately after a truncation rule that delinks the Aperture Node of the theme vowel. Aperture then becomes a floating node that is reassociated by the Universal Association Convention. One might notice that the alternations are not motivated by the consonant that immediately follows the target vowel, but they are predictable by the verbal paradigm, that is, shifting vowels are morphologically conditioned. If VH in verbs is a categorical phenomenon, (i.e., if VH interacts with verbal morphology), we might expect that the variable form of VH will also have similar interactions in nouns.

# 3 PRE-STRESSED VOWEL PRODUCTION

## 3.1 Introduction

In the literature about BP VH there is no consensus about the role of adjacent consonants. Many studies have proposed that previous consonants raise pre-stressed vowels, especially when triggered by a raising vowel neutralization rule (*raising without an apparent motivation*, Bisol, 2009; Klunck, 2007). Other researchers claim that the intervening consonant may trigger vowel raising alone (Bisol, 1981, 1989; Schwindt, 1995, 1997; Sandalo et al., 2013). Also, there are only a few experimental studies dedicated to analyzing these vowels acoustically. As mentioned in the Introduction chapter, the very first experimental research studies on BP VH were conducted by Kentowicz and Sandalo (2016). Thus, given the lack of enough experimental research, a production experiment was designed to contribute to the discussion about the role of consonants and the vowel-to-vowel relationship in order to shed light on the VH phenomenon. Some Romance languages have been described as harmonic systems – McCarthy (1982) for Spanish; Nguyen and Fagyal (2008) for French; and Nibert (1998) for Italian) –, which suggests the need for further investigation about harmonic aspects shared by BP with these languages.

In order to investigate cross-dialect differences between GA and BA in VH, an experiment with nonce words[11] was carried out. It is aimed at measuring the acoustic properties of vowels that occur in a phonological environment where VH applies. The method and the results of this experiment are discussed in this chapter.

## 3.2 Method

### 3.2.1 Participants

The production of two groups separated by dialect was tested in the experiment. In order to recruit reliable GA and BA participants, all selected speakers had to be undergraduate (or graduate) students without prior backgrounds in phonetics and phonology. They had to fulfill the following requirements: having always lived in the Rio Grande do Sul (GA dialect) or Bahia (BA dialect) before moving to Campinas; be monolingual; having been living in Campinas for no longer than one year. They were selected from groups of volunteers on the campus of the State University of Campinas, and they were contacted directly by the

[11] See Kawahara (2016) for an in-depth discussion on psycholinguistic methods applied to phonology. Also, see Traxler and Gernsbacher (2011) for an overview of the field.

researcher. To ensure the participants did not speak any foreign languages, they answered a questionnaire originally designed by Rauber (2006) and adapted to this research.

Six speakers of BP, three men and three women, were recorded. The GA speakers consisted of one man and two women with a mean age was 23 (*SD* = 2.64) years, while the BA speakers consisted of two males and one female, with a mean age of 23.67 (*SD* = 4.16) years. This gender discrepancy between the dialects could not be resolved, considering the participation requirements.

(33)

Table 6. Background information about *Gaucho* and *Baiano* female and male participants.

| Participant | Gender | Age | City of Origin | Dialect |
|---|---|---|---|---|
| S1 | M | 20 | Pelotas | Gaucho |
| S2 | F | 25 | Pelotas | Gaucho |
| S3 | F | 24 | Porto Alegre | Gaucho |
| S4 | F | 19 | Salvador | Baiano |
| S5 | M | 27 | Feira de Santana | Baiano |
| S6 | M | 25 | Vitória da Conquista | Baiano |

### 3.2.2 Corpus

The corpus consisted of 735 nonce words in which the five prestressed vowels /i, e, a, o, u/ were inserted, combined with voiceless stops and liquid consonants and seven stressed vowels /i, e, ɛ, a, ɔ, o, u/, organized within a trochaic phonological structure /C1V1.'C2V2.pa/ (where: C1 = first consonant, V1 = target vowel, C2 = second consonant; V2 = stressed vowel), with the stress on the penultimate syllable. The final unstressed syllable /pa/ was kept invariable. As VH applies only to unstressed vowels, a three-syllable word was required to simulate the appropriate phonological context.

The nonce words were divided into two groups of consonantal classes: stops and liquids. For the stop group, the voiceless /p, t, k/ were selected; and for the second one, the BP liquids /l, ʎ, ɾ, r/[12] appeared in C2 position combined with /p, t, k/ in C1 position. Each structure presented in the table below generates 35 nonce words (5 unstressed vowels × 7 stressed vowels). Thus, for stops, the total number of nonce words was 315 (9 combinations of consonants × 5 unstressed vowels × 7 stressed vowels). The liquid group resulted in 420 nonce words (12 combinations of consonants × 5 unstressed vowels × 7 stressed vowels).

[12] For the production of the (voiced and voiceless) glottal fricative in BP as a realization of the phoneme /r/, see Barbosa and Madureira (2015).

(34)

Table 7. Nonce word templates divided by group of stop and liquid consonants.

| Phonological Context | Nonce Word Templates | | |
|---|---|---|---|
| *Stop* | pV$_1$ ˈpV$_2$ pa | tV$_1$ ˈpV$_2$ pa | kV$_1$ ˈpV$_2$ pa |
| | pV$_1$ ˈt V$_2$ pa | tV$_1$ ˈtV$_2$ pa | kV$_1$ ˈtV$_2$ pa |
| | pV$_1$ ˈk V$_2$ pa | tV$_1$ ˈkV$_2$ pa | kV$_1$ ˈkV$_2$ pa |
| *Liquid* | pV$_1$ ˈ ɾ V$_2$ pa | tV$_1$ ˈɾ V$_2$ pa | kV$_1$ ˈɾV$_2$ pa |
| | pV$_1$ ˈlV$_2$ pa | tV$_1$ ˈlV$_2$ pa | kV$_1$ ˈlV$_2$ pa |
| | pV$_1$ ˈʎV$_2$ pa | tV$_1$ ˈʎ V$_2$ pa | kV$_1$ ˈʎV$_2$ pa |
| | pV$_1$ ˈrV$_2$ pa | tV$_1$ ˈrV$_2$ pa | kV$_1$ ˈrV$_2$ pa |

The 3-syllable nonce words were read while embedded in the following carrier sentence: *Digo CVCVpa baixinho.*[13], which means *(I) Say CVCVpa softly.* The words and repetitions (each word was repeated three times) yielded a corpus of 2205 tokens, and approximately 30% of filler sentences. The filler words were disyllabic and had an iambic stress pattern, such as *amor* (love) and *café* (coffee). These different patterns with nonce words were selected to avoid a possible tongue-twister effect during the task (McCutchen et al., 1991). The nonce words, repetitions and distractors yielded a final corpus with a total of 2865 sentences.

### 3.2.3 Data Collection Procedure

The recordings were made in a soundproof room with a TASCAM DR-05 linear PCM Recorder, with a sample rate of 44.1 kHz and 16-bit quantization. The recordings were made at the Language Studies Institute in the campus of the State University of Campinas.

The sentences were arranged randomly three times in eight blocks: four blocks for the stop group and another four blocks for the liquid group. The nonce word notations followed BP orthography and were presented on a computer screen. Thus, the vowels /i, e, ɛ, a, ɔ, o, u/ were shown respectively as i, ê, é, a, ó, ô and u.

Participants were asked to read the sentences at a normal speech rate. If they misread a word, changed the stress pattern, hesitated or paused within a sentence they were asked to repeat that particular sentence. When participants did not follow the instructions, the nonce word was not analyzed. Also, some tokens were discarded because the target vowels were devoiced or completely deleted. This happened more frequently when /i/ was preceded by /t/,

[13] For details about the use of this carrier sentence for Portuguese, see Barbosa and Madureira (2015).

which is produced as the affricate [tʃ] in both dialects. Thus, a total of 7915 tokens were analyzed: 3982 produced by GA speakers and 3933 produced by BA speakers.

### 3.2.4 Acoustic Analysis

In order to investigate how GA and BA speakers produce pre-stressed vowels and whether their quality is affected by the following vowel (V2), the acoustic properties of duration, F1 and F2 were measured for the vowels, as the main goal was to check how F1 of pre-stressed vowels is affected by the other vowels and consonants. It was important to analyze F1 as this formant frequency is inversely related to vowel height.

All measurements were made automatically with a script using the software PRAAT, version 6.0.07 (Boersma & Weenink, 2015). The script was written by Boersma (2006), and each vowel and consonant was labeled manually before running it.

For duration measurements – the start and end points for vowels – were considered to be the first and last periodic pulses on the waveform that had steady F2 and considerable amplitude. The start point of the C1 consonant coincides with the end of the last vowel /o/ of the word *digo* and its end point is defined at the beginning of the first vowel of the target word. For C2, the beginning of the consonant coincides with the end of the first vowel and the end of it coincides with the beginning of the second stressed vowel of the nonce word, as shown in the left panel in Figure 1 for the words *pekipa* and *pelapa*. For the stop group, it was quite easy to determine the start and end points since all consonants were voiceless.

(35)

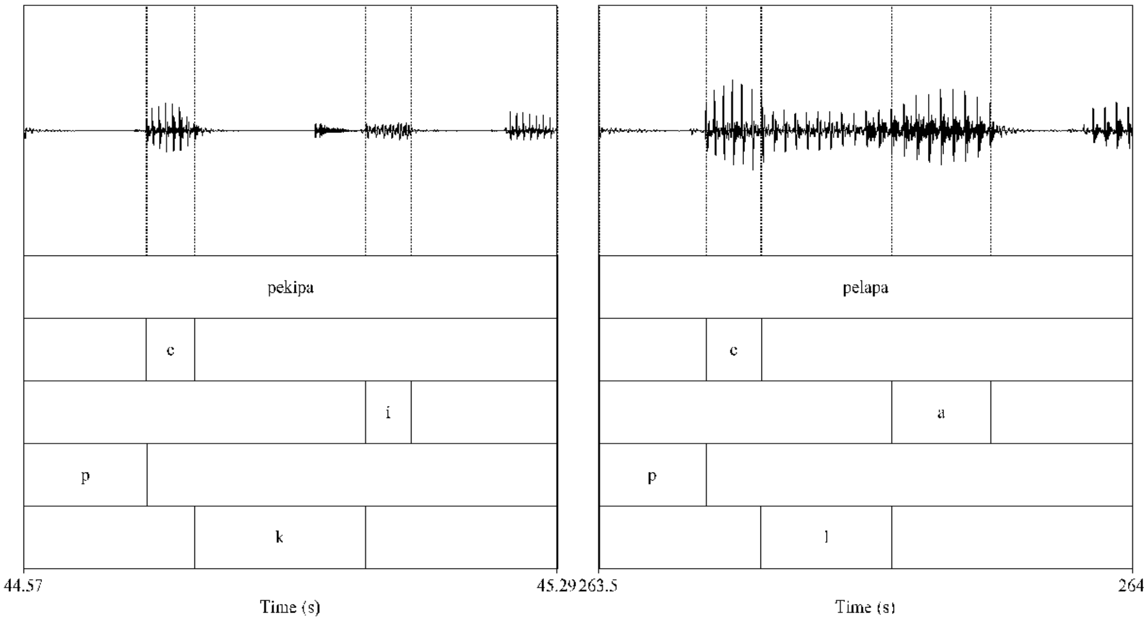



Figure 1. Segmentation of the pseudowords *pekipa* and *pelapa*, representing stops and liquids produced by a Gaucho female participant.

For the liquid group, laterals were labeled considering the F2 movement of the surrounding vowels and the amplitude of the waveform. The right panel in Figure 1 exemplifies a segmentation of the target word *pelapa*. For rhotics, different criteria were followed: the tap /ɾ/ was labeled by following the same criteria used to label voiced stops. Phonological /r/[14], orthographically represented as *rr*, is realized in most cases as a voiced glottal fricative [ɦ] in both dialects. Then, F1, F2, and F3 transitions, amplitude and noise in the waveform were also considered to label this consonant in PRAAT. F1 formant measurements for F1, F2 and F3 were determined with the Burg algorithm (Anderson, 1978) built on PRAAT, following the same procedures of Rauber (2006) and Escudero et al. (2009).

### 3.2.5 Statistical Analysis

In order to investigate whether vowel heights differ significantly according to place and class of the adjacent consonants, the following vowel, dialect and gender, I ran three statistical models. The first two were repeated-measures Multivariate Analysis of Variance (RM-MANOVA) aimed at evaluating mean difference of F1 and F2 of the pre-stressed and stressed vowels according to dialect and gender. The third model was a Linear Mixed-Effect

[14] For debuccalization of /r/ in BP, see Abaurre and Sandalo (2003). And for the variation on the /r/ production, see Cristófaro-Silva (2014) and Barbosa & Madureira (2015).

Regression (LMER), which was run to test whether F1 of the pre-stressed vowel differs significantly according to place and manner of articulation of the adjacent consonants, the following vowel, dialect and gender. For this model, the variable *PARTICIPANTS* (unordered factor, with levels corresponding to the six participants of the experiment) was set as the random factor and the fixed effects were set as:

(1) *DIALECT*: a two-level unordered factor, with levels corresponding to GA and BA dialects.
(2) *GENDER*: a two-level unordered factor, with levels corresponding to the gender of the participant.
(3) *V2* or following vowel: a seven-level unordered factor, with levels corresponding to all seven BP stressed vowels /i, e, ɛ, a, ɔ, o, u/.
(4) *PLACE-C1*: a three-level unordered factor, with levels corresponding to the consonants /p, t, k/ which are labial, coronal and dorsal, respectively.
(5) *CLASS-C2*: a two-level unordered factor, with levels corresponding to stops and liquids.

The use of Linear Mixed-Effect Regression instead of repeated-measures ANOVA was preferred because LMER controls the variance associated with the random factors (Baayen, Davidson, & Bates, 2008; Judd, Westfall, & Kenny, 2012). Then, by defining *Participants* as a random factor, I could control the influence of the different F1 means associated with each speaker. Also, I present only the F-tests from the LMER results, which are the type III Wald F-tests with Satterthwaite's Approximation for degrees of freedom. The assumptions of models (normality and homoscedasticity of residuals) were checked. I expected pre-stressed vowels to depend on dialect; furthermore, I assumed that this dependency would vary according to the combination of the following vowel and consonants. For this reason, in addition to these main effects, I included all the interactions up to three into the model.

There was a colinearity effect with Class-C2 when I included Place-C2 into the model, hence I dropped the Place-C2 variable. In addition, as these BP dialects have the allophone [t͡ʃ] before a vowel [i], the factor Place-C1 also would have this level, that is, nonce words such as *tipipa*. However, it would not make sense to include such a level since it occurs only in this context, hence, as this consonant does not affect other vowels, this level was dropped from the analysis. Hence, Place-C1 presents only three levels, instead of four.

For each acoustic measurement, the mean, median and standard deviation (SD) were computed for each dialect and phonological context. The dependent variables (*F1* and *F2* of the pre-stressed and stressed vowels) were normalized by the Lobanov method (Lobanov, 1971) and then used in the models. All the analyses were conducted with the software *R* (R Core Team, 2014), in which the repeated-measures MANOVA was run with the *manova()* function of the *stats* package and the Linear Mixed-Effect Model was run with the *lmer()* function of the package *lme4* (Bates, Maechler, Bolker, & Walker, 2015). Still, some specific packages were used to plot vowel space and normalize the acoustic data, namely, *phonTools* (Barreda, 2015), *phonR* (McCloy, 2015), and *ggplot2* (Wickham, 2009).

## 3.3 Results

This section reports the results of the production test carried out in this research, focusing on the differences between the two dialects in the production of the BP subset of pre-stressed vowels and the whole set of BP stressed vowels. The acoustic parameters F1 and F2 were analyzed. The gender effects will not be discussed in depth for these parameters, since the goal of the analysis is to investigate the general differences between dialects in terms of vowel height and whether the latter is affected by other acoustic properties. Furthermore, this chapter will report results on how these parameters are also affected by place of articulation and phonological class of the surrounding consonants.

## 3.4 Pre-stressed Vowels

### 3.4.1 First and Second Formants

The aim of this subsection is to describe F1 and F2 of the pre-stressed vowels, in order to check their acoustic properties according to dialect and gender. Considering that F1 reflects mainly vowel phonological height, it is expected that in VH systems this parameter will be dependent on the height of the next vowel. Therefore, in order to determine how targets are affected by the stressed vowels, firstly, it is important to determine the F1 and F2 characteristics of the whole pre-stressed vowel system. Hence, one should examine the behavior of all five pre-stressed vowels together, according to dialect and gender. The mean, median and SD of each vowel are shown in the following table.

(36)

Table 8. Mean, median and SD F1 and F2 values of GA and BA pre-stressed vowels produced by female and male participants (values in Hertz).

| Dialect | Gender | Formant | | *i* | *e* | *a* | *o* | *u* |
|---|---|---|---|---|---|---|---|---|
| Gaucho | F | *F1* | mean | 395 | 490 | 831 | 540 | 411 |
| | | | median | 399 | 478 | 838 | 537 | 414 |
| | | | SD | 39 | 60 | 71 | 72 | 38 |
| | | *F2* | mean | 2526 | 2185 | 1394 | 1032 | 986 |
| | | | median | 2599 | 2428 | 1370 | 1015 | 942 |
| | | | SD | 338 | 566 | 278 | 202 | 237 |
| | M | *F1* | mean | 351 | 410 | 632 | 423 | 367 |
| | | | median | 344 | 399 | 614 | 409 | 361 |
| | | | SD | 47 | 48 | 84 | 73 | 51 |
| | | *F2* | mean | 2093 | 2054 | 1528 | 1062 | 1215 |
| | | | median | 2135 | 1099 | 1577 | 1023 | 1055 |
| | | | SD | 267 | 227 | 209 | 256 | 508 |
| Baiano | F | *F1* | mean | 370 | 404 | 829 | 519 | 399 |
| | | | median | 369 | 383 | 831 | 503 | 397 |
| | | | SD | 34 | 71 | 44 | 83 | 38 |
| | | *F2* | mean | 2418 | 2343 | 1708 | 1084 | 1002 |
| | | | median | 2457 | 2355 | 1715 | 1039 | 956 |
| | | | SD | 181 | 89 | 157 | 230 | 251 |
| | M | *F1* | mean | 293 | 421 | 681 | 470 | 338 |
| | | | median | 288 | 418 | 677 | 467 | 333 |
| | | | SD | 35 | 60 | 52 | 74 | 35 |
| | | *F2* | mean | 2103 | 1887 | 1358 | 988 | 947 |
| | | | median | 2137 | 1907 | 1386 | 977 | 901 |
| | | | SD | 160 | 142 | 167 | 136 | 291 |

The next two plots[15] represent the vowel acoustic space for the first and second formants in BA and GA dialects.

(37)

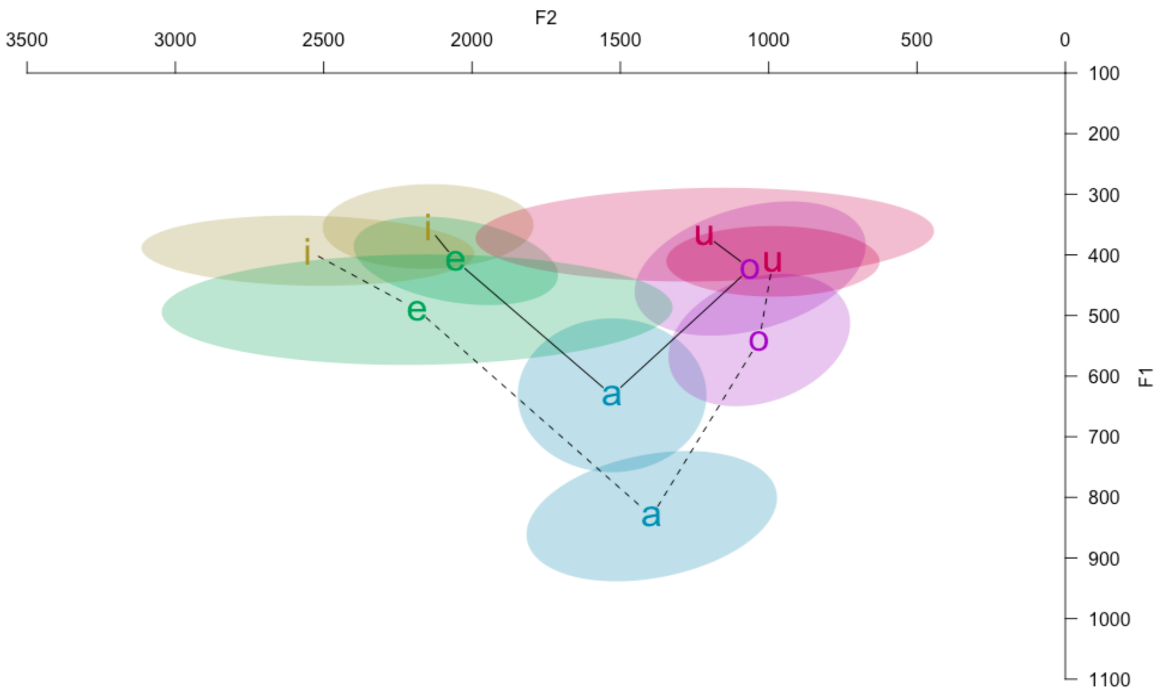



Figure 2. First and second formants of 3982 tokens of pre-stressed vowels produced by Gaucho speakers. Solid lines = males; dashed lines = females.

[15] The ellipses are drawn based on the default argument of the function **plotVowels**() from the package *phonR()*.

(38)

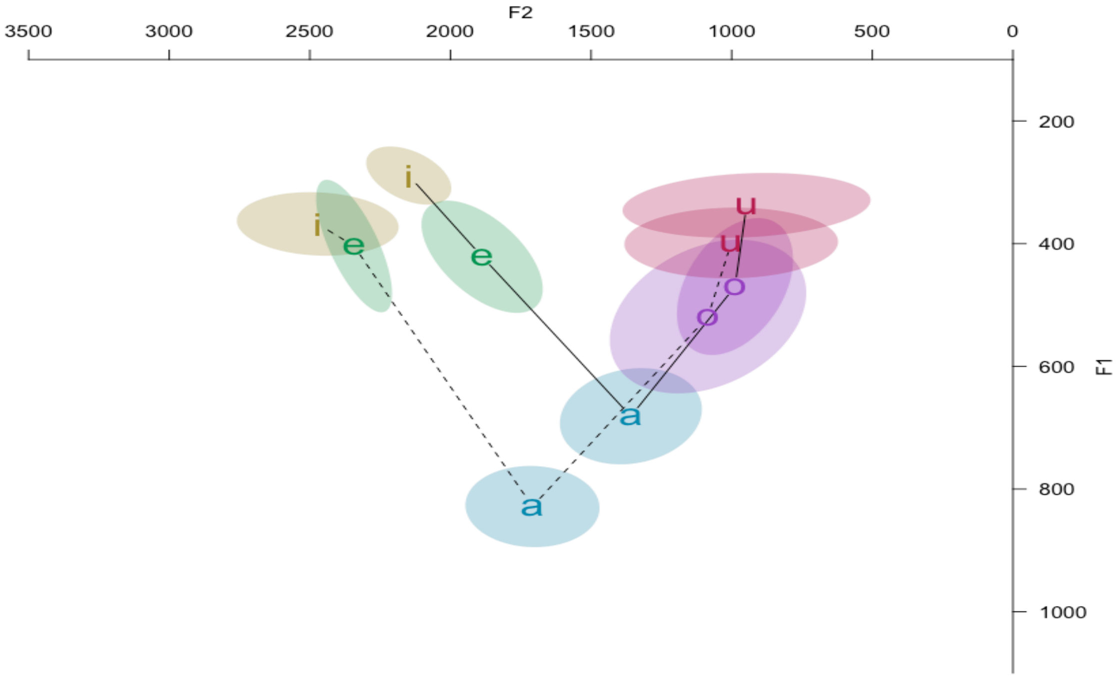



Figure 3. First and second formants of 3933 tokens of pre-stressed vowels produced by Baiano speakers. Solid lines = males; dashed lines = females.

For simplicity, I present one plot that reproduces the previous vowel spaces of each dialect based on the median single values of first and second formants for each of the five pre-stressed vowels. The median is used here to minimize the effects of extreme scores and measurement errors.

(39)

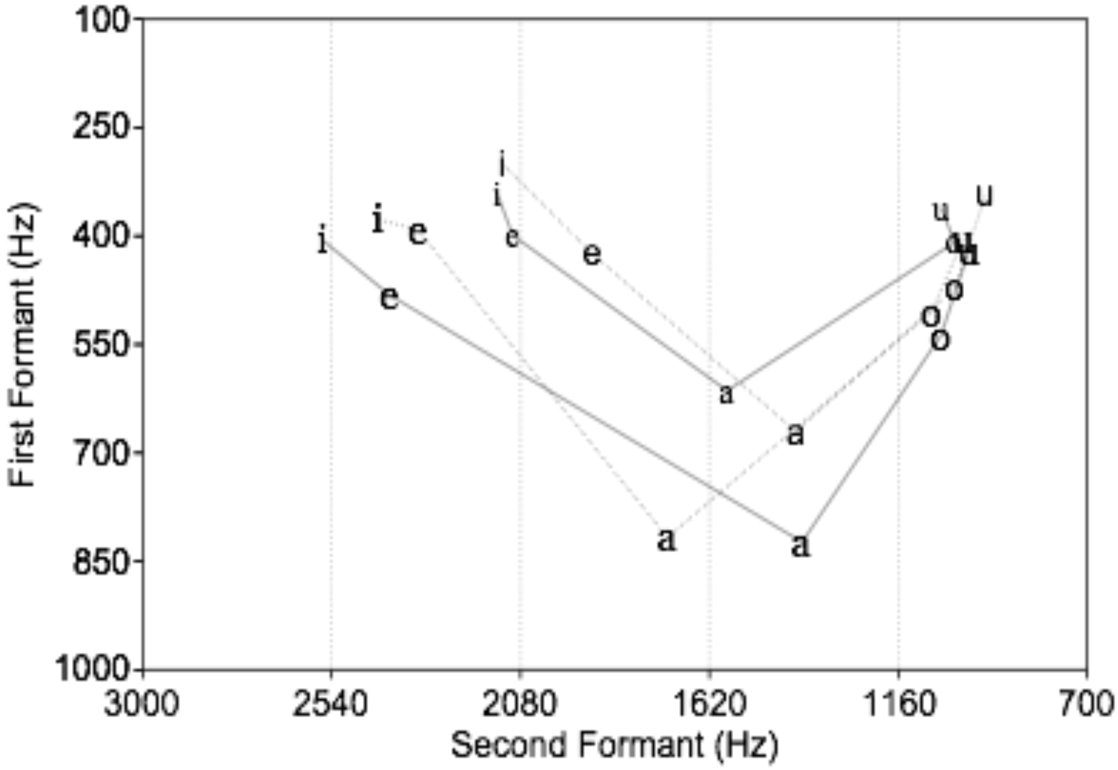



Figure 4. Median of the first and second formants of the five pre-stressed vowels produced by Gaucho and Baiano speakers. Solid lines = *Gaucho*; dashed lines = *Baiano*. Large font and bold: women; small font: men.

The repeated-measures MANOVA with dialect, gender, V2 as factors and the interaction between dialect *versus* pre-stressed vowel and dialect *versus* gender reveals a significant influence of dialect ($\Lambda[1,7338] = 0.993$, $p = 3.186 \times 10^{-11}$), a marginally significant value of gender (Wilks' $\Lambda[2,7339] = 0.87$, $p = 0.046$), a significant effect of V2 ($\Lambda[12,14676] = 0.872$, $p = 2.2 \times 10^{-16}$), gender *versus* dialect (Wilks' $\Lambda[1,7338] = 0.99$, $p = 5.386 \times 10^{-05}$), dialect *versus* pre-stressed vowel ($\Lambda[1,14676] = 0.053$, $p = 2.2 \times 10^{-16}$).

Tukey's post-hoc test revealed no significant inter-dialect differences in F1 for the vowels /e/, /a/, /u/ and /i/ ($p > 0.05$). The only vowel which was different between the dialects was /o/ ($p = 0.03$), which indicates that this vowel does not seem to have the same height, in both dialects. However, although GA /o/ is different from BA /o/, the *p*-value is marginally significant (i.e., very close to the alpha value of 0.05). For the parameter F2, similar results were found for the subset of vowels, which is {/a, e, i, o, u/}. The pairwise comparison showed that these vowels were not significantly different according to dialect ($p > 0.05$).

However, the interaction between BA and GA was significant and it might be hypothesized that there is also a difference in the distance between vowels, as the vowel distance between, for example, /e-i/ or /e-a/, should present the same patterns in both dialects. To check that, the Euclidian Distance (ED) was measured and a paired t-test was run. The model returned no significant difference between ED means of the dialects (t = –0.044, df = 5.99, $p$ = 0.97). Table 4 shows the ED values for each vowel pair.

(40)

Figure 5. Euclidean Distance between vowels in Gaucho and Baiano dialects (in Hz).

| Vowel Pairs | Gaucho | Baiano |
|---|---|---|
| /e-i/ | 224.83 | 175.76 |
| /e-a/ | 712.82 | 668.57 |
| /o-u/ | 98.79 | 127.90 |
| /o-a/ | 483.64 | 582.48 |

It was hypothesized that vowel distances could be one of the parameters to trigger VH, as it was expected that vowels that are closer to each other would tend to change their category in favor of the closest vowel, as the pair /o-u/ for instance. However, as seen in the table above, the shortest distances between vowels were found in the pairs of mid-high with high vowels, and these mid-high vowels do not seem to change their quality in favor of high vowels, but the opposite tendency does occur: mid vowels change into low vowels (see Chapters 4 and 5).

It is important to know these values, since the measures of the pre-stressed vowels will be used to determine how these vowels behave in relation to the stressed ones. As vowels can change their phonological category motivated by the categories of the following vowel, their values have to be defined without such alternating conditions. In such a case, information is required about F1 and F2 of both pre-stressed and stressed vowels. Thus, the next section is dedicated to describing stressed vowels.

## 3.5 Stressed Vowels

### 3.5.1 First and Second Formants

This section describes the acoustic parameters F1 and F2 of the seven BP stressed vowels. Considering that stressed vowels are VH triggers in BP and the most reliable vowels for extraction of the acoustic parameters of a language, determining F1 and F2 of each vowel is extremely useful since they are reference values when comparing target-trigger assimilation. In other words, one can expect that it is possible to determine a range of frequencies that define the phonological space of each of the seven vowel categories. The mean, median and SD of F1 and F2 of the seven BP stressed vowels are shown in Table 9, and the next plots present the vowel space in GA and BA, considering the seven BP phonological vowels.

(41)

Table 9. Mean, median and SD F1 and F2 values of GA and BA stressed vowels produced females and males participants (values in Hertz).

| Dialect | Gender | Formant | | *i* | *e* | *ɛ* | *a* | *ɔ* | *o* | *u* |
|---|---|---|---|---|---|---|---|---|---|---|
| Gaucho | F | *F1* | mean | 372 | 455 | 710 | 892 | 787 | 505 | 407 |
| | | | median | 377 | 449 | 710 | 896 | 787 | 497 | 410 |
| | | | SD | 53 | 47 | 76 | 68 | 78 | 63 | 48 |
| | | *F2* | mean | 2678 | 2400 | 2113 | 1455 | 1136 | 994 | 943 |
| | | | median | 2724 | 2533 | 2261 | 1468 | 1099 | 954 | 864 |
| | | | SD | 195 | 413 | 405 | 267 | 152 | 181 | 326 |
| | M | *F1* | mean | 324 | 381 | 561 | 759 | 616 | 414 | 339 |
| | | | median | 322 | 379 | 567 | 769 | 619 | 411 | 337 |
| | | | SD | 26 | 28 | 47 | 84 | 61 | 33 | 28 |
| | | *F2* | mean | 2203 | 2184 | 1966 | 1419 | 1118 | 947 | 1012 |
| | | | median | 2239 | 2187 | 1972 | 1404 | 1069 | 899 | 853 |
| | | | SD | 245 | 119 | 144 | 212 | 164 | 275 | 520 |
| Baiano | F | *F1* | mean | 295 | 329 | 475 | 836 | 555 | 404 | 329 |
| | | | median | 294 | 329 | 478 | 834 | 555 | 400 | 322 |
| | | | SD | 19 | 23 | 49 | 46 | 56 | 40 | 32 |
| | | *F2* | mean | 2642 | 2524 | 2288 | 1662 | 1013 | 838 | 778 |
| | | | median | 2647 | 2525 | 2286 | 1658 | 982 | 831 | 755 |
| | | | SD | 60 | 59 | 76 | 141 | 206 | 200 | 260 |
| | M | *F1* | mean | 291 | 358 | 509 | 709 | 539 | 393 | 336 |
| | | | median | 285 | 358 | 508 | 704 | 530 | 392 | 334 |
| | | | SD | 35 | 23 | 41 | 59 | 53 | 31 | 27 |
| | | *F2* | mean | 2193 | 2064 | 1867 | 1298 | 953 | 889 | 842 |
| | | | median | 2212 | 2067 | 1874 | 1270 | 936 | 886 | 804 |
| | | | SD | 99 | 63 | 87 | 146 | 105 | 147 | 217 |

(42)

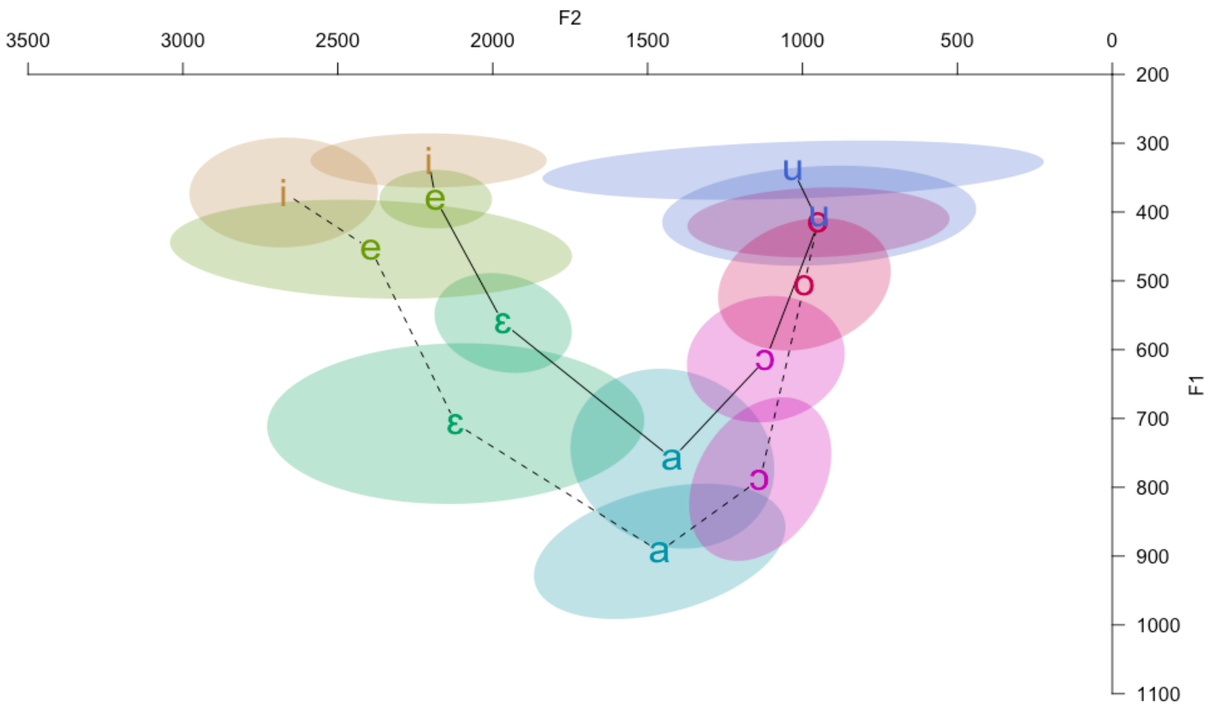



Figure 6. The first and second formants of 3982 tokens of the stressed vowels produced by Gaucho speakers. Solid lines = males; dashed lines = females.

(43)

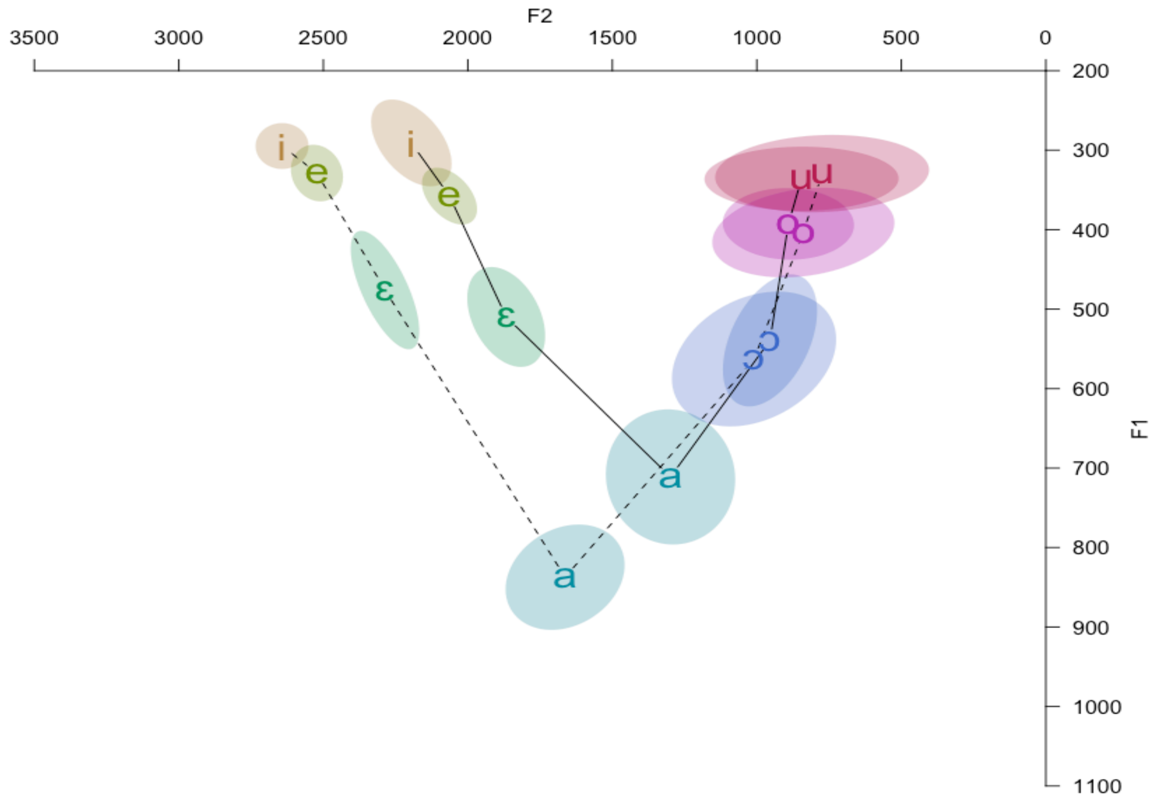



Figure 7. The first and second formants of 3933 tokens of the stressed vowels produced by Baiano speakers. Solid lines = males; dashed lines = females.

A MANOVA was performed on F1 and F2 values of the stressed vowels with dialect and gender as factors; both the effects and their interactions were significant. The main effects are (Λ[1,3867] = 0.990, $p = 1.478 \times 10^{-08}$) for gender and (Λ[1,3867] = 0.961, $p = 2.2 \times 10^{-06}$) for dialect, and there was a significant difference for the interaction between gender and dialect (Λ[1,3867] = 0.965, $p = 2.2 \times 10^{-06}$).

For the set of stressed vowels, the repeated-measures MANOVA with dialect and gender as factors and the interaction between dialect *versus* V2 and dialect *versus* gender reveals a significant influence of all variables and the interaction. Dialect has a significant effect on F1 and F2 (Λ[1,7340] = 0.823, $p = 2.2 \times 10^{-16}$), gender (Wilks' Λ[1,7340] = 0.978, $p = 2.2 \times 10^{-16}$), gender *versus* dialect (Wilks' Λ[1, 7340] = 0.870, $p = 2.2 \times 10^{-16}$), dialect *versus* stressed vowel (Λ[12,14680] = 0.013, $p = 2.2 \times 10^{-16}$). Tukey's post-hoc test revealed no significant inter-dialect differences in F1 and F2 for the whole set of stressed vowels {/i, e, ɛ, a, ɔ, o, u/} ($p > 0.05$). As was found for the pre-stressed subset of vowels, the pairwise comparison showed that these vowels were not significantly different according to dialect (*p* > 0.05) for the two acoustic parameters, thus indicating that the dialects have similar vowel parameters, that is, the similar acoustic region was found for BA and for GA vowels and the differences may be explained by the other factors of the model.

(44)


Figure 8. Median of the first and second formants of the seven stressed vowels produced by Gaucho and Baiano speakers. Solid lines = Gaucho; dashed lines = Baiano. Large font and bold: women; small font: men.

It is also expected that vowels that differ in one acoustic parameter will also differ in their spectrum properties across the two dialects. It should be noted that the difference is greater for F1 than F2; we can see in the plot above that Baiano vowels are higher than Gaucho. Also, we found that vowels produced by females are higher than those of males, which is expected due to anatomical characteristics of the oral tract and seems to be universal (Peterson & Barney, 1952). Hence, the fact that vowels are higher or lower depending on the dialect does not explain why these dialects show the same sort of VH that we found in our experiment.

Figure 8 shows that front vowels and the vowel /a/ differ more in terms of their single median than back vowels, especially /o/ and /u/, which seem to use a very close acoustic region. Although the result is quite reliable, it should be mentioned that the sample is unbalanced for gender since the participants are one man and two women for GA and one woman and two men for BA. Although gender unbalance might be an issue, I will not investigate the effect of this factor. The main interest of this section is to describe stressed vowels and determine differences between the two dialects, as pointed out at the beginning of the section.

Having determined the main characteristics of pre-stressed and stressed F1 and F2, we can now investigate the effects of the surrounding consonants on the target vowel. The next section is dedicated to preceding consonants.

### 3.6 Plots of GA and BA vowels

(45) Pre-Stressed Vowels by Dialect

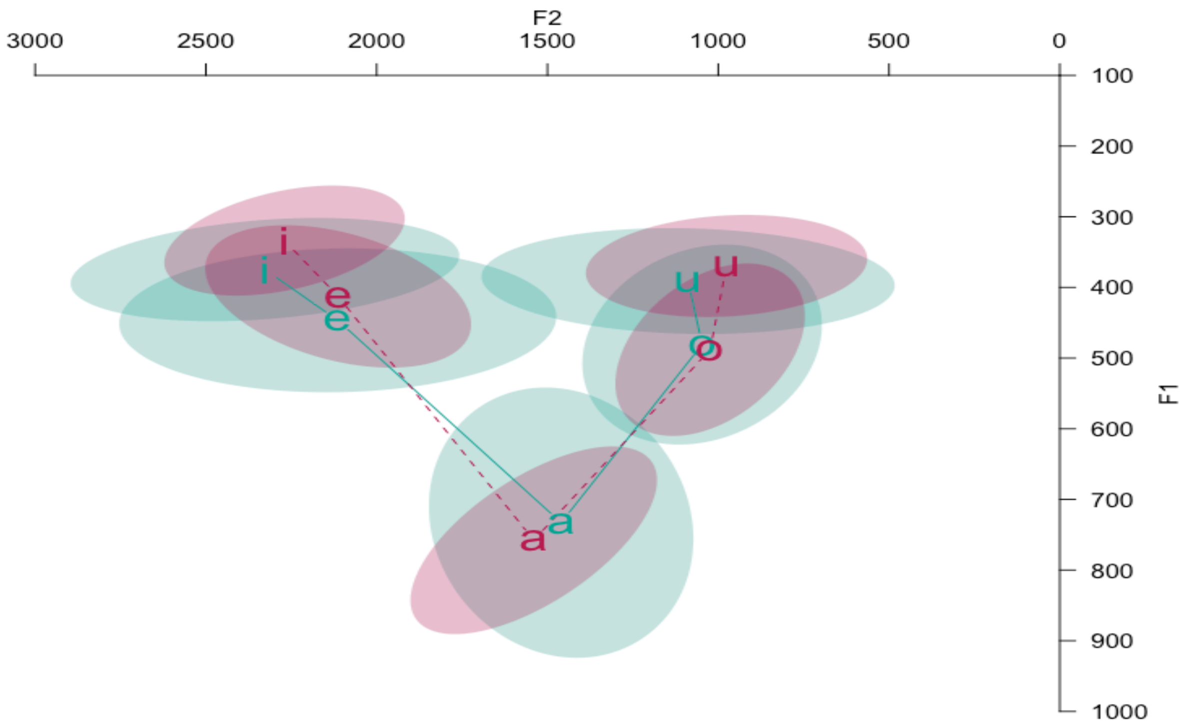



Figure 9. First and second formants of the five pre-stressed vowels produced by Gaucho and Baiano speakers. Solid lines and green ellipses= Gaucho; dashed lines and red ellipses= Baiano.

(46) Stressed Vowels by Dialect

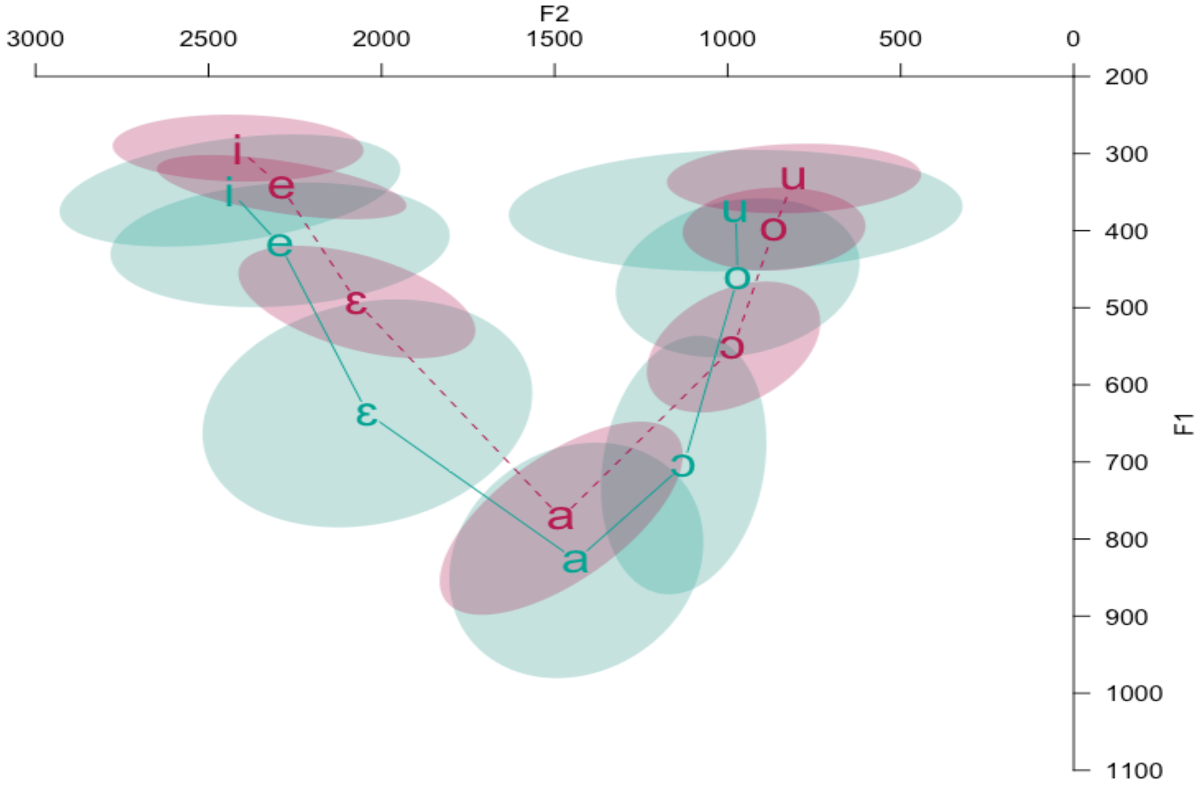



Figure 10. First and second formants of the seven stressed vowels produced by Gaucho and Baiano speakers. Solid lines = Gaucho; dashed lines = Baiano.

(47) Stressed versus Pre-Stressed Vowels

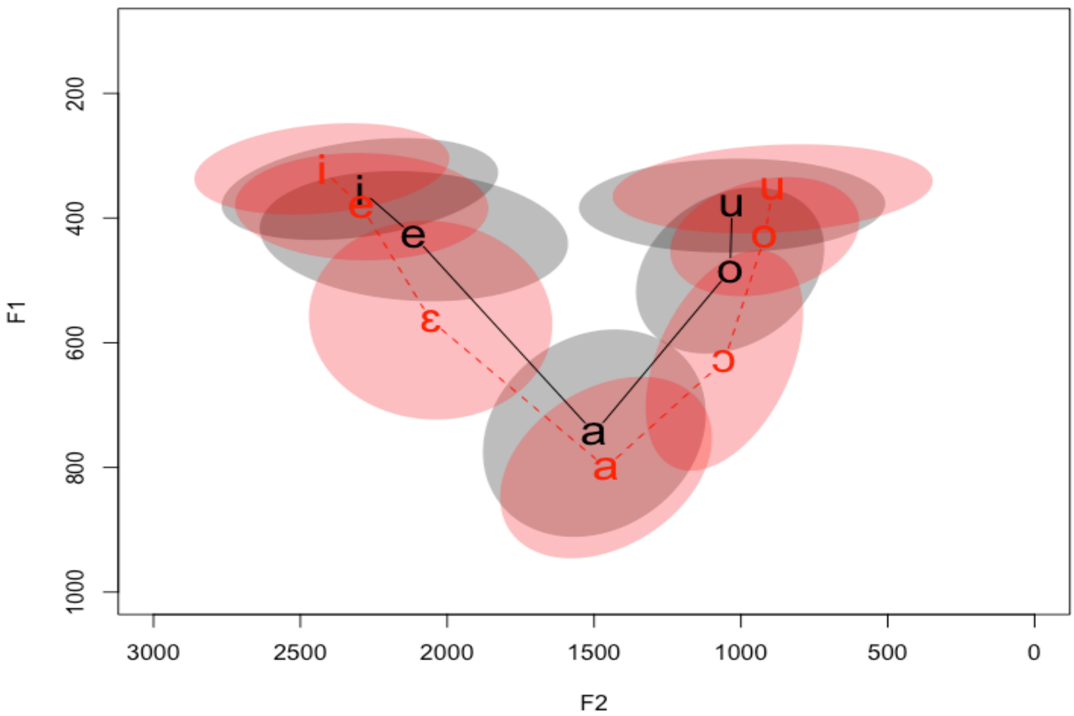



Figure 11. First and second formants of the stressed vowels and pre-stressed vowels in BP produced by Gaucho and Baiano speakers. Solid lines and grey ellipses = pre-stressed vowels; dashed lines and red ellipses = stressed vowels.

(48) Stressed versus Pre-Stressed Vowels in GA and BA

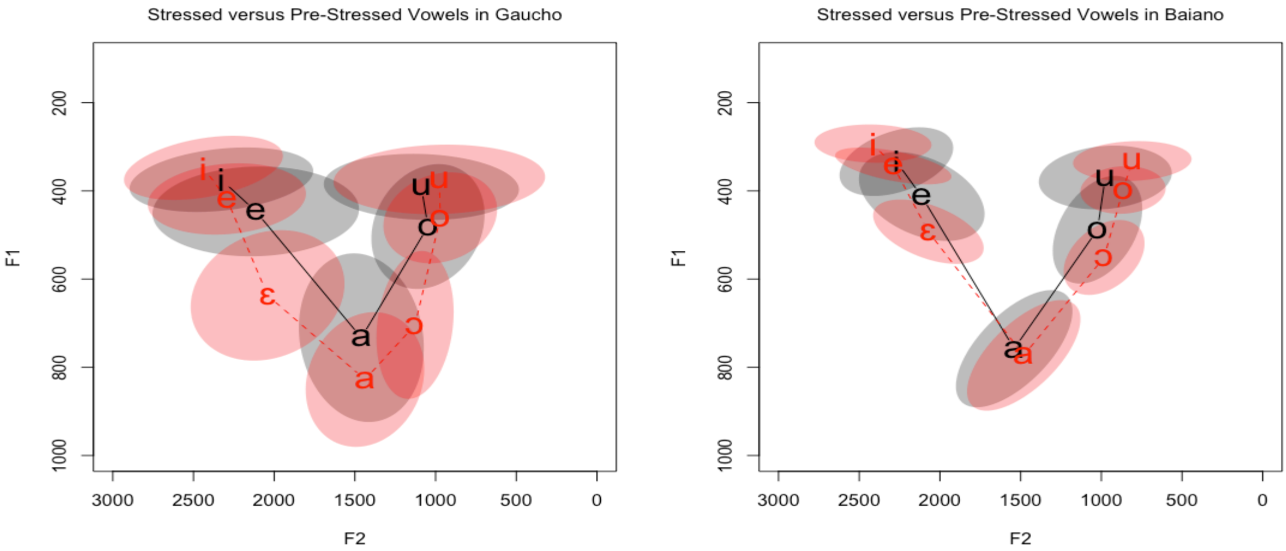



Figure 12. First and second formants of the stressed vowels and pre-stressed vowels in BP produced by Gaucho and Baiano speakers. Solid lines and grey ellipses = pre-stressed vowels; dashed lines and red ellipses = stressed vowels. *Left panel = Gaucho; Right panel = Baiano*

## 3.7 C-to-V Analysis

This section reports the results for C-to-V relations. It investigates whether the first consonant can affect the harmony of the target vowel. As described in Section 3.4, this position will only have stop consonants and the affricate [tʃ], allophonically motivated when /i/ is the next vowel (V1). Therefore, C1 refers to all three voiceless stop phonemes /p, t, k/ and the affricate allophone [tʃ]. The linguistic issue is whether the place of articulation of the consonant adjacent to the unstressed vowel can predict the behavior of the latter for phonological height. I will not investigate characteristics of the spectrum of burst in stops consonants, since I am not interested in fine details of their realizations, but I will treat place of articulation as a level of the factor Place-C1.

### 3.7.1 Place of Articulation

As place of articulation is an important characteristic of consonants that directly influences both height and back-front movements of the tongue (Ladefoged, 1996; Stevens, 1998), one might hypothesize that vowels which undergo harmony may be influenced by the previous consonant within a syllable. Moreover, the literature has pointed out that velar consonants might influence vowel raising even if there is no high vowel in the next contiguous syllable.

Thus, the goal of this analysis is to determine how the height of pre-stressed vowels may be affected by Place-C1. The F-test from the LMER model returned that Place-C1 has a significant influence on pre-stressed vowel F1, $F(2, 7336) = 31.700$, $p = 1.95 \times 10^{-14}$, but the interaction between Place-C1 and dialect has no significant effect on vowel F1 $F(2, 7336) = 0.168$, $p = 0.31$, indicating that the difference in place of articulation of stops can affect vowels differently, but there is no difference among the stops between the dialects, as can be seen in Figure 13, where the median of vowel F1 is similar for almost the three stops.

(49)

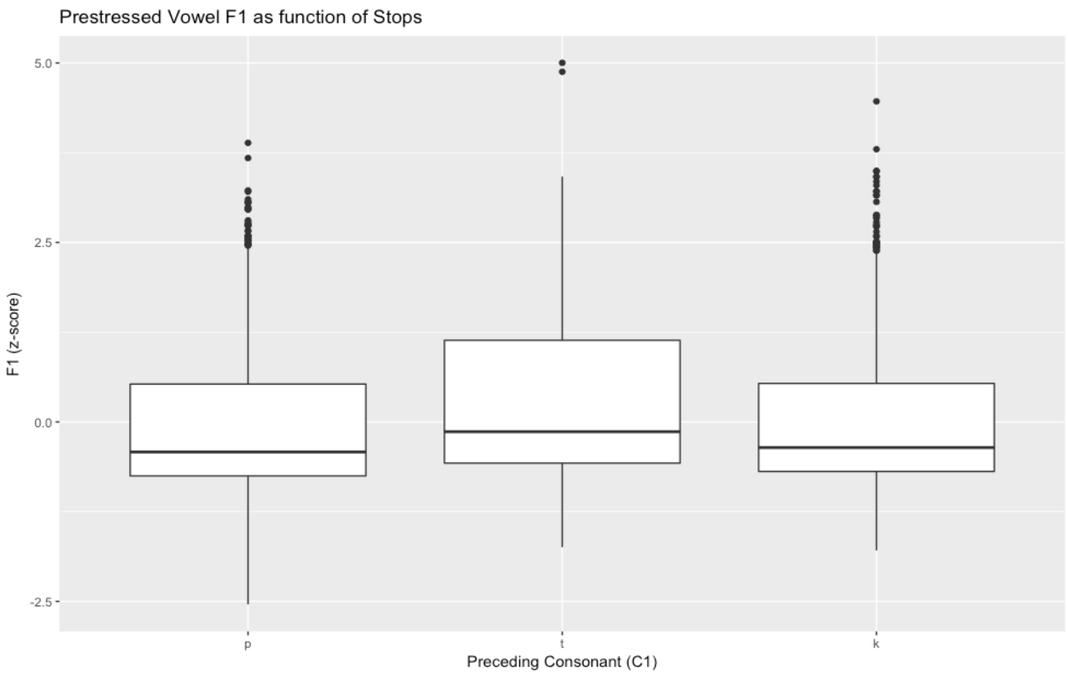



Figure 13. Normalized F1 of the pre-stressed vowels for the three stops in C1 position.

Tukey's HSD post-hoc analysis indicates that F1 of the pre-stressed vowels is not significantly different according to /p/ and /k/ ($p = 1$), but /t/ is different from /k/ ($p = 9.85 \times 10^{-08}$) and from /p/ ($p = 2.79 \times 10^{-08}$). The mean and SDs of each consonant are presented below.

(50)

Table 10. Mean and Standard Deviation (SD) of the F1 of the pre-stressed vowels followed by the three stops in C1 position.

| **Preceding Consonant** | **Pre-Stressed Vowel F1** | | | |
|---|---|---|---|---|
| | Mean | | SD | |
| | z-score | Hertz | Hertz | z-score |
| p | –0.003 | 479 | 167 | 1.03 |
| t | 0.22 | 513 | 162 | 1 |
| k | 0.029 | 483 | 160 | 0.99 |

However, as these results are relative to the whole set of pre-stressed vowels, one cannot determine how VH targets are affected. Chapter 4 is dedicated to the investigation about the effects of consonants, particularly on the target vowels /e/ and /o/.

### 3.8 V-to-C Analysis

I have argued so far that consonantal classes play an important role in BP VH. In Section 3.4, I briefly explored this issue, asserting that liquids may be more transparent consonants for BP [ATR] harmony. This section is aimed at determining the role of C2 consonants in VH targets of GA and BA, in order to investigate the effect of the intervening position between target and trigger vowels.

An additional LMER model was run to test C2, since the full model returned colinearity with Class C2. Although not necessary, I decided to run this test to determine which consonants would differ between the dialects. The F-test revealed a significant effect of C2 in interaction with dialect on the subset of pre-stressed vowels $F(1, 7341) = 2.66$, $p = 0.006$). A further investigation with Tukey's post-hoc reveals that the significant differences do not come from comparisons between the same consonants cross-dialectally, but from spurious comparisons such as /p/ and /l/, which is totally expected. For all pairwise comparisons of the same phoneme of the two dialects, we have not found significant differences ($p > 0.05$).

Considering that the variable C2 returned a significant effect on pre-stressed vowel F1 mean, Class-C2 is discussed in depth in the next section.

### 3.8.1 Consonantal Class

The model yielded significant main effects of Class-C2, $F(1, 7336) = 31.700$, $p = 2.783 \times 10^{-06}$, and its interaction with dialect regarding F1 of the pre-stressed vowels, $F(1, 7336) = 6.086$, $p = 0.013$. However, Tukey's post-hoc reveals that the significant differences are only intra-dialect and inter-class, since inter-dialect and intra-class differences are not significant, indicating that GA and BA liquids have similar effects on vowel F1 ($p = 0.06$) neither for pairs of GA and BA stops ($p = 1.00$). An interesting result was found for the effect of consonantal class, in which the inter-class difference (i.e. liquids and stops) in BA is not significant ($p = 0.55$), but inter-class difference is found for GA ($p = 1.95 \times 10^{-06}$). The pairwise comparisons with the correspondent p-value are presented below[16].

(51)

Table 11. Tukey Post-Hoc Results for comparison between Dialect and Class-C2.

| **Pairwise Comparison** | **p** |
|---|---|
| Baiano Stops vs. Baiano Liquids | 0.55 |
| Gaucho Liquids vs. Baiano Liquids | 0.06 |
| Gaucho Stops vs. Baiano Stops | 1.00 |
| Gaucho Stops vs. Gaucho Liquids | $1.95 \times 10^{-06}$ |

[16] Inter-class and inter-dialect comparisons are omitted, for example GA Liquids vs. BA Stops. This sort of comparison is given by the test, however the results are not interpretable, since what is important are intraclass comparisons with different dialects and interclass comparisons in the same dialect.

(52)

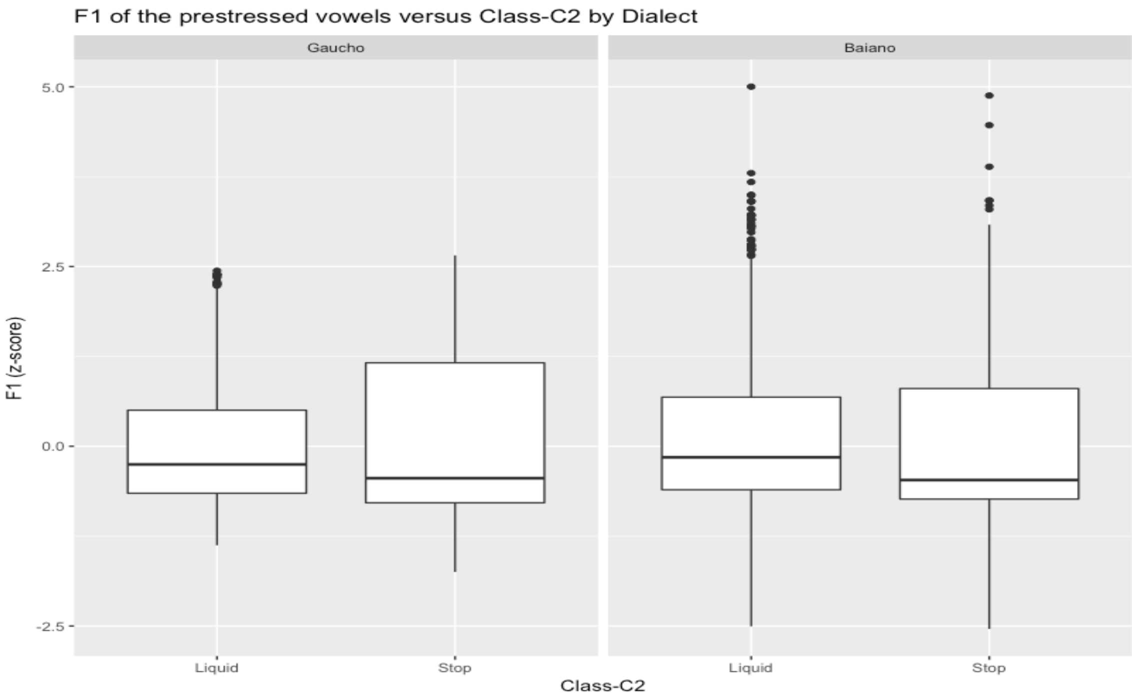



Figure 14. Normalized F1 values of pre-stressed vowels according to Class-C2 in Gaucho and Baiano dialects.

As we can see in the plot above, F1 of the pre-stressed vowels for the two C2 classes have different means within dialects, but there is no inter-dialect difference. Although this result does not confirm the hypothesis that the type of surrounding consonants can influence VH, it indicates an interesting target's sensitivity to phonological class of the environment. This is confirmed because there is no difference between classes in BA; however, in GA, stops and liquids affect vowels. Further research on this effect on VH targets is necessary in order to highlight the role a phonological class can play in triggering vowel shift in a VH system.

### 3.9 Conclusion

This chapter had two main goals: (1) to describe the acoustic parameters F1 and F2 of the pre-stressed and stressed vowels in GA and BA, and (2) to determine how the phonological environment (i.e. the preceding consonant, the following consonant) could affect pre-stressed vowels.

No main effect of gender and its interaction with dialect on pre-stressed vowels has been found, but dialect effect, as well as its interaction with vowels were significant factors in predicting the behavior of vowels. This is confirmed not only for pre-stressed vowels, but also for the stressed ones, whose F1 medians are presented below.

(53)

Table 12. Median of F1 (in Hz) values for all BP vowels produced by BA and GA speakers in stressed and pre-stressed syllables.

| | | **i** | **e** | **ɛ** | **a** | **ɔ** | **o** | **u** |
|---|---|---|---|---|---|---|---|---|
| Stressed | *Gaucho* | 337 | 411 | 613 | 847 | 687 | 448 | 362 |
| | *Baiano* | 289 | 344 | 493 | 791 | 540 | 394 | 326 |
| Pre-stressed | *Gaucho* | 378 | 436 | | 754 | | 480 | 400 |
| | *Baiano* | 334 | 395 | | 767 | | 482 | 367 |

As we can see, all BA stressed vowels are higher than those of GA: F1 values for all BA vowels are higher than for GA vowels. However, the difference is not significant when vowel pairs are compared. The same result was found for pre-stressed vowels, except for /a/ and /o/, whose values for BA are higher than those of GA, but still very close to one another.

As no vowel difference was found between dialects, it was hypothesized that the ED could explain the behavior of the targets /e/ and /o/, thus indicating cases of raising or lowering. However, it could be seen that the distances means between /e-i/, e-a/ and /o-i/ and /o-a/ were not significant between the two dialects; that is, the ED between the target vowel and the high vowel and the low /a/ was the same in both GA and BA. Therefore, this hypothesis was discarded, as discussed in Section 3.9.1.

There was a significant effect of C1 on F1 values of the pre-stressed vowels; however, the interaction between C1 and the dialects did not return significant results, indicating that C1 may affect vowels in the same way in both BA and GA. A surprising fact was found related to the role of consonantal class (Class-C2), that is, BA stops and liquids have the same effect on pre-stressed vowels; however, GA is not affected by stops even though it is affected by liquids. This finding possibly indicates that liquids are more transparent than stops, since this class has significant effects on vowel F1 values of both GA and BA. So far, we cannot support this claim, because these results are related to the whole subset of pre-stressed vowels that includes the vowels /i, a, u/ which are not VH targets. In order to make this claim, research is required on the effect of stops and liquids related specifically to the vowel targets /e/ and /o/. This will be discussed in depth in Chapter 4.

The effect of the stressed vowel in the precedent vowel which is a VH target will be discussed in detail in the next chapter, as well as the effects on the preceding and following consonants. The results reported in this chapter reveal tendencies of the whole subset of pre-stressed vowels and the characteristics of the stressed ones. Such description and the exploratory analysis are necessary to determine how these vowels are produced and their major differences according to stress and dialect. Some questions arise from these results:

1) If vowels are not different between dialects and the distances between vowels do not reveal any tendency, how does VH affect the targets /e/ and /o/?

2) Which phonetic cues could be relevant in production to predict the emergent categories in the pre-stressed position in both dialects?

3) It was seen that liquids are possibly transparent to VH, but is this class transparent to raising or lowering processes?

4) Are all the vowels affected by V2 quality or only the targets /e, o/ are affected?

These questions will be addressed in the next chapter, which is dedicated to investigating the effects on VH targets /e/ and /o/ of all the aspects explored in this chapter.

# 4 THE TARGET VOWELS /e/ AND /o/

## 4.1 Introduction

The aim of the previous chapter, in addition to describing the pre-stressed vowels of GA and BA, was to explore the role the preceding and intervenient consonants in vowel raising or lowering. However, it is necessary to determine how the targets /e/ and /o/ are affected by the immediately following stressed vowels as well the consonants the analysis involved the whole set of phonological pre-stressed vowels {/i, e, a, o, u/}.

The questions to be answered in this chapter refer specifically to VH targets, and can be stated as follows:

1) How does the height of the stressed vowels affect the targets /e/ and /o/?

2) Do the preceding consonants affect the targets?

3) Is there an effect of a consonantal class in BP VH systems?

Particularly as regard to question 3, it was hypothesized in the previous chapter that BP VH is sensitive to liquids. In such case, we could also hypothesize that consonantal classes can be opaque or transparent.

Finally, considering that only mid-high vowels are the targets of VH, the main interest is to figure out how the mid-high vowels /e, o/ are affected in their F1 acoustic parameter, since BP is reported to be a height-oriented harmonic system. Therefore, in addition to describing the behavior of the targets in different phonological contexts, this chapter determines the extent of VH in both dialects in order to investigate their differences and similarities.

## 4.2 The Targets /e/ and /o/ in Gaucho and Baiano

### 4.2.1 Relative Height of /e/ and /o/

In this section we will determine how the targets are distributed along the acoustic space in GA and BA. Thus, the relative height (RH) of /e/ and /o/ was calculated in both dialects. The goal was to determine whether their RH can predict the behavior of the target, that is, whether /e/ and /o/ may be raised or lowered depending on their RH. In order to assess that, RHs were computed by using the same method defined by Escudero et al. (2009). This measure can predict whether the vowels are raised or lowered within a normalized acoustic space.

The relative height within the front vowel space for /e/ and for the back space for /o/ is seen below, in (51a) and (51b) respectively:

(54)

(a) $\frac{\log F1(a) - \log F1(e)}{\log F1(a) - \log F1(i)}$ (b) $\frac{\log F1(a) - \log F1(o)}{\log F1(a) - \log F1(u)}$

According to the formula and as the authors state, "If all vowels were equally spaced along the log(F1) dimension, the lower-mid vowels would have a relative height of 0.333" (Escudero et al., 2009, p. 1387). It was found that, regardless of dialect, /e/ is higher than /o/, which has an RH of 0.79 *versus* 0.78 for /e/ in the Gaucho and Baiano dialects, respectively. The vowel /o/ has an RH of 0.86 in Gaucho versus 0.89 in Baiano. These results seem to contradict what some authors have found for BP, at least for the vowel /e/, which has an RH of 0.73 (Escudero et al., 2009, p. 1387).

The RH of /o/ was 0.75, which is very similar to that of /e/ for BP in general. Thus, this measure shows that [o] is closer to [u] than [e] is to [i]. As the mid-high vowels are closer to the high vowels than to the low vowel /a/, it was expected that the targets would be raised quite easily. However, what we see is an opposite tendency was found; the targets tend to be lowered, but not raised, despite their RH. The next section describes their behavior in detail.

### 4.3 Targets Lowered by [–ATR] Vowels

It is widely assumed in the literature that the phonological value of BP/VH is [+High]; therefore, the feature that triggers harmony is borne by the high vowels /i/ and /u/, which immediately follow the targets. Nevertheless, the result of the experiment does not show any tendency of raising vowels, rather, an inter-dialect harmonization based on [ATR] is observed.

### 4.4 Statistical Analysis

Since the vowels /e/ and /o/ form a subset of the pre-stressed vowels, I built a general model with values relative to these vowels only. Then, an LMER model was run with the normalized F1 as the response variable and *V2, dialect, C1* and *Class-C2* were defined as fixed effects. The *Participants* variable was set as the random factor. Interactions were also introduced in the model, namely *V2 versus dialect, C1 versus dialect and Class-C2 versus dialect.* This Linear Mixed-Effect Model is similar to the one run for the whole set of pre-stressed vowels in the previous chapter.

### 4.5 Results

### 4.5.1 Targets lowered in GA and BA triggered by [–ATR] vowels

A significant effect of V2 on the first formant of the target vowels, $F(6, 3078) = 178.86$, $p = 2.2 \times 10^{-16}$) was found, but no difference was found between the dialects, $F(1, 3.95) = 0.03$, $p = 0.87$), indicating that targets tend to have the same behavior in both dialects, and their tendency to lower vowels can be predicted by the category of the second vowel. Figure 15 shows that the stressed low vowels /ɛ, a, ɔ/ are responsible for attracting the targets, thus increasing the F1 means of the latter. Additionally, stressed /i, u, e, o/ have the same effect on F1 on the target vowels. This suggests that the VH in these dialects is triggered by the value of [ATR], since we could clearly split the set of vowels into two groups: the first one with the vowels /i, u, e, o/, and the second one, constituted of the trigger vowels, composed of /ɛ, a, ɔ/.

(55)

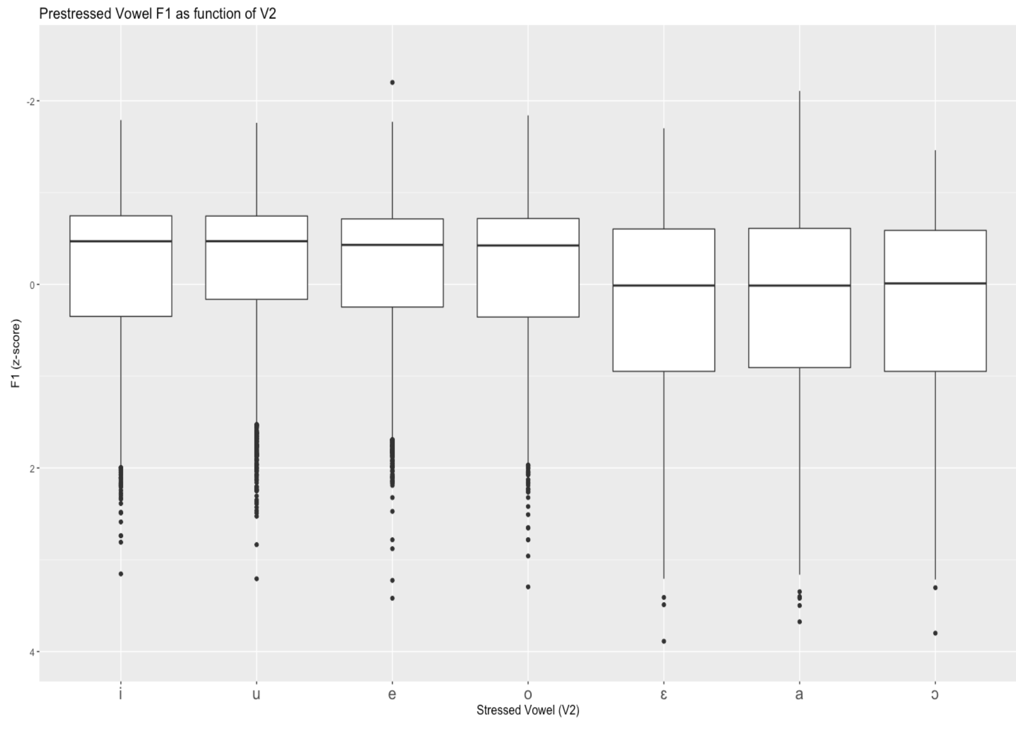



Figure 15. Normalized F1 values of the pre-stressed vowels according to the seven stressed vowels in V2 position.

The effect on F1 is not significant when the stressed vowel is one of the group of [+ATR] or [–ATR] vowels ($p > 0.05$), but when the compared pair differs in [ATR], the test returns a significant p-value ($p < 0.05$). This allows us to conclude that [–ATR] vowels trigger harmony, which is surprising, since BP is reported to have [+High] as the harmonic feature.

Furthermore, this claim is supported by the fact that there is no significant in effect between high vowels /i, u/ and mid-high vowels /e, o/, indicating that the effect of this vowel cannot be explained by the feature [High], but by the feature [+ATR], which they have in common.

This analysis takes into account the effect of V2 in both targets, but it is worth determining how V2 affects each vowel separately and considering the other variables as dialectal and consonantal contexts. The next section, then, reports the results for /e/ and /o/ separately, with a statistical model relative to each vowel.

### 4.5.2 The Target /e/

For the vowel /e/, the test confirms what was found in the full model. The effect of V2 is still significant, $F(6, 1544) = 142.875$, $p = 2.2 \times 10^{-16}$) and differences were not found between the dialects on the effects of F1 of /e/, $F(1, 2) = 0.048$, $p = 0.847$). A further analysis with Tukey's post-hoc test confirms what was found for the full model; that is, the significant effect of V2 is given by the difference between [+ATR] and [–ATR] stressed vowels. There were no differences among the [–ATR] vowels for both dialects and most of the pairs of [+ATR] vowels have the same results. There were, however, two pairs within the [+ATR] group with significant differences, namely, the pair /e/-/u/ in BA ($p = 0.003$). Also, the comparison between /o/ and /i/ showed a significant effect of the F1 value of these vowels on the target /e/ ($p = 0.0002$).

(56)

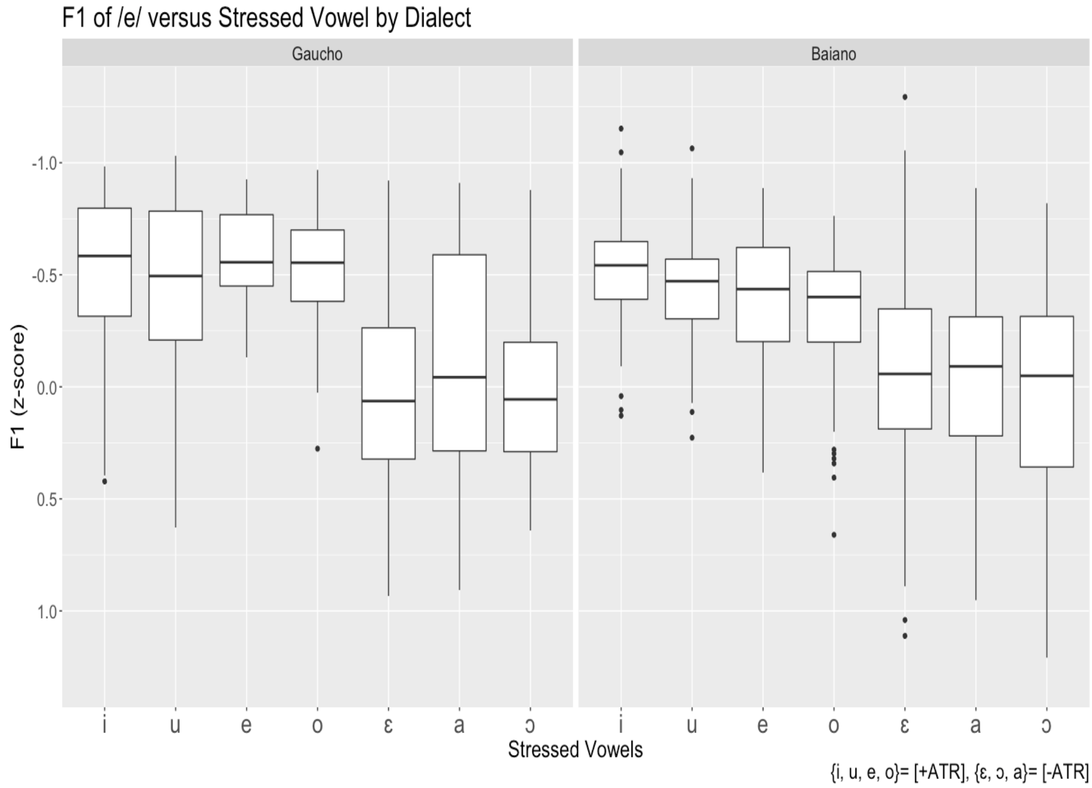



Figure 16. Normalized F1 of a phonological vowel /e/ according to all seven stressed BP vowels in Gaucho and Baiano dialects.

As indicated by the panels and confirmed by the statistical test, the median for F1 is higher (which means that vowels are lowered) when /e/ is followed by the low vowels /ɛ, a, ɔ/, indicating that both dialects tend to change the target vowel in favor of [–ATR] harmonization. In addition, the vowel /e/ has higher F1 when followed by the mid-high vowels /e, o/ than when followed by high vowels in BA, which is an expected V-to-V coarticulation effect, and it is seen by the decreasing tendency in GA when the vowel is [+ATR]. This fact seems clearer in the GA than in the BA dialect.

Also, an interesting dissimilatory effect can be seen in BA, in which the F1 of /e/ is lowered when the stressed vowel is /u/. This is the opposite to what would be expected if the BP harmony system were [+High] oriented. Because /u/ is a high vowel, it should influence F1 by raising rather than lowering the vowel. Although I cannot assert that this /e/ is lowered and that it has been changed to [ɛ], it obviously seems that this /e/ is not being raised.

### 4.5.3 The Target /o/

With regard to the back target vowel /o/, the model confirms a significant effect of the stressed vowel $F(6, 1520) = 91.397$, $p = 2.2 \times 10^{-16}$) and its interaction with dialect $F(6, 1520) = 4.921$, $p = 5.384^{-05}$). However, the effect of dialect itself on the F1 of /o/ is not significant, $F(6, 2.87) = 0.041$, $p = 0.853$). Tukey's post-hoc test reveals that the main significant difference consists of pairs of vowels with opposite values for [ATR]; moreover, there was no significant difference within the groups of [–ATR] and [+ATR] vowels.

(57)

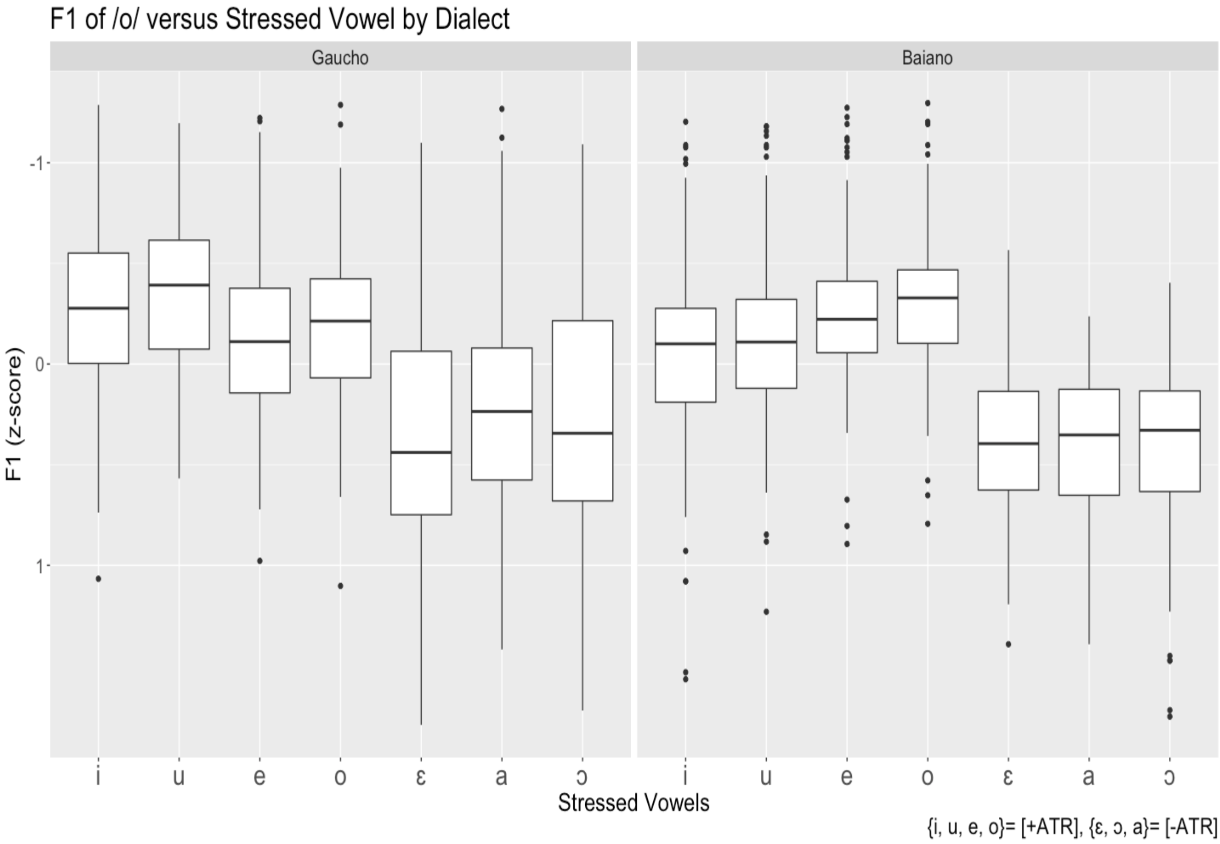



Figure 17. Normalized F1 of a phonological vowel /o/ according to all seven stressed BP vowels in *Gaucho* and *Baiano* dialects.

As can be seen in the panels, the pre-stressed vowel /o/ showed the same behavior as its front counterpart /e/, that is, they are both different according the [ATR] value of the stressed vowel. Additionally, it is consistent for BA to have lowered /o/ when the stressed vowels are the high ones, therefore, an unexpected dissimilatory effect might be a characteristic of this dialect, as this characterizes the behavior of both target vowels. Although no major conclusions can be drawn from this finding, one can hypothesize that the dialect is moving from a dissimilatory stage to an assimilatory one, in which VH is the main trigger. This hypothesis is plausible, since there are a few descriptive studies reporting the existence of low vowels in the pre-stressed position regardless of the height of the second vowel, as reported in Chapter 2.

The next section presents the results of the effect of the preceding consonants on the VH targets.

### 4.5.4 (Non)-Influence of the Preceding Consonants

In order to investigate how target vowels are affected by the first consonant, an LMER was run specifically for the subset of mid-high vowels to determine whether /e/ and /o/ are lowered or raised depending on the place of articulation of the immediately previous consonant.

(58)

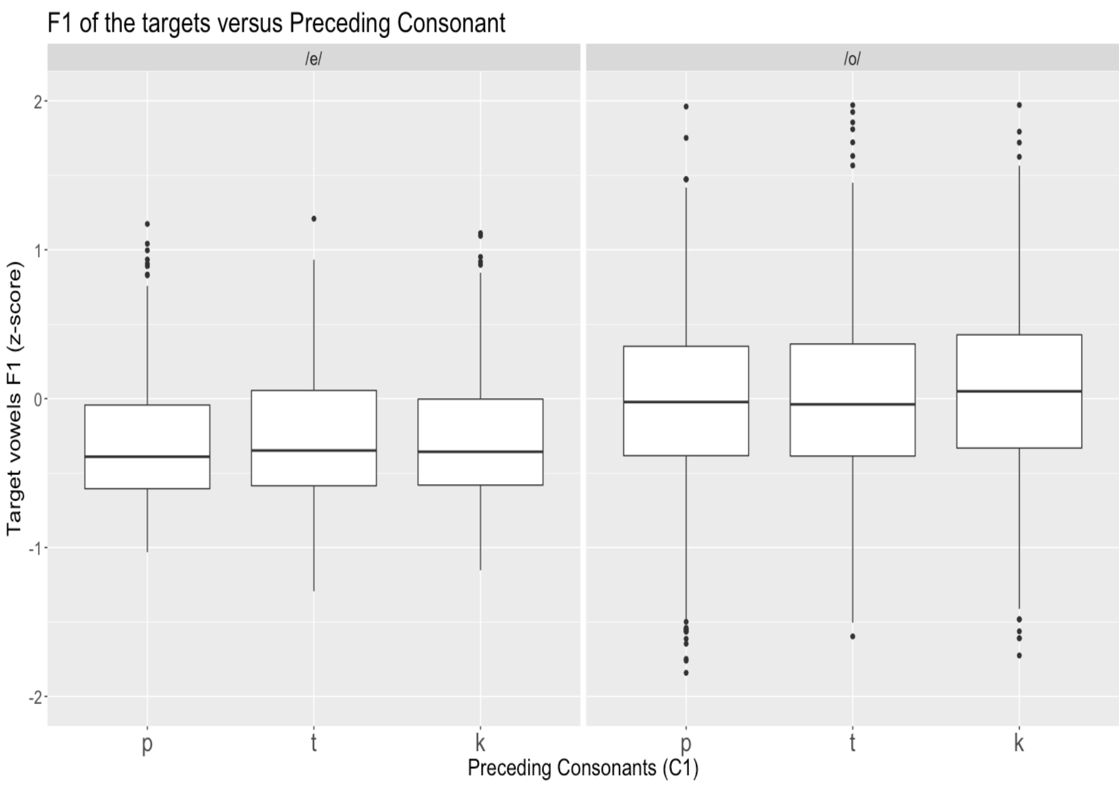



Figure 18. Normalized F1 of the pre-stressed vowels /e/ and /o/ according to the three stop phonemes as preceding consonants.

Figure 18 shows that /e/ is higher than /o/ because the F1 median of /e/ is equal to 429Hz (SD = 68.9Hz), whereas the F1 median of /o/ is equal to 484Hz (*SD* = 87.9Hz) regardless of place of articulation of the preceding consonant. The test revealed that the effect of C1 consonants on the pre-stressed vowels /e, o/ is significant $F(2, 3078) = 3.31$, $p = 0.036$; however, there is no dialectal difference in the effects of dialect on the preceding consonants of the targets, $F(2, 3078) = 1.28$, $p = 0.27$. Further, an investigation on the effect of C1 with Tukey's HSD post-hoc test revealed that there is no significant difference among the consonants /p, t, k/ within the same vowel category: the F1 mean of /e/ is not statistically different according to the preceding consonant and the same is valid for /o/, although the F1 mean of /e/ is significantly different from the F1 mean of /o/, as previously shown.

These results lead to the conclusion that Place-C1 does not play any role in raising or lowering vowels, although coronal /t/ has significantly greater effect on pre-stressed F1 mean relative to the whole set of vowels. However, particularly for VH targets, whose phonological height is supposed to change as influenced by the preceding consonant, the tests revealed that the place of articulation of stops shows the same effect on the targets.

The next section presents the results for the V-to-C analysis concerning consonantal class. Such analysis is important because it has been suggested that the intervenient consonant between the target and the trigger influences VH systems. Many systems have opaque (Krämer, 2003; Nevins, 2005) or transparent consonants (Mahanta, 2008) for harmony. In BP, Schwindt (2002) and Sandalo et al. (2015) have pointed out that liquids tend to influence the behavior of /e/ and /o/.

### 4.5.5 Effect of Consonantal Class in Target-Trigger Intervenient Position

Considering that the main goal of this section is to determine how target vowels may be affected by the surrounding consonants and by the stressed vowels, one needs to check whether Class-C2 could trigger changes in the height of the vowel targets /e/ and /o/. In Chapter 3, it was reported that there is a main effect of Class-C2, and BA and GA show different behaviors as regards stops or liquids: whereas no effect of stops or liquids was found in BA, GA seems sensitive to this sonorant contrast. In this section, therefore, I will investigate the effect of Class-C2 on the VH targets not only in its interaction with dialect, but also in the interaction between dialect and the trigger vowels.

The LMER model yielded a significant effect for Class-C2 on F1 of the pre-stressed vowels /e/ and /o/ ($F(1, 3078) = 429.08$; $p = 2.2 \times 10^{-16}$); and an effect was found for the interaction between Class-C2 and Dialect. Tukey's post-hoc test reveals, however, that the source of the significant value for Class-C2 is due to an inter-class difference within the same dialect: stops and liquids have different effects in BA and also in GA ($p < 2.2 \times 10^{-6}$), but BA liquids are not different from GA liquids, and the same is valid for the effect of stops.

### 4.5.6 Influence of Consonantal Class by Dialect and Stressed Vowel

These results do seem to indicate that Class-C2 is an important cue in triggering VH as suggested to in the previous section. Now, it is necessary to inquire how each vowel target is affected by consonantal class. The hypothesis is that liquids could be more transparent to phenomena involving vowels rather than consonants, because the sonority value of the former is closer to that of vowels (Clements, 1981, 1991). This issue will be addressed in the following sections by analyzing the effect of Class-C2 on each target and dialect separately.

### 4.5.7 The Target /e/

#### 4.5.7.1 Target /e/ in the context of Stop Consonants

Concerning the role of stops on the target /e/, a significant effect on the F1 of /e/ according to the interaction between dialect, Class-C2 and V2 ($F$(13, 3000] = 19.831, $p$ = 0.015) was found. A post-hoc Tukey's test showed that the [+ATR] and [–ATR] vowel groups differed significantly for $p < 0.05$ in all the pairs for BA; thus, for Baiano speakers, this difference is indeed relevant for the harmonization of the target /e/. Also, no difference was found among the [–ATR] vowels, but there was a marginally significant difference within the subset of [+ATR] for the pairs /e/ *vers*us /u/ ($p$ = 0.04) and for /u/ *versus* /i/ ($p$ = 0.01), whose behavior can be seen in the plot below. The behavior of /e/ when the stressed vowel is /u/ in BA is surprising because it shows a dissimilatory effect that is not expected in harmony systems. However, although significant results were found with respect to the effect of the vowel /u/ in BA, Figure 19 shows that such behavior is likely to be language-specific since the vowel /e/ is also lowered when followed by /u/ in GA.

(59)

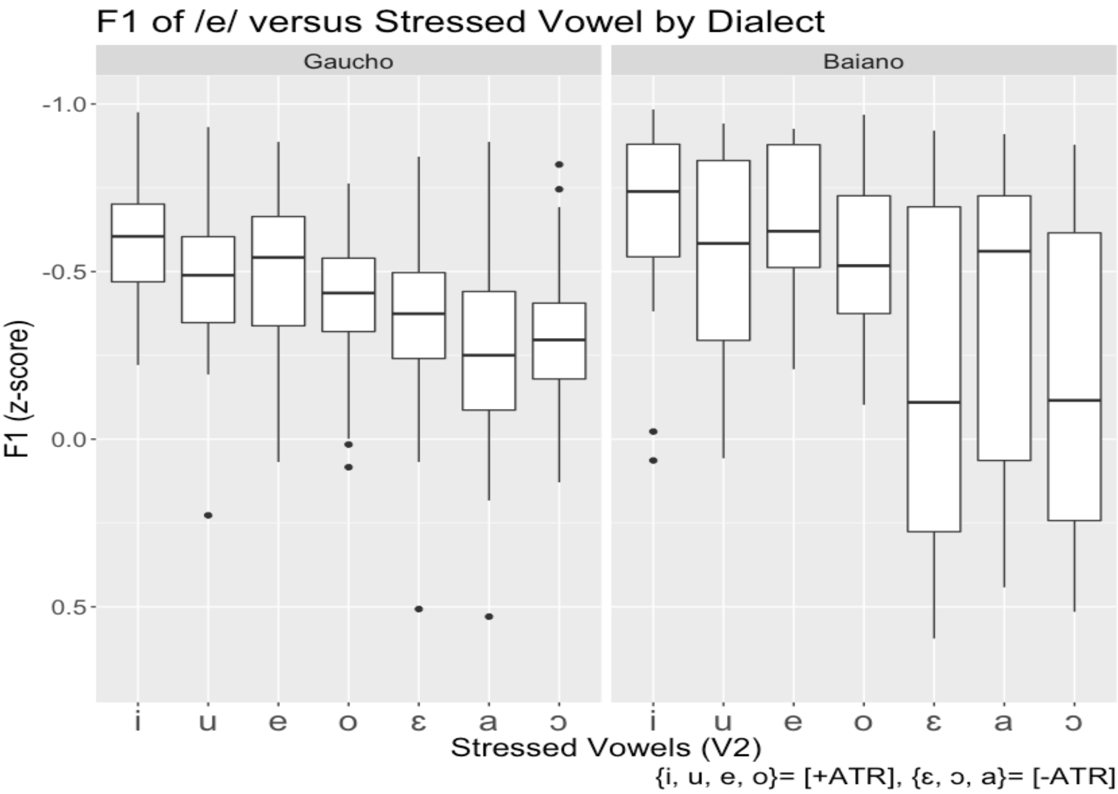



Figure 19. Normalized F1 of pre-stressed vowel /e/ according to the seven stressed vowels for Gaucho and Baiano dialects in the context of stops as intervenient consonants.

For the GA variety, the pairwise post-hoc test returned that the comparison among the three [–ATR] vowels is not significant at $p < 0.05$, indicating that the vowels /ɛ, a, ɔ/ have the same effect on the target /e/. The significant difference between [–ATR] and [+ATR] vowels is confirmed for almost all pairs, with four non-significant difference exceptions ($p > 0.05$), which were the pairs: a) /e/ *versus* /ɛ/, b) /o/ *versus* /ɔ/, c) /o/ *versus* /ɛ/, and d) /u/ *versus* /ɛ/. Although there was a decreasing tendency for GA and also significance for [–ATR] *versus* [+ATR], we cannot clearly see two groups of [+ATR] and [–ATR] vowels as can be seen in the BA dialect. We can, however, point out that GA vowel /e/ is, to a great extent, influenced by the height of the following vowel, since the lower the stressed vowel, the lower the first formant of /e/ is.

#### 4.5.7.2 Target /e/ in the context of Liquid Consonants

The behavior of vowel /e/ in the context of liquid consonants demonstrates that harmonization between target and trigger vowels occurs freely regardless of the intervening consonants. This fact is confirmed by the LMER model, which yielded a significant effect of *V2* in the interaction between *Class-C2* and *Dialect,* $F(13, 3.601) = 58.302$, $p = 0.0012$). In the next plot, such harmony behavior with [–ATR] can easily be seen for both dialects.

(60)

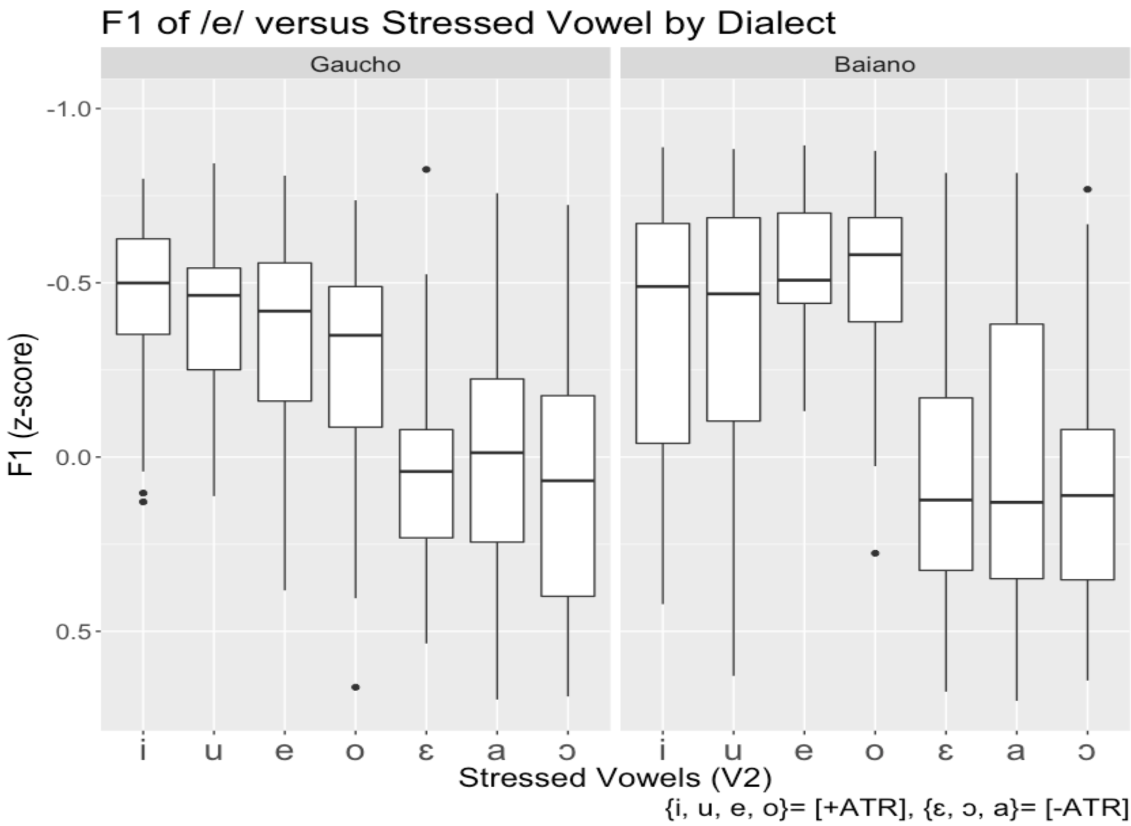



Figure 20. Normalized F1 of pre-stressed vowel /e/ according to the seven stressed vowels for Gaucho and Baiano dialects in the context of liquids as intervenient consonants.

As one can see in all four panels, vowel /e/ is lowered in the context of the subset of phonological low stressed vowels both in stops and in liquids. Tukey's post-hoc test revealed that vowels can be grouped according to the value of the feature [ATR]. For all pairs between [+ATR] and [–ATR], the test is significant with $p < 0.001$, while for comparisons between vowels that share the same values for [ATR], the test is non-significant at the level of 0.05 for both dialects. The exception is the pair /o/ *versus* /i/ in GA, which showed a significant difference ($p = 0.004$). However, this does not seem to overrule the generalization about the role of the feature [ATR] in explaining the behavior of the target /e/.

### 4.5.8 The Target /o/

#### 4.5.8.1 Target /o/ in the context of stop consonants

Similar results are attested to for vowel /o/. The influence of stops in the interaction with dialect showed a significant main effect ($F(13, 2.9688) = 19.831$, $p = 0.016$). For the GA dialect, Tukey's post-hoc test returned that vowel /a/ has the same effect presented by [+ATR] vowels, with $p > 0.05$ for comparison with each [+ATR] vowel. On the other hand, all pairwise comparisons between /ɛ/ and all [+ATR] vowels returned $p < 0.001$ and the same was found for the back counterpart /ɔ/, which also showed a significant difference with $p < 0.001$.

Figure 21 shows that in the environment of stops, the target /o/ seems to be lowered for [–ATR] vowels in GA, but not for /a/, as confirmed by the post-hoc test. However, BA is clearly divided by the feature [ATR], as can be clearly seen in the plot.

(61)

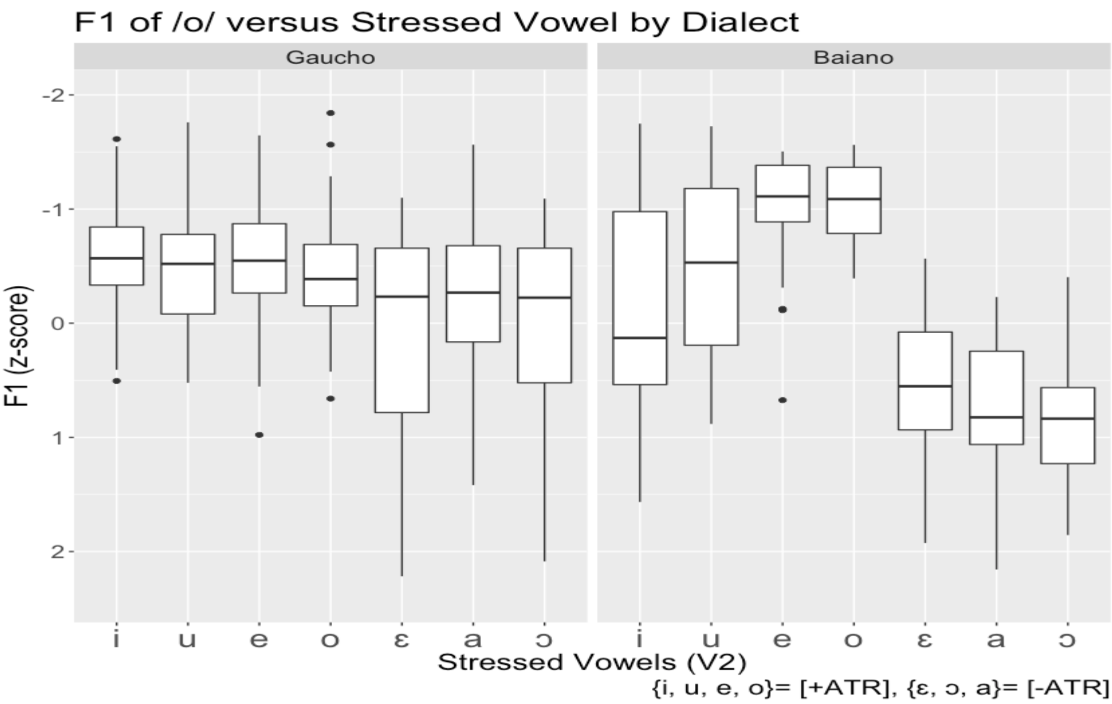



Figure 21. Normalized F1 of pre-stressed vowel /o/ according to the seven stressed vowels for Gaucho and Baiano dialects in stops context as intervenient consonants.

Tukey's post-hoc test confirms that BA VH is indeed triggered by [–ATR] vowels, since a significant difference was found for comparisons among all [+ATR] and [–ATR] vowels ($p < 0.001$). Additionally, expected significant values were not found for comparisons with [+ATR] for the pair /e/ *versus* /i/ ($p = 0.0013$) and /o/ *versus* /i/ ($p = 0.04$), indicating a significant dissimilation for the target /o/ when /i/ is the stressed vowel in BA. The plot above shows that both high vowels tend to lower the F1 of /o/ in BA, in contrast with the mid-high vowels, although only /i/ is significantly different from the mid-high vowels.

In general, the behavior of the target vowel /o/ confirms the finding for its front counterpart, indicating that stops in GA do not seem to be transparent to VH. However, there are some cases of significant differences between [+ATR] and [–ATR] for GA, for example, the intervenient stop consonants tend to block harmonization between target and trigger vowels, while for BA, stops do not block harmonization.

#### 4.5.8.2 Target /o/ in the context of liquid consonants

For the GA variety, a main significant effect of *V2* was found in the interaction between *Class-C2* and *Dialect* on the pre-stressed F1 of /o/ ($F(13, 991) = 51.422$, $p < 2.2 \times 10^{-16}$). A further Tukey's post-hoc test confirmed that the comparisons of all [+ATR] and all [–ATR] vowels are significantly different ($p < 0.05$) in both dialects, suggesting that liquid consonants form a transparent environment for VH.

(62)

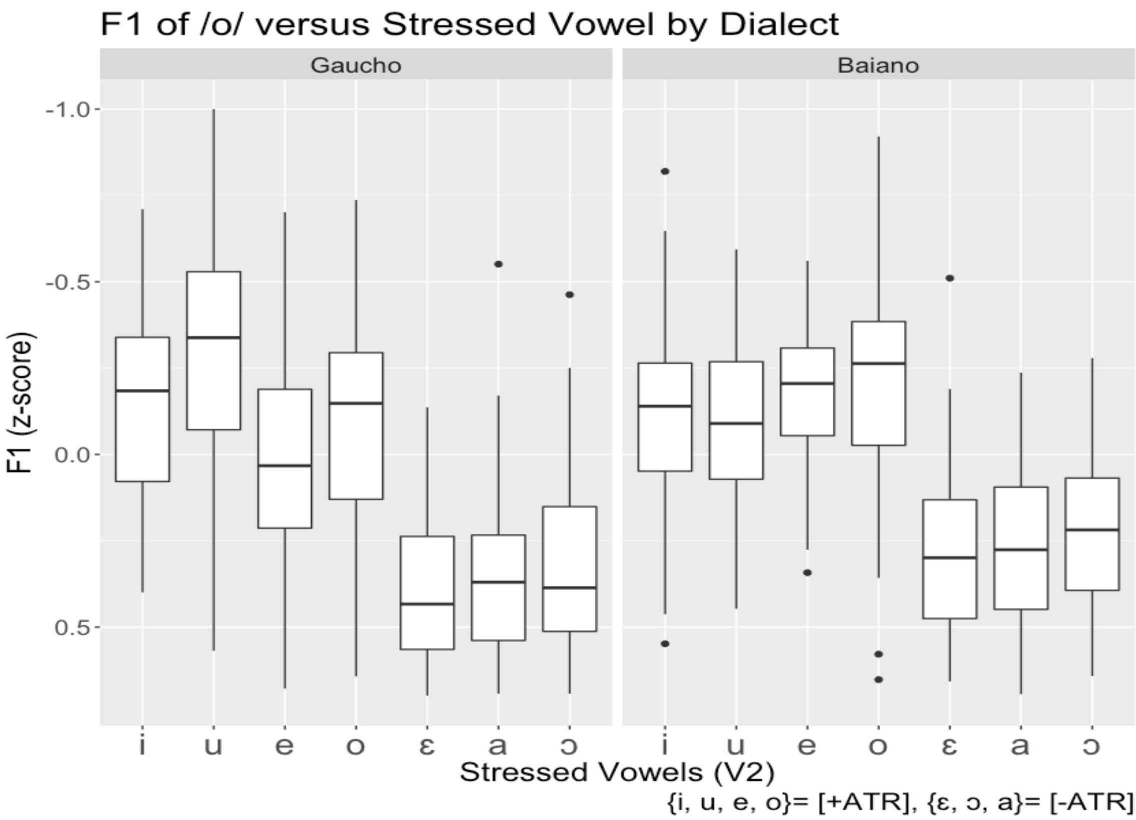



Figure 22. Normalized F1 values of pre-stressed vowel /o/ according to the seven stressed vowels for Gaucho and Baiano dialects in liquid contexts as intervenient consonants.

The pairwise test confirms that there is no significant difference among [–ATR] vowels either in BA or in GA, suggesting that the vowels /ɛ, a, ɔ/ trigger VH in the same way. For the comparisons among the [+ATR] vowels, BA does not show any difference within the subset of [+ATR], whereas [+ATR] of GA are significantly different only for comparisons with the vowel /u/. The pairs /u/ *versus* /e/, /u/ *versus* /o/ and /u/ *versus* /i/ are significantly different ($p < 0.05$). However, this difference does not mean that these vowels trigger [+ATR] harmony; actually, this only means that the vowel /u/ has a significantly different effect on the target /o/ than the other [+ATR] vowels. The target /o/ is a bit higher when followed by /u/, but this value is not sufficient to indicate that /o/ has been raised.

In fact, we can conclude that the target /o/ is more coarticulated with /u/ than with the other [+ATR] vowels /e, o, i/. In order to conduct a further investigation on the target-trigger coproduction, the next section is dedicated to discussing the results about the V-to-V coproduction by investigating the association between the first formant for the target and trigger vowels.

### 4.5.9 Target-Trigger First Formant Association

This section determines how the F1 of the target vowels may be predicted by the F1 of the stressed vowels. In other words, the goal is to investigate how these parameters are correlated. The hypothesis is whether /e/ or /o/ are harmonized in the context of [–ATR] vowels. It should be noted that the regression line slope for /e/ and /o/ in such context has to be close to zero, since these vowels are already harmonized; therefore, they share the same values.

### 4.5.10 Statistical Analysis

To investigate the association between target-trigger F1, a Linear Mixed-Effects Regression Model was run. The response variable was set as *F1V1* (normalized F1 of the target) and the fixed factors were *F1V2* (normalized F1 of V2), *ATRV2* (the value for [ATR] of the stressed vowels) and the variable *ATR* itself. The random factor was set for the variable *Participants*. The model is similar to the one that has been used throughout this work, as well as the variables; the only difference here is the variable *F1V2*, which is a continuous variable. Also, as F1V2 values come from the measurements of different vowel categories, such variable is nested within the value for [ATR] of the stressed vowels, hence the model has to predict this behavior by defining *F1V2* in interaction with *ATRV2* and also by adding *ATR* as another fixed factor. The Linear Mixed-Effects Regression was applied for each target /e/ and /o/ separately, and is presented in the next two sections.

### 4.5.11 Results

#### 4.5.11.1 The Target /e/

A marginal significant effect of the [ATR] feature itself, $F(1, 1156) = 4.155$, $p = 0.041$) was found, but there was a larger significant effect for [ATR] in the interaction with *F1V2*, $F(2, 1556) = 4.671$, $p = 0.009$), indicating that the value of [ATR] associated with F1 of the stressed vowels may correctly predict the behavior of the vowel target /e/.

(63)

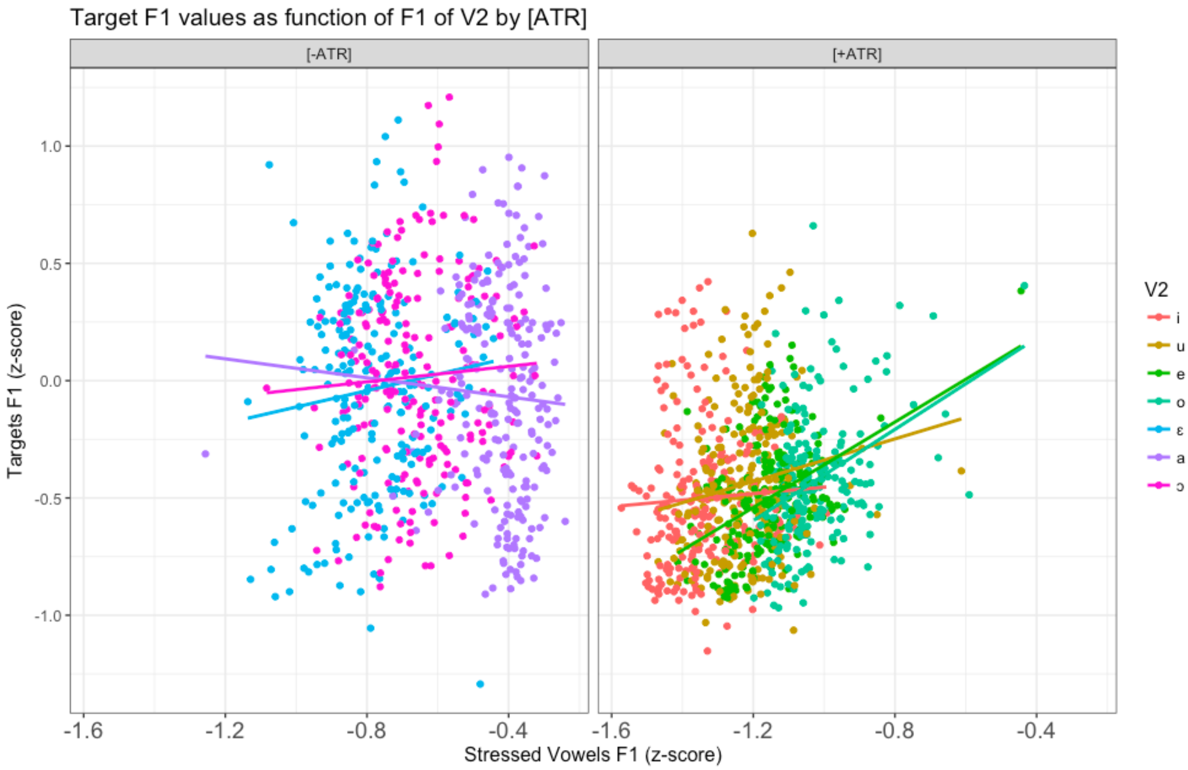



Figure 23. Normalized F1 values of the vowel target /e/ as function of the F1 values of the stressed vowels according to the value of the feature [ATR].

(64)

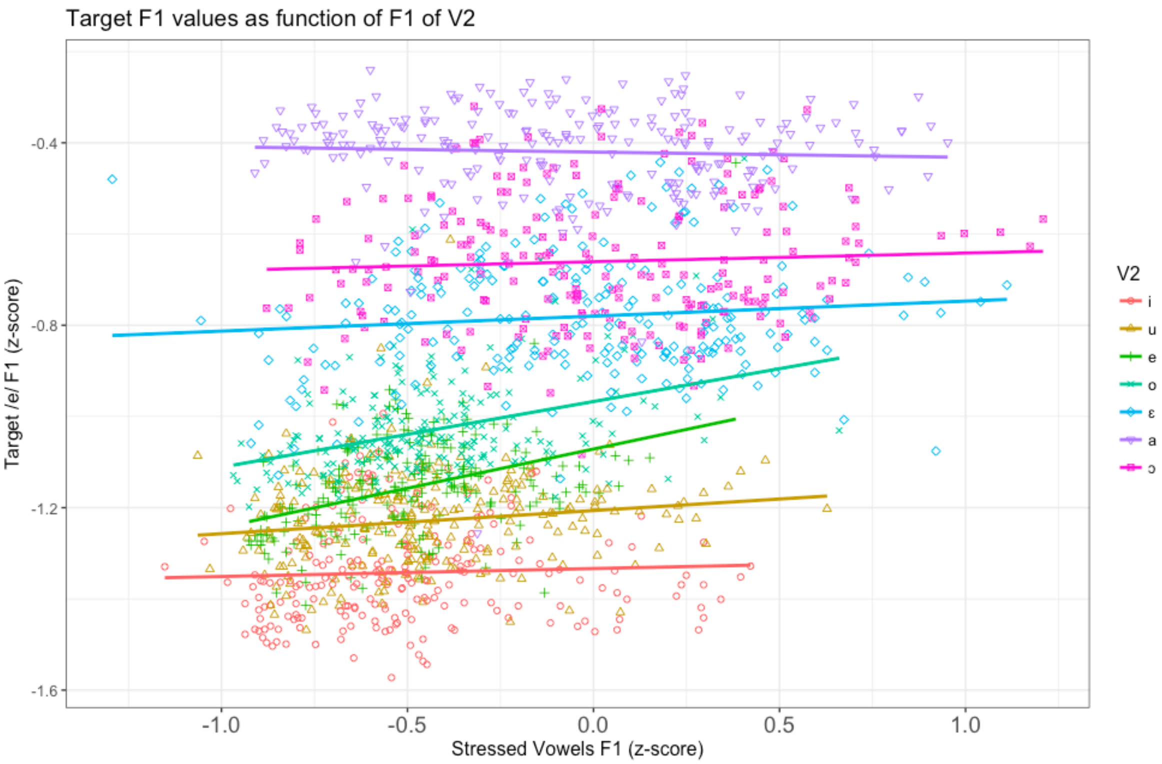



Figure 24. Normalized F1 values of the vowel target /e/ as function of the F1 values of the stressed vowels.

It can be seen that F1 of the target /e/ is highly influenced by the [ATR] value of the stressed vowel, as can be seen on the vertical variation in Figures 23 and 24. When defining [–ATR] as a baseline, [+ATR] is marginally significant in influencing the F1 of /e/, indicating that /e/ when followed by an [+ATR] vowel is different from an /e/ followed by [–ATR], and also its interaction with *F1V2*. This is highly expected, since I argue that pre-stressed /e/ has already changed to [ɛ]; thus, the influence of [–ATR] will not be significantly different from the baseline.

(65)

Table 13. Linear Mixed-Effects Regression Model for the vowel target /e/.

| | Estimate | SE | df | *t* | *p* |
|---|---|---|---|---|---|
| (Intercept) | –0.015 | 0.096 | 4.5 | –0.16 | 0.876 |
| *ATR* = [+ATR] | –0.191 | 0.094 | 1556 | –2.03 | 0.041 |
| F1V2:[–ATR] | 0.021 | 0.065 | 1556.8 | 0.335 | 0.737 |
| F1V2:[+ATR] | 0.220 | 0.072 | 1557.2 | 3.053 | 0.002 |

The results for [ATR] show that the distribution for the vowel /e/ across the F1 axis presents more variance when the target is followed by [–ATR], therefore confirming that /e/ is indeed more affected by the stressed /ɛ, a, ɔ/ than by /i, u, e, o/. In other words, we could say that /e/ preserves its phonological identity in the [+ATR] context. In conclusion, /e/ lowering is triggered by [–ATR] vowels. The next section presents the results for the target /o/.

#### 4.5.11.2 The Target /o/

The model for the vowel /o/ returned a highly significant effect of the [ATR] feature itself on the target /o/, $F(1, 1535) = 18.626$, $p = 1.692 \times 10^{-05}$), but for the [ATR] feature in interaction with *F1V2* a significant effect was found, $F(2, 1510) = 3.692$, $p = 0.02$), which is the opposite tendency found for the vowel /e/.

Figure 25 shows that the regression lines for each [+ATR] vowel are close to zero, indicating that /o/ followed by such vowels is less influenced by the F1 of stressed /I, u, e, o/. This is expected, because it is hypothesized that if vowels are harmonized in [+ATR] and in [–ATR] contexts, the regression lines have to be closer to zero, as the targets have already changed. The difference consists of the degree to which [+ATR] and [–ATR] can affect the first formants of the targets, that is, whether a subset of vowel affects the targets more than other vowel subset. From the plot, it can be seen that vowels can be sharply divided by the feature [ATR].

(66)

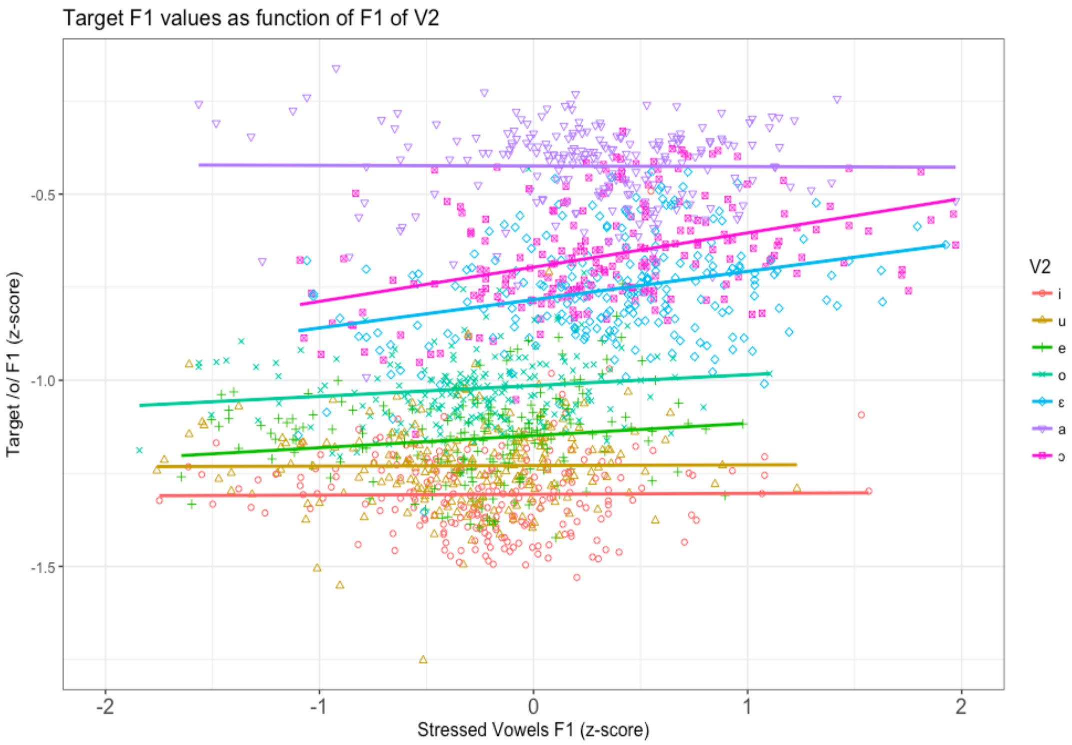



Figure 25. Normalized F1 values of the vowel target /o/ as function of the F1 values of the stressed vowels.

(67)

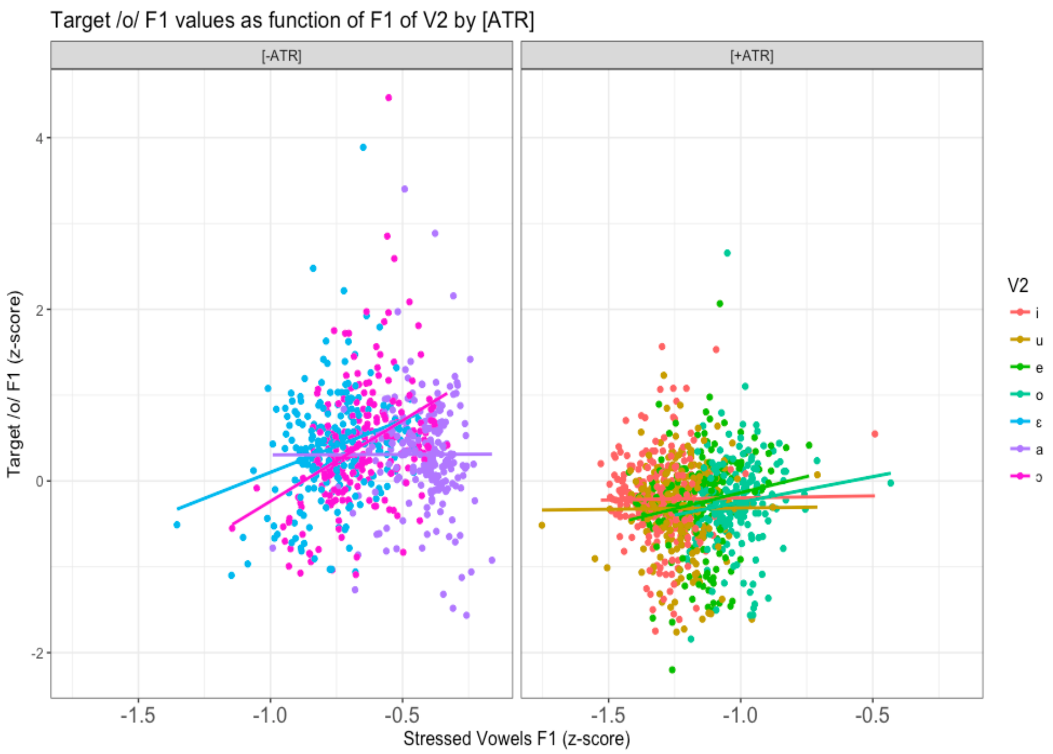



Figure 26. Normalized F1 values of the vowel target /o/ as function of the F1 values of the stressed vowels according to the value of the feature [ATR].

Because the role of the [ATR] vowel /o/ shows similar behavior to that of /e/, but with a much highly significant p-value. The result for the regression shows that an /o/ followed by [+ATR] is different from an /o/ in [–ATR] contexts ($p$ = 1.69 x $10^{-05}$). However, the results for the interaction between *F1V2* and *V2* suggest that the category of /o/ might not have changed to [ɔ] yet, as the influence of the variable interaction reveals that in [–ATR] contexts the F1 of /o/ increases by 0.31 for each unit of *F1V2.*

(68)

Table 14. Linear Mixed-Effects Regression Model for the vowel target /o/.

| | Estimate | SE | Df | *t* | *p* |
|---|---|---|---|---|---|
| (Intercept) | 0.575 | 0.083 | 96.7 | 6.918 | 4.97 x $10^{-10}$ |
| *ATR*=[+ATR] | –0.734 | 0.170 | 1535.9 | –4.316 | 1.69 x $10^{-05}$ |
| F1V2:[–ATR] | 0.314 | 0.117 | 1504.9 | 2.677 | 0.0075 |
| F1V2:[+ATR] | 0.078 | 0.131 | 1516.8 | 0.598 | 0.55 |

The results for the vowel /o/ suggests [–ATR] harmonization. Moreover, both targets are highly influenced by the low vowels, shifting their phonological identity in favor of a harmonization that is triggered by the phonological value of [ATR].

### 4.5.12 Conclusion

This chapter discussed the role of the phonological environment in the harmonization process that reaches the targets /e/ and /o/. Thus, the goal was to determine how the height of /e/ and /o/ is affected by the stressed vowels and by the preceding and following consonants.

The results for the V-to-V relationship suggest that stressed low vowels are responsible for lowering the targets to implement a low harmonization process. However, the high vowels do not act as triggers in the contexts controlled in the experiment. On the contrary, high vowels have the same role as the mid-high ones, leading us to conclude that BP harmony can be adequately explained by the feature [ATR]. Table 15 shows that the targets /e/ and /o/ are produced as [e] and [o] in [+ATR] contexts, but harmonized triggered by [–ATR] vowels.

(69)

Table 15. Behavior of the targets according to the value of [ATR].

| | | *Triggers* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | [+ATR] | | | | [–ATR] | | |
| | | i | u | e | ɔ | ɛ | a | ɔ |
| *Targets* | /e/ | [e] | [e] | [e] | [e] | lowered | lowered | lowered |
| | /o/ | [o] | [o] | [o] | [o] | lowered | lowered | lowered |

Additionally, the targets /e/ and /o/ have similar behavior in BA and GA dialects, when only the main effect of the stressed vowels is taken into account. This indicates that the VH system of target and triggers is basically the same. The difference is due to the effect of the intervening consonant, which varies according to the class of the consonant.

(70)

Table 16. Behavior of the targets according to stops and liquids as intervening consonants.

| | *Targets* | *Stops* | *Liquids* |
|---|---|---|---|
| *Gaucho* | /e/ | Opaque | Transparent |
| | /o/ | Opaque | Transparent |
| *Baiano* | /e/ | Transparent | Transparent |
| | /o/ | Transparent | Transparent |

Table 16 summarizes the findings for each target vowel in the two dialects. As can be seen, the liquids are transparent to low assimilation in our experiment, but the stops have such behavior only for BA. The results concerning the opaqueness of the stops in GA might be an overgeneralization, since some pairwise comparisons for the target /e/ revealed that there is no difference between the effect of the stressed /e/-/ɛ/, /o/-/ɔ/, /o/-/ɛ/ vowels and /u/-/ɛ/. However, the results about the target /o/ consistently indicate that there are no differences in the effects of [+ATR] and [–ATR] trigger vowels, suggesting that stops are more opaque for this vowel than for /e/. As the effect of speakers was controlled by inserting the variable *Participants* as a random factor in the models, we do not expect this result to be related to a specific speaker.

For this reason, the opaqueness of stops may be dialect-specific, but this requires further research.

Finally, another goal of this chapter was to determine how the F1 of the stressed vowel could predict the F1 of the target. The results confirmed the hypothesis that [–ATR] vowels, which have higher F1 values, can predict the height of the targets. However, although we can argue that /e/ and /o/ seem to assimilate the height of the [–ATR] vowels and remain as mid-high in [+ATR] contexts, we cannot conclude that these vowels are indeed lowered to [ɛ] or [ɔ], respectively. It is difficult to draw a line between coarticulation and VH, that is what is a phonetically lowered version of a vowel, and what is a different vowel that results from phonological VH.

The aim of the next chapter is to determine how vowel category boundaries could be predicted in VH systems. The goal is to propose a measure that can provide threshold values for vowel variation in a given category. Such measure would make it possible to estimate if speakers of a given dialect present a harmonic system or whether they only present an effect of vowel-to-vowel coarticulation.

# 5 VOWEL THRESHOLDS

## 5.1 Introduction

The goal of this chapter is to investigate vowel-to-vowel relationships based on the acoustic measurements of the first and second formants of pre-stressed and stressed vowels. After the analyses of the measurements presented in the previous chapter, I now attempt to predict the behavior of target vowels based on the trigger vowel formants, for each speaker of the GA and BA dialects. I also concluded that vowels tend to be lowered in [–ATR] environments and thus proposed the [ATR] VH for BP.

The linguistic question that needs to be addressed in this study may be stated as follows: How do we predict pre-stressed vowel phonological height based on phonetic measurements? Although one may determine a value based on vowel formant values of stressed vowels, it is known that pre-stressed vowels are centralized and more reduced (Crosswhite, 2001). Also, it is not simple to accurately determine whether a vowel can be considered a raised or lowered version of the same vowel or whether the phonological quality has been changed. It is, therefore, worth addressing a question about how to determine a boundary between a lowered [e̞] or raised [e̝] and a canonical [e]. Can we still consider it an [e] or has it changed to [ɛ] or [i], respectively?

Bearing in mind the considerations above, I present a proposal of a measurement that could estimate vowel categories based on values of F1 and F2 of both vowels involved in assimilation. The measure estimates vowel shifts based on the measurements of F1 and F2 of a given V-to-V sequence.

## 5.2 The Measurement: Vowel Threshold Applied to V-to-V Sequences

The measurement consists in estimating how vowel targets move up or down depending on the height of the following vowel or how a vowel moves along the front-back axis. We assume that all vowels are affected by the following vowels but not all vowels change their category in favor of the category of another vowel (Öhman. 1996; Fowler & Saltzman, 1993). That is, vowels can be affected by another vowel, but that does not necessarily represent a change in terms of a phonological category.

In order to assess whether a vowel has changed its phonological category, both F1 and F2 of all pre-stressed vowels of a V-to-V sequence will be considered, where the first vowel is pre-stressed and the second one is stressed. For the purposes of assessing height shift, the *first formant* is used as an acoustic parameter (Recasens, 1985), and for assessment of front-back movements, the *second formant* is used. The equation, therefore, aims to predict *vowel* *thresholds* for a given phonological V-to-V context. Hence, the measure will be mentioned as VT (for *Vowel Threshold*).

For computing VT, we need, first, to determine a *critical F1,* which can be defined as the *median of the normalized F1* of a vowel considered to be an example of the height of the investigated vowel. The prototype of the height of a vowel will be considered a *vowel V* that immediately precedes the same *vowel V* category in a specific phonological context, and the median of the F1 of /i/ before another /i/ is set as a *control value.* It is therefore assumed that the sequence /iCi/ represents the best tokens of an [i] which one might consider as the prototypical realization of /i/. The second step is to compute the worst [i] (i.e., the one which is considered as the lowest [i]); in this case, the median of F1 of an [i] is computed in a /iCa/ sequence. The *control F1* minus the lowest [i] is divided by the *control F1.* The result of the computation is considered a VT, which is expressed in module. The VT defines a control value for vowel variation within a given category.

The formula presented below, followed by a table with medians of F1 for all V-to-V combinations, is used to exemplify its application to our data. In practice, the interpretation is: the closer to zero the more likely a vowel is to preserve its category.

(71) Control F1 Value:

$$\textit{Control F1}_{\mathrm{V1}} = \mathrm{Mdn}(\mathrm{F1}_{\mathrm{V1\,=\,V2}})$$

Where:

*Mdn(F1) is the median value of the first formant of a vowel, and*

*V1 = V2 means that the phonological category of V1 is equal to a phonological category of V2.*

(72) Vowel Threshold:

$$\textit{Vowel Threshold}_{V1,Vy} = \left|\frac{CF1_{V1} - F1_{Vy}}{CF1_{V1}}\right|$$

Where:

*$CF1_{V1}$ is the Control F1 for the vowel whose threshold will be determined, and*

*$F1_{Vy}$ is the normalized F1 of a vowel under test.*

Table 17 summarizes the median for normalized F1 values for each V-to-V combination used in the experiment described in Chapter 3. Some values will be used to exemplify the procedure to determine VT.

(73)

Table 17. Median of F1 for all V-to-V patterns produced by Gaucho and Baiano speakers (z-score).

| | | *i* | *e* | *ɛ* | *a* | *ɔ* | *o* | *u* |
|---|---|---|---|---|---|---|---|---|
| *Gaucho* | *i* | –0.92 | –0.78 | –0.75 | –0.72 | –0.77 | –0.82 | –0.88 |
| | *e* | –0.54 | –0.05 | –0.05 | –0.09 | –0.05 | –0.40 | –0.47 |
| | *a* | 1.61 | 1.57 | 1.79 | 1.82 | 1.70 | 1.60 | 1.54 |
| | *o* | –0.29 | –0.11 | 0.44 | 0.24 | 0.39 | –0.22 | –0.40 |
| | *u* | –0.74 | –0.63 | –0.64 | –0.66 | –0.60 | –0.72 | –0.72 |
| *Baiano* | *i* | –0.92 | –0.91 | –0.86 | –0.83 | –0.84 | –0.88 | –0.79 |
| | *e* | –0.58 | –0.56 | 0.06 | –0.04 | 0.06 | –0.55 | –0.49 |
| | *a* | 1.71 | 1.59 | 1.62 | 1.72 | 1.71 | 1.68 | 1.70 |
| | *o* | –0.11 | –0.24 | 0.40 | 0.36 | 0.35 | –0.34 | –0.16 |
| | *u* | –0.67 | –0.65 | –0.56 | –0.52 | –0.57 | –0.68 | –0.65 |

The use of the measurement will be exemplified with the pre-stressed /i/ of the Gaucho dialect, whose values are expressed in the table above. The steps below show how VT is set for the pre-stressed /i/.

(74)

- *Step 1:* Getting the *Control F1* value for the vowel /i/ produced by Gaucho speakers

$$\textit{Control F1}_{\mathrm{i}} = \mathrm{Mdn}(\mathrm{F1}_{\mathrm{i,i}})$$

$$\textit{Control F1}_{\mathrm{i}} = -0.92$$

- *Step 2:* Setting the VT for /i/ before /a/ produced by Gaucho speakers

$$VT_{i,a} = \left|\frac{-0.92-(-0.72)}{-0.92}\right|$$

$$VT_{i,a} = |0.22|$$

VT for GA's /i/ is equal to |0.22|, which indicates that /i/ can vary within the same category within the threshold from –0.22 to 0.22. Naturally, the movement is due to vowel height, then, for instance, an [i] token with VT = 0.10 and another one with VT = –0.09 represent differences in height for both tokens, but the first and the second can still be considered examples of a phonological /i/. This conclusion is allowed by the fixed VT equal to |0.22|, which represents the threshold for a category change. $VT_{i,a}$ = |0.22| is considered to be the lowest [i]. Considering that V2 vowels have a direct influence on V1 articulation, it is expected that an [i] before [a] is lowered; on the other hand, it is well known that in BP there is no reported pre-stressed /i/ changing to [e] or another low vowel, thus one might conclude that this VT is a reliable value.

The next section discusses the VT measurement applied to the three cardinal vowels, in order to investigate whether VT is consistent in capturing vowel movements within a specific phonological category. The use of VT for estimating the behavior of cardinal vowels is important to test the measure when applied to the VH targets.

### 5.3 Vowel Threshold for F1 in Cardinal Vowels

We started testing the measurement with the cardinal pre-stressed vowels /i/, /a/ and /u/. These three vowels are within the same context of the target vowels /e/ and /o/, whose height behavior will also be investigated. Testing VT in cardinal vowels is important because these vowels do not undergo any phonological process in BP that imposes a structural change in the pre-stressed position, that is, they are maximally faithful to their phonological representation, although phonetic centralization is reported (Barbosa & Albano 2004; Kenstowicz & Sandalo 2016, among others). Also, /i, a, u/ represent extreme vowel points in the vocal-tract in terms of front-back and high-low tongue position. The location of those vowels determines the shape and acoustic values of the maximum vowel space for a given speaker in a given language within which all other vowels can be located (Lefebvre et al., 2013, p. 261).

Assuming that centralization imposes F1 and F2 movements, pre-stressed vowels show variation for height and for the front/back axis. VT is an attempt at modeling these movements by considering that vowels that have the same category would tend to zero (VT = 0). Then, if /i/, /a/ and /u/ do not change in favor of another vowel which is characteristic of VH, maximum F1 and F2 variation is expected of these vowels, which might reflect the threshold of what can be considered a variation within the same vowel category.

Then, it is assumed that the highest VT of a vowel variation can be taken as a *critical VT* for what might be considered *variation within a category* and *variation between categories*. For computing VT for the three cardinal vowels, the most distant vowel was considered for each cardinal vowel. For /i/, it is assumed that the "lowest" [i] would be the result of its articulation in the context of the central vowel /a/, so VT was computed while considering /a/ as the basis, and the same was set for /u/. For the vowel /a/, the most distant vowel is /i/, since [u] is not as high as [i] in the acoustic space (see Chapter 3 for our results). As VT values are expressed in module, they represent a range within vowel tokens can vary within category. Table 18 shows the VT for the cardinal vowels in the two dialects.

(75)

Table 18. VT values for the three BP cardinal vowels produced by Gaucho and Baiano speakers.

| Vowel Threshold Values | | |
|---|---|---|
| *Gaucho* | i | 0.22 |
| | a | 0.12 |
| | u | 0.08 |
| *Baiano* | i | 0.10 |
| | a | 0.01 |
| | u | 0.22 |

Considering only *F1* for computing VT values, they express the extent of the vertical movements of the vowels. Hence, observing the table above, we can see that in GA the order from greater to lesser variation is i > a > u, whereas in BA the order is u > i > a. Although we cannot conclude that high vowels present more variation for height, it would be interesting to investigate whether the measure can predict this type of vowel behavior. However, one might interpret that high vowels tend to present more variation, because at least one of the two BP high vowels presents the greatest VT value in each dialect. Instead, it is only possible to speculate that some vowels are more affected than others, depending on the dialect.

Considering that cardinal vowels do not change their quality in the pre-stressed position and assuming, also, that vowels show some degree of variation in the height scale, we set the highest VT value as a **critical VT**, which stands for /i/ or /u/ with |0.22|. This means that |0.22| will be considered the threshold between variation **within** and **between** categories of a given *vowel V*. In other words, a VT value between –0.22 and 0.22 means that a *vowel V* does not change to another category when the vowel is followed by a *vowel V'*. As the critical VT is categorically chosen based on the measures of the cardinal values expressed in module, it is in fact a range within which vowels show their assimilatory or dissimilatory coarticulation movements.

Thus, any value lower or greater than the critical VT value indicates that vowels have changed their category, assimilating or dissimilating the height of *V'*. For the analyses of the GA and BA dialects, if VT is greater than 0.22, then the vowel had been raised by VH and if it is lower than –0.22, the vowel has been lowered.

### 5.3.1 Pre-stressed /i/

The prediction that the vowel /i/ does not show any tendency towards changing to [e], for instance, can be confirmed in the Figure 27. The VT values for /i/ as a function of the seven stressed vowels are within the range defined by the critical VT, which was set at |0.22|.

(76)

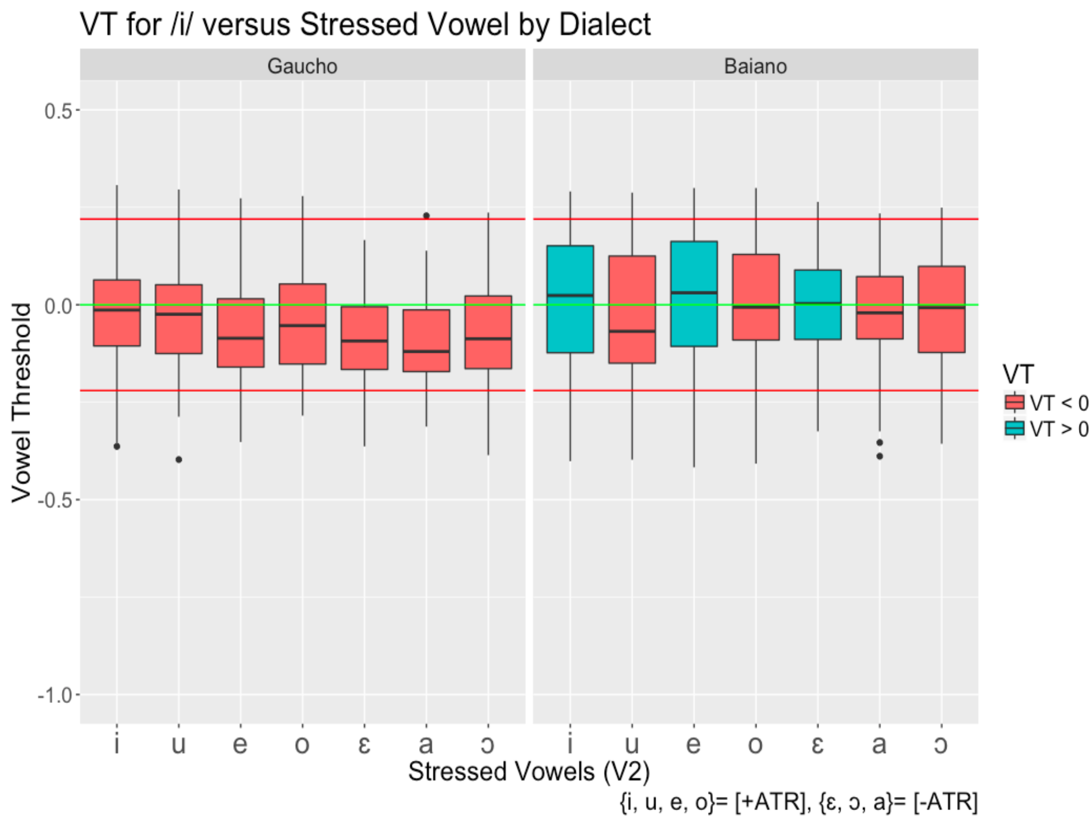



Figure 27. VT for /i/ as a function of the seven BP stressed vowels. Left panel = Gaucho; Right panel = Baiano. The red lines represent the critical VT value set at |0.22| while the green line stands for VT equal to zero. The red color stands for VT medians less than zero, and the green color stands for VT medians greater than zero.

An LMER model was run to test whether the VT for /i/ would differ significantly if second vowel (V2), dialect and V2 *versus* dialect interaction were fixed factors; the variable "speakers" was set as the random factor. Type III Analysis of Variance revealed that there was a significant main effect for *V2* as a predictor variable $F(6, 1027) = 3.306$, $p = 0.003$), a non-significant effect of dialect, $F(1, 2) = 0.1537$, $p = 0.73$, and a significant effect for the interaction between dialect and *V2*, $F(6, 1027) = 2.799$, $p = 0.001$. The significant result for V2 suggests that the category of the second vowel influenced the VT values of /i/; however, a further investigation with Tukey's post-hoc test reveals that within the dialects there were significant differences for the vowel pairs /a/-/i/ ($p = 0.008$) and /a/-/u/ ($p = 0.03$) in GA variety. This confirms that /i/ is not particularly affected by V2, since only two pairs in one dialect returned significant differences.

This result suggests that the effects of the following vowel on /i/ are triggered by V-to-V coarticulation, but they do not reflect a phonological process that would affect /i/. This interpretation is reliable since all the boxplots are within the red line area, thus confirming that variation for /i/ lies within the category that is supposed to include the tokens of a phonological /i/.

### 5.3.2 Pre-stressed /a/

The results for the vowel /a/ are similar to those found for /i/. As we can see in Figure 28, the median of VT values according to the seven V2 is quite raised in GA, but very close to zero in BA. Also, GA's /a/ shows greater variation than BA. There was a significant effect of V2, $F(6, 1640) = 6.653$, $p = 5.735 \times 10^{-07}$, in its interaction with dialect, $F(6, 1640) = 3.882$, $p = 0.0007$; however, there was no effect of dialect on VT for /a/, $F(1, 2) = 0.163$, $p = 0.72$.

(77)

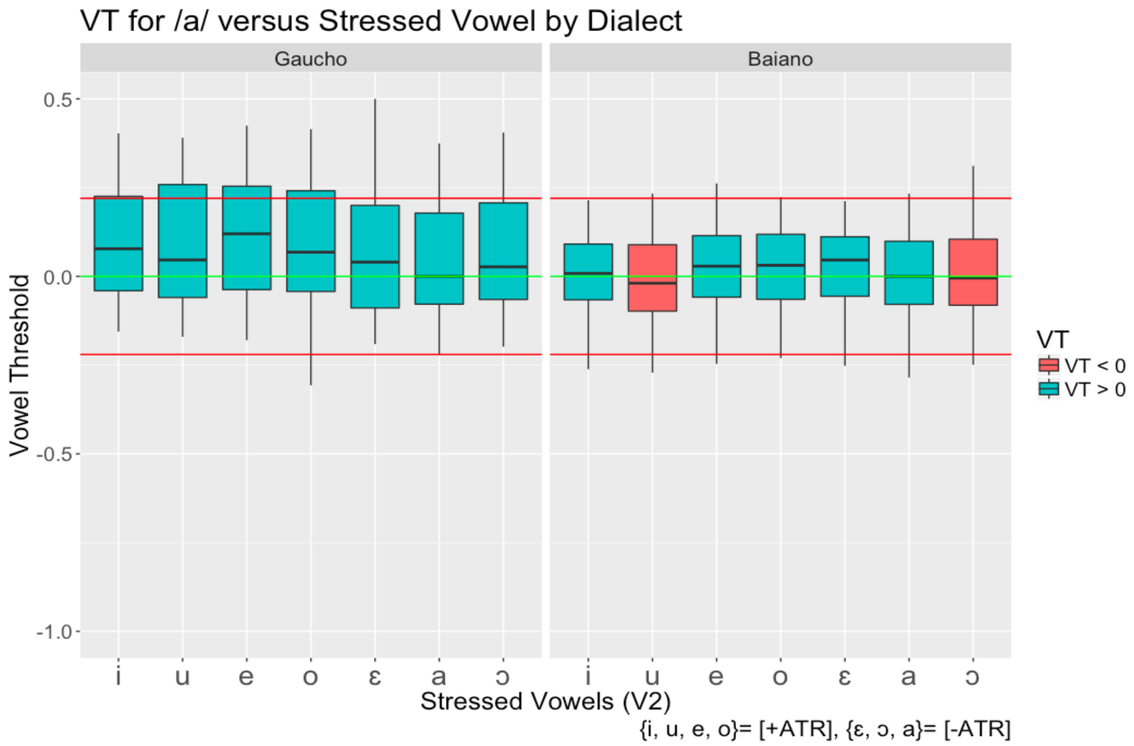



Figure 28. VT for /a/ as a function of the seven BP stressed vowels. Left panel = Gaucho; Right panel = Baiano. The red lines represent the critical VT value set at |0.22| while the green line stands for VT equal to zero. The red color stands for VT medians less than zero, and the green color stands for VT medians greater than zero.

As we can see above, the median of VT values for GA's /a/ is above zero regardless of the quality of the second vowel. The VT median for the vowel /a/ followed by /a/ is greater than zero only at the tenth decimal, what means practically zero. This reveals that the sequence /a/-to-/a/ is perfectly co-produced, that is, there is no raised or lowered [a] before an /a/.

For the GA dialect, the VT values for pre-stressed /a/ are significantly different in a comparison between the stressed /a/ vowel and the whole subset of [+ATR] vowels /i, u, e, o/ ($p < 0.001$), thus confirming that these vowels affect the pre-stressed vowel differently. However, it also confirms that they can be grouped as a natural class. Additionally, GA's /ɛ, ɔ/ have a marginally significant and different effect than the vowel /e/ on pre-stressed /a/ ($p < 0.05$). Although the [–ATR] vowels are not different from the whole set of [+ATR], the mid-low vowels are opposed to mid-high /e/ for this dialect.

The results for GA were not significant at the 0.05 level. The VT values are close to zero and do not differ from the mean VT that was obtained for /a/ as V2. This is an impressive result because it was expected that these vowels, even with some sort of variation within the boundaries, would show significant difference. This fact might be dialect-specific, since GA's pre-stressed /a/ is affected by the value of [ATR] of the second vowel in a V-to-V sequence.

### 5.3.3 Pre-stressed /u/

The effect of the [ATR] feature can also be seen for the vowel /u/, whose VT values tend to be less than zero in an [–ATR] environment and greater than zero when the second vowel is [+ATR]. There was a significant effect of V2 on the VT values of /u/, $F(6, 1540) = 13.211$, $p = 1.232 \times 10^{-14}$, but there were no significant effects of dialect, $F(1, 2) = 0.003$, $p = 0.95$, and of the interaction between dialect and V2, $F(6, 1540) = 1.559$, $p = 0.15$. This suggests that there is no difference in the effects on the vowel /u/ that could be explained by dialects. The main effect is due to the second vowel.

(78)

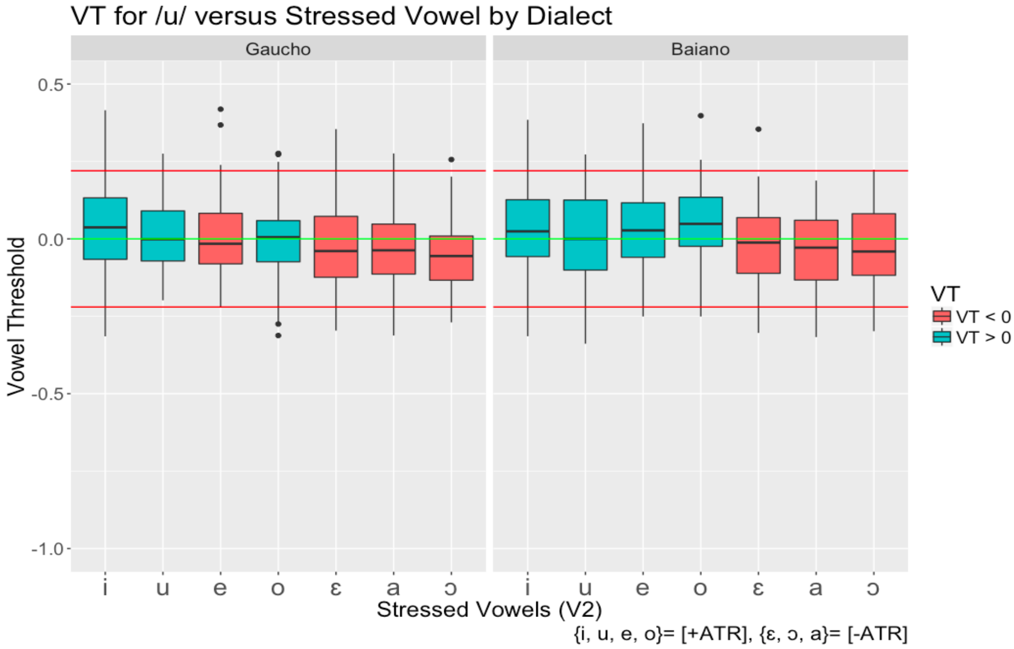



Figure 29. VT for /u/ as a function of the seven BP stressed vowels. Left panel = Gaucho; Right panel = Baiano. The red lines represent the critical VT value set at |0.22| while the green line stands for VT equal to zero. The red color stands for VT medians less than zero, and the green color stands for VT medians greater than zero.

Tukey's post-hoc test reveals that only an intra-dialect significant difference can be found. For the VT values of GA's /u/, there was a significant different effect in the comparison of /i/ and /ɛ, ɔ/ ($p < 0.001$) and /u/ versus / ɔ/ ($p < 0.001$). In BA, the attested significant difference was due to the /a/ versus the [+ATR] vowels /i, u, e, o/ ($p < 0.01$), and for the front mid-high [+ATR] vowels /e, i/ versus the [–ATR] mid-low /ɛ, ɔ/ ($p < 0.05$). These results are consistent with the results for the pre-stressed /a/ vowel, thus confirming the role of the feature [ATR] even in the non-harmonic subset of vowels, that is, the pre-stressed vowels /i,a,u/.

The red/green color of the box plots confirms that [–ATR] vowels tend to lower vowels, while [+ATR] vowels have the opposite effect (i.e., to raise them), although without shifting vowel categories. Additionally, it can be seen that [+High] vowels have the same effect of /e/ and /o/, especially in BA. This suggests that the V-to-V relationship in BP is not due to the value of [High], but for the value of [ATR].

The results of height variation for all cardinal vowels confirm that variation lies within the boundaries of a predictable phonological category. They show some influence of the second vowel but still within the acceptable range of variation given by the VT value |0.22|.

There is no tendency toward raising or lowering these vowels as the result of a phonological process, which is expected for the cardinal vowels in the pre-stressed position.

Therefore, the measurement seems reliable for application in the VH targets. For these vowels, therefore, the VT values for the targets are expected to cross the boundaries defined by the threshold, since VH changes the vowel category of its targets. As the range of variation is set within the acoustic space of a vowel's F1, the targets /e/ and /o/ are expected to cross the limits defined by the critical VT.

The next section analyzes the use of the VT measure in VH targets, in order to determine the behavior of /e/ and /o/ cross-dialectally and intra and inter-speaker. This discussion will allow us to demonstrate that /e/ and /o/ show the same tendency of lowering in [–ATR] contexts. The measurements strengthen the argument in favor of [ATR] harmony presented in Chapter 7.

### 5.4 Testing Vowel Threshold on the VH Targets /e/ and /o/

As we have pointed out throughout this study, BP has been described as a height harmony language (Bisol, 1981, 1989). Some studies, however, described some BP dialects as [ATR]-based VH systems (cf. Lee and Oliveira 2003, for the dialects of Belo Horizonte, Alagoas and Ceará; Hora and Vogeley 2013) for the BP spoken in Recife, among others – while others claim that lowering of pre-stressed vowels is not motivated by VH – Lee and Oliveira (2003) for Baiano.

In the previous section, the VT criterion proposed in this study was presented and tested with BP cardinal vowels. The behavior expected for VH targets is that they will cross the boundary defined by the critical VT value while expressing their harmony behavior triggered by the stressed vowel. If this is the case, it will be possible to determine: 1) whether the targets are raised in [+High] environments; or 2) whether they will continue to be produced as the mid-high vowels [e] and [o], in case they stay within the range, or whether they are lowered to [ɛ] and [ɔ]. The measurement will be able to express whether a vowel has been lowered, raised, or if it reflects the quality of the underlying vowel. According to Kenstowicz and Sandalo (2016, p. 10), there is "a regressive height harmony between the tonic and pretonic open and close mid vowel in BP". The authors conclude that the only important characteristic of BP VH is the open-close nature of the stressed vowel (2016, p. 12). They also confirm that there is "a height harmony between pretonic mid vowels and the following tonic resulting in a seven-vowel pretonic inventory that parallels the tonic" (2016, p. 1).

The experiment presented in Chapter 3 supports this assumption, which means that the target vowels are only lowered, not raised. The issue to be discussed in this section concerns the behavior of the targets in the GA and BA dialects. The goal is to estimate whether the vowels change their category or whether they are only coarticulated with the next vowel. In the next sections, I will present: (1) analyses of the vowel targets, comparing their behavior in BA and GA; and (2) an speaker-based analysis, with a discussion about the influence of the speaker in the definition of critical VTs.

### 5.4.1 Cross-Dialectal Comparison

#### 5.4.1.1 The Target /e/

The results for the vowel /e/ are different in the two dialects. In GA, the vowel /e/ has VT values smaller than zero when followed by [–ATR] vowels (VT for /ɛ/ = –0.09, /a/ = –0.1, /ɔ/ = 0.15) and very close to zero when followed by [+ATR] vowels (VT for /i/ = 0.03, /u/ = 0.01, /e/ = $10^{-10;}$ and /o/ = –0.02). For [–ATR] vowels, the VT median of /e/ is around 0.1, whereas for [+ATR] VT is around zero, suggesting that /e/ tends to remain as [e] when followed by [+ATR] vowels, but it is considerably lowered in an [–ATR] environment, although no change to [ɛ] can be assumed. However, VT values for /e/ followed by [–ATR] are totally different in BA. As we can see in Figure 30, VT medians for /e/ followed by [–ATR] vowels cross the critical VT value, confirming that in these environments dialect /e/ changes to [ɛ].

Type III Analysis of Variance confirms that V2 has a significant effect on VT values of /e/, $F(6, 1546) = 139.588$, $p < 2.2 \times 10^{-16}$, as well on its interaction with dialect, $F(6, 1546) = 14.731$, $p = 2.2 \times 10^{-16}$. On the other hand, there was no significant effect of dialect only on the VT for /e/, $F(1, 2) = 0.55$, $p = 0.533$, suggesting that the vowel /e/ has the same behavior in both varieties.

(79)

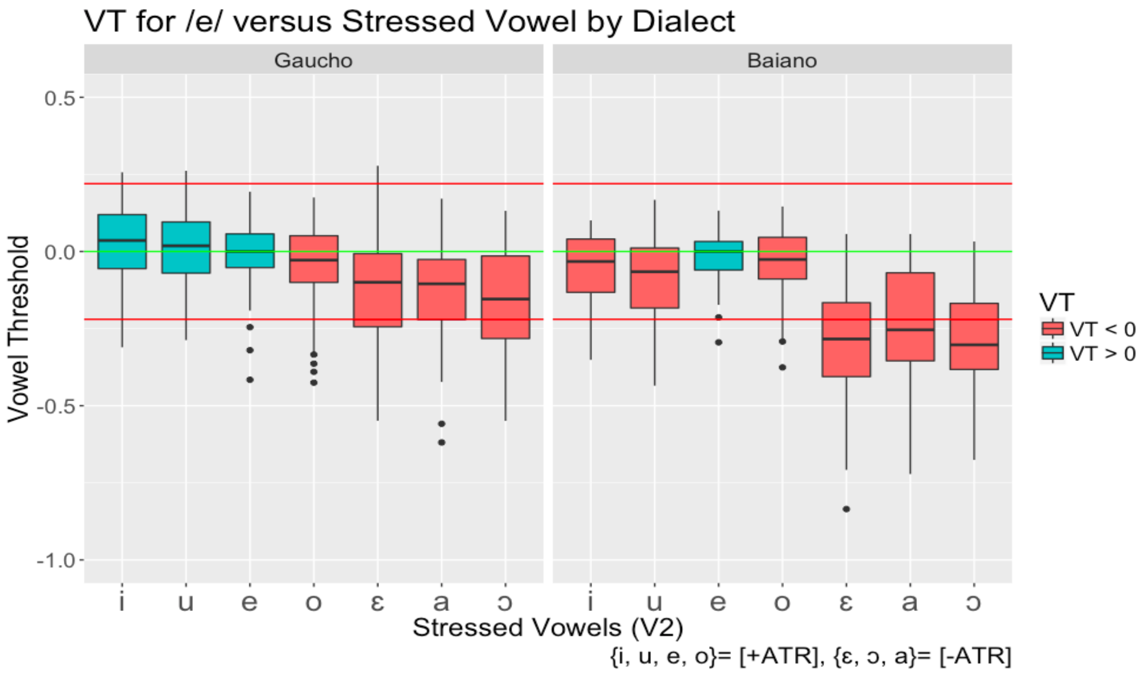



Figure 30. VT for /e/ as a function of the seven BP stressed vowels. Left panel=Gaucho; Right panel = Baiano. The red lines represent the critical VT value set at |0.22| while the green line stands for VT equal to zero. The red color stands for VT medians less than zero, and the green color stands for VT medians greater than zero.

As can be seen, /e/ tends to be lowered in both dialects, but only in BA it can be suggested that /e/ has been harmonized with the stressed [–ATR] vowel. However, Tukey's post-hoc test confirms that the difference among [–ATR] and [+ATR] vowels is significant in both dialects. There was also a dissimilatory effect in BA with a significant difference between /u/ and /e/ ($p$ = 0.0003) and /u/ and /o/ ($p$ = 0.03), indicating that F1 /e/ is significantly lower when followed by /u/ than when followed by /e/ and /o/, as shown in the right panel.

The findings for the behavior of /e/ allow us to assert that this vowel is a lowered version of a prototypical [e] in GA, but not a vowel [ɛ]. For Baiano, [ATR] harmony is to demonstrate when VT values for /e/ cross the interval of |0.22|. The agreement between [–ATR] vowels is clear in the panel. The panels above also give information about /e/ followed by [+ATR] vowels and it is clear that there is no raising movement indicating [+High] agreement for both dialects. This finding is surprising because it has been claimed in the literature that vowels /e/ and /o/ change to [i] and [u] before phonologically high vowels. The findings, however, do not support this claim.

#### 5.4.1.2 The Target /o/

The behavior of the vowel /o/ is similar to that of /e/ in both dialects. I found a significant effect of V2, $F(6, 1522) = 110.931$, $p < 2.2 \times 10^{-16}$ and its interaction with dialect, $F(6,1522) = 8.200$, $p = 9.464 \times 10^{-16}$, suggesting that each stressed vowel of BA and GA have different effects on /o/. However, there was no significant main effect of dialect, $F(1, 4) = 0.676$, $p = 0.45$; thus, without considering other variables, dialect difference cannot explain the behavior of the target /o/.

(80)

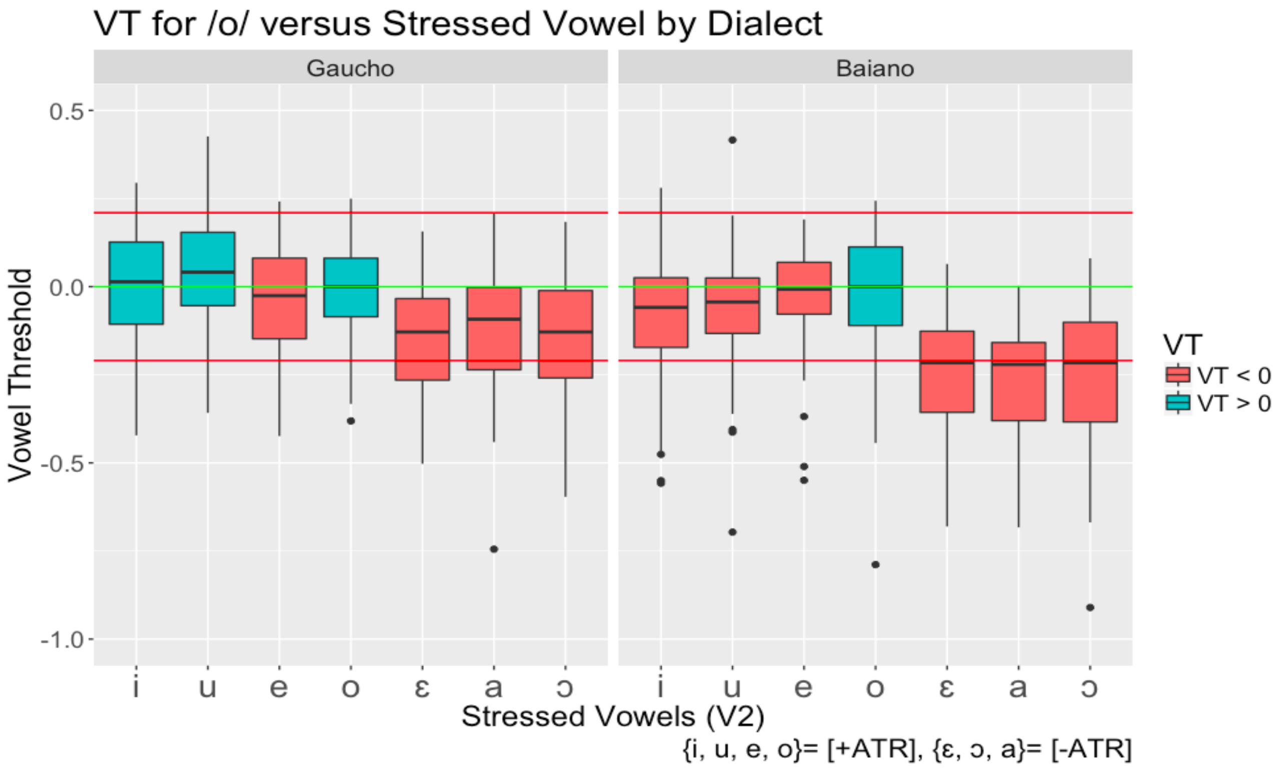



Figure 31. VT for /o/ as a function of the seven BP stressed vowels. Left panel = Gaucho; Right panel = Baiano. The red lines represent the critical VT value set at |0.22| while the green line stands for VT equal to zero. The red color stands for VT medians less than zero, and the green color stands for VT medians greater than zero.

Tukey's post-hoc test confirms the findings for the front vowel. All pairwise comparisons between a [–ATR] vowel and a [+ATR] vowel were significant within dialects with $p < 0.001$ for all pairs. This suggests that even in GA whose /o/ does not present VT values crossing the threshold consistently, VT values of the [–ATR] subset are significantly different from those of the [+ATR] vowels. In BA, on the other hand, not only this difference is significant but the median of VT values for stressed [–ATR] vowels crosses the critical VT of |0.22|, as can be seen in right panel of the Figure 31.

Also, there was a significant dissimilatory effect in BA for the vowel /o/, which tends to be lowered when followed by /i/. Tukey's post-hoc test showed that there is a significant difference for the VT mean of /o/ considering the pairs /e/ versus /i/ ($p = 0.03$) and /o/ versus /i/ ($p = 0.04$). As can be seen, /o/ has negative VT values when the next vowels are the high vowels /i/ and /u/ in comparison with the mid high ones. This confirms what was found for /e/, which presents similar behavior in a high environment. Although this might be BA-specific, since GA does not show the same tendency, it is surprising because no dissimilatory effect is reported in the literature about the role of dialects or language-specific processes on V-to-V relationships.

## 5.5 Intra-Speaker Variation

Using the VT measurement for the analysis of dialects can be very useful in predicting vowel-to-vowel relationships, not only for VH, but also for the investigation of dissimilatory processes; this has been found in BA and is also documented in several languages (Tilsen, 2007; Rodrigues, 2010). This is one of the reasons for conducting an exploratory analysis of pre-stressed vowels for the participants in the experiment. Another reason is to test the measurement and the critical values chosen to determine vowel category shifts for each speaker. Such procedures will allow us to discuss the role of speakers' acoustic space, how such speakers produce their vowels and how their production affects VTs. Also, considering that men and women have different acoustic spaces and F1 is gender-sensitive, it is important to explore the results while taking into account the speakers' gender.

However, as noted in Chapter 3, there were some exclusion criteria, and not all tokens of all vowels were considered for the analysis. In this regard, speakers S3 and S6 were excluded, because their tokens of the pre-stressed /i/ were most often deleted or were too short. Thus, their measurements would not be precise or possible. Therefore, we present one female and one male speaker of each dialect. First, VT values were determined for the three cardinal vowels. The greatest VT value of each speaker is considered the critical VT value of vowel category shift. For example, speaker S1 has |0.30| as the critical VT value; in this case, when the VT value of each vowel token is lower than –0.30 or greater than 0.30, the vowel is considered to have changed its height in favor of another category.

(81)

Table 19. VT values for cardinal vowel produced by Gaucho and Baiano male and female speakers.

| | | Speaker | i | a | u | *Average by Speaker* |
|---|---|---|---|---|---|---|
| Gaucho | Male | S-1 | 0.30 | 0.21 | 0.12 | 0.21 |
| | Female | S-2 | 0.13 | 0.09 | 0.07 | 0.10 |
| Baiano | Male | S-4 | 0.14 | 0.10 | 0.23 | 0.16 |
| | Female | S-5 | 0.14 | 0.03 | 0.11 | 0.09 |
| | | *Average by vowel* | 0.18 | 0.11 | 0.13 | |

It is noticeable that high vowels are the ones with the greatest variation in height. The average of VT values reveals that /i/ and /u/ are the vowels with the greatest variation within the F1 scale, whereas the low /a/ shows less variation, according to the average by vowel. Regarding height variation for sex, male speakers present greater variation than females, which was consistent among the speakers in both dialects.

In the previous section, it was seen that BA shows [ATR] VH while in Gaucho the pre-stressed vowels are coarticulated within the same category. That is, in BA, /e/ and /o/ are harmonized, while in GA the vowel is considerably lowered but without any shift. Therefore, this section will analyze the behavior of the targets /e/ and /o/ for each speaker in order to determine the effect of speakers on the variation of the height of the target vowels.

### 5.5.1 Gaucho Dialect Speakers

#### 5.5.1.1 Vowel Threshold for /e/ and /o/ of Speaker 1

Figure 32 shows the behavior of /e/ and /o/ of a GA male speaker (S-1). As can be seen in the plot, S-1 target vowels seem to be affected by the groups of [–ATR] and [+ATR] triggers. For both targets, the effect of these groups is clearly indicated in the plot by the color of the box plots. A one-way ANOVA was conducted to compare the effect of the stressed vowel on the vowel targets in the seven stressed vowel conditions. There was a significant effect of V2 on targets at the $p < 0.05$ level for the seven stressed vowels [$F(6, 835) = 41.95$, $p < 2 \times 10^{-16}$].

(82)

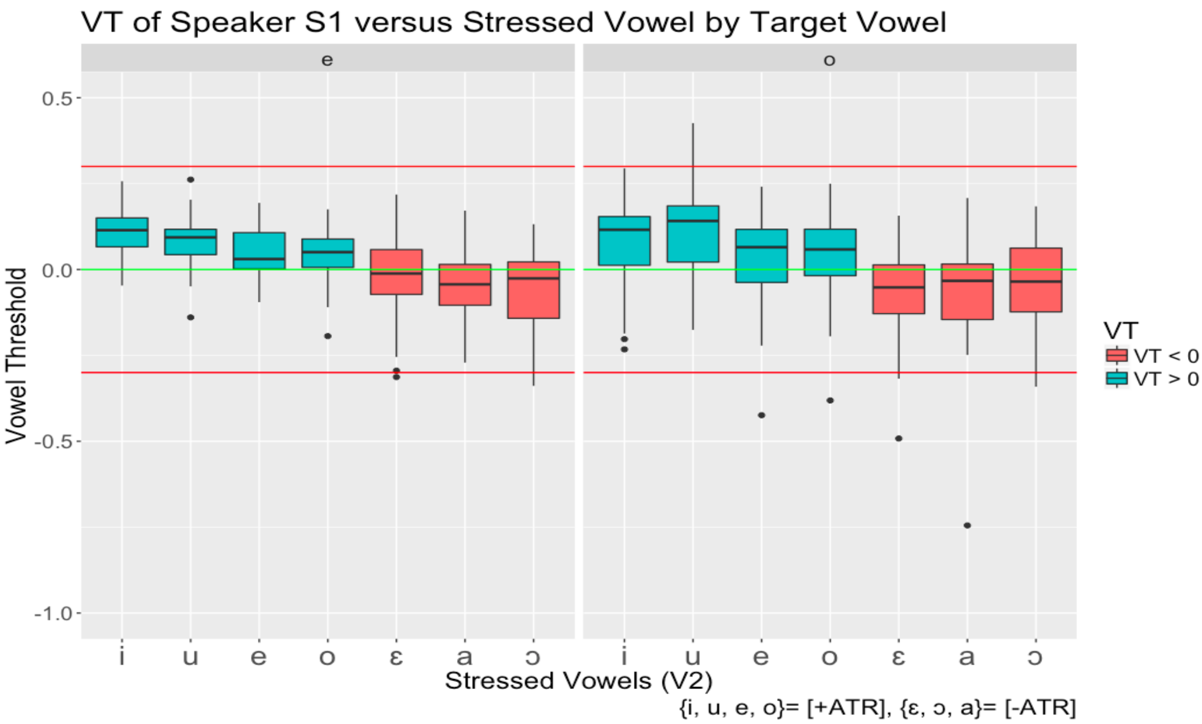



Figure 32. VT for /e/ and /o/ as a function of the seven BP stressed vowels of the Gaucho male speaker S-1. The red lines represent the critical VT value set at |0.30|.

Although the effect of each stressed vowel is different on the targets of the speaker S-1, can be seen that there is no reason to defend the claim that high vowels have a different effect than mid-high ones. Both sets of vowels have VT median greater than zero, indicating that /o/ is considerably raised even in non-high environments, and lowered when followed by [–ATR]. In fact, S-1 presents an ideally assimilatory behavior and his vowels are coarticulated according the height of V2. Tukey's post-hoc test reveals that there is a significant difference between /e/ and the high vowels /i/ and /u/ ($p$ = 0.02 for both), and between /o/ versus /i/ ($p$ = 0.003) and /o/ versus /u/ ($p$ = 0.002).

As can be noticed, S-1 target vowels have a perfect assimilation to the following vowel. This interpretation is possible because VT values are lower when low vowels are the following ones and when the highest VT values come from /i/ and /u/ as following vowels; when the targets are followed by their homorganic vowels, VT values are in the mid-range. As the critical value for S-1 was set at |0.30|, this suggests that there is no raising or lowering, but a stable system which only reflects V-to-V coproduction. We can also point out that VT values for the targets followed by low vowels are close to zero, which strongly suggests that /e/ and /o/ remain as [e] and [o], regardless of phonological context.

5.5.1.2 Vowel Threshold for /e/ and /o/ of Speaker 2

While male speaker S-1 shows a V-to-V coarticulation without any variation between categories, the GA female speaker S-2 shows a well-established [ATR] harmony, in which VT values shift across the boundaries established by the critical VTs. The speaker also presents some asymmetry between /e/ and /o/, with a complete [ATR] VH for /e/ and lowering of /o/ to [ɔ] when followed not only by low vowels but also by the front [+ATR] vowels /e/ and /i/, as can be seen in the plots below, with critical value set at |0.13|.

(83)

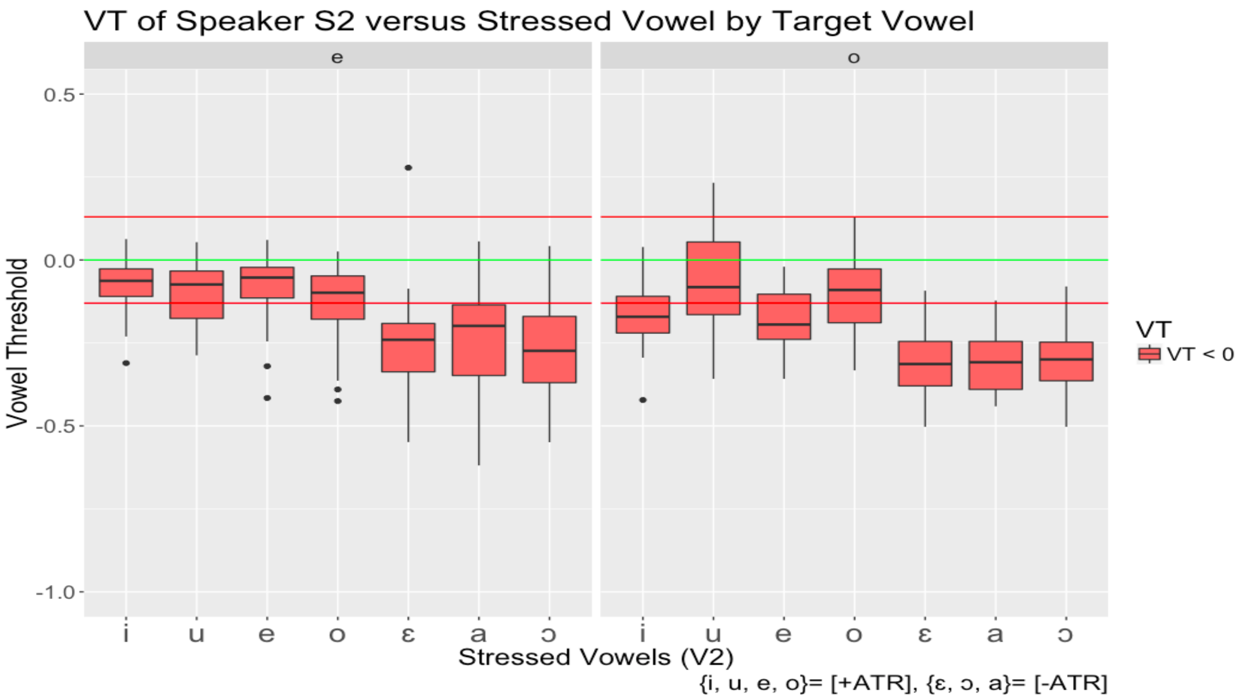



Figure 33. VT for /e/ and /o/ as a function of the seven BP stressed vowels of the Gaucho female speaker S-1. The red lines represent the critical VT value set at |0.13|.

The behavior of the targets produced by S-2 are strongly affected by the category of the stressed vowel. A one-way ANOVA revealed a significant effect of V2 on targets for the seven stressed vowels, [$F(6, 590) = 49.92$, $p < 2 \times 10^{-16}$]. Differently from the male speaker S-1, targets produced by S-2 seem to be influenced not only by height, but also by the feature [back]. In Figure 33, the effect of /i/ is similar to the effect of /e/ (but /u/ does affect the target /o/ as would be expected for height coarticulation) and the same occurs for the back counterparts. This is even more obvious for the target /o/, which is lowered to [ɔ] when followed by /e, i/, but not by /o, u/. The behavior of /o/ in such case can be understood as disharmony, since the vowel /ɔ/ is the result of lowering in a [+ATR] environment.

Tukey's post-hoc test reveals that significant differences are only found in comparisons of [–ATR] and [+ATR] vowels for both targets, whereas there were no significant differences for pairwise comparisons within the subset of vowels that share the same value for [ATR]. This raises an issue about the challenge of setting a critical VT value. As we can see, both targets are lower than zero regardless of the quality of the stressed vowel, suggesting that S-2 already produces most tokens of /e/ and /o/ a little lower than as predicted by the measurement. This is an open issue that challenges the use of the measurement, which will be discussed at the end of the chapter.

### 5.5.2 Baiano Dialect Speakers

#### 5.5.2.1 Vowel Threshold for /e/ and /o/ of Speaker 4

A dissimilatory effect seems to be consistent in the BA dialect, where F1 of the targets does not reflect assimilation with high vowels. On the contrary, VT values confirm that the production of /e/ and /o/ are lowered in [+High] environments in comparison with their mid vowel counterparts. The one-way ANOVA confirms a significant effect of the stressed vowels on the targets of male speaker S-4, [$F(6, 650) = 9.795$, $p < 2 \times 10^{-16}$].

(84)

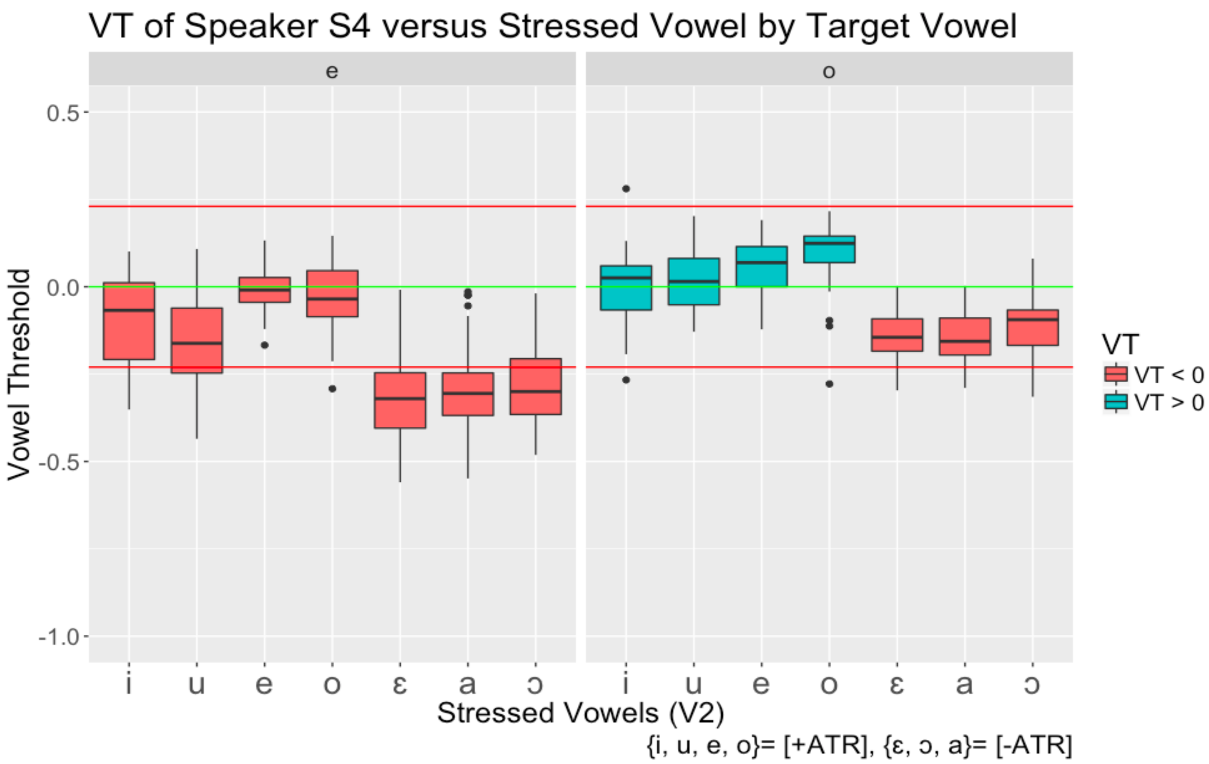



Figure 34. VT for /e/ and /o/ as a function of the seven BP stressed vowels of the Baiano female speaker S-4. The red lines represent the critical VT value set at |0.23|.

Figure 34 shows that the feature [ATR] clearly plays a role in triggering VH, especially for the vowel /o/, whose median of VT values is greater than zero for all [+ATR] vowels. Tukey's post-hoc test confirms a significant difference for comparisons among all [+ATR] and [–ATR] vowel pairs ($p < 0.001$ for all pairs); however, within the set of [+ATR] vowels, there are some significant differences for pairs in which mid vowels are compared to high vowels, that is: /e/ versus /i,u/ ($p < 0.001$ for both) and /o/ versus /i, u/ ($p < 0.001$ for both). Therefore, the test confirms a significant dissimilatory effect for the targets followed by high vowels, whose F1 tendency is to be lowered, contradicting the literature for [+High] harmony where mid vowels tend to be raised.

It should be noted that there is asymmetry for S-4. While /e/ is harmonized with [–ATR] vowels, being produced as [ɛ], the VT values for target /o/ are within the range for /o/; that is, /o/ has not changed to [ɔ], but remains as a lowered [o̞]. Such behavior of the targets is confirmed for S-5, whose results are described next.

5.5.2.2 Vowel Threshold for /e/ and /o/ of Speaker 5

The behavior of the targets produced by S-5 confirms what has been systematically found for BA speakers: /e/ is harmonized with [–ATR] vowels, whereas /o/ is lowered in the same environment but it does not cross the range delimited by the critical VT of |0.14|. The one-way ANOVA confirms a significant effect of the stressed vowel on the targets, [$F(6, 648) = 16.59$, $p < 2 \times 10^{-16}$].

(85)

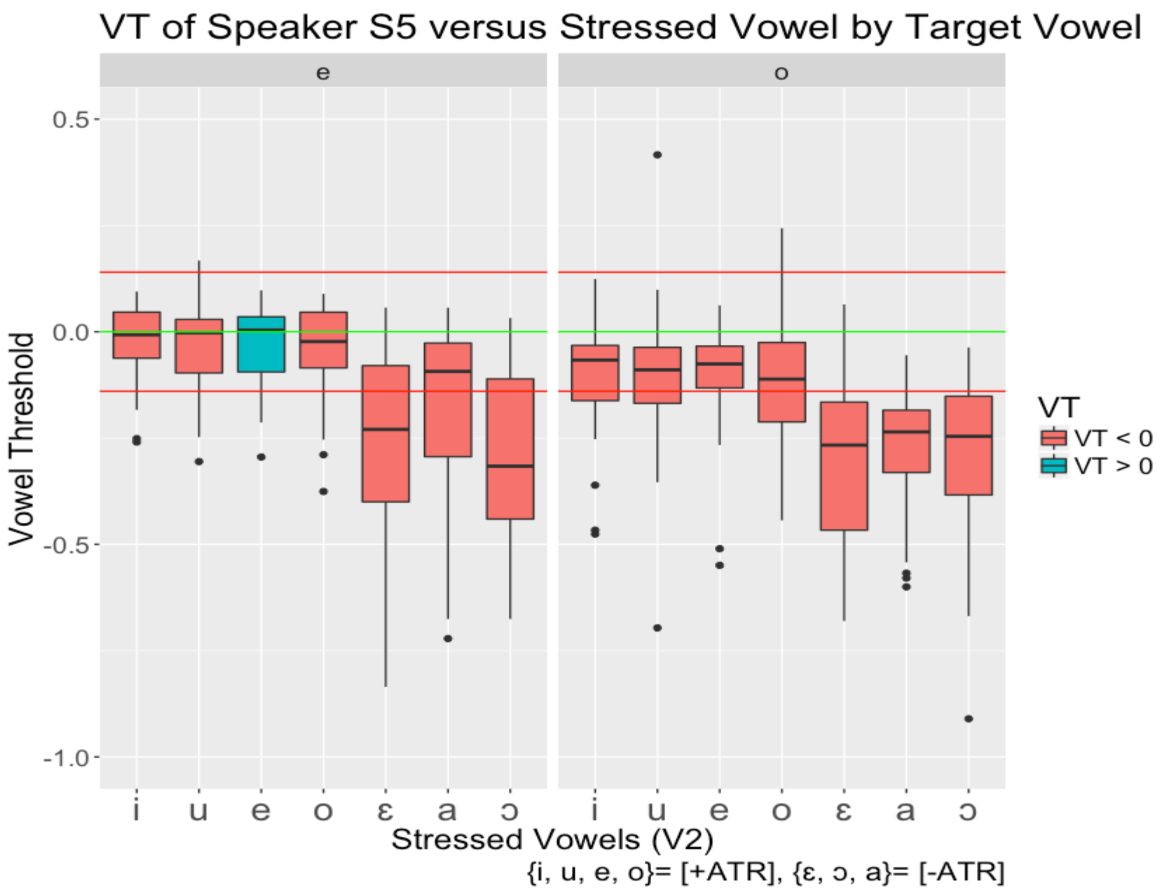



Figure 35. VT for /e/ and /o/ as a function of the seven BP stressed vowels of the Baiano male speaker S-5. The red lines represent the critical VT value set at |0.14|.

Although /o/ has been produced as an [ɔ], it is clear in Figure 35 that the production of the targets is affected by two groups of vowels, which are defined in terms of the value of the feature [ATR]. This fact is consistent not only for S-5, but also for the four speakers analyzed in this chapter and for all speakers in the analysis described in Chapter 3. The VH system is clear for both speakers, whose vowel system tends to split the set of BP vowels based on [ATR]. Three out of these four speakers clearly present an [ATR]-based system. There is some intra- and inter-speaker variation, but low-to-low agreement is favored in most of the cases.

## 5.6 Testing the Vowel Threshold for F2

In this section, I have applied the VT formula to the second formant of the vowel targets. In the VT analysis based on F1 values, the targets move vertically and are lowered when followed by [–ATR] vowels, but there is no tendency of raising agreement with high vowels. Therefore, the goal is to check whether vowels move horizontally influenced by the value of [Back], that is, by the frontness-backness of the stressed vowel.

The VT for F2 is then computed similarly to the way VT was computed for F1. However, the pairs of counterpart vowels were chosen according to the opposite vowel in the front-back axis of the BP phonological vowel set. For example, the **control F2** for computing VT for the vowel /i/ coincides with the median of all tokens of the pre-stressed /i/ followed by the stressed /i/. The **critical VT** value is computed by defining the "worst" example of a vowel /i/ (e.g. the furthest back vowel [i]). The furthest back [i] is considered to be the /i/ followed by its back counterpart vowel within the set of BP vowels, which is the vowel /u/. The same criterion was used to compute the VT values for /u/ and /a/. However, vowel /a/ will be treated specifically since it is a central vowel with no counterpart forming a contrastive pair in the front-back axis.

### 5.6.1 Testing Vowel Threshold for F2 in the Cardinal Vowels

Although VT was calculated for the cardinal vowels based on F2, I will not set a critical VT value for this parameter, given the phonological behavior of the pre-stressed vowels. BP does not have distinct pairs of front or back vowels; that is, there is no front counterpart of [e], such as the rounded [ø] in French and German. These vowels, although phonetically distant in terms of F1, are distinguished by lip rouding, which is reflected in their F2 value. Therefore, it is hard to delimit a VT for a vowel that can move freely within the back-front axis, since it does not have a linguistic competitor for a given area within the vowel acoustic space. On the other hand, BP has [–ATR] high vowels [ɪ] and [ʊ], which could be used as a parameter to delimit a critical VT, but they occur in post-stressed position (Barbosa & Albano, 2004).

Critical VT values were computed for F2 according to the procedure mentioned in the previous section, but they will be used only as a parameter of the front-back movement of the vowel. The VT values for the cardinal vowels are given in the next table.

(86)

Table 20. Vowel Threshold Values for the cardinal vowels in Gaucho and Baiano.

| | | |
|---|---|---|
| | i | 0.06 |
| *Gaucho* | a | 0.60 |
| | u | 0.15 |
| | i | 0.70 |
| *Baiano* | a | 0.55 |
| | u | 0.11 |

Setting a VT value based on F2 for the vowel /a/ is challenging because this vowel does not have a contrastive vowel for [Back] sharing the same value for [High], such as [ɑ], for instance. Hence, it becomes difficult to set an area where /a/ can be produced within the same category.

The movements of the vowels on the F2 scale will be discussed while taking into account the behavior of the cardinal vowels only. The front-back behavior of the targets will be addressed in comparisons with the results obtained for F1.

5.6.1.1 Pre-stressed /i/

The movement of the vowel /i/ is near zero for all the seven stressed vowels, as can be seen in Figure 36. Although GA has shown more variation, the median in all boxes is close to zero for both dialects, suggesting that the production of /i/ is not affected by the frontness or backness characteristic of the following vowel. This is confirmed by the Type III Analysis of Variance, which does not return a significant effect of dialect ($F[1,2] = 1.938$, $p = 0.299$) and its interaction with V2, $F[6,1027] = 0.570$, $p = 0.75$. However, a significant effect was found for V2, $F[6, 1027] = 3.086$, $p = 0.005$).

(87)

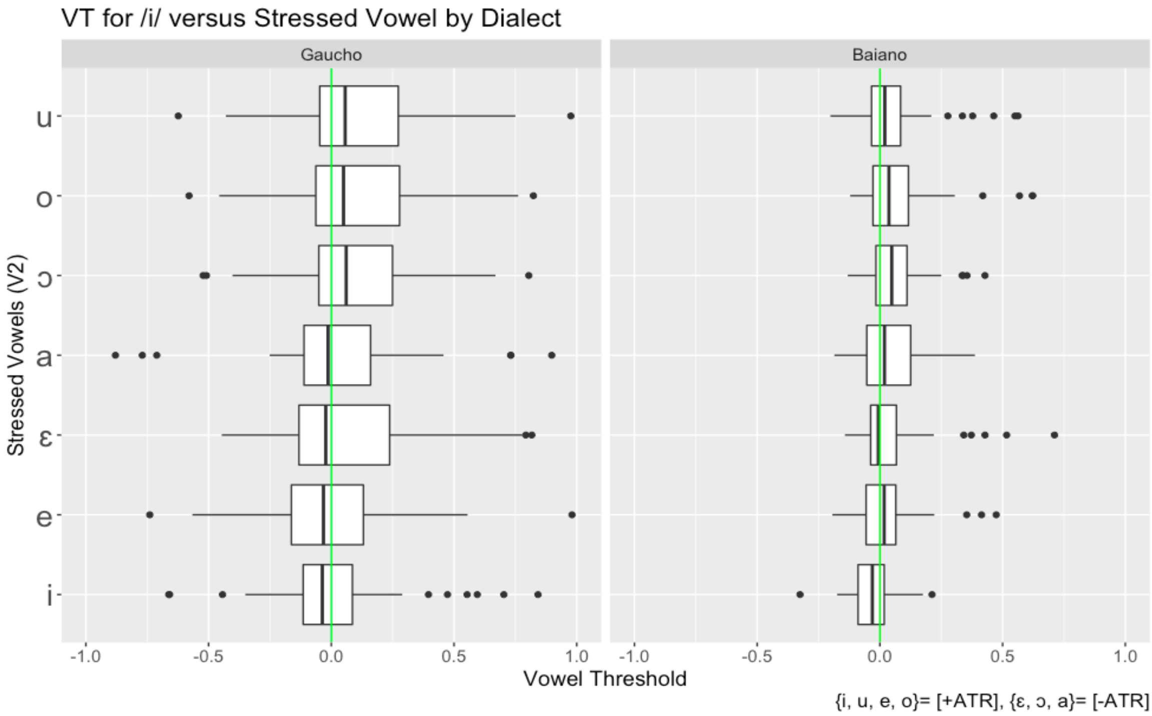



Figure 36. VT values of /i/ based on F2 for Gaucho and Baiano as a function of the seven BP stressed. The green line stands for VT equals to zero.

Tukey's post-hoc test, however, does not reveal a significant difference for all the pairwise comparisons in both dialects. This finding is important because it confirms that the second formant of the vowel remains the same regardless of the quality of the following vowel. This is expected, since /i/ does not undergo a phonological process that could trigger a backward movement.

5.6.1.2 Pre-stressed /a/

Unlike the vowel /i/, the VT results for /a/ are more interesting. This vowel seems to be affected by all seven stressed vowels in both dialects, which means that the tokens of /a/ show fronting and backing depending on the front-back nature of the stressed vowel.

(88)


Figure 37. VT values of /a/ based on F2 for Gaucho and Baiano as a function of the seven BP stressed. The green line stands for VT equals to zero.

The F-test run in the LMER model returns a significant main effect for V2, $F(6, 1640) = 4.729$, $p = 8.735 \times 10^{-05}$) and for the interaction between V2 and dialect on the VT values for /a/, $F(6, 1640) = 11.485$, $p = 1.27 \times 10^{-12}$). For the vowel targets, there was no significant effect of dialect $F(1, 2) = 0.608$, $p = 0.51$). These results, then, confirm that /a/ is more sensitive to the front-back characteristics of the vowel immediately following in comparison with the results for /i/ and /u/. A post-hoc Tukey confirms /a/ sensitiveness to front-back movements for GA dialect: there is a significant difference in the effect for all back vowels /u, o, ɔ, a/ in comparison with the front vowel /i/ ($p < 0.001$), and this is similar for the vowel /u/, which shows a significant difference in comparison with the whole set of front vowels /i, e, ɛ/ ($p < 0.001$ for all pairs). Also, the effect of the vowel /e/ is significantly different from all back vowels ($p < 0.001$ for all comparisons). However, GA shows that front vowels have a fronting effect on /a/; on the contrary, back vowels have an effect of vowel-fronting while front vowels turn /a/ more back. It is worth mentioning, however, that this is valid for GA only, since in BA the vowel /i/ has a vowel-fronting effect on /a/, as can be seen in Figure 37. The results for GA show a dissimilatory effect that affects the F2 dimension, which is surprising because F1 dissimilation was found for GA speakers.

It can be hypothesized that /a/ moves more horizontally than high vowels because /a/ is the only vowel that is placed the lowest region in the acoustic vowel space. Unlike /i/ and

/u/, which are natural competitors at the top of the acoustic space, /a/ does not have a competitor. Also, for the production of /a/, the jaw is more open and the tongue is lax, which decreases the muscular activity involved in the articulation of such vowel (Abercrombie, 1967; Crystal, 1987; Shriberg & Kent, 2003).

5.6.1.3 Pre-stressed /u/

The results for the vowel /u/ movements on the F2 scale is similar to /i/. Both vowels are significantly affected by V2, but if dialect and the interaction between dialect and V2 are considered, there is no significant effect on the VT values. This means that both vowels have a similar behavior both in GA and BA regardless of the vowel. The F-test run in the LMER model returns a significant effect for V2, $F(6,\ 1540) = 6.032$, $p = 2.986 \times 10^{-06}$), and its interaction with dialect, $F(6,\ 1540) = 0.505$, $p = 0.80$), but there was no significant effect of dialect, $F(1,\ 2) = 0.626$, $p = 0.51$).

(89)

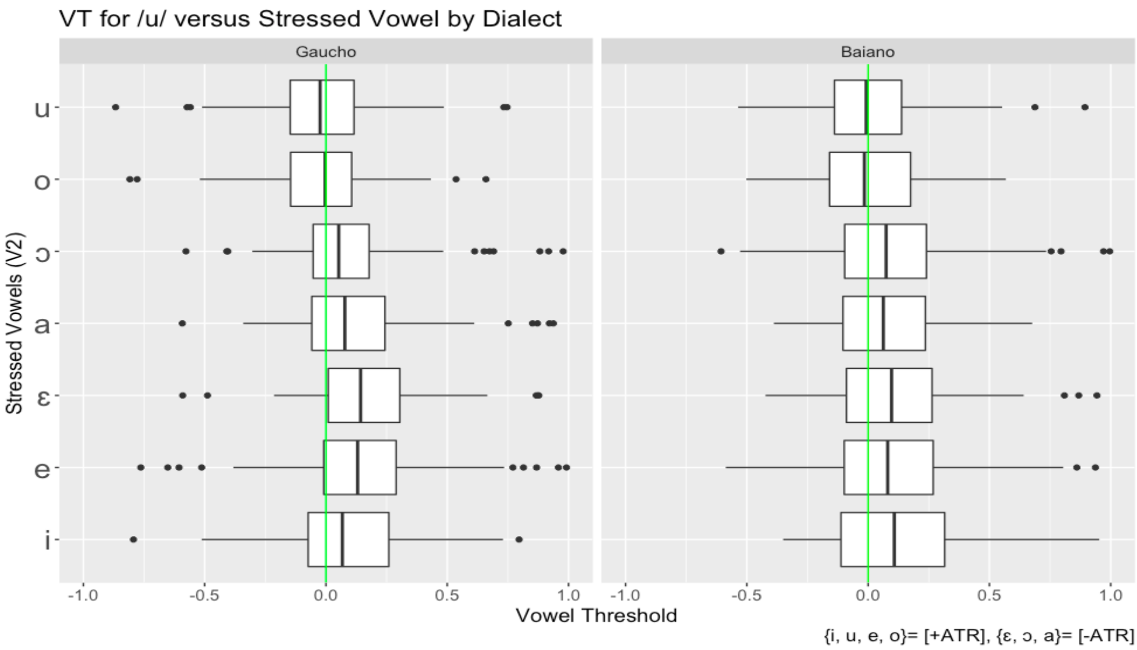



Figure 38. VT values of /u/ based on F2 for Gaucho and Baiano as a function of the seven BP stressed. The green line stands for VT equals to zero.

The results for the vowel /u/ movements on the F2 scale are similar to those for /i/. The median of the VT values in the box plots shows that they are really close to zero for both vowels in both dialects. This means that the vowels do not move much in the F2 scale, since the VT measurement predicts that the closer to zero the more likely the vowel is to remain within the acoustic space predicted to be assigned to a given phonological category. If high vowels are close to zero for F2, therefore, they are not being affected in terms of this parameter as much as they are for F1. If VT values based on F1 and on F2 tend to zero, they represent an ideal zero, which would stand for a production of a vowel with no biases. This will be explored in the next section.

## 5.7 Vowel Threshold for F1 and F2: the Zero Point

### 5.7.1 The Zero Point

The goal of the VT measure is to provide two main pieces of information about the behavior of a vowel in a V-to-V sequence: 1) to estimate how vowels move vertically or horizontally in the acoustic space, and 2) to predict a zero point that would represent the prototypical token of a vowel (i.e. the expected value of a category). The first was discussed throughout this chapter in order to explore the possibilities of vowel movements and to determine whether the vowels have been harmonized or dissimilated under the influence of the second vowel of the sequence. The second topic, although less discussed in the text, introduces a theoretical concept that is behind the measurement itself and can be formulated as:

(90) The zero point:

> If Vowel $V_1$ in a $V_1$-to-$V_2$ sequence is not biased by the phonological environment, the Vowel Threshold value for $V_1$ is equal to *zero*.

The **zero point** is an important assumption of the VT measurement, since it represents a tendency for a vocalic category. Its importance was stated at the beginning of this chapter as "*the closer to zero the more likely a vowel is to preserve its category.*" For example, considering F1 and F2 of a vowel, if this vowel is not affected by the vowel in the sequence, its production will tend to be equal to *Control F1* and *Control F2*. If equal, VT can be assumed to be equal to zero. With the VT of both parameters equal to zero, the vowel is in a location named the **zero point**, as graphically expressed below.

(91)

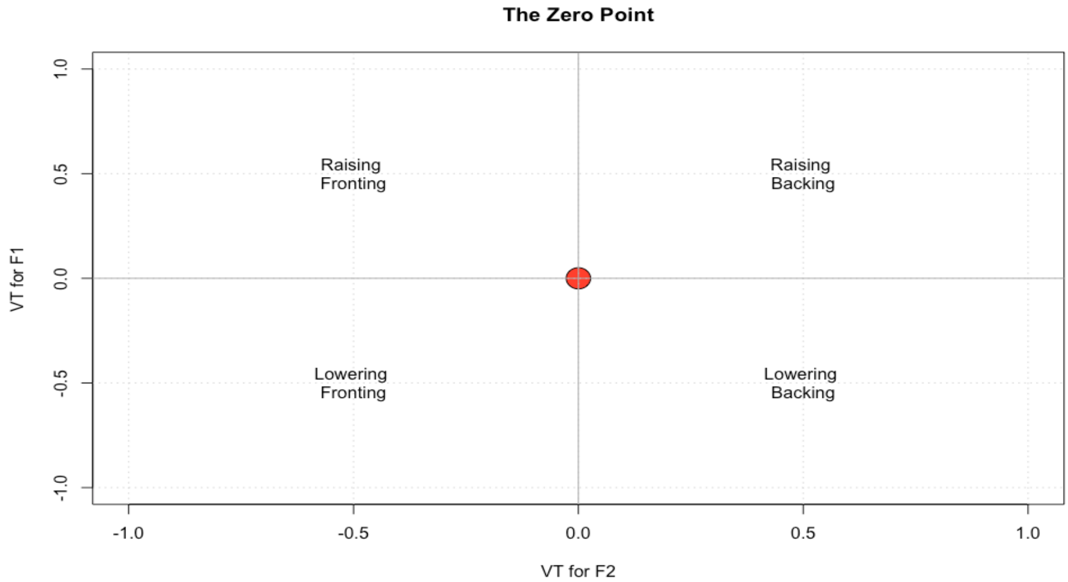



Figure 39. The Zero Point with the four possibilities of vowel movements in each quadrant.

Figure 39 shows a token of a vowel whose VT values for F1 and for F2 were equal to zero. The result is a point where $x = 0$ and $y = 0$. Naturally, the zero point is an ideal value of a VT. It expresses, to a great extent, the best examples of a token of a vowel, since zero is the expected value of a category. Nonetheless, in the real production of speakers, vowels are extremely affected by the properties of the vowels in the sequence, by the consonantal environment, rhythmic processes, and so on. This is the case, of course, for VH, which imposes melodic changes on its targets, moving vowels up or down, backwards or towards the front. Then, by computing VT for both parameters, the measure can estimate four possibilities of movements expressed in the four quadrants of the figure. The furthest the VT value is from zero, the more likely it is that the vowel is undergoing a change. This issue will be discussed by presenting the behavior of the five BP pre-stressed vowels.

### 5.7.2 F1 versus F2

By plotting VT values computed from vowel F1 and F2, we can estimate how the set of pre-stressed vowels has been affected in both scales and how close they are to zero. As can be seen, the production of the vowels /i, u, e, o/ is minimally affected in the F2 parameter, but such vowels are largely affected vertically, that is, in their F1. This suggests that these vowels are not being moved frontwards or backwards, but rather are preserving their position in the front-back axis. On the other hand, the VT values based on F1 reveal that these vowels are being moved up and down, suggesting that one characteristic of BP pre-stressed vowels is to have their height affected.

(92)

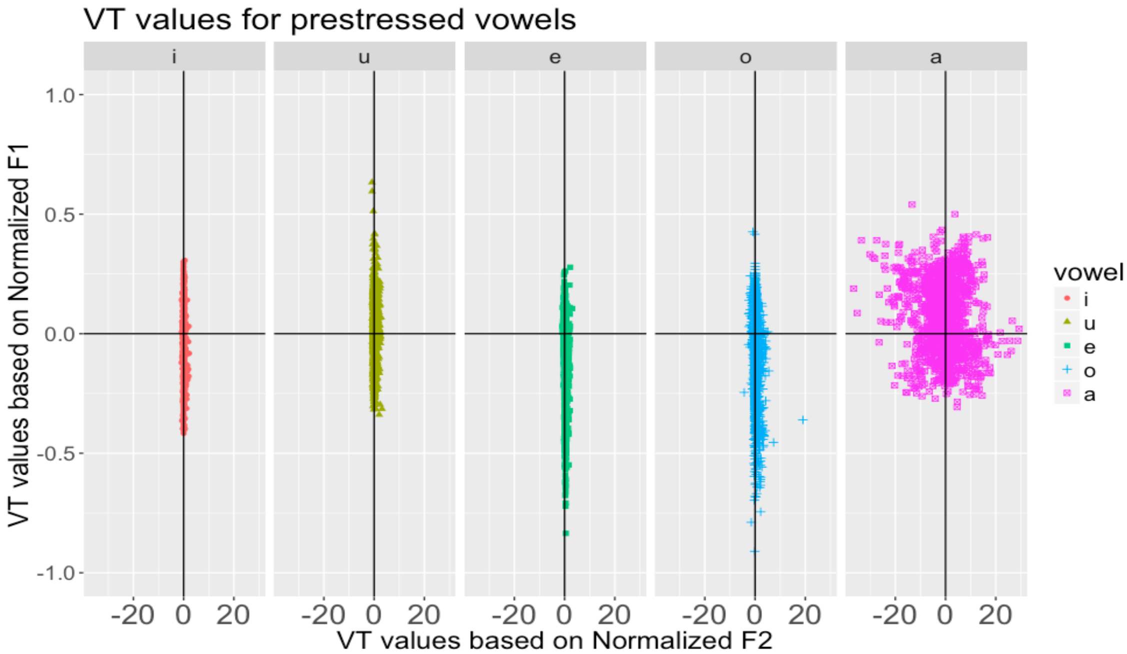



Figure 40. The Zero Point for the five pre-stressed vowels.

As mentioned in §5.3, high vowels strongly preserve their category, which could be determined by the critical VT values. This is distinct to the findings for the targets /e/ and /o/, whose height is changed in favor of the height of the following vowel. As can be seen, Figure 40 confirms that these vowels tend to be lowered, which can be observed in the portion of negative values in contrast with the positive ones along the y-axis. While high vowels show proportionally negative and positive values, the /e, o/ targets have more negative values. The only vowel that presents large variation in both scales is /a/. This vowel seems to be the most affected by the height and frontness characteristics of the following vowel in the V-to-V sequence.

Figure 41 presents the results of the VT values for all speakers and vowels computed from the formants F1 and F2. The panels are organized by dialect.

(93)

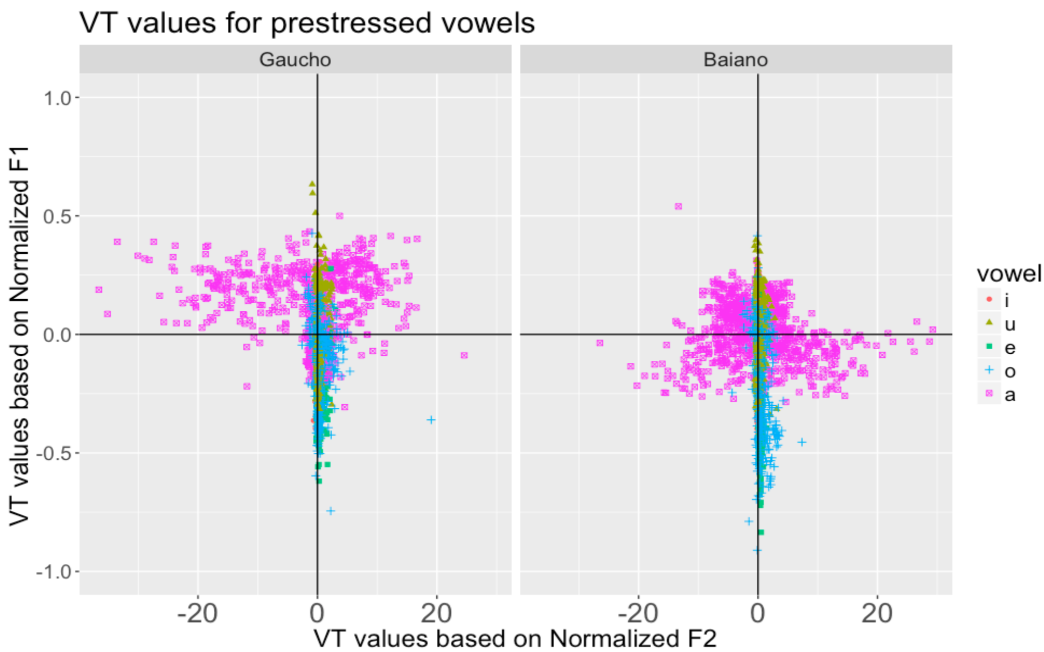



Figure 41. The Zero Point for Gaucho and Baiano dialects in the five vowels conditions.

Figure 41 shows that vowels surround the *zero point*; even though there are some biases that affect vowels towards one movement or the other, the phonological category is a strong force that attracts the vowel and forces it to remain as faithful as possible to its category, which is showed by the zero point. Although some cross-dialect difference can be seen, the zero point can be considered the tendency for both GA and BA vowels. GA's vowel /a/ seems to be more fronted and raised than BA's /a/, whose portion of negative values is greater than the positive ones in the y-axis, and such /a/ is more lowered in comparison with GA's /a/. Also, /a/ in both dialects is affected by the frontness-backness characteristic of the following vowel, which can be seen on the x-axis.

The measure proposed here indicates that estimating vowel movements can be a possible path to determine vowel categories. There are, however, some limitations and issues that have to be considered, but the measure worked for the purpose of determining the behavior of vowel targets. The open and remaining issues will be addressed next.

## 5.8 Conclusion

The issue underlying the discussion presented in this chapter is related to a theoretical linguistic problem that goes back to at least Jakobson, Fant, and Halle (1951) – the wish to account for the phonetics–phonology mapping; in other words, how continuous/phonetic information is mapped onto abstract phonological units. The goal was to check whether vowel

F1 and F2 could provide substantial phonetic information to help predict the vowel category produced by speakers. I departed from V-to-V measurements of F1 and F2 and offered a measurement that might help linguists determine the vowel movements on F1 and F2 scales.

The VT measure can estimate the vowel movement based on a given acoustic parameter computed by the analyst. To present the measurement, I chose vowel F1 because I attempted to demonstrate that VT could predict whether a vowel target of VH would be harmonized in height with the immediately following vowel or whether it would be faithful to its phonological category in its production. The assumptions of VT are based on the assumption that vowels are coarticulated in V-to-V sequences – the phonetic information of one vowel can be predicted by another vowel, which is a characteristic of vowel assimilation. However, vowels can also be dissimilated because an acoustic parameter of the vowel can move on the acoustic space in the opposite direction of the nearby vowel to which it should be assimilated. If one vowel have similar characteristics of another in a sequence then vowels are expected to show degrees of anticipatory or carryover assimilation. These degrees can be logically interpreted as:

1) vowels can be influenced by another in a given parameter, which would characterize *coarticulation*;
2) vowels can be totally affected by another vowel, which could be defined as *VH*;
3) vowels can be influenced by another vowel, but the parameters are being dissimilated, *vowel dissimilation;* and
4) vowels can be completely dissimilated, which would be the case of *disharmony*.

The measurement proposed in this work is an attempt to map continuous phonetic information onto a phonologically discrete value. The advantage of the measurement is the use of a scale. The central point is zero, which stands for a value that is considered the best example of such a category. This is an advantage of the measurement, since all vowel movements can be determined with the same method. VT informs two main aspects of the acoustic parameters of the vowels in V-to-V sequences:

a) It offers two cutting points for a given vowel category defined by the module of the critical VT value.
b) VT provides a range of variation within a phonological vowel category.

The two main aspects are crucial to our purposes, since they provide information about the effect of the vowels in the V-to-V sequence on the vowel being tested. As VT provides information on the movements of the vowels within and between categories, one can also determine to which degree the vowel is affected by a certain parameter, such as F1 for height, as previously seen.

An advantage of VT is that it removes vowel overlapping in the acoustic space. As observed cross-linguistically, the production of vowels in the acoustic space shows many overlapping areas which often stand for tokens of two vowel categories. As the zero point is based on a control value set of median (control F1 or control F2) defined in the formula, the analysis by VT removes the acoustic overlapping issue, since all categories will tend to zero, and each vowel can be analyzed considering the VT threshold.

### 5.8.1 F1 versus F2

The impact of the measure computed from F1 values seems strong enough to allow us to make some generalizations about the behavior of the targets /e, o/. The scale of vowel targets movement given by VT are defined below:

(94)

Table 21. The VT scale for values based on F1 and F2 with the possible intra- and inter-category movements for /e, o/.

| | | Zero | | |
|---|---|---|---|---|
| $VT_{F1}$: | ← [ɛ, ɔ] | ← Lowering ← | → Raising → | [i, u] → |
| $VT_{F2}$: | ← | ← Fronting ← | → Backing → | → |
| | *Critical Negative VT* | | *Critical Positive VT* | |

For VT-F1, the measure can predict four possibilities: raising and lowering within category, and lowering and raising to another vowel category, which are represented by [ɛ, ɔ] and [i, u], respectively. It is important to highlight that there are no vowels [i] and [u] derived from /e/ and /o/ in our results; rather, only the mid-low counterparts were seen for both dialects.

This scale can also predict vowel-fronting and vowel-backing if we compute VT values based on the second formant of the vowels. However, for this measurement, it is difficult to determine thresholds that could predict vowel category shifts on the front-back axis. On the other hand, VT yields a zero, which is to a great extent a measure of a central tendency, since if the VT of the token is statistically equal to the *Control Median* defined in the formula, VT equals zero. As zero is the central point, all productions can be defined on the basis of how distant they are from zero, resulting in a shift if a given VT value crosses the critical points.

Based on those assumptions, an analysis was made of both dialects for all four speakers. There were assimilations towards [–ATR] VH, but also dissimulations in height. The conclusions about the behavior of height of the targets are discussed next.

### 5.8.2 V-to-V Relations

The most important issue raised by these findings concerns the fact that high-to-high agreement that most studies reported in the literature have claimed about the behavior of /e, o/ in pre-stressed syllables was not found. It is also surprising that vowel lowering seems to be a tendency regardless the two dialect, while the majority of the studies claim the opposite. Table 22 summarizes the major findings:

(95)

Table 22. Behavior of the targets /e/ and /o/ according to the seven stressed vowels.

| | | | $V_2$ | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | i | u | e | o | ɛ | a | ɔ |
| $V_1$: | *Gaucho* | */e/* | – | – | – | – | ⇣⇣ | ⇣⇣ | ⇣⇣ |
| | | */o/* | – | – | – | – | ⇣⇣ | ⇣⇣ | ⇣⇣ |
| | *Baiano* | */e/* | – | ⇣ | – | – | ✓ | ✓ | ✓ |
| | | */o/* | ⇣ | – | – | – | ✓ | ✓ | ✓ |

*Note: (–) no significant movement; (⇣⇣) significant lowering and harmony patterns;* (⇣) dissimilatory lowering; *(✓) significant harmony*

According to VT results, the F1 values of the targets /e, o/ are significantly affected by [+ATR] vowels and VT values are near zero without significant differences among them, especially for the GA variety. On the other hand, comparisons between [–ATR] and [+ATR] vowels are consistently significant and for both dialects the observed tendency is lowering. There is, however, a minor difference that lies in the degree of lowering: while in GA the median in the box plot does not cross the VT boundaries, BA seems fully harmonized. This difference is small and is more closely related to an interpretation of harmonization than to consideration regarding non-lowering in GA. In fact, the vowels are lowered, but the procedure assumed by VT is to consider that the median must be higher than the critical VT. And what is observed for GA vowels is that harmony occurs in many tokens, where the median is higher than the critical VT (see §5.5.1).

Also, /e, o/ are dissimilated in height when followed by /i/ and /u/. This is also surprising for BP for two reasons: 1) pre-stressed syllables undergo assimilation in the language and 2) dissimilation[17] might be dialect-specific. In addition to being opposite to those of Rodrigues (2010), who argues that dissimilation occurs in BP exclusively in stressed syllables, our findings also report dissimilation affecting VH targets. Rodrigues (2010) points out that pre-stressed syllables show only assimilation to the next vowel, but our results indicate that dissimilation can also occur triggered by other aspects that deserve further detailed investigation.

To sum up, the results presented in Chapter 4, and in this chapter, suggest that the [ATR] feature value initiates harmonization with immediately preceding vowels, which is consistent for both dialects for at least three speakers. As expected in this phonological process, [ATR] harmony in BP is triggered by a natural class and also affects another natural class of [–High, +ATR] vowels, since [+High] vowels are not affected. As there was no high-vowel agreement in the experiment and the VT measurements confirm that vowels are not raised, it is worth discussing the [+High] VH found mainly by Bisol (1981) and Barbosa da Silva (1989) in GA and BA dialects, respectively. Therefore, the next part of this work discusses the phonology of BP VH and compares the experimental findings reported so far with previous proposals in the literature in order to determine the phonological characteristics of [ATR] harmony.

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[17] In terms of phonological rule, this dissimilation process could be formulated as: V[-high] → [+low] /__V [-(α back), +high].

# 6 CORPORA ANALYSES

## 6.1 Introduction

In this chapter, I will discuss the first two major works on VH in BP: Bisol (1981) and Barbosa da Silva (1989). The first one investigates pre-stressed vowel behavior in a Brazilian southern dialect, Gaucho, and the second focuses on the Baiano dialect. Both studies use the same theoretical approach, the Labovian framework known as Variation Theory (Labov, 1972). Since then, several studies about VH have been carried out. I will not discuss all of them thoroughly but mention those that are relevant for the present analysis. The goal of this chapter is to clarify the relationship between the target and the trigger vowels in VH and the role of place of articulation and consonantal class of the consonants surrounding the target vowel.

In the following sections I will discuss two aspects considered by Bisol as the main triggers for VH in BP: the following vowel (henceforth V2), and the surrounding consonants, which will be discussed according to their place of articulation and phonological class. For this analysis, I used two corpora: the first corpus was used by Bisol in her doctoral dissertation and the second one was created by Barbosa da Silva in 1989 for her doctoral dissertation.

However, unlike the authors, who used token frequencies, I analyzed only type frequency of the data. Such a distinction could not have been made at that time because their aim was to investigate the occurrence of the variants of a phonological pattern, and the discussion about frequency effects on phonological patterns was not yet established (see Pierrehumbert (1994) for an in-depth discussion).

## 6.2 Gaucho Dialect: Bisol's Corpus

### 6.2.1 Corpus

The corpus used by Bisol (1981) was extracted from sociolinguistic interviews with 60 participants from four different regions of Rio Grande do Sul: (1) Porto Alegre, (2) the region on the border with Uruguay, and regions where (3) German and (4) Italian colonization took place. The selected sample considered all the words with the vowels /e/ and /o/ in the pre-stressed position (V1), combined with all seven vowels of BP in the second position (V2). The original sample has 15,496 occurrences of words.

The present analysis consists of 4596 types and 13,146 tokens. All data were annotated while considering the target vowels, the place of articulation and the phonological class of the surrounding consonants. Thus, the analysis ended up with 2379 types with front vowels and 2217 back vowels in the position of harmony targets. From the original data, 2350 tokens were excluded when words were formed by: a) diminutive suffixes, such as *-inho* and *-zinho*; b) the suffix-*mente*; c) initial unstressed *es*-; d) initial prefixes *re-* and *per-*; e) the prefix *tele*-; and f) hiatus between target and trigger vowels within the prosodic word.

### 6.2.2 Variables

The response variable of the upcoming analysis is the vowel quality of the pre-stressed vowels (V1), which is a four-level unordered factor, corresponding to the vowels [i], [e], [o], and [u]. V1 vowels will be expressed in square brackets. Four independent variables were considered for the analyses:

- *Place-C1*: an unordered factor with four levels, corresponding to four places of articulation of the immediately previous consonant: labial, coronal, palatal and dorsal.
- *Place-C2*: an unordered factor with four levels, corresponding to the places labial, coronal, palatal and dorsal of the immediately next consonant.
- *Class-C1*: an unordered factor with five levels corresponding to the class of stops, fricatives, nasals, laterals and rhotics of the previous consonant.
- *Class-C2*: an unordered factor with five levels, corresponding to the classes stops, fricatives, nasals, laterals and rhotics.

### 6.2.3 Statistical Analysis

In order to test the association between the variables, several chi-square tests of independence were performed, followed by the observed-to-expected ratio (O/E Ratio) and a measure of association, namely Cramer's V. For our purposes, O/E Ratio is relevant because it provides a measure of the relative frequency of a phonological structure (Pierrehumbert, 1993). If such structure is found less often than expected (O/E near 0), this combination tends to be unacceptable; on the other hand, if it is found more often than expected (O/E > 1), it suggests that the combination is preferred in the language. An alpha level of 0.05 was used to determine statistical significance for all analyses.

### 6.2.4 Results

#### 6.2.4.1 V-to-V

In this section, the analysis will consider the natural classes based on the feature [High] in order to determine the behavior of high vowels according to their feature specification. The results showed a significant association between V1 and the [High] feature values with strong Cramer's V. The percentage of high pre-stressed vowels that co-occurred with high vowels was significantly different regarding the value of the feature [High] $\boldsymbol{X}^2$(*3,* N = 4596) = 566.27, $p < 2.2 \times 10^{-16}$, V = 0.35), as can be seen in the tables below:

(96)

Table 23. Absolute values of co-occurrence patterns of V1 with the value of [High] in V2 in Bisol's data.

| | | | V2 | | |
|---|---|---|---|---|---|
| | | | [+High] i,u | [–High] e, ɛ, a, ɔ, o | Total |
| $V_1$ | Front | i | 344 | 41 | 385 |
| | | e | 699 | 1295 | 1994 |
| | Back | u | 280 | 181 | 461 |
| | | o | 526 | 1230 | 1756 |
| Total | | | 1849 | 2747 | 4596 |

In Bisol's dataset, high vowels are most likely to be combined with high vowels and non-high vowels with non-high vowels. In the plot and in Table 24, this distribution is clearly seen. Vowel [i] co-occurs with [+High] in more than 80% of the cases and [u] in ≅60%, while [e] and [o] co-occur >60% of the cases with [–High].

(97)

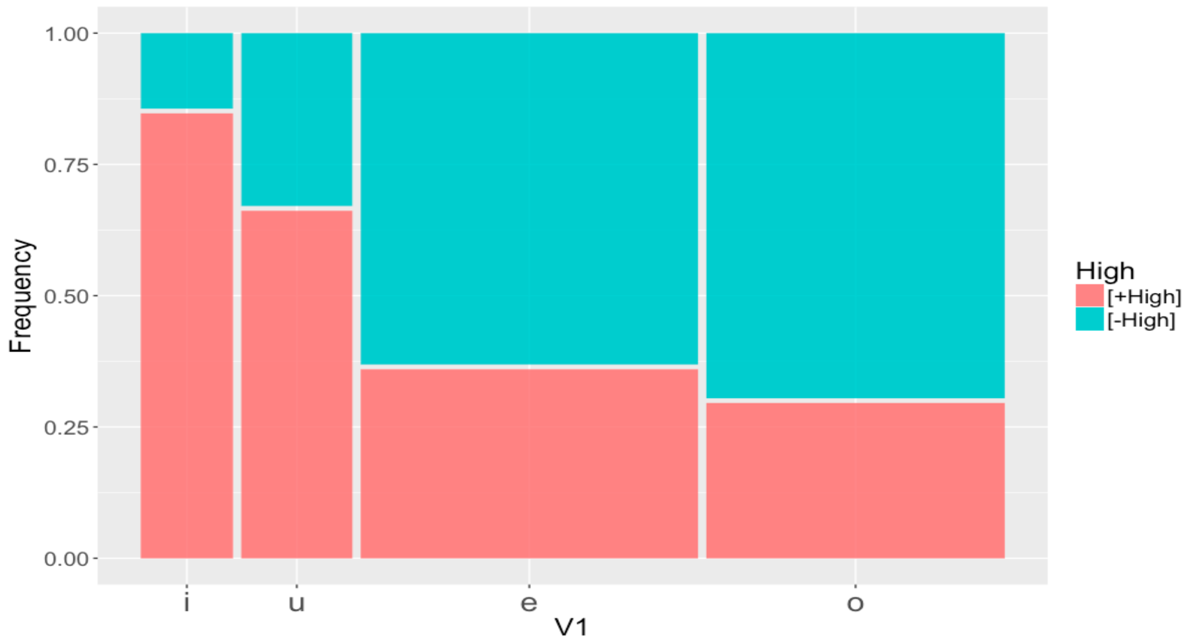


Figure 42. Frequency of co-occurrence of [i, u, e, o] with [+High] and [–High] vowels in V2.

The observed-to-expected ratio is a useful method to analyze the data cell-by-cell, since it gives a probability measure for each co-occurrence pattern. As we can conclude from the table below, the BP pre-stress vowel system seems symmetrical in terms of agreement with the following syllable, generally a stressed one. The high vowels co-occur with high vowels and the mid-high vowels /e/ and /o/ co-occur with the subset of [–High] vowels of the system.

(98)

Table 24. O/E Ratio values for co-occurrences between V1 and [High] in V2 ins Bisol's data.

| | | | V2 | |
|---|---|---|---|---|
| | | | [+High] i,u | [–High] |
| $V_1$ | Front Vowels | i | 2.22 | 0.18 |
| | | e | 0.87 | 1.09 |
| | Back Vowels | u | 1.51 | 0.66 |
| | | o | 0.74 | 1.71 |

*Note: O/E > 1 in shaded cells.*

Bisol (1981, 1989) claims that pre-stressed vowels change to high vowels, which seems to be confirmed. However, this only partially explains such a fact, since there is another force that does not allow vowels to change their [±High] specification. This means that height harmony is not related to raising of /e/ and /o/, but to the fact that these vowels maintain their feature value as [–High].

Table 25 shows the V-to-V co-occurrence patterns found in Bisol's corpus. A chi-square test of independence was performed to examine the relation between pre-stressed vowels and the immediately following vowel in the next syllable. The relation between these variables was significant, $X^2(18, N = 4596) = 905.9$, $p < 2.2 \times 10^{-16}$ and V = 0.26. Pre-stressed high vowels were most likely to co-occur with high vowels in V2 position.

(99)

Table 25. Absolute values of V-to-V co-occurrence patterns in Bisol's data.

| | | | $V_2$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | i | e | ɛ | a | ɔ | o | u | Total |
| $V_1$ | *Front Vowels* | i | 317 | 18 | 0 | 4 | 10 | 9 | 27 | 385 |
| | | e | 579 | 482 | 30 | 554 | 49 | 180 | 120 | 1994 |
| | *Back Vowels* | u | 185 | 101 | 46 | 32 | 1 | 1 | 95 | 1756 |
| | | o | 375 | 408 | 111 | 567 | 32 | 112 | 151 | 461 |
| Total | | | 1456 | 1009 | 187 | 1157 | 92 | 302 | 393 | 4596 |

According to these results, it seems that raising is triggered by the following vowel. However, there are vowels that co-occur with [–high] vowels, as previously reported in the literature (Bisol, 2010; Klunck, 2007; Monaretto, 2014). The analysis of the relationship between V1 and V2 showed that the main trigger may be the presence of a high vowel in the following syllable, although other vowels co-occur with raised vowels in pre-stressed position. These cases are clearly not motivated by the height harmony process, but by some sort of dissimilation instead.

As shown above, the values suggest that there is a phonotactic constraint that prohibits /e/ from changing to [i] when the pre-stressed vowel is followed by /ɛ/, for example, the word *peteca* [pe'tɛ]ca (shuttlecock) cannot be produced as *[pi'tɛ]ca. The same occurs for the back counterpart /o/ followed by /o/ and /ɔ/. For the co-occurrence patterns [u-ɔ] and [u-o], there is only one item, respectively: the words *conforme* (according to) and *conotação* (connotation). This phonotactic constraint in raising back vowels was firstly noted by Freitas (2009) and Abaurre and Sandalo (2012), for whom this behavior could be examples of parasitic harmony[18] in BP. Below is a summary of attested and unattested patterns in Bisol's corpus involving /ɛ, o, ɔ/ as V2 vowels.

(100)

Table 26. Examples of V-to-V patterns with high vowels in V1 and non-high vowels in V2 in Bisol's data.

| $V_1$-to-$V_2$ | Count | Example | Phonetic Form | Gloss |
|---|---|---|---|---|
| i-e | 18 | pequeno | pi'ke]nʊ | small |
| i-ɛ | zero | Not found | – | – |
| u-o | 1 | conotação | kuno]ta'sɐ̃w̃ | connotation |
| u-ɔ | 1 | conforme | kũ'fɔɾ]mɪ | according to |

The attested type column shows that the sequences of a high vowel followed by a low vowel that agrees in backness tends to be prohibited in the language. In other words, we could say that BP favors patterns such as *e-ɛ*, *o-o* and *o-ɔ;* in fact, sequences such as those are already harmonized by the feature [–High]. According to Freitas (2009), the behavior of back vowels in BP is an example of parasitic harmony, for which harmonizing is required by the features [high] and [rounding], which need to share the same values. I will not discuss her analysis in detail, but I argue that a necessary harmonic requirement could be not only [high] but also [back]. This role of backness agreement is also addressed by Abaurre and Sandalo (2012,
p. 22), who claimed that in sequences such as *e-o,* the front mid-vowel /e/ cannot be raised. In this work, the status of the claimed BP parasitic harmony, and it should be noted that some harmonic patterns are more likely to occur in the BP lexicon than others. The V-to-V co-occurrence patterns may be expressed in terms of O/E ratio. This methodology will allow us to determine whether Gaucho is a high-to-high harmonic dialect, as assumed by Bisol, or whether high vowels are followed by non-high vowels. Table 27 shows the O/E values for Gaucho V-to-V patterns.

[18] Parasitic harmony is a phenomenon that requires mutual dependency of the features of target and trigger vowels (Cole, 1987; Klaun, 2004; Kramer, 2003; Nevins, 2009).

(101)

Table 27. O/E Ratio values for V-to-V co-occurrence patterns in Bisol's data.

| | | | $V_2$ | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | i | e | ɛ | a | ɔ | o | u |
| $V_1$ | *Front Vowels* | i | 2.60 | 0.21 | 0 | 0.04 | 1.30 | 0.36 | 0.82 |
| | | e | 0.92 | 1.10 | 0.37 | 1.10 | 1.23 | 1.37 | 0.70 |
| | *Back Vowels* | o | 0.67 | 1.05 | 1.55 | 1.28 | 0.91 | 0.97 | 1.00 |
| | | u | 1.27 | 0.99 | 2.45 | 0.27 | 0.10 | 0.03 | 2.41 |

*Note: O/E > 1 in shaded cells.*

This result confirms the asymmetry found by Bisol for the target and trigger vowels, in which only the back vowel is symmetrically harmonized with the two high vowels. This asymmetry is not because the articulation of /u/ is not as high as that of /i/, but can be explained by two properties that need to be conjoined for raising /e/ to [i] in V2: height and agreement in backness. Considering that BP VH is a height-oriented system, this result poses a problem, because /u/ should also trigger harmonization, since this vowel is phonologically [+High].

Considering the subset of V1 vowels and the whole set of BP vowels in V2, the association between these variables is significant, which suggests that V1 may be associated with the vowel type of the following syllable. The results show that raised vowels [i] and [u] have an asymmetric distribution: [i] is most likely associated with a V2 /i/ whereas [u] co-occurs with both high vowels /i/ and /u/. This raised a question about why /u/ is not an optimal trigger to raise a phonological /e/ to [i]. These results, therefore, confirm the assumptions made by Bisol (1981) about the role of /i/ in V2 as the main phonological trigger; conversely, why there are some special cases of high vowels co-occurring with [–High] vowels in a language in which vowels are supposed to agree in height remains unanswered.

In order to explain the disagreement patterns where vowels are raised without a high vowel as a trigger, Bisol argues that surrounding consonants may surface high vowels in pre-stressdc syllables. The author claims that the fact that palatals and velars are [+High] consonants, according to Chomsky and Halle (1968), would explain that. The following sections will focus on the association between place of articulation and consonantal class and the target's vowel height.

#### 6.2.4.2 C-to-V

This section aims to determine the role of place of articulation and of the class of the previous consonant (henceforth Place C1 and Class C1, respectively). The following table expresses the results for V1 as a function of place or articulation in Bisol's dataset. A chi-square test of independence showed that V1 was significantly dependent of Place C1, $X^2(9, N = 4227) = 744.98, p < 2.2\ x\ 10^{-16}$ V = 0.24.

(102)

Table 28. Absolute values of the co-occurrence patterns of vowels and place of articulation of the preceding consonant

| | | | Labial | Coronal | Palatal | Dorsal | Total |
|---|---|---|---|---|---|---|---|
| $V_1$ | *Front Vowels* | i | 143 | 142 | 8 | 30 | 323 |
| | | e | 707 | 762 | 89 | 233 | 1791 |
| | *Back Vowels* | u | 126 | 46 | 3 | 269 | 444 |
| | | o | 515 | 341 | 63 | 750 | 1669 |
| Total | | | 1491 | 1291 | 163 | 1282 | 4227 |

Although there is an association between Place C1 and pre-stressed vowels, it is moderate (V = 0.24). The graphic below shows that [i] and [u] co-occur in about 20% of the sample but not in a significant proportion for the other places. In other words, one may claim that Place C1 is not consistent in predicting the association of high vowels with a specific place, since about 80% are combinations of mid vowels with the three places of articulation.

(103)

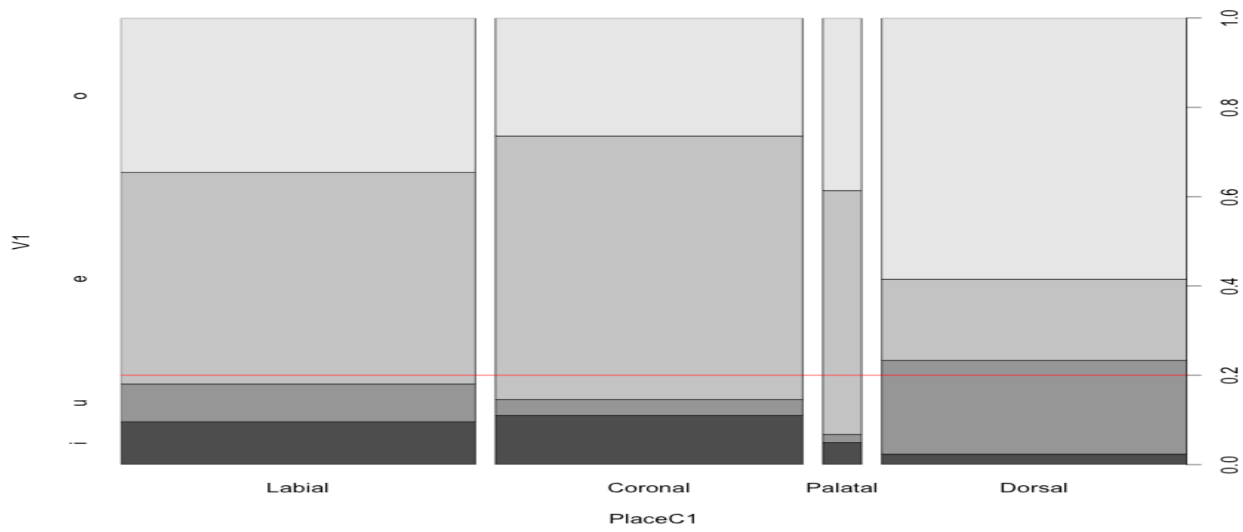


Figure 43. Frequency of co-occurrence of [i, u, e, o] with the four places in C1.

For the preceding consonants, Place C1 shows consistent O/E> only for dorsal place with back vowels, that is, back vowels are most likely to occur with dorsal consonants. Labials, coronals and palatals are likely to co-occur with front vowels, as shown below.

(104)

Table 29. O/E ratio for co-occurrence patterns between target vowels and Place C1.

| | | | Place C1 | | | |
|---|---|---|---|---|---|---|
| | | | Labial | Coronal | Palatal | Dorsal |
| $V_1$ | *Front Vowels* | i | 1.25 | 1.44 | 0.64 | 0.31 |
| | | e | 1.12 | 1.39 | 1.29 | 0.43 |
| | *Back Vowels* | u | 0.80 | 0.34 | 0.18 | 1.99 |
| | | o | 0.87 | 0.67 | 0.98 | 1.48 |

*Note: The shading cells specify O/E>1.*

These results are not surprising and do not seem to reflect special behavior for the Gaucho dialect or even of BP. There are some studies whose findings show that front vowels tend to co-occur with front consonants and back vowels with back consonants, which would be a universal indicator of human language phylogenetic development (MacNeilage, 1998; MacNeilage & Davis, 1990, 2000). In addition, O/E values also show that labials and coronals are most likely to co-occur with vowels with different height values in the front vowel subset and the same occurs for dorsal consonants with back vowels. Thus, we may conclude that the role of Place C1 is not that of selecting height but rather of selecting vowels in the front-back axis.

Class C1 shows a moderate role in class-to-vowel association; the chi-square test showed that the relation between V1 and Class C1 is significant, $X^2(12, N = 4227) = 608.46$, $p < 2.2 \times 10^{-16}$, V = 0.22.

(105)

Table 30. Absolute values of the co-occurrence patterns of vowels and consonantal class of the preceding consonant.

| | | | Stop | Fricative | Nasal | Lateral | Rhotic | Total |
|---|---|---|---|---|---|---|---|---|
| $V_1$ | *Front Vowels* | i | 91 | 136 | 49 | 23 | 24 | 323 |
| | | e | 671 | 567 | 200 | 122 | 231 | 1791 |
| | *Back Vowels* | u | 368 | 38 | 31 | 3 | 4 | 444 |
| | | o | 1083 | 292 | 199 | 47 | 48 | 1669 |
| | Total | | 2213 | 1033 | 479 | 195 | 307 | 4227 |

This result for class-to-vowel association is similar to the finding for Place C1: approximately 20% or less of all co-occurrences are with high vowels, as shown by the red line in the next plot.

(106)

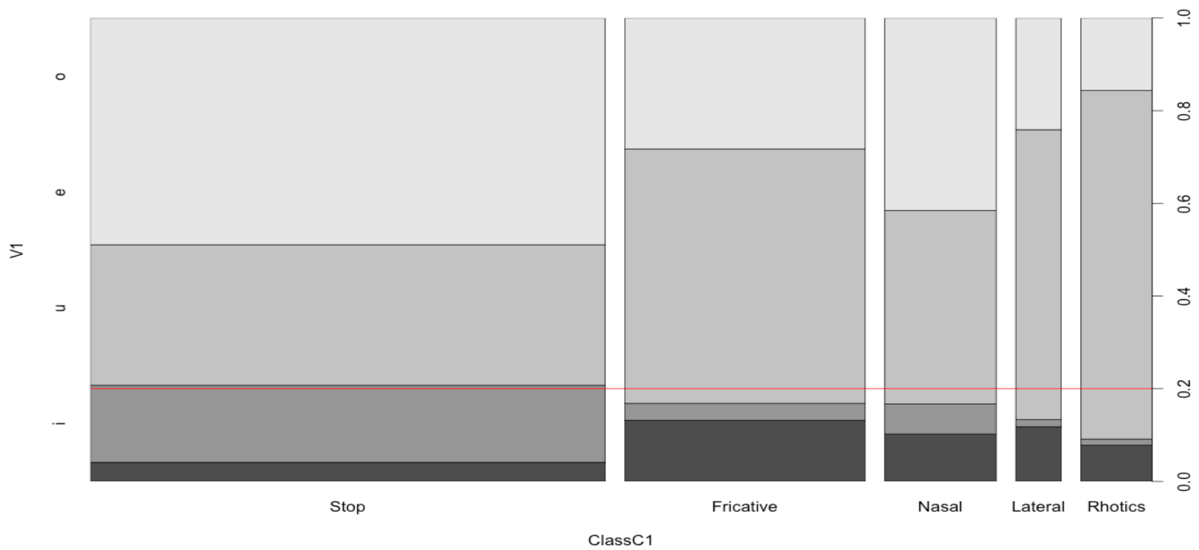


Figure 44. Frequency of co-occurrence of [i, u, e, o] with the five consonantal classes in C1.

O/E ratio values show that front vowels co-occur in almost all the classes, except for stops. These result indicate that stops co-occur with back vowels may be due to the fact that two thirds of dorsal consonants are the stops /k/ and /g/, which may be reflected in the results for the class. As can be seen, there is no preference for high vowels in almost the whole table; on the contrary, only nasals co-occur with [i], and the mid vowels are preferred also for the back vowels.

(107)

Table 31. O/E ratio for co-occurrences patterns between the target vowels and Class C1.

| | | | Class C1 | | | | |
|---|---|---|---|---|---|---|---|
| | | | Stop | Fricative | Nasal | Lateral | Rhotic |
| $V_1$ | *Front Vowels* | i | 0.54 | 1.72 | 1.34 | 1.54 | 1.02 |
| | | e | 0.72 | 1.3 | 0.99 | 1.48 | 1.78 |
| | *Back Vowels* | u | 1.58 | 0.35 | 0.61 | 0.15 | 0.12 |
| | | o | 1.24 | 0.72 | 1.05 | 0.61 | 0.4 |

*Note: The shading cells specify O/E>1.*

These results do not allow us to state which consonantal class triggers raising of a pre-stressed vowel. Although a moderate Cramer's V indicates that there is an association, one cannot make generalizations about what kind of phonological class may raise vowels. Moreover, the fact that 20% of the types in Bisol's dataset show co-occurrence with high vowels does not allow any generalization about the role of consonants (place and class) in raising pre-stress mid vowels, since 20% do not represent a tendency towards raising vowels with previous consonants as triggers.

#### 6.2.4.3 V-to-C

For the analysis of vowel-to-consonant association, the chi-square test returned a significant association between V1 and Place C2, $X^2(9, N = 4463) = 155.68$, $p < 2.2 \times 10^{-16}$. However, Cramer's V result was weak: V = 0.10.

(108)

Table 32. Abolute values of co-occurrence patterns between target vowels and Place C2.

| | | | Labial | Coronal | Palatal | Dorsal | Total |
|---|---|---|---|---|---|---|---|
| $V_1$ | *Front Vowels* | i | 43 | 246 | 18 | 68 | 375 |
| | | e | 403 | 1169 | 85 | 276 | 1933 |
| | *Back Vowels* | u | 160 | 206 | 57 | 33 | 456 |
| | | o | 466 | 957 | 90 | 186 | 1699 |
| | Total | | 1072 | 2578 | 250 | 563 | 4463 |

Pre-stressed vowels as a function of Place C2 are shown in Figure 45, and as we can see, vowels [i] and [u] are associated with all places in about 20%, of occurrences not more than that. Even with a significant association, this result does not allow the conclusion that a specific Place C2 is responsible for predicting a high vowel in an unstressed syllable, as claimed in the literature.

(109)

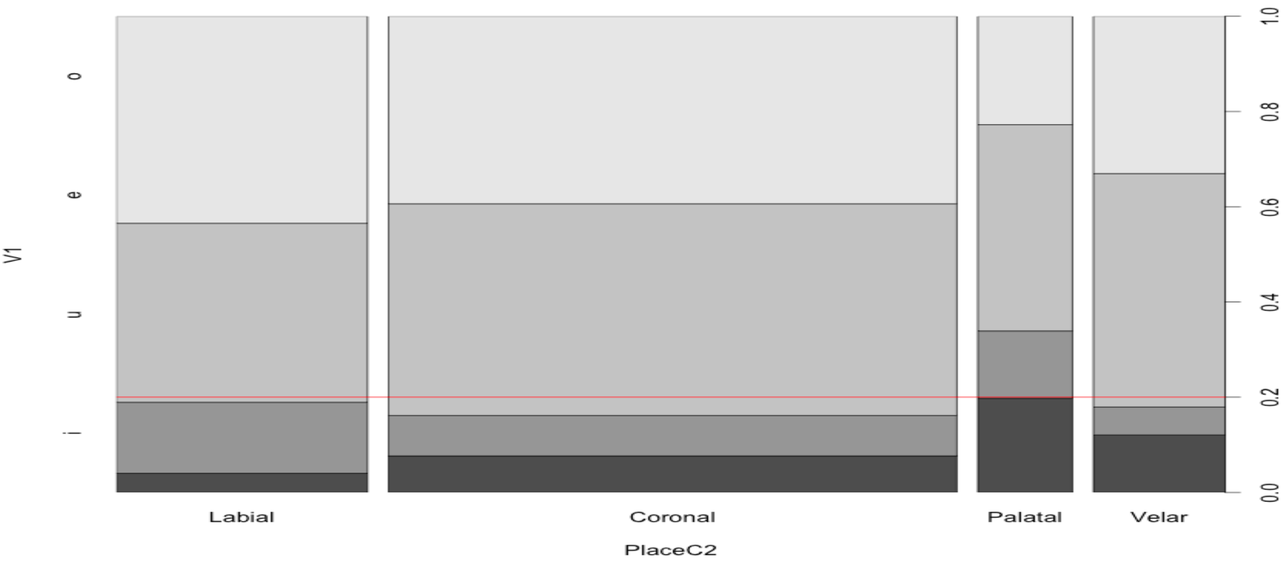


Figure 45. Frequency of co-occurrence patterns between target vowels and Place C2.

In fact, some generalizations about a universal trend in CV syllables (MacNeilage & Davis, 2000) are also found for VC structures. O/E ratios show that rounded vowels co-occur with labial consonants; mid-high vowels,[19] with coronal Cs; and high vowels, with palatals. The only unexpected result is that dorsal consonants are associated with front vowels, which are supposed to co-occur with front consonants.

[19] According to Clements (1990) and Clements and Hume (1995), /e/ and /o/ have a [coronal] feature linked to V-Place.

(110)

Table 33. O/E ratios for co-occurrences patterns between the target vowels and Place C2.

| | | | Place C2 | | | |
|---|---|---|---|---|---|---|
| | | | Labial | Coronal | Palatal | Dorsal |
| $V_1$ | *Front Vowels* | i | 0.48 | 0.9 | 2.36 | 1.44 |
| | | e | 0.87 | 1.03 | 1 | 1.32 |
| | *Back Vowels* | u | 1.46 | 0.83 | 1.38 | 0.57 |
| | | o | 1.14 | 1.03 | 0.6 | 0.87 |

Contrasting with Bisol's findings for Place C2, only palatals are most likely to co-occur with high vowels, and even for [e]-palatal pattern, O/E is equal to 1, which means that this pattern is randomly distributed. In other words, Bisol's findings are not consistent and O/E results do not support her generalizations about the role of Place C2. Similar inconsistencies with Bisol's results were found for the role of consonantal class that immediately follows V1. Class C2, though, shows a significant result in the chi-square test, $X^2$ (12, N = 4462) = 238.38, $p < 2.2 \times 10^{-16}$; also, it has a weak Cramer's V (V = 0.13), which compromises the analysis.

(111)

Table 34. Absolute values of co-occurrences patterns between the target vowels and Class C2

| | | | Stop | Fricative | Nasal | Lateral | Rhotic | Total |
|---|---|---|---|---|---|---|---|---|
| $V_1$ | *Front Vowels* | i | 179 | 103 | 32 | 24 | 37 | 375 |
| | | e | 156 | 102 | 140 | 38 | 20 | 456 |
| | *Back Vowels* | u | 821 | 604 | 155 | 115 | 238 | 1933 |
| | | o | 708 | 362 | 264 | 140 | 224 | 1698 |
| | Total | | 1864 | 1171 | 591 | 317 | 519 | 4462 |

(112)

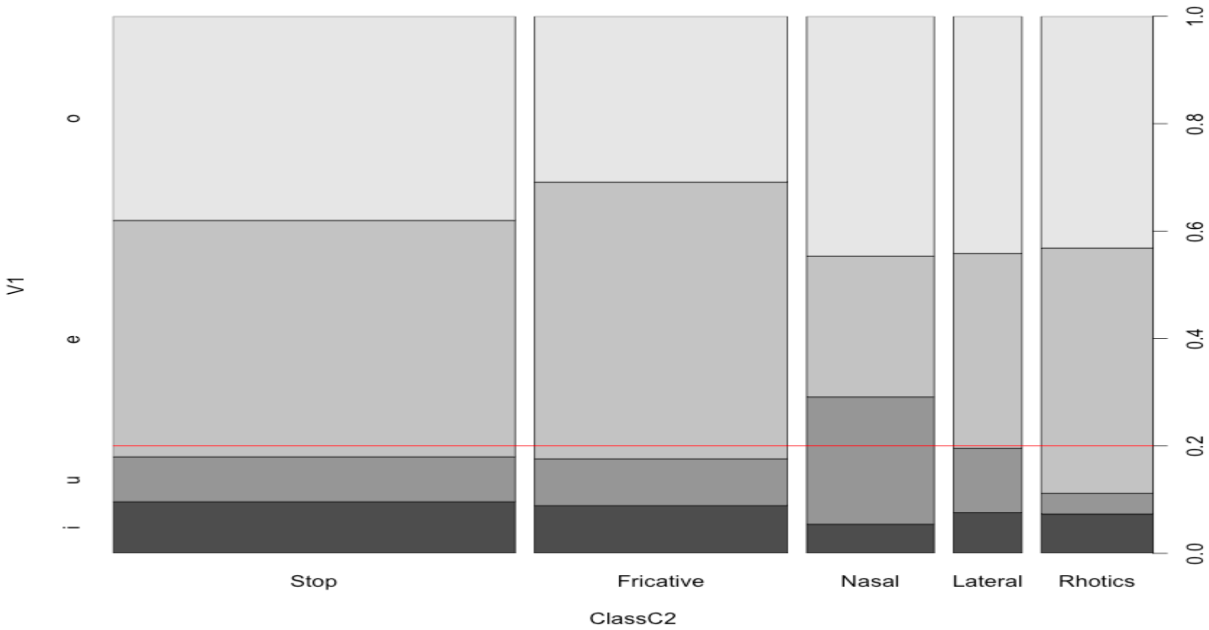


Figure 46. Frequency of co-occurrences patterns between the target vowels and Place C2.

These results also show that high vowels co-occur with about 20% of each class, and the other 80% are reserved for co-occurrence patterns of mid-high vowels. O/E ratios show that stops and fricatives are most likely to co-occur with both front vowels, whereas nasal and laterals, with the back ones. For these cases, one might speculate that in a V-to-C association, front vowels prefer obstruents and back vowels prefer sonorants, while rhotics prefer non-high vowels. Nevertheless, O/E ratios show that high vowels do not present any pattern of co-occurrence with a particular class of consonants. On the contrary, rhotics (which are the only class that shows some preference) reject high vowels, in fact.

(113)

Table 35. O/E ratio for co-occurrences between target vowels and Class C2.

| | | | Class C2 | | | | |
|---|---|---|---|---|---|---|---|
| | | | Stop | Fricative | Nasal | Lateral | Rhotic |
| $V_1$ | *Front Vowels* | i | 1.14 | 1.05 | 0.64 | 0.9 | 0.84 |
| | | e | 1.02 | 1.19 | 0.61 | 0.84 | 1.06 |
| | *Back Vowels* | u | 0.82 | 0.85 | 2.32 | 1.17 | 0.38 |
| | | o | 0.99 | 0.81 | 1.17 | 1.16 | 1.13 |

Obstruents are most likely to co-occur with front vowels while back vowels prefer nasals and laterals, without differentiation between high and non-high vowels. According to Schwindt (1997, p. 60), VH tends to be blocked when the class of a C2 consonant is a liquid. However, this is not valid for laterals, but only for the class of rhotics, which shows preference of co-occurrence with non-high vowels.

## 6.3 Baiano Dialect: Barbosa Da Silva's Corpus

In this section, I present a reanalysis of Barbosa da Silva's (1989) study. As discussed in Chapter 2, the set of pre-stressed vowels of BA differs from that of GA. Thus, the aim of this section is to determine if the dialects show the same sort of VH or whether their vowel inventory undergoes different types of phonological processes.

### 6.3.1 Corpus

The corpus used by Barbosa da Silva (1989) was extracted from sociolinguistic interviews with 24 participants from Salvador, the capital of the state of Bahia. The sample consisted of all the words with mid-high and mid-low vowels in the pre-stressed position (V1) co-occurring with all BP seven vowels in second position (V2). Thus, there might be 42 co-occurrence patterns, as opposed to GA, which has only 35 vowel combinations.

The sample size consists of 1291 word types and 3008 tokens. The subset of pre-stressed occurring vowels is composed of [i, e, ɛ, u, o, ɔ]. The same exclusion criteria were applied as in Bisol's data (see §6.3.1).

### 6.3.2 Variables

The same variables used to investigate harmony of GA vowels were considered for analyses of BA.

### 6.3.3 Results

#### 6.3.3.1 V-to-V

Unlike Gaucho, the northeastern dialect Baiano has mid-low vowels in an unstressed position. These vowels are expected to surface triggered by the quality of V2. In order to determine the association between V1 and V2 vowels, a chi-square test was run and the results were significant, $X^2(30, N = 1291) = 397.57$, $p < 2.2 \times 10^{-16}$, V = 0.25. The values for each co-occurrence pattern are shown below.

(114)

Table 36. Absolute values of V-to-V co-occurrence patterns in Silva's data.

| | | | V₂ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | i | e | ɛ | a | ɔ | o | u | Total |
| $V_1$ | *Front Vowels* | i | 89 | 10 | 1 | 3 | 2 | 0 | 10 | 115 |
| | | e | 52 | 63 | 2 | 17 | 0 | 16 | 5 | 155 |
| | | ɛ | 116 | 77 | 28 | 163 | 19 | 16 | 25 | 444 |
| | *Back Vowels* | u | 51 | 15 | 4 | 10 | 0 | 1 | 14 | 95 |
| | | o | 48 | 30 | 7 | 10 | 1 | 23 | 16 | 135 |
| | | ɔ | 72 | 27 | 24 | 154 | 20 | 16 | 34 | 347 |
| Total | | | 428 | 222 | 66 | 357 | 42 | 72 | 104 | 1291 |

As can be seen in Figure 47, a descendent line can be drawn from the high vowel to the mid-low vowels in the *x*-axis.

(115)

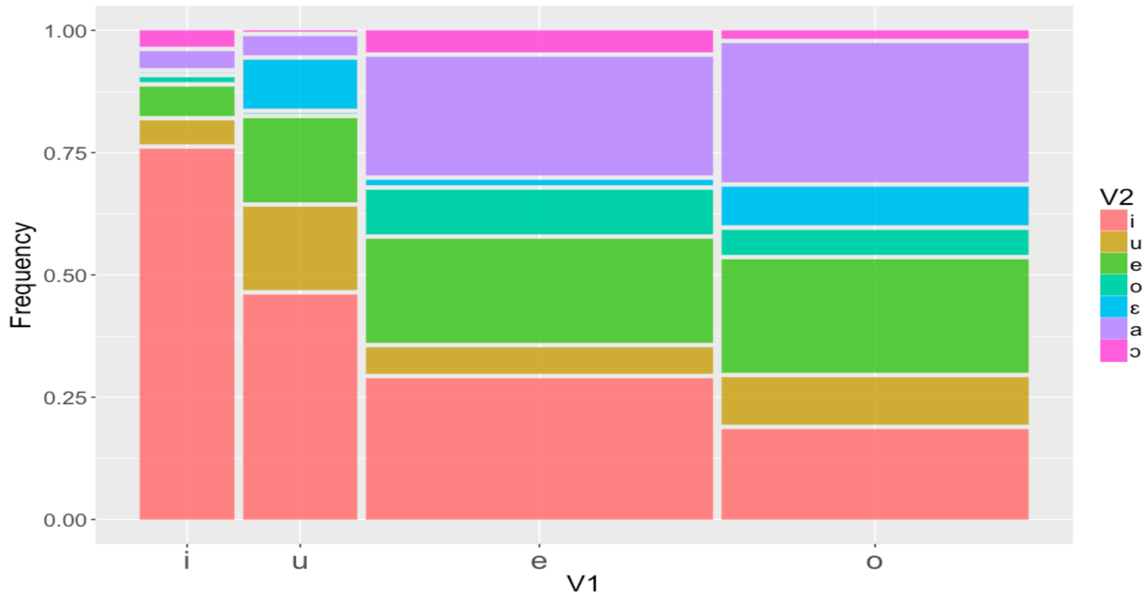


Figure 47. Frequency of V-to-V co-occurrence patterns in Siva's data.

The O/E ratio values show that high vowels co-occur with high vowels, mid-high with mid-high ones, and mid-low with mid-low ones and with the low vowel /a/ for the front subset of V1 vowels. This aspect of the dialect leads to the conclusion that Baiano is not different from GA, since the harmony of BA vowels is related to the a value of [High].

(116)

Table 37. O/E ratio of V-to-V co-occurrence in Silva's data.

| | | | V2 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | i | e | ɛ | a | ɔ | o | u |
| $V_1$ | *Front Vowels* | i | 2.33 | 0.51 | 0.17 | 0.09 | 0.53 | 0 | 1.08 |
| | | e | 1 | 2.36 | 0.25 | 0.39 | 0 | 1.85 | 0.4 |
| | | ɛ | 0.79 | 1 | 1.23 | 1.33 | 1.32 | 0.65 | 0.69 |
| | *Back Vowels* | u | 1.62 | 0.92 | 0.82 | 0.38 | 0 | 0.19 | 1.82 |
| | | o | 1.07 | 1.29 | 1 | 0.26 | 0.22 | 3.06 | 1.47 |
| | | ɔ | 0.63 | 0.45 | 1.35 | 1.6 | 1.77 | 0.82 | 1.22 |

One can also conclude that vowels tend to preserve the same height, which means that Baiano takes into account at least two distinctive phonological features. In other words, we can say that if the dialect were only [+high]-oriented, no distinction would be expected among the non-high vowels. However, the O/E values show that the co-occurrence patterns of high vowels prefer agreement in the height parameter and the vowels require not only the feature [High], but also [ATR]. Thus, this dialect does not seem to be so different from Gaucho, because VH in Baiano is also due to height, although the difference is due to the harmonic features involved in both dialects. In other words, the evidence of [High]&[ATR] agreement comes from co-occurrence patterns such as /eCe/ and /oCo/, which indicate that the agreement must account for these two features, otherwise, in pairs like /e…ɛ/ and /o…ɔ/, the targets would keep the same phonological height, since they are both [–High].

#### 6.3.3.2 C-to-V

Regarding the place of articulation of the previous consonant, there was a significant association between Place C1 and the quality of the target $X^2(15, N = 957) = 100.33$, $p < 1.28 \times 10^{-14}$, V = 0.19. The observed patterns are shown in the next table.

(117)

Table 38. *Absolute values of the co-occurrence patterns between vowels and Place C1 in Silva's data.*

| | | | Labial | Coronal | Palatal | Dorsal | Total |
|---|---|---|---|---|---|---|---|
| $V_1$ | *Front Vowels* | i | 27 | 48 | 2 | 5 | 82 |
| | | e | 44 | 73 | 3 | 7 | 127 |
| | | ɛ | 144 | 161 | 18 | 15 | 338 |
| | *Back Vowels* | u | 32 | 25 | 3 | 24 | 84 |
| | | o | 42 | 36 | 2 | 21 | 101 |
| | | ɔ | 89 | 70 | 12 | 54 | 225 |
| Total | | | 378 | 413 | 40 | 126 | 957 |

(118)

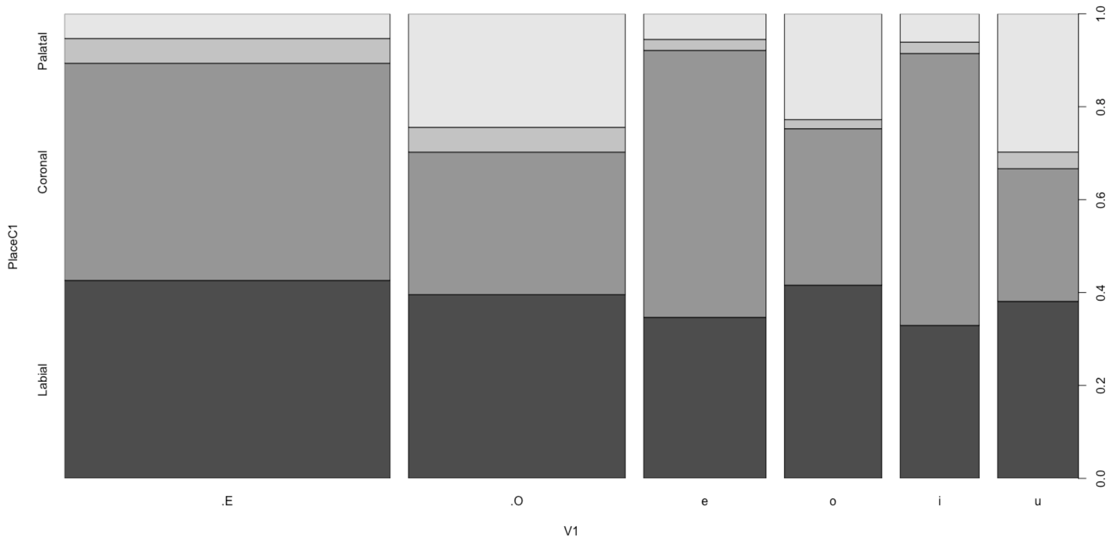


Figure 48. Frequency of co-occurrence of vowels and Place C1 in Silva's data

The observed patterns may reflect the co-occurrence patterns encoded in the lexicon and do not seem to reflect any probabilistic tendency as the result of phonological processes such as VH, or any others. This fact can be seen in the O/E values below, which show a different combination and no specific preference of certain vowel for a certain consonant place.

(119)

Table 39. O/E ratio of co-occurrence patterns between vowels and Place C1 in Silva's data.

| | | | Place C1 | | | |
|---|---|---|---|---|---|---|
| | | | Labial | Coronal | Palatal | Dorsal |
| Types | *Front Vowels* | i | 1.08 | 1.1 | 1.27 | 0.34 |
| | | e | 1 | 0.73 | 1.28 | 1.82 |
| | | ɛ | 0.88 | 1.33 | 0.57 | 0.42 |
| | *Back Vowels* | u | 0.83 | 1.36 | 0.58 | 0.46 |
| | | o | 1.05 | 0.83 | 0.47 | 1.58 |
| | | ɔ | 0.96 | 0.69 | 0.85 | 2.17 |

Although there is a significant association between vowels and Place C1, O/E values do not show any tendency of high vowels combined with dorsals and palatals, as argued in the literature. The front high vowel [i] co-occurs with all front consonants and the interesting fact is that [e] co-occurs with these consonants. The back vowels [o] and [u] seem to have some preference for dorsals, and [o] co-occurs with labials as well. Although these findings also hold true for the Gaucho dialect, the O/E values do not allow any generalizations because the co-occurrence patterns found for Baiano are difficult to interpret.

Another tendency is seen for co-occurrences between Class C1 and V1, in which vowels show some preference for certain consonantal classes. Regarding the class of the previous consonant, there was a significant association between Class C1 and the target vowel $X^2(20, N = 957) = 54.216$, $p < 5.373 \times 10^{-5}$, V = 0.12. The observed patterns are shown in the next table.

(120)

Table 40. Absolute values of co-occurrence patterns between vowels and Class C1 in Silva's data.

| | | | Stop | Fricative | Nasal | Lateral | Rhotic | Total |
|---|---|---|---|---|---|---|---|---|
| Types | *Front Vowels* | i | 32 | 37 | 8 | 0 | 5 | 82 |
| | | e | 68 | 34 | 13 | 6 | 6 | 127 |
| | | ɛ | 158 | 111 | 28 | 21 | 20 | 338 |
| | *Back Vowels* | u | 50 | 14 | 17 | 1 | 2 | 84 |
| | | o | 51 | 20 | 20 | 5 | 5 | 101 |
| | | ɔ | 112 | 63 | 39 | 5 | 6 | 225 |
| Total | | | 471 | 279 | 125 | 38 | 44 | 957 |

(121)

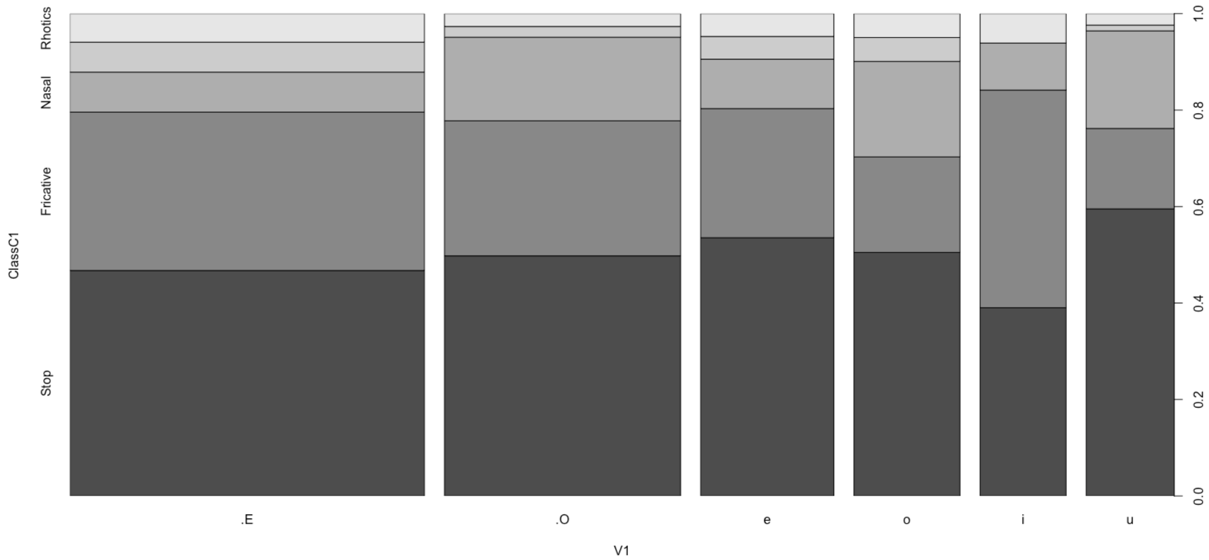


Figure 49. Frequency of co-occurrence of vowels and Class C1 in Silva's data.

It can be seen that fricatives have O/E > 1 only for front vowels, whereas nasals only for the back subset of vowels, which also are more likely to co-occur with stops than with front consonants. The class of rhotics shows some preference for front consonants and for the mid vowel [o]. In addition, these values for Class C1 do not allow satisfactory conclusions, as can be seen below.

(122)

Table 41. O/E ratio of co-occurrence patterns between vowels and Class C1 in Silva's data

| | | | Class C1 | | | | |
|---|---|---|---|---|---|---|---|
| | | | Stop | Fricative | Nasal | Lateral | Rhotic |
| Types | *Front Vowels* | i | 0.79 | 1.54 | 0.75 | 0 | 1.32 |
| | | e | 1.09 | 0.92 | 0.78 | 1.89 | 1.03 |
| | | ɛ | 0.94 | 1.13 | 0.63 | 1.56 | 1.28 |
| | *Back Vowels* | u | 1.21 | 0.57 | 1.55 | 0.3 | 0.52 |
| | | o | 1.03 | 0.68 | 1.52 | 1.25 | 1.08 |
| | | ɔ | 1.01 | 0.96 | 1.33 | 0.56 | 0.58 |

Note: Gray cells represent O/E ratio >1 in both frequencies.

In addition, Cramer's V results confirm that both Place C1 and Class C1 have a very weak effect on the association with the target vowels. This is possibly because the associations are not only affected by some phonological process, but there is a role played by the lexicon in selecting both consonants and vowels. This is not surprising, since VH systems are not expected to be strongly sensitive to the consonant environment of the trigger or the target.

6.3.3.3 V-to-C

Unlike Gaucho findings for Place C2, Baiano did not show a significant association between the place of the following consonant and pre-stressed vowels, hence only Class C2 will be discussed. The observed patterns due to Place C2 are presented in this section. For Place C2, the chi-square test $X^2(15, N = 1218) = 14.27$, $p = 0.505$, whereas for Class C2 the result was significant $X^2(20, N = 1209) = 84.379$, $p = 7.004 \times 10^{-10}$, V = 0.13.

(123)

Table 42. Absolute values of co-occurrence patterns between vowels and Place C2 in Silva's data.

| | | | Place C2 | | | | Total |
|---|---|---|---|---|---|---|---|
| | | | Labial | Coronal | Palatal | Dorsal | |
| V1 | *Front Vowels* | i | 17 | 71 | 2 | 19 | 109 |
| | | e | 42 | 85 | 7 | 17 | 151 |
| | | ɛ | 95 | 247 | 17 | 66 | 425 |
| | *Back Vowels* | u | 29 | 50 | 5 | 10 | 94 |
| | | o | 28 | 78 | 4 | 15 | 125 |
| | | ɔ | 86 | 177 | 9 | 42 | 314 |
| Total | | | 297 | 708 | 44 | 169 | 1218 |

(124)

Table 43. Absolute values of co-occurrence patterns between vowels and Class C2 in Silva's data.C2.

| | | | Stop | Fricative | Nasal | Lateral | Rhotic | Total |
|---|---|---|---|---|---|---|---|---|
| $V_1$ | *Front Vowels* | i | 32 | 54 | 7 | 4 | 12 | 109 |
| | | e | 50 | 65 | 9 | 10 | 17 | 151 |
| | | ɛ | 176 | 112 | 45 | 29 | 63 | 425 |
| | *Back Vowels* | u | 31 | 27 | 9 | 7 | 10 | 84 |
| | | o | 42 | 32 | 12 | 16 | 24 | 126 |
| | | ɔ | 152 | 49 | 41 | 36 | 36 | 314 |
| Total | | | 483 | 339 | 123 | 102 | 162 | 1209 |

(125)

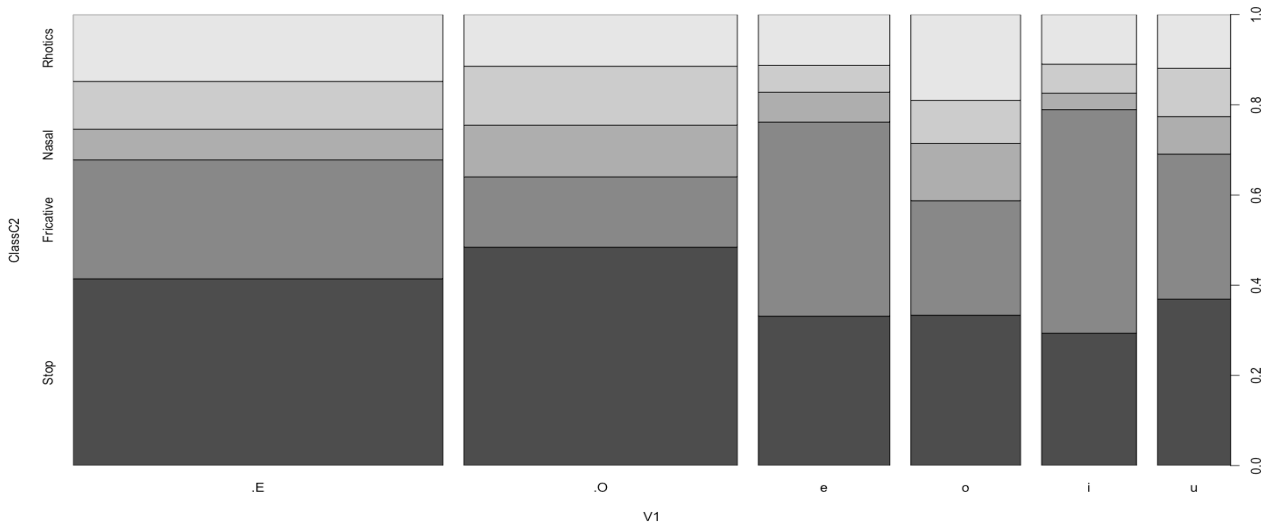


Figure 50. Frequency of co-occurrence between vowels and Class C2 in Silva's data.

For Class C2, O/E values greater than 1 are similar to the values found in Gaucho only for fricatives and nasals, which have preferences for front and back vowels, respectively. None of the other classes show consistency amongst the subset for target vowels. In fact, O/E values show that [i], for instance, is most likely to co-occur only with fricatives, whereas [u], with fricatives and laterals. The results are not consistent and reflect a weak Cramer's V value.

(126)

Table 44. O/E ratio of co-occurrence patterns between vowels and Class C2 in Silva's data.

| | | | Class C2 | | | | |
|---|---|---|---|---|---|---|---|
| | | | Stop | Fricative | Nasal | Lateral | Rhotic |
| Types | *Front Vowels* | i | 0.73 | 1.77 | 0.43 | 0.63 | 0.82 |
| | | e | 0.83 | 1.53 | 0.78 | 0.59 | 0.84 |
| | | ɛ | 1.04 | 0.84 | 0.81 | 1.05 | 1.11 |
| | *Back Vowels* | u | 0.92 | 1.14 | 0.98 | 1.05 | 0.89 |
| | | o | 0.83 | 0.91 | 1.51 | 0.93 | 1.42 |
| | | ɔ | 1.21 | 0.56 | 1.36 | 1.28 | 0.86 |

We cannot conclude that sonority or other phonological properties, together with VH, trigger a low or a high vowel in the pre-stressed position. In fact, what is shown by these values is inconclusive about the role of Class C2. I cannot claim that the consonantal class in intervenient position is responsible for triggering vowel harmonization.

## 6.4 Conclusion

Throughout this chapter I revisited the findings of Bisol and Barbosa da Silva, from the 1980s, about the behavior of pre-stressed vowels in Gaucho and Baiano dialects of BP. As I have previously emphasized, these two dialects are well known for the difference in their subset of vowels in the pre-stressed position. There is a widespread assumption that southern dialects of Brazil have only five vowels [i, e, a, o, u], whereas the northeastern dialects have seven surface vowels [i, e, ɛ, a, ɔ, o, u]. In addition, we mentioned that only mid-high vowels change to high vowels in Gaucho, but the same is not true for Baiano, which also presents mid-low vowels [ɛ] and [ɔ] in the pre-stressed position and [i] and [u] as a result of phonological processes. The above-mentioned authors assert that VH is the phonological process underlying vocalic change, triggering vowel shifts in upward or downward in the vocalic space.

However, Bisol and Barbosa da Silva found in their studies that high vowels also occur in cases in which the trigger is assumed to be a non-high vowel. These cases of "raising" were then called, by Bisol (1981, 2010) and others, "*vowel raising without an apparent motivation*" (literal. *from Portuguese*). Consequently, this raises a question about why a language characterized by VH in a certain domain also allows disharmony patterns in the same phonological context. Many explanations have been offered since Bisol's observations, and the authors claim that this disharmonic behavior is triggered by the consonants surrounding the target vowels. This gives rise to controversy over what we should consider harmonic domain, or even about harmonic targets and triggers. Hence, this chapter was designed to apply different statistical methods and do different data analysis by separating type and token frequency.

The results are summarized in the next table, which shows the main findings for each pattern analyzed in the two dialects. The goal of this procedure is to see beyond the strictly phonetic observations made by Bisol and Barbosa da Silva and to offer a phonological approach to make some generalizations about the behavior of BP pre-stressed vowel system. I will report the main results followed by Cramer's V measure of association for all the analyses presented before.

As can be seen in Table 45, the greatest and strongest Cramer's V values come from the vowel-to-vowel analyses only, which have tested target-trigger independence. All other patterns showed moderate (0.20<0.25) or weak (0.15<0.20) and very weak (<0.15) association. Generally, Cramer's values are considered acceptable from moderate range, and for weak and very weak values it is assumed that there is no association between the factors.

(127)

Table 45. Co-occurrence patterns found in Bisol's and Silva's data with Cramer's V values.

| Phonological Structure | | Dialect | |
|---|---|---|---|
| | | Gaucho | Baiano |
| V-to-V | | [±High] | [High] & [ATR] |
| | Cramer's V | 0.35 | 0.25 |
| Place C1 | | {lab, cor} – $V_{front}$<br>PAL – {e}<br>DOR – $V_{back}$ | LAB, COR, PAL – V{i}<br>PAL, DOR – V {e}<br>DOR – V {o,ɔ} |
| | Cramer's V | 0.24 | 0.19 |
| Place C2 | | $V_{back}$ – LAB<br>$V_{front}$ – DOR<br>$V_{high}$ – PAL<br>{e, o} – COR | non-significant |
| | Cramer's V | 0.10 | – |
| Class C1 | | {stop} – $V_{back}$<br>{fric, nas, lat, rho} – $V_{front}$ | {lateral}– V {e, ɛ}<br>{rho} – $V_{front}$<br>{stop, nasal} – $V_{back}$ |
| | Cramer's V | 0.22 | 0.12 |
| Class C2 | | $V_{front}$ – {stop, fric}<br>$V_{back}$ – {nas, lat}<br>V{e,o} – {rho} | inconclusive |
| | Cramer's V | 0.13 | 0.13 |

The vowel-to-vowel relationship shows strong dependence on one another in both dialects, suggesting that pre-stressed vowels may be predicted by the following vowel. The analyses showed that [i] can be predicted by a phonological /i/ as V2 for both GA and BA, but the same is not valid for [u], which is likely to occur with non-high vowels as V2 and with another [u] in GA or with all back vowels in BA. The surfaced [u] triggered only by /u/ has been explained by the role of surrounding consonants by many authors since Bisol (1981), and as we have seen in this chapter, this is valid only for BA, since O/E values for pre-stressed [u] are higher than 1 with stressed /ɔ, o, u/. These mentioned aspects as well as the analyses conducted through the text and the results of our experiment have led us to conclude that both dialects have the same kind of VH, as shown by some arguments based on the datasets of Bisol and Barbosa da Silva.

Firstly, high and non-high pre-stressed vowels are not similar or equally distributed in the Bisol dataset, in which [i] and [u] are equal to 18.4% against 81.6% for [e] and [o]. A similar trend occurs in BA, for which the dataset has 16.3% of [i] and [u] and 83.7% of [e, ɛ, o, ɔ]. Obviously, an argument based only on frequency distribution is not strong enough to confirm any phenomenon in any language; however, this confirms that non-high vowels probably have a strong role in comparison to the high vowels. Figures 51 and 52 illustrate the distribution of each pre-stressed vowel in GA and BA.

(128)

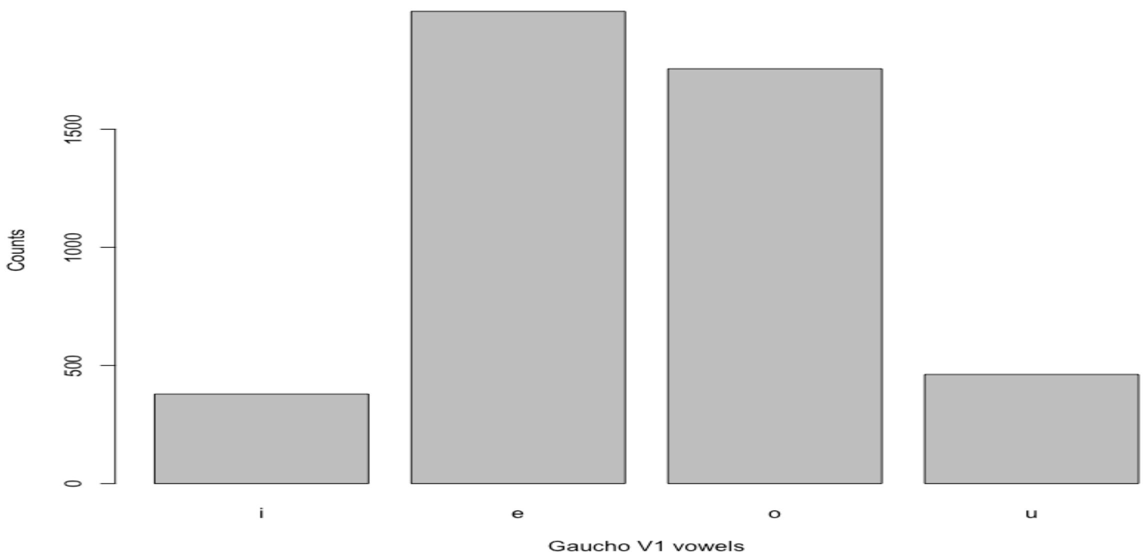


Figure 51. Counts of the pre-stressed vowels in Bisol's data.

(129)

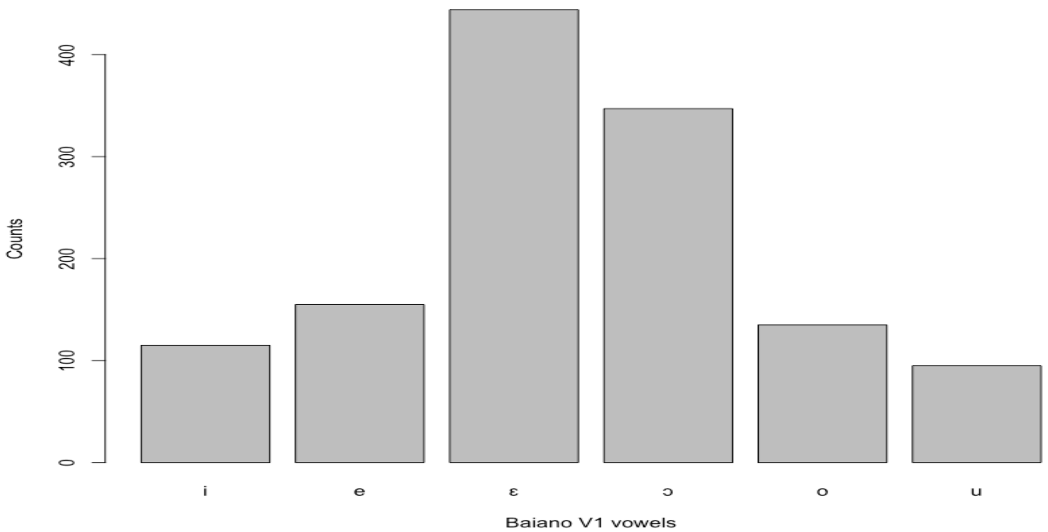


Figure 52. Counts of the pre-stressed vowels in Silva's data.

Pre-stressed vowel frequencies may be explained by backness and frontness of the vowels, with front vowels being the most frequent position. Although this aspect may be language-specific, it also reflects that high vowel frequency is not biased by the VH process, which is expected from a height-harmonic language. In addition, as far as height is concerned, and consistently in both dialects, the high vowel [i] is the most frequent vowel whereas the back counterpart [u] is the least frequent.

Assuming that only V-to-V patterns are strongly associated, we can assume that pre-stressed vowels are associated to the quality of the following vowel. Then, considering the reported results, we can conclude that GA VH in Bisol's dataset is characterized by [+High] harmonization but also by [–High], since mid pre-stressed vowels are likely to co-occur with [–High] vowels. Bisol claims that /e/ and /o/ change to [i] and [u]; however, [e] and [o] also participate in harmonization, since they keep the same value for the [High] feature. To sum up, if high vowels appear to be triggered by high vowels in V2, the same is valid for non-high vowels that remain non-high when triggered by non-high vowels. We could say that [+High] harmonization in GA, as claimed by Bisol (1981, 1989) partially accounts for it, because this interpretation is strict to the vowel shift, based on the assumption that mid vowels /e/ and /o/ are the phonological representations, and most of the cases influenced by orthography. Although I will not discuss the underlying representations per se, it is worth discussing them, since there are several words that can be assumed to have underlyingly high vowels because these words do not show variation in their forms, which can be seen in many words of Bisol's dataset, such as *[si]guro* (safe), *[si]nhor* (mister), *[ki]rido* (dear).

The analyses of Barbosa da Silva's dataset reveal that the vowel system of BA shows the same behavior as that of GA, the difference lying only in the subset of vowels surfaced in pre-stress positions. While GA has only high and mid-high vowels, the mid-low vowels of BA are triggered by low vowels in V2. Additionally, the system of BA shows that VH is triggered by [ATR], as [u, o] are surfaced triggered by the [+ATR] subset [i, e, o, u]. This is seen especially for the back subset, but the front counterparts also have a similar behavior. Considering the experimental results presented in the first chapters of this dissertation, we could hypothesize that GA has the same tendency, although Bisol had not considered mid-low vowels in pre-stress position in GA. Our results do not support the claim that BA and GA have different behaviors for pre-stressed vowels as claimed by many authors; on the contrary, the analyses of the datasets used by Bisol and Barbosa da Silva and the experimental results conducted in this work suggest that they present a similar tendency to lower vowels.

In addition to the similar behavior of the harmonic systems of BA and GA, and the asymmetries found in the behavior of /i/ and /u/ as triggers, we showed that the investigation about the role of consonants that would explain the asymmetries and also the disharmonic patterns do not support the claim that consonants influence vowel raising or lowering. The main arguments that support this claim may be summarized as follows:

(1) Place C1 results show universal trends widely reported in the literature;

(2) Significance of results on chi-square tests was inconsistent for both dialects for Place C2;

(3) Non-acceptable Cramer's V values for association between pre-stressed vowels and Class C2 for GA and BA; and

(4) Multinomial Logistic Regression[20] confirms significant results only for V-to-V associations, whereas V-to-C and C-to-V relations are not significant for all levels of the factors.

Regarding Place C1, the analyses showed that labial, coronal and palatal consonants are likely to co-occur with front vowels, and back consonants are likely to co-occur with back vowels. This result confirms a universal phonological trend found by MacNeilage and Davis (1990, 2000), and MacNeilage (1998), who claim that the prevalence of intrassilabic (or CV)

[20] The complete report of this test is given in Appendix D.

regularities in early and adult speech provides evidence of speech evolution. The fact that some consonants are likely to co-occur with specific vowels represents the core of what these authors referred to as *Frame-then-Content Theory*. Considering that our specific goal is to investigate target vowels of a harmonic process interacting with their previous consonant is interesting because it reveals that consonants either do not have a role or, if they do, it is secondary. With regard to the interaction between place of articulation and height of the target vowel, specifically, palatals show more preference for [e] than for [i], which does not support Bisol's claim that the consonantal feature [+High] of palatals and dorsals would force the vowel to change to [i] or [u]. The same occurs for dorsal consonants whose O/E > 1 values correspond to combinations with the whole back subset of vowels in GA and with the [–High, +Back] vowels [o] and [ɔ] in BA. Thus, the fact that a C is [+High] does not imply raising of pre-stressed /e/ or /o/ to their [+High] counterparts.

If Place C1 does not explain vowel raising, Place C2 plays an even smaller role. There is a very weak association between the target vowel and the following consonant; furthermore, the place of articulation of the intervenient consonant between target and trigger vowel does not provide information about its influence on VH. The results for GA have a weak association, and they are non-significant for BA. This fact reveals a problem of the analysis presented in this work, which is chi-square sensitiveness to sample size, which is a problem for analyses because it induces a Type I error, which is an incorrect rejection of a true null hypothesis. In such a case, we may incorrectly state that target vowels and Place C2 are associated, when in fact they are not. This may indeed be the case, since the results for Place C2 are significant only for GA, whose sample size is 3.66 times greater than that of BA. In order to examine this assumption, I carried out a Multinomial Logistic Regression for all the analyses made in this chapter. The test returned that most associations are non-significant, especially for combinations of vowels with place and classes. A detailed view of the Multinomial Logistic Regression is shown in Appendix D.

Chi-square sensitiveness to sample size is also seen on Cramer's V values, which are greater for GA, as is the case of Class C1, whose association measurement has moderate Cramer's V, whereas BA returns weak values for this measurement. As the GA dataset is three times larger than the BA dataset, this difference on Cramer's V is expected. The same seems to be valid for Class C2, whose association with the target vowels is weak and inconclusive for BA, whose preferred patterns are phonologically discrepant. Although the characteristic of this test does not invalidate all the analyses carried out, it restricts our interpretations.

The tests were important because they allowed us to interpret all the possibilities of co-occurrence between vowels and consonants. Moreover, our goal was to investigate how Bisol's and Barbosa da Silva's datasets show VH according to different analyses of the data. In these analyses, we distinguished type and token frequency in order to determine how pre-stressed vowels may be predicted by other factors in these two dialects. Also, the tests were important to discuss the claims made in the literature because these two major studies were published in the 1980s, and their importance has reflected and has influenced all research on BP VH conducted so far.

The next chapter of this dissertation is dedicated to the discussion of the implications of the findings of my work to phonological interpretations. I will discuss the experimental results, the analyses carried out on these corpora, and other phonological assumptions about BP VH.

# 7 THE [ATR] HARMONY IN BRAZILIAN PORTUGUESE

## 7.1 Introduction

Throughout this work I have addressed the phenomenon of VH in BP by analyzing the production of speakers from different regions in the states of Bahia and Rio Grande do Sul. The production experiment described in Chapter 3 considered vocalic and consonantal contexts, and its goal was to determine the extent of the VH phenomenon in BP, in addition to addressing the issues posed by the literature about the role of the consonant.

My proposal is based on the results of the experiment and it concerns VH itself. I argue that **BP vowel harmony is based on the value of the feature [ATR]**, and that it is not [High]-oriented, as has been claimed. The results of the experiment do support this analysis and suggest that BP speakers do not tend to raise vowels regardless of dialect, as it was demonstrated through the chapters. Additionally, the analyses of the corpus used by Bisol (1981) and the one used by Barbosa da Silva (1989) showed that the [+High] agreement is presented in their data, however other patterns of high pre-stressed vowels followed by non-high vowel arise as well. The fact that [+High] harmony occurs in such corpora demands that we discuss in depth our reasons for conducting a reanalysis of this phenomenon by proposing another approach to it. This fact and other arguments will be also discussed in this chapter.

This chapter goes beyond the recapitulation of the results of the experiment, the measurement proposed and reanalysis of the corpora. I support the proposal bringing other recent studies that also report low-vowel harmonization, which fall under the approach of an [ATR]-based harmony system. New arguments are introduced in favor of such harmonization based on the discussion of linguistic facts that illustrate the rejection of [+High] harmony by BP speakers. For this purpose, the discussion considers aspects addressed by the literature on VH in the world’s languages, the choice of the underlying forms, the interaction between phonology–morphology in BP, secondary stress and consonantal blocking. Also, I address some sociolinguistic findings that support the claim that BP avoids [+High] harmony.

## 7.2 The BP [ATR] Vowel Harmony

### 7.2.1 Phonological Properties of BP [ATR] Harmony

For the purposes of this work, BP was assumed to have an active [ATR] harmony system which non-contrastive mid vowels undergo, leading a lowering harmonization with the immediately [–ATR] vowel, generally stressed. BP [ATR] harmony description is given in (128).

(130) Structural Description:

A vowel V within a prosodic word with a specification of [–ATR] spreads leftwards its feature to an adjacent vowel specified for [–High, +ATR].

Some vowel behaviors can be captured by this definition. Firstly, [+ATR] vowels do not change if followed by [+ATR], since the harmonic feature is [–ATR]. In fact, the $V_{[+ATR]}$-to-$V_{[+ATR]}$ are harmonic forms that do not require structural changes. The targets have to be unstressed, but the triggers are not always stressed and the trigger vowel can be a pre-stressed vowel as well. Additionally, BP is an [ATR] system characterized as dominant-recessive which presents [–ATR] spreading from the affixes to the root and from root to prefixes.

### 7.2.2 The Target-Trigger Vowels and the Harmonizing Feature

The **target vowels** of the VH process are the mid-high vowels /e, o/ and the **trigger vowels** are the low segments of the inventory /ɛ, a, ɔ/. They can be defined in terms of features as in (131):

(131)

Table 46. Subset of target and trigger vowels according to their feature specification

| | | Features |
|---|---|---|
| Targets | / e, o / | [–High, +ATR] |
| Triggers | /ɛ, a, ɔ/ | [–ATR] |

The target vowels are always pre-stressed but the trigger vowels can be stressed or pre-stressed. As the subset of pre-stressed vowels is /i, e, a, o, u/, the targets /e, o/ need to be specified for both [High] and [ATR]. The reason for this is that defining them only as [+ATR] would not be sufficient because it would include /i, u/, and defining them as [–High] without specification of [ATR] would include the vowel /a/. In this sense, BP VH changes the value of [+ATR] to [–ATR] for the pre-stressed [–High, +ATR]. Therefore, the **harmonizing feature of BP VH is [–ATR]**, which is spread to the nearest upper-mid vowel, and can be posed as the reason for not considering BP as harmony for the feature [low].[21] For our purpose, the reason concerns the fact that [low] harmony is not frequent cross-linguistically, and there is much controversy about the choice of the feature and its definition.

It could be posed that this type of harmony is not consistent with the traditional notion of markedness, in which marked features are spread to segments that bear the non-marked feature value. This seems to be the case of [-ATR] spreading in BP that I am proposing here. Although the discussion or markedness is not central to this work, it is worthy to mention that there are many well-attested languages whose dominant feature is [-ATR] in VH systems, as for instance Akan (Stweart, 1967), Yorubá (Archangeli & Pulleyblank 1989), progressive [-ATR] harmony in Komo (Otero, 2015). A deeply discussion about both types of [ATR] dominance can be found in Casali (2014), who asserts that the dominance of one feature value or another is correlated with the distinctions of [ATR] among the high vowels of the inventory. According to this author, if there is a distinction [ATR] among the high vowels, such as the case of /i, u/ versus /ʊ, ɪ/, then [+ATR] dominance is expected. Otherwise, if such a distinction is not present in the inventory, there is [−ATR] dominance.

[ATR] harmony is not triggered by post-stressed vowels, which can be [–ATR], since the post-stressed vowels in light syllables are the vowels [ɪ, ɐ, ʊ]. These vowels do not belong to the harmonic domain. Harmonization can start from a stressed or pre-stressed vowel, but never from a post-stressed one[22]. The examples in (132) show this behavior.

[21] For details of this discussion, see Clements (1991), Goad (1993), Archangeli and Pulleyblank (1994), Beckman (1995), van der Hulst and van de Weijer (1995), Pulleyblank (1996), Rose and Walker (2011).

[22] The role of stressed syllables in harmony systems was discussed by Flemming (2004).

(132) [–ATR] Spreading:

a) Stressed Trigger Vowels:

| | | | |
|---|---|---|---|
| i. | i. /lotada/ | lɔ'**ta**dɐ | crowded |
| ii. | ii. /senario/ | sɛ'**na**ɾjʊ | scene |
| iii. | iii. /legado/ | lɛ'**ga**dʊ | legacy |
| iv. | iv. /remɛdio/ | ɦɛ'**mɛ**dʒjʊ | medicine |

b) Pre-stressed Trigger Vowels:

| | | | |
|---|---|---|---|
| i. | i. /peʒoɾa'tʃivʊ/ | pɛʒ**ɔ**ɾa'tʃivʊ | pejorative |
| ii. | ii. /pekaminozo/ | pɛ**ka**mi'nozʊ | sinful |
| iii. | iii. /veɾsatilidade/ | vɛɾ**sa**tʃili'dadʒɪ | versatility |
| iv. | iv. /volatilidade/ | vɔ**la**tʃili'dadʒɪ | volatility |

Examples such as (132b-i) could raise a question about the stress status of the vowel, since the syllable [ʒ**ɔ**] in [pɛʒɔɾa'tʃivʊ] could bear the secondary stress. It could be hypothesized that only stressed vowels, primary or secondary-stressed[23], would be the triggers, but this might not be true, as can be seen in examples (132b–ii–iii). There is a tendency of secondary stress /e, o/ to be lowered to [ɛ, ɔ],[24] but this motivation is not triggered by VH.

### 7.2.3 Directionality, Locality and Recursivity

The [–ATR] harmonization is always **regressive**[25], with the direction of harmonization being from the trigger on the right to the left target vowel. The spreading involves only **strictly adjacent vowels** and harmonization can be **recursive**. The findings in Barbosa da Silva's dataset presented in Chapter 6 are consistent with this one, and are

[23] A further investigation on the role of secondary stress in lowering vowels is needed, since the syllables that bear the secondary stress can vary within the PW.
[24] In section 7.5.5, see the examples (148a, b, d) and the discussion about this topic.
[25] Santana (2015, p.127) reports cases of [-ATR] vowels [ɛ, ɔ] in post-stressed syllables, in words as *célebre* 'notorious', *diâmetro* 'diameter' and *córrego* 'stream'. Although the author does not consider these cases as vowel assimilation from the stressed [-ATR] vowel, it seems that these words can be cases of progressive [-ATR] VH.

defended by Ní Chiosáin and Padgett (2001), and Gafos (1999), who claim that harmony does not skip intervening segments. This differs from Bohn (2014), and Abaurre and Sandalo (2012), who argue that [ATR] harmony does not require strict adjacency. In our view, if the vowel [ɛ] or [ɔ] appears in a long-distance relation with the trigger, the process involved in such change is secondary stress assignment[26]. The examples in (133) show vowel lowering without a harmony trigger in the following syllables:

(133) Vowel Lowering in Secondary-Stressed Syllables

| | | | | |
|---|---|---|---|---|
| a. | ˌm**e**todoloˈʒiɐ | ~ | ˌm**ɛ**todoloˈʒiɐ | methodology |
| b. | aˌ**e**ɾoˈpoɾtʊ | ~ | aˌ**ɛ**ɾo'p**o**ɾtʊ | airport.SING |

The example (133b) is a tricky one because VH is dependent on the prosodic parsing, that is: one can have the forms $[\text{aeɾo}]_{Pw}[\text{poɾto}]_{Pw}$ parsed as two PWs or $[\text{aeɾopoɾto}]_{Pw}$ parsed as a single prosodic unit.

(134) Possible outputs for *'aeroporto'*

a) /aeɾo-poɾto/ airport.SING

i. aˌ**e**ɾo'p**o**ɾtʊ

ii. aˌ**ɛ**ɾo'p**o**ɾtʊ

These two possibilities of outputs for the singular form of the word *aeroporto* depend on what one considers the underlying vowel of the stem *aero-*. We have three possibilities of analysis: in the first one, the UF for *aero-* is /aeɾo/ as in the examples in (134a). In the example (134a–i), the target vowels /e, o/ do not have any [–ATR] vowel on their right side, therefore the output is [aˌ**e**ɾo'p**o**ɾtʊ]. In (134a–ii), we can have two interpretations: 1) the vowel [**ɛ**] is produced in [aˌ**ɛ**ɾo'p**o**ɾtʊ] because the syllable coincides with the secondary stress, or 2) the UF of *aero-* is /a**ɛ**ɾo/, then the output is faithful to the UF, with no need to postulate a phonological process such as lowering. To choose the latter view, it is necessary to

[26] The low vowel production in secondary-stressed syllables might be an epiphenomenon of the higher *f0* in those syllables. As *f0* covaries with F1, the vowels will tend to have higher F1 as well, then the vowel is lowered. The *f0* is reported as an important acoustic correlate of stress. For the discussion on secondary stress see (Adisasmito-Smith & Cohn 1996, for Indonesian; Arantes 2010, for Brazilian Portuguese; Plag, Kunter &Schramm 2011, for North American English, among others).

admit that *aero-* is an independent PW, with its own primary stress, which falls exactly on the vowel /ɛ/. However, before concluding in favor of one or another analysis, it is necessary to consider the plural form of the word *aeroporto,* whose primary stress is the phonological /ɔ/, categorically motivated by metaphony[27]. In this form, an [–ATR] vowel can trigger harmony.

(135) Vowel Harmony:

| /aeɾopɔɾtos/ | | | | | airports.PL |
|---|---|---|---|---|---|
| | i. | i. ae**ɾo**'pɔɾtʊs | → | non-harmonic | |
| | ii. | ii. aeɾ**ɔ**'pɔɾtʊs | → | not possible | |
| | iii. | iii. a**ɛ**ɾ**ɔ**'pɔɾtʊs | → | harmonic | |
| | iv. | iv. a**ɛ**ɾo'pɔɾtʊs | → | not possible[28] | |

In (135a–i), a non-harmonic form can be produced, like in the singular form *aeroporto.* In the example (135a–ii) the [–ATR] spreading cannot reach one target only (the nearest one from the trigger vowel /ɔ/), which would produce an unacceptable form. However, in the form [aɛɾɔ'pɔɾtʊs] in (135a–iii), the word is fully harmonized, that is [–ATR] was spread to all targets that were found leftward. In (1325–iv), the intervening [+ATR] vowel is not allowed between two [–ATR] vowels, indicating that harmony has to be applied to all targets as in (135a–iii). This raises an issue about the structure of the PWs involved in VH, which is discussed in the next section.

### 7.2.4 Domain

The **PW is the domain of VH** as in majority of the world's languages, as discussed in Chapter 2. A language whose vowel harmonization relies within a phrase greater than a PW is rare. Tonelli (2014) presents thirteen mainly phonological processes described in the literature for a PW identification in BP: (i) vowel harmony, (ii) vowel neutralization, (iii) diphthongization, (iv) vowel *liaison* (which is known in Brazilian phonological literature as external sandhi), (v) nasal assimilation, (vi) palatalization, (vii) fricative voicing, (viii) haplology, (ix) tone assignment, (x) phonological focus, (xi) emphasis, (xii) PW initial stress, and (xiii) secondary stress.

Additionally, in BP there is controversy about the status of the affixes, which can be adjoined to a base forming a single PW or constitute a PW itself. Schwindt (2000) classifies

[27] See Miranda (2000) about nominal metaphony in Portuguese.
[28] The output [aɛɾo'pɔɾtʊs] considering that UF /aero/ and the [ɛ] is resulted by VH. However, if the analyst considers that the UF is /aɛro/, then this form is possible and it occurs variably with [aɛɾɔ'pɔɾtʊs].

the prefixes into two categories: *authentic prefixes* or *compositional prefixes*.[29] The former are unstressed syllables that adjoin to a base forming a single PW and the latter constitute a PW[30] by themselves. For the author, *compositional prefixes* can be stressed and can be a syntactic word themselves, which he calls "free-form", whereas the authentic prefixes cannot be stressed and are always attached to a base. According to the author, VH does not reach compositional prefixes, which bear stress, as the prefix *hiper-* in *hip[e]rglicemia ~ *hip[i]rglicemia.* However, *authentic prefixes* with target vowels also do not undergo [+High] VH, suggesting that VH does not support the difference between authentic and compositional prefixes. This is noticed by the author as well, who admits that this is an unsolved issue for his analysis.[31]

The occurrence of VH depends on prosodic parsing, that is, VH spreading depends on how the prosodic words are parsed whether in one PW or in two PWs. An example that *aero-* is parsed as a PW itself comes from the word *aeronaval* 'naval air' whose phonetic form is [aɛɾuna'vaw]. In such case, the evidence that /aero/ forms a single PW is given by changing /o/ to [u] in [a'ɛɾ**u**]. Raising pos-stressed vowels in light syllables is categorical in the language and, in this example, [a'ɛɾ**u**] would have its own primary stress which triggers post-stress raising. However, this case and others may be examples of lexicalized items since there are many other words in which raising the vowel /o/ would produce ungrammatical forms, as in the examples below:

(136) The prosodic status of /aero/

| | | | | |
|---|---|---|---|---|
| a. | aeronáutica | [aɛɾ**o**ˈnawtʃicɐ]$_{PW}$ | *[aˈɛɾ**u**]$_{PW}$[ˈnawtʃicɐ]$_{PW}$ | aeronautics |
| b. | aeronave | [aɛɾ**o**ˈnavɪ]$_{PW}$ | *[aˈɛɾ**u**]$_{PW}$[ˈnavɪ]$_{PW}$ | aircraft |
| c. | aeromoça | [aɛɾ**o**ˈmosɐ]$_{PW}$ | *[aˈɛɾ**u**]$_{PW}$[ˈmosɐ]$_{PW}$ | flight attendant |

Forming a single prosodic word, the target vowel /o/ of /aero/ can undergo [-ATR] VH. The fact that the raising of /o/ to [u] is blocked because it results in ungrammatical forms, but VH is not, is evidence that /aero/ is parsed as a single PW unit:

[29] From the original: prefixos legítimos e prefixos composicionais, respectively.
[30] This view is also assumed by Lee 1997 for BP, Vigário 2003, for European Portuguese, Peperkamp 1997, for Italian.
[31] In my point of view, [+High] harmony was root-dependent and reached targets exclusively within the root. This is discussed in Section 7.5.1, where I claim that this sort of VH is not active in BP anymore and many of the words claimed to be harmonic outputs are nowadays lexicalized items.

(137)

a. aeronáutica [aɛɾ**o**ˈnawtʃicɐ] ~ [aˈ**ɛɾɔ**ˈn**a**wtʃicɐ] aeronautics

e. aeronave [aɛɾ**o**ˈnavɪ] ~ [a**ɛɾɔ**ˈn**a**vɪ] aircraft

On the other hand, [–ATR] VH can reach targets within the root or within prefixes, regardless of the status of the prefix. In the examples below, I discuss the relationship between PW and prefix.

(138) PW versus prefix status

| a. | b. | c. |
| --- | --- | --- |
| [aero]$_{PW}$[p**ɔ**ɾtʊs]$_{PW}$ | *[ae**rɔ**]$_{PW}$[p**ɔ**ɾtʊs]$_{PW}$ | [a**ɛ**ɾ**ɔ**p**ɔ**ɾtʊs]$_{PW}$ |

In (133a) the prefix can be parsed as a PW, then harmony cannot spread to the targets. On the other hand, (138b) is a partially harmonized output and this form is not possible in the language, whereas (138c) is perfectly acceptable. If we contrast two possibilities of PWs, we might conclude that the status of the stem when adjoined to a base does not give substantial arguments in favor of one proposal or another, since there are still two possibilities of outputs: a non-harmonic form [aerop**ɔ**ɾtʊs] (as in 138a) or a fully harmonic form [a**ɛ**ɾ**ɔ**p**ɔ**ɾtʊs] as in (138c).

(139) Partial Harmonic forms are not allowed

*a) Strict-Local*

| i. | ii. |
|---|---|
| *↶ | *↶ |
| *[a**erɔ**]PW[p**ɔ**ɾtʊs]PW | *[aer**ɔ**p**ɔ**ɾtʊs]PW |

*b) Non-Local:*

| i. | ii. |
|---|---|
| *[a**ɛ**ɾo]PW[p**ɔ**ɾtʊs]PW | *[a**ɛ**ɾop**ɔ**ɾtʊs]PW |

As we can see in the examples (139a–b), non-local harmony is avoided, regardless of what is considered the underlying vowel in *aero-*, whether an /e/ or /ɛ/**.** An intervenient [+ATR] vowel between two [–ATR] is not allowed, a harmonic form being produced, [a**ɛ**r**ɔ**p**ɔ**ɾtʊs]. Although we consider that there might be dialect differences on the acceptability of these forms, [–ATR] harmonization is largely accepted with authentic or compositional prefixes. Also, harmonization can spread cyclically from a suffix to a prefix.

(140) From Suffixes to Root:

| | | | |
|---|---|---|---|
| a. | √amoɾ-ɔza | am**ɔ**ɾ'**ɔ**zɐ | lovely |
| b. | √kok-ada | k**ɔ**'kadɐ | coconut candy |
| c. | √ʒel-ada | ʒ**ɛ**'l**a**dɐ | alcoholism |

(141) From Root to Prefixes:

| | | | |
|---|---|---|---|
| d. | re-√faz-eɾ | ɦ**ɛ**f**a**'zeɾ | to redo.INF |
| e. | ipeɾ-√meɾk-ado | ip**ɛ**ɾm**ɛ**ɾ'k**a**dʊ | hypermarket |
| f. | re-√kareg-ado | ɦ**ɛ**kaɦɛ'gadʊ | reloaded.PCTP |

(142) Within the Root:

| | | | |
|---|---|---|---|
| g. | √bonɛ-ziɲo | b**ɔ**n**ɛ**'ziɲʊ | little hat.DIM |
| h. | √elɛtɾ-iko | **ɛ**'l**ɛ**tɾikʊ | electric |
| i. | √kolɛt-a | k**ɔ**'l**ɛt**ɐ | gathering |

Specifically with regard to the role of prefixes, it might be concluded that [–ATR] VH can spread to prefixes, indicating therefore that they form of a single PW with the base. If VH is a test to determine PW boundaries, [–ATR] VH seems to support that possibly all prefixes are "authentic" in Schwindt's terminology. Naturally, we must take into account that some harmonic forms might be dialect-specific, and this issue needs further investigation and discussion. The goal here is to explore the VH domain by discussing its occurrence within the PW.

## 7.3 Consonantal Transparency

In the experimental results, I found that intervenient stop consonants block [ATR] harmony in GA, but not in BA. Although not conclusive, such results seem to suggest a dialect-specific constraint on stops that needs further investigation. Kenstowicz and Sandalo (2016) also report the same effect of stops in their study, which compares stop and sonorants as intervenient consonants.

## 7.4 More Experimental Evidence on [ATR] Assimilation

### 7.4.1 Kenstowicz and Sandalo (2016)

Kenstowicz and Sandalo (2016) investigate vowel reduction (henceforth, VR) and VH in four varieties of BP. The study had five participants: three female speakers, with one from Rio Grande do Sul (GA dialect, southern), one from Campinas (southeastern) and another one from Minas Gerais (southeastern), and two males speakers, with one from Minas Gerais and another from Recife (northeastern). The goal of the study was to investigate both VR and VH in BP to determine the acoustic characteristics of each phenomenon. For this purpose, they worked with two datasets with real words from the language. One dataset was composed of 23 words with antepenultimate stress and 23 with penultimate stress[32] that were embedded within a carrier sentence, while the other was composed of 170 words with a penultimate stress pattern only and CVCVCV phonotactics. This set was used to investigate the relationship between pre-stressed and stressed vowels.

Regarding VH, the authors concluded that there is a right-to-left height harmonization from the stressed vowels to the pre-stressed ones and confirmed that mid-low vowels act as triggers initiating the height vowel agreement with seven pre-stressed vowels. However, they

[32] This experiment is similar to the one that was carried out in this work. The difference, however, is that the experiment in this dissertation uses nonce words, instead of real words.

claimed that this sort of harmonization is an “extension of the height harmony noted by Bisol” (K&S, 2016, p. 4), finding significant effect of high, mid-high, mid-low and the low vowels on F1 of the pre-stressed targets.

They tested the normalized F1 of the mid vowels /e/ and /o/ as a function of the F1 of the stressed vowels. Instead of testing each vowel as a level of the factor as I did in this work, the predictor variable height of the stressed vowels was analyzed into four levels, which are the groups of high vowels (/i, u/), close vowels (/e, o/), open vowels (/ɛ,ɔ/) and the low vowel (/a/). This division is problematic because it creates an inter-group unbalance of the data as the level which are formed by pairs of vowels will have in principle the double of the data compared to the level "low vowel" height. The authors assert that "*there is a significant difference in the height of the pretonic vowel as the tonic is changed from high to close and close to open. The change from open to low is not significant*" (K&S, 2016, p. 10).

The conclusion of the authors indicates that the low vowel is not a trigger of harmonization, which is confirmed in a follow up study made by Abaurre & Sandalo (2017), who point out that "*the results of the tests suggest a regressive effect of height harmony between a stressed and a pre-stressed vowel, except for the stressed low vowel /a/* [my translation]" (Abaurre & Sandalo, 2017, p. 490). This conclusion is an incorrect interpretation of the statistical results reported in K&S model number 13. In fact, the result is that the effect of the open vowels /ɛ, ɔ/ is not significantly different from the low vowel /a/ (p=0.1578) (K&S, p.10). The correct interpretation would be that the mid-low vowels and the low vowel have the same effect on the target vowels of the VH process, that is, mid-low vowels are not different from the low vowel /a/ in acting as triggers of regressive assimilation. This is totally different from considering that /a/ does not trigger VH. Although they do not conclude it in such way, their results confirm what I found on the production experiment conducted in this research, where /ɛ, a, ɔ/ form a single group of triggers: a [-ATR] subset of trigger vowels.

K&S also conclude that the target vowels height can be "*separated into open and close variants that mimic the location of open and close tonic vowels [...] This confirms experimentally the claims of Abaurre and Sandalo (2009) and Freitas (2010) that the height harmony induced by tonic high vowels documented by Bisol (1989) also occurs with the tonic mid vowels*" (K&S, 2016, p. 13-14). Such conclusion supports what I have found for BA and GA dialects of BP and, therefore, the proposal of an [ATR] harmony. The difference of this work form that of K&S is the fact that they found harmonization to be triggered by high vowels. However, inspecting their sets of words used for data collection, one could see that there are many lexicalized words in which the claimed underlying pre-stressed vowels are the orthographic "e" and "o", although they often produced as the high vowels [i] and [u]. The set of words with a pre-stressed /e/ followed by high vowels is a count of 10, where six (60%) of them cannot be considered good candidates to test VH, once the pre-stressed /e/ is produced as [i]. These are the cases of the words "*pepino*", "*peruca*", "*ferido*", "*fedida*", "*perigo*" and "*ferida*". The set of words for the vowel /o/ followed by high vowels consisted of eight words, in which five of them (63%) are part of the group which I argue that is not reliable to test VH. The words are "*cozida*", "*bonita*", "*fodida*", "*coruja*" and "*corucha*". Probably, the results of height harmonization were biased by production of these words which ended up with 60% of the context of high vowels in a stressed position following the targets.

In addition to this problematic methodological issue, the sets used in the experiment by the authors had not controlled the morphological structure, i.e., they had monomorphemic and bimorphemic words. Type of suffix, for instance, can trigger or block harmony. The vowel /i/ from diminutive in BP does not trigger height harmony, thus, the word "fofinha", used by K&S, is expected to be produced as [f**o**fi]inha but never *[f**u**fi]nha, otherwise it would create an unacceptable form. I discuss the issue of considering morphological boundaries in §7.5.7. To avoid using lexicalized items or being biased by word-internal morphology or even by orthography I conducted an experiment with nonce words in this research, which seems the best option to test vowel-to-vowel assimilations in BP.

### 7.4.2 Miranda, Yacovenco, Tesch & Meireles (2017)

In a study about the influence of the speaking style on vowel variation, Miranda et al. (2017) investigated the coarticulation between pre-stressed and stressed vowels of the Capixaba dialect spoken in Vitória and Vila Velha (the southeastern coastal region of Brazil). Based on Miranda's dissertation, the work investigates the production of the vowel in two styles of reading, which are sentences and texts. To assess the hypothesis that speakers monitor their production according to text style, they measured F1, F2 and spectral slope of both pre-stressed and stressed vowels embedded in a trochaic phonologically three-syllable long pattern.

The findings of the study confirm the tendency to lower vowels regardless of the reading style. The pre-stressed /i, u, a/ tend to be preserved in comparison with their stressed counterparts, whereas /e, o/ are strongly affected by the stressed vowels with an overall tendency for lowering. A consistent lowering of /e/ and /o/ was found in low-vowel contexts in both styles, with raising being found only for /e/ when speakers were reading the texts, suggesting that raising can be more a result of speech rate or style than a product of VH.

## 7.5 Notes on the Avoidance of a Synchronically BP [+High] Harmony

This section addresses not only linguistic facts of BP phonology that interact with the phenomenon of VH, but discusses the crucial role of underlying representations or phonological form (henceforth UR) and the necessity of questioning what is the right choice when the linguist chooses a form as a UR and states another as the surface form (SF). This task is not trivial and can have a considerable impact on the analysis. For this reason, I address important evidence for the claim that BP speakers currently avoid rising vowels. Nonetheless, it is worth pointing out that I do not argue that [+High] VH does not exist in the language, but my data and my analysis lead to defense of another approach.

### 7.5.1 Underlying Representations Biased by Orthography

The first problem concerns the work of the linguist in choosing the best UR, which is crucial to any analysis of VH, regardless of the language. The UR for the target vowel is the basis of the analysis, since this form will undergo the VH process. If the analyst departs from a mistaken assumption, the whole analysis will be jeopardized. This is possibly part of the explanation for proposal of the two BP phenomena of *[+high] VH* (Bisol, 1981) and the *pre-stressed vowel raising* (Bisol, 1981, 2009; Klunck, 2007). Table 47 uses data from Bisol (1981) for discussion.

(143)

Table 47. Possible words with UR forms biased by orthography.

| Phenomenon | Phonological Form | Phonetic Form | Gloss |
|---|---|---|---|
| *[+High] Harmony* | /menino/ | mi'ninʊ | boy |
| | /pɾegisa/ | pɾi'gisɐ | laziness |
| | /seguɾa/ | si'guɾɐ | hold-PRS.3SG |
| *Pre-stressed Vowel Raising* | /seɲɔɾa/ | si'ɲɔɾɐ | madam |
| | /konvɛɾsa/ | kuŋ'vɛɾsɐ | conversation |
| | /bonɛka/ | bu'nɛkɐ | doll |

None of these forms presented any variation in Bisol's data, which could be evidence in favor of underlying /i/ and /u/. The author, however, assumed the near-orthographic form as the phonological one. These forms exemplify the cases in which a UR updating is necessary from the perspective of the linguist, since they pose the question: How could we consider that the UR has a vowel that never goes to the surface?

The notion of updating a UR is discussed in Nevins and Vaux (2006), who assert that this is possible, based on evidence from alternations in the language. In those cases, where there is no variation, then the answer to the question should be that the URs are wrong. However, the use of our orthographic knowledge to propose UR is not the main problem, since in many cases variation may confirm the URs or in other cases evidence can be found in the morphological processes, such as derivation and inflection, which is suggested by McCarthy (1992) as a method to propose URs.

The problem of those URs concerns an orthographic bias, without any available evidence from the speaker's usage that the form is the claimed one. Given those forms, they lead the analyst to inflate his analysis, which seems the case of the *pre-stressed vowel raising* mainly. Although discussing UR is not the goal here, this is an important issue that should be taken into account when analyzing BP VH, because there are many words that have phonetic forms that have been lexicalized. And if lexicalized, there is no process involved.

Lexicalization of the high pre-stressed vowels was discussed by Oliveira (1991, 1992, 2003), who found two directions for these vowels: categorical [i]s or [e]s, both showing resistant forms. The author points out that there are three main boundaries for sound change: (1) proper names, (2) social class reaction, and (3) formal speech style. Therefore, a study whose goal is to investigate [+High] harmonization must discuss in depth how to choose an appropriate UR and how to interpret the phonetic form. At this stage, raising this issue is sufficient to alert to the fundamental problem that involves [+High] VH in BP. However, more issues can be posed concerning the behavior of the high vowel in certain conditions of harmony, which will be presented next.

### 7.5.2 Target Contrastiveness

This section discusses the effects of vowel neutralization that affects opposition between /e/ and /ɛ/ and /o/ and /ɔ/ in pre-stressed syllables in BP. This is an important argument in the defense of [–ATR] agreement for BP, since in most of the attested VH systems the process tends to apply to vowels that are not contrastive within a specific domain

(Krämer, 2003). In order to proceed with this discussion, I will firstly introduce the neutralization process, showing that the phenomenon is more complex than the literature has considered, and present arguments that show categorically [–ATR] vowels, but also cases where [ɛ] and [ɔ] are surfaced triggered by [ATR] harmony.

### 7.5.3 Mid-vowel Neutralization

The neutralization of BP mid-low vowels was noted by Camara Jr. (1977), who pointed out that the seven vowel phonemes are reduced to a five-vowel system in the pre-stressed position. Such reduction neutralizes the opposition between /e/ and /ɛ/ and /o/ and /ɔ/, the mid-high vowels being preferred in that position in the language. Within the FG approach, Wetzels (1992) proposes that BP vowel neutralization can be understood as [Open-3] delinking when mid-low vowels go to an unstressed position through the derivation cycle (Wetzels, 1991, 1992, 1995). The author asserts that BP vowels can be characterized as having four degrees of opening with three features [Open-*x*], as can be seen in Table 48.

(144)

Table 48 . BP Contrastive features according to Wetzels (1992) within FG approach.

| Vowels | Open-1 | Open-2 | Open-3 |
|---|---|---|---|
| i, u | – | – | – |
| e, o | – | + | – |
| ɛ, ɔ | – | + | + |
| a | + | + | + |

Given this system, the author can exclude the vowel /a/ from the rules in a very simple way. Postulating a rule that delinks [Open-3] when a stressed vowel becomes pre-stressed, formalizes this behavior in the examples below:

(145)

| | | | | | |
|---|---|---|---|---|---|
| a. | ˈpɛlɪ | → | p**e**ˈladʊ | skin | nake-PTCP |
| b. | 'p**ɔ**brɪ | → | p**o**'brezɐ | poor | poverty |
| c. | ˈl**ɔ**tʃɪ | → | l**o**'tadʊ | batch | crowded |

Bisol (2003, p. 276) considers that the result of this neutralization is "an unstressed system with five vowels, a natural class: /a e i o u/".[33]. However, formulations such as that made by Bisol can lead us to assume an incorrect notion of an implicational relationship between neutralization and complementary distribution of the vowels (Schwindt, 2013). The fact that vowels are neutralized in the pre-stressed position can lead the linguist to assume that /ɛ/ and /ɔ/ are in complementary distribution with /e/ and /o/ in pre-stressed syllables. In fact, this claim of a reduced system is not true, because all dialects have pre-stressed mid-low vowels /ɛ/ and /ɔ/ whose appearance at surface interacts with word-formation processes, secondary stress and VH itself.

### 7.5.4 Pre-stressed /ɛ, ɔ/ surface governed by word-formation rules

The interaction between neutralization and morphology was exhaustively discussed by Wetzels (1991, 1992, 1995) and Lee (1995). Although it will not be discussed in detail here, it is necessary to address this issue since pre-stressed [–ATR] vowels also trigger VH. According to Lee (1992, 1995), the existence of /ɛ, ɔ/ is due to differences in the suffixes attached to the morphological base. Within the Lexical Phonology approach, the author divides the Portuguese suffixes into two groups (α-suffixes and β-suffixes) according to the level of lexicon they belong to (alpha or beta stratum). The neutralization rule affects only the words formed by α-suffixes, while β-suffixes do not undergo the rule.

(146) Root + α-suffixes:

| | | | | |
|---|---|---|---|---|
| a. | √l**ɛ**v-eza | → | l**e**'vezɐ | lightness |
| b. | √pel**ɔ**t-ense | → | pel**o**'tensɪ | pelotas-LOC |
| c. | √f**ɛ**st-eiɾo | → | f**e**s'tejɾʊ | partying-NOUN |

(147) Root + β-suffixes:

| | | | | |
|---|---|---|---|---|
| d. | √k**ɔ**fɾ-iɲo | → | k**ɔ**'fɾiɲʊ | safe-DIM |
| e. | √s**ɔ**l-ziɲo | → | s**ɔ**w'ziɲʊ | sun-DIM |
| f. | √ab**ɛ**ɾt-isimo | → | ab**ɛ**ɾ'tʃisimʊ | open-SUPERLATIVE |

[33] Originally: "*o resultado é um sistema átono de cinco vogais, uma classe natural: /a e i o u/*" (Bisol, 2003, p. 276)

Wetzels (1992, p. 35) considers that the suffixes *-inho*, *zinho,*[34] *íssimo* and others constitute themselves as independent PWs. As the words in (147d–f) would have a structure such as [PW] +[ PW], neutralization does not find a context to occur. Then, as /ɛ, ɔ/ remain in the PW compound and they are not the target of [+High] VH, such a rule does not have a context either.[35] Nonetheless, considering the final output of the derivation in words formed by β-suffixes, the mid-low vowels remain in the output. Given that, the formed words bear only one lexical stress, the general rule that changes these vowels to /e, o/ in unstressed syllables is not a good explanation. This rule is only valid if we conceive of the lexicon as having multiple strata and cyclic rules. In output-oriented grammars, such as Optimality Theory and Harmonic Grammar, neutralization would again be an unsolved issue. Yet the failed neutralization cases in words with specific suffixes are not the only examples of pre-stressed mid-low vowels in the output, since they also appear in secondary stress syllables in all dialects.

### 7.5.5 Phonetic [ɛ, ɔ] are attracted by secondary-stressed syllables

Collischonn (1994) points out that the secondary stress in BP is assigned binarily to pre-stressed syllables from right to left. It builds binary feet iteratively departing from the syllable that bears the primary stress to the leftmost edge of the PW, but ternary feet can also be created. This ternary pattern can result from an odd number of syllables within the secondary stress domain or from the application of processes like stress shift, which is the avoidance of stress clash. This pattern of secondary stress assignment is assumed by Sandalo et al. (2006), who mention that, in odd-syllable words, there is a tendency to delete syllables to keep binary feet within the domain. On the other hand, trochaic influence was not confirmed by Arantes (2010) in an experimental study, who found an initial prominence within the stress group of an utterance. For this author, duration, *f0* and vowel openness cooperate to enhance secondary prominences.

I will not discuss in detail the algorithm of secondary stress assignment in BP. For our purposes, it suffices to highlight the fact that secondary-stressed syllables seem to present a tendency to be produced with mid-low vowels instead of the phonological upper-mid /e, o/.

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[34]Some authors consider *-zinho* and *-inho* to be independent prosodic words (PW), which would explain why VH does not interact with this particle (Camara Jr. 1970; Moreno, 1977). However, others consider only *–zinho* to be an independent PW (Leite 1975). Others consider them both as normal suffixes (Bisol 2010; Faggion 2006; Ferreira 2005; Lee 1999; Menuzzi 1993). I will not discuss the status of these suffixes, but it is worth mentioning the controversy around diminutives in BP.

[35] For a detailed discussion, see Lee (1995).

Although neutralized with /e, o/, the vowels [ɛ, ɔ] appear freely in syllables that bear secondary stress. Their production is variable, and the choice of one vowel or another is probably better explained by sociolinguistic reasons, that is, the form can be dialect-specific. Some examples are given in (148):

(148) [e ~ ɛ] and [o ~ ɔ] alternations:

| | | | | |
|---|---|---|---|---|
| a. | ˌm**e**todoloˈʒiɐ | ~ | ˌm**ɛ**todoloˈʒiɐ | methodology |
| b. | aˌ**e**ɾoˈpoɾtʊ | ~ | aˌ**ɛ**ɾoˈpoɾtʊ | airport |
| c. | ˌpɾ**o**babiliˈdadʒɪ | ~ | ˌpɾ**ɔ**babiliˈdadʒɪ | probability |
| d. | ˌd**e**pɾ**i**ˈmentʃi | ~ | ˌd**ɛ**pɾiˈmentʃi | depressing |

From these examples, it is important to emphasize that there is no possibility of a surfaced [i] and [u] in these cases, even for the example (148d), where the /e/ is followed by a phonological /i/. The [+high] harmonized form *[ˌdʒ**i**pɾ**i**ˈmentʃi] is not accepted for BP speakers, while mid-low vowels are.

### 7.5.6 Vowel Raising avoidance: contrastiveness

It might be hypothesized that this tendency can be explained by the fact that mid-low and mid-high pre-stressed vowels are totally neutralized, whereas the opposition for [+High] remains important in that position. This can be seen in minimal pairs (149a–b) and (150a–b), whose meaning remains the same in words with mid-high and mid-low vowels, but is different for the high vowels.

(149) Opposition /ɔ/ – /o/ – /u/:

| | | | | |
|---|---|---|---|---|
| a. | /ɔ/ | → | ʃ**ɔ**ˈpadɐ | m**ɔ**ˈɾadɐ |
| b. | /o/ | → | ʃ**o**ˈpadɐ | m**o**ˈɾadɐ |
| | | | event of chop | residence |
| c. | /u/ | → | ʃ**u**ˈpadɐ | m**u**ˈɾadɐ |
| | | | suck.PTCP | wall.PTCP |

(150) Opposition /ɛ/ – /e/ – /i/:

| | | | | |
|---|---|---|---|---|
| a. | /ɛ/ | → | f**ɛ**ˈʃadʊ | p**ɛ**ˈkadʊ |
| b. | /e/ | → | f**e**ˈʃadʊ | p**e**ˈkadʊ |
| | | | close.PTCP | sin |

c. /i/ → **fi**ˈʃadʊ **pi**ˈkadʊ
register.PTCP chopped

In the examples above, minimal pairs evidence non-contrastiveness between non-high vowels, that is, [–High, αATR]. The distinction in the value of [High] is, however, maintained in the pre-stressed position. In other words, I argue that if BP VH tends to change vowels, it is more likely the VH reaches non-contrastive vowels in a given context than the contrastive subset of phonemes, which play a functional role in the distinction of words.

Moreover, in harmonic language systems, non-contrastive vowels have a strong relationship with VH, being targets of the process or transparent, as is the case for [back] in Hungarian, in which the vowel /i/ is transparent to palatal harmony (Benus & Gafos, 2005), or [ATR] for the vowel /a/ in Tagale (Nevins, 2005). The transparency of non-contrastive vowels is fully discussed in Nevins (2005) who argues that locality of the harmony relations among vowels can be predicted based on the structure of the inventory.

### 7.5.7 [+High] Harmony is Blocked by Word-Internal Morphology

As discussed in Chapter 2, affixes usually participate in harmony systems. For example, Turkish is a classical language that exemplifies it, since the vowel of the affix is affected by the vowel of the root, creating harmonic allomorphs. In BP, affixes avoid participating in the claimed [+High] harmony. Even in optimal structural descriptions (target vowel adjacent to a high vowel), the height harmony seems to be blocked by morphological boundaries (see examples 151 to 153 in §7.5.7). Schwindt (2012, p. 119) asserts that height VH shows low productivity when the trigger vowel is part of a nominal suffix (≈8%), and the same situation occurs for diminutives in –zinho and –inho. Also, the author confirms that there is no evidence that VH has access to word-internal morphology, stating that only contiguity, stress and homorganic target and triggers would be sufficient to account for VH[36]. By contrast, this poses an issue which is: if stressed high vowels in a suffix do not trigger [+High] harmonization, how could we consider that stress, contiguity, etcetera, are sufficient phonological conditions to satisfy the structural description of the [+High] harmony? So, if all

[36] In the author's words: "*não se pode falar em qualquer evidência de acesso à morfologia interna da palavra por parte do processo de harmonia vocálica variável, podendo seu condicionamento explicar-se na base de restrições fonológicas, envolvendo contiguidade, tonicidade e, possivelmente, homorganicidade de alvo e gatilho*" (Schwindt 2012: 119).

these conditions are satisfied, what is the domain of height harmony? Indeed, these facts constitute significant evidence that [+High] harmony is probably blocked by word-internal morphology, being restricted to root internal conditions, or even that it is not an active BP process anymore. The examples in (151) show that stressed trigger vowels do not spread [+High] across boundaries.

(151) From Suffixes to Root:

| | | | |
|---|---|---|---|
| a. | √tort-uɾa | *t**u**ɾ'**tu**ɾɐ | torture |
| b. | √manobɾ-ista | *man**u**'bɾ**i**stɐ | valet parker |
| c. | √alkol-izmo | *awk**u**'l**i**zmʊ | alcoholism |

The examples in (151) show that height harmonization creates unacceptable forms when target and triggers are part of different morphemes. If they are impossible in terms of grammaticality, it suggests that this sort of harmony is probably blocked. And this can be observed in the relation between root and prefixes.

There are no allomorph prefixes with [+High] vowels whose motivation is VH, as expected, since this is commonly attested to typologically in many well-known harmonic languages. Even if a high vowel was found acting as a trigger within the root, prefixes are not raised by [+High] assimilation. Instead, raising the underlying vowel creates unacceptable forms, as in (152):

(152) From Root to Prefixes:

| | | | |
|---|---|---|---|
| a. | re-√lig-o | *ɦ**i**'l**i**gʊ | reconnect-1.SG |
| b. | re-√lut-o | *ɦ**i**'l**u**tʊ | bereluctant-1.SG |
| c. | poli-√silab-o | *p**u**li's**i**labʊ | polysyllable |

Schwindt (2000) considers some prefixes to be independent PWs, and as the VH domain does not cross PWs, mid-low vowels of the prefixes are not targets of height assimilation. The author takes VH as evidence for this argument, among other phenomena. However, as I have discussed, while the [+High] harmony domain is likely the root, [–ATR] can spread from suffixes to root and from root to prefixes. The only requirement is that the [–ATR] trigger satisfies the strict locality condition.

Another restriction for [+High] can be observed root-internally. In this phonological context, several words could be found in which vowels do not share their [+High] feature, as in (153).

(153) Within the Root:

| | | | |
|---|---|---|---|
| d. | √polid-es | *p**u**l**i**'des | politeness |
| e. | √termin-o | *t**i**ɾm**i**'nʊ | finish-1.SG |
| f. | √komun-izmo | *k**u**m**u**'n**i**zmʊ | communism |
| g. | √kolun-a | *k**u**'**lu**nɐ | column |

The examples attest that strict local relationships within the root for this sort of harmonization are irrelevant. Even with structural conditions satisfied, as claimed by Schwindt, VH does not occur. In this regard, it might be hypothesized that [+High] VH is not active in the grammar of BP speakers. The linguistic facts presented so far support the claim that [+High] is not a constraint to phonology structure itself, but also to the interplay between phonology and morphology. It is not my goal to deny the existence of the claimed [+High] harmony, but to bring arguments that evidence that BP speakers are avoiding raising vowels for the reasons that have been exposed. It must be emphasized that this tendency can be been Casagrande's (2004) results.

### 7.5.8 Consonantal Blocking Effect

Still considering [+High] harmony as an active process, as some authors claim, this process is prevented by a blocking effect of the coronal stops /t/ and /d/ when followed by the vowel /e/. We argue that the contrastive role of [High] in pre-stressed vowels also blocks VH in /e/ contexts. If the vowel undergoes harmony, then ungrammatical forms are created.[37]

(154) **The /t, d/ Blocking Effect:** do not raise /e/ to [i] if the immediately preceding consonant is /t/ or /d/.

| | | | | |
|---|---|---|---|---|
| a. | temido | ***tʃi**'m**i**dʊ | ***ti**'m**i**dʊ | fear-PTCP |
| b. | tesido | ***tʃi**'**si**dʊ | ***ti**'**si**dʊ | tissue |
| c. | deprimente | ***dʒi**pɾi'mente | ***di**pɾi'mente | depress-ADV |
| d. | delirio | ***dʒi**'liɾjʊ | ***di**'liɾjʊ | delusion |

[37] It needs to be emphasized that these postulated ungrammatical forms might be found in some dialects or in older people's speech. As my interest is to comprehend the reasons of not raising vowels in /t, d/ contexts, I think that this formulation may be correct for some group of BP speakers. Further sociolinguistic investigation is needed.

The outputs in (154a–d) are prohibited in BP, which allow us to argue that phonological pre-stressed /e/ cannot be pronounced as [i], even in [+High] harmony contexts with all structural descriptions satisfied. However, this is not valid for phonological pre-stressed /i/, whose production after /t, d/ categorically conditions of the occurrence of the affricate allophones [tʃ, dʒ]. Without this observation, I would make an incorrect generalization prohibiting pre-stressed [tʃ] and [dʒ].

It is necessary to emphasize that the prohibition is to raise /e/ after /t, d/, not the production of [tʃ, dʒ] itself. Their non-existence is a consequence of faithfulness of the output to the phonological /e/, whose raising is blocked by the consonantal environment. If we analyze this in a rule-based and derivational phonological model, we could have two scenarios: the first, where VH applies before the palatalization of /t, d/ (henceforth, PAL), and a second scenario when PAL is applied before VH. The two rules are stated as follows:

(155) Phonological Rules:

a. *Vowel Harmony (VH):* /e, o/ → [i, u] / __i,u (Bisol, 1981)
b. *Palatalization (Pal)*: /t, d/ → [tʃ, dʒ] /__i (Bisol, 1986)

(156)

Table 49. Rule ordering possibilities of VH and PAL.

| Order 1 | | Order 2 | | Order 3 | | Order 4 | |
|---|---|---|---|---|---|---|---|
| | /tesido/ | | /tesido/ | | /tesido/ | | /tesido/ |
| VH | **ti'si**do | PAL. | – | VH (variable) | – | PAL | – |
| PAL | **tʃ**i'sidʊ | VH | **ti'si**do | PAL | – | VH (variable) | – |
| | *[tʃi'sidʊ] | | *[ti'sidʊ] | | [te'sidʊ] | | [te'sidʊ] |

Logically, only two scenarios are needed: AB and BA. Nonetheless, as can be observed in Table 49, Order 1 and Order 2 result in incorrect phonetic forms. In Order 1, which is expected in dialects with palatalization, as in BA and GA, VH feeds PAL. Order 2 would create an opaque output because the rules are in counterfeeding ordering for PAL dialects. Also, the second output would be expected in non-PAL dialects, but I am not aware of the existence of previous work that mentions a blocking effect in VH motivated by the stop coronal consonants.

With the Orders 3 and 4, we obtain the real outputs of the language and they stand for the non-application of the two rules. As we can see, their non-application allows non-harmonic forms on the surface and the fact the harmony is blocked is shadowed by the argument that VH is variable. If variable, it is possible for it to be applied or not applied, since all linguistic variable phenomena are sensitive to extralinguistic factors, such as age and education. On the other hand, the linguist fails to comprehend the role of /t, d/ in blocking VH and fails in predicting the order of rules in the languages within the rule-ordering approach.

Additionally, saying that one rule or another does not apply because it is variable may lead us to fall into a fuzzy area where everything is possible. Words such as the one considered here may have led some analysts to the incorrect generalization that VH is variable because harmonization forms are never produced for some items, albeit possible. The notion of possibility can be tricky because languages do have variable phenomena, but this variation is governed by linguistic structure in most cases. For instance, in BP the /ɾ/ in coda can be produced in a variety of ways, such as tap, velar or glottal fricative, or approximant, but variation of this consonant is always restricted to coda position and does not occur in onset. Concerning [+High] VH, what we see in these cases is that there is no possibility of variation; on the contrary, a harmonic form is forbidden. Thus, a rule-ordering approach faces difficulty in explaining why the language avoids it, even if we postulate variable rules. It fails to capture the fact that the surfaced forms with [e] are preferred over forms with [i], because [i] also triggers another process. Somehow, avoiding one change is more economical for the speaker, because if he makes one structural change another rule has to be applied that is triggered by the first. In a certain way, it is better to be faithful to one form than to make two changes.

Considering, then, that PAL dialects do not allow [+High] harmonic forms because of the reasons explained, a possible explanation for the blocking effect would be to consider that a grammar compares forms of possible outputs. This phenomenon is well known as *output-output correspondence*[38] (Benua, 1997; Burzio, 2002) within constraint-based grammars approaches. Within such approaches, one might posit a faithfulness correspondence relationship among output forms related by derivation, in which one is called the "base" to another output candidate.

[38] There are a lot of studies on OO-Correspondence, but for further discussion of this topic see Archangeli (1997), Bybee (1985), Burzio (1998), Crosswhite (1996).

I raise this issue as a hypothesis considering the following context. If PAL dialects prefer forms as [te'sidʊ], then the form *[tʃiˈsidʊ] has been blocked for comparison as well as the third one *[tiˈsidʊ]. In these cases, the reason for blocking is to avoid two outputs, but, in order for them to be avoided, they have to be generated. This is one of the assumptions made by such approaches. I will not propose any solution within one approach or another, since the goal here is only to identify the phenomena in order to enrich the discussion for the linguists interested in BP [+High] VH.

### 7.5.9 Height Harmony Avoidance: Sociolinguistic Evidence

#### 7.5.9.1 Avoidance in Nouns

Sociolinguistic studies have shown that education and age are significantly associated with the less frequent use of harmonic forms. These studies have shown that highly educated people and young people avoid the use of high-to-high forms. Schwindt (1995) shows that older people are more likely to use [+High] forms, while the youngest tend to avoid this use (39% compared with 36% for the youngest), and that the higher the education, the lower the harmonic form usage (41.5% for elementary school students, compared with 29.5% for high school students). These results reveal that access to standard usages of the language makes people avoid a form that is used in colloquial speech.

Casagrande (2004) analyzed VH in two different decades: the 1970s and 1990s. She found that in both decades the production of harmonic forms is about 15% for young people against approximately 20% for people greater than 50 years old. Although in Schwindt (1995) age does not reveal a crucial difference, these two studies return quite similar findings for such an extralinguistic factor. As already known, age grading is evidence of cross-generational instability of a phenomenon, indicating structural changes in a diachronic view (Labov, 2001; Wagner, 2012). On the other hand, age might indicate that height harmony is a socially stigmatized phenomenon, which explains the fact that youngster avoid raising vowels in favor of harmonization.

Rocha and Brandão (2015) analyzed several studies about the behavior of the pre-stressed vowels of BP spoken in northeastern dialects, concluding that the overall tendency is for vowels to be produced as [e] and [o]. They analyzed the results of data that were gathered in Espírito Santo, Rio de Janeiro, São Paulo, and Minas Gerais, and in almost all the regions the production of mid-high vowels was around 60%, except São Paulo, where the production of [e] is about 85%. In other words, one might conclude that [+High] harmony is in fact a phenomenon whose productivity in spoken BP is too small. Besides the orthographic biases discussed in this chapter, which could have inflated the results, the avoidance of such forms is not only linguistically motivated, but extralinguistic aspects reveal that the phenomenon has been largely avoided by BP speakers.

#### 7.5.9.2 Avoidance in Verbs

Schwindt and Quadros (2009) investigated the productivity and transparency of [+High] the categorical VH. They analyzed verb entries available in the dictionary and conducted two experiments to determine which root vowel would be produced, since such vowels are categorically changed, motivated by the verbal paradigm. In the analysis of the 2nd and 3rd paradigm for an oral experiment, the authors found the prevalence of mid-high vowels produced by the speakers (>60% for [e,o] against <20% for [I,u] forms). For an AB forced choice instrument that evaluated VH transparency in writing, they found that the participants chose more often the forms with mid-high vowels in agreement with the root vowel, although forms with high-vowel agreement between root and thematic vowel were considered relevant (70% for [e] forms against ≈55% for [i, u]). The authors conclude that [+High] VH is not a productive process in BP, since its recoverability in novel words was not observed in their experiments.

Non-high vowel tendency was also observed in the results of a sociolinguist study conducted by Carmo (2009). The author found that /e/ is raised to [i] in 16% of all verbs, while /o/ is even less raised (10%), which confirms that high vowels triggered by VH are not frequent in the verbal paradigm. The author, however, does not offer an interpretation as I did in this dissertation. She concludes that morphophonological aspects might explain outputs with raised vowels, but none is mentioned. This constitutes a challenge for most sociolinguistic studies, which are usually restricted to reporting linguistic facts. Most of these studies fail to give an explanation, or their analyses are merely speculative and limited to the mapping of phonological contexts for an optimal rule application of the variable phenomenon observed by the researchers. The main problem with such an approach is that the phenomenon, per se, is not investigated, whereas all linguistic structures are analyzed exhaustively. Most sociolinguistic studies are interested only in computing counts of words and exploring preceding and following contexts most likely to co-occur with a given phenomenon.

## 7.6 Conclusion

Sociolinguistic facts suggest that the observed [+High] harmony is residual from an old active process in Portuguese. It might be indeed still active, as observed by Camara Jr. (1952) and Bisol (1981), but the facts presented here lead us to argue that VH has been rejected by a new generation of BP speakers. The remaining words that show variation between mid-low and high vowels in [+High] harmony context will probably result in one form being completely lexicalized. This seems to be the case for words such as *menino*, *bonito*, *coruja,* and *perigo*, whose pre-stressed vowel is always produced as [i]. Unless one considers orthography, phonetic occurrence does not provide evidence to postulate an underlying /e/. Also, in words where mid vowels still show variation with high ones (p**e**t**i**sco ~ p**i**t**i**sco), it is not possible to predict what form will be chosen or whether the variation will be maintained through the years and generations. And the reason for that is simple: BP VH is nowadays an [ATR]-based system and variations for feature [High] within the subset of [+ATR] vowels does not affect [ATR] harmony. Thus, variations such as [e~i] or [o~u] can still be observed, although the tendency will be to agree with the value of [–ATR], but maintain the upper-mid vowels elsewhere.

Our proposal suggests that BP is [ATR]-oriented and is opposite to Bisol's (2013) proposal that claims partial and total effects of harmonization in order to take into account the production of [ɛ] and [ɔ] in pre-stressed syllables of BP spoken in the northeastern dialects. This sort of phenomenon is not typologically attested, and our results do not support such division. There is, in fact, an [–ATR] agreement tendency, which is observed cross-dialectally. It has been claimed that southern dialects maintain only /e, o/ in pre-stressed syllables, but I have shown that this is not true, and that a seven-vowel system appears, instead, to be triggered by VH and by morphological word-formation rules.

These are the reasons why I offer an analysis that takes into account the realizations of pre-stressed vowels in GA and BA, showing that the tendency is vowel lowering. The production of the speakers seems to agree with what has been observed in other dialects about the production of [ɛ] and [ɔ] in pre-stressed syllables. The analysis, then, suggests that [+High] harmony has been replaced by [ATR] harmony, where speakers prefer low vowels than high-vowel agreement. To support this claim, I have brought in arguments that show why speakers avoid [+High] harmony but do not avoid [ATR] harmonic forms, and such arguments are more linguistically than sociolinguistically motivated. This aspect is indeed important because this proposal might be a turning point in what has been largely considered the behavior of BP pre-stressed vowels in the literature.

# 8 CONCLUSIONS AND FUTURE DIRECTIONS

In the final part of this dissertation, I will summarize the findings on BP [ATR] harmony, which were discussed in Chapters 3 through 7, while exploring the implications of postulating [ATR] harmony instead of [+High] VH for BP. I propose that these two processes cannot coexist in the language as part of speaker's knowledge because the subset of target vowels and phonological property under change are the same. Although there are languages with more the one VH system, when this is the case, those two processes reach different phonological properties. For example, in Turkish, only high vowels participate in rounding harmony, whereas all vowels of the language participate in palatal harmony. By comparing Baiano and Gaucho BP dialects, which are known for having different sets of vowels in pre-stressed syllables, my aim was to investigate whether VH would be different between these dialects. However, I found that pre-stressed vowel targets tend to be lowered in both dialects, which suggests that speakers present the same sort of harmony system. Furthermore, I argue that BP/VH is an [ATR] system in which the feature [–ATR] is spread to the closest pre-stressed non-high [+ATR] vowel.

## 8.1 Summary of the Dissertation

The present work started with the remark that a subset of pre-stressed target vowels of VH does not always respect the phonological height specification of the stressed vowel. This has led us to examine the realization of pre-stressed mid-low vowels in two dialects and to investigate how that well-known height harmony interacts by raising or lowering vowels. The lack of experimental studies describing pre-stressed vowels was a motivation for me to conduct an experiment to investigate phonetic V-to-V coarticulation effects and, hence, determine how vowels shift the targets to agree in height. Therefore, this work also addressed the role of consonants which are adjacent to the target, in order to examine whether their phonological class or place of articulation could have significant effects on height shifts in non-harmony contexts, as observed in the literature (Bisol, 1981, 2009). In Chapter 2, we explored the phonological properties of VH in the world's languages: locality, directionality, recursivity, domain and harmonic features. We also addressed BP height harmony in BA and GA dialects with a view to examining the explanations about the phonology of VH reported by Bisol (1981) and the ternary alternations attested in the Baiano pre-stressed vowel system, as reported by Barbosa da Silva (1989).

In Chapter 3, I described the production experiment designed to investigate the phenomenon of VH. This chapter summarized the results on vowel F1 and F2 of the pre-stressed and stressed vowels produced by BA and GA speakers. The goal was to examine the acoustic characteristics of the whole set of pre-stressed and stressed vowels in those dialects, as well as to investigate how the pre-stressed vowels are affected by the following vowels and by the neighboring consonants. The results indicated that vowels in BA and GA have similar characteristics in both dialects, which is confirmed by the Euclidian Distance results. We hypothesized that the closer the vowels the more likely could affect one another as far as height is concerned. However, the ED results did not confirm significantly different vowel distances between dialects. With regard to consonantal effects, we found that the effect of the consonant on the pre-stressed vowels is the same in both dialects.

Chapter 4 presented the results for the effects of vowels and consonants on the harmony target vowels /e/ and /o/. The results consistently showed that /e/ and /o/ become the low vowels [ɛ] and [ɔ], respectively, as they are triggered by the low vowels in the next syllable. This behavior was found to occur in the two dialects. This is an important finding because /e/ and /o/ were expected to change into [i] and [u] in favor of the alleged knowledge of height harmony of native speakers of BP. There was unexpected low-vowel agreement in Gaucho, rather than [+high] harmony, which is widely accepted. What remains to be further investigated is why the expected harmonization did not occur in the present study, whereas the opposite unexpected trend took place. It can be assumed that BP VH is highly influenced by coarticulation with the following vowel and that intra- and inter-speaker variation is an undeniable fact; in addition, one may wonder how to delimit vowel categories boundaries.

To determine how vowel movements interact with vowel shifts, in Chapter 5 I presented a measure called Vowel Threshold (VT), which is a method I proposed to estimate vowel category boundaries. The method allows an analyst to determine fine phonetic details of the movements that occur within and between vowel categories in V-to-V sequences. This method is applied to V-to-V sequences and can predict whether a vowel is being harmonized by the trigger vowel or whether the vowel remains faithful to its phonological category, albeit intra-category movement can occur, as motivated by coarticulation. Based on vowel F1 and F2 acoustic measurements, VT establishes a scale where zero is considered to be the prototype value of a vowel if no other bias is added in vowel production. The VT results revealed that GA speakers produce pre-stressed vowels in the same way as BA speakers. Although there was inter-speaker variation, it could be seen that [ATR] harmony occurred to a certain degree, which is consistent for BA speakers, whereas [ATR] harmony in sensitive to the target vowel for GA speakers.

Chapter 6 was dedicated to analyzing the corpora built by Bisol and Barbosa da Silva, which showed that height VH is consistent only for /e/ as target and /i/ as trigger; however, the target /o/ is raised in other vowel contexts in Gaucho. There were also consistent co-occurrence patterns between a high vowel with a low vowel, hence indicating that height harmony in such data might not be a better explanation for the behavior of pre-stressed vowels in GA. The results for Baiano showed that vowels agree in three ways: high vowels agree with high vowels, mid-high with mid-high ones and low with low vowels. The explanations given in this work for proposing an [ATR] system finds support in the findings of our experiment and in those of Sandalo (2012), Sandalo et al. (2015), Kenstowicz and Sandalo (2016) and Miranda et al. (2017). These studies suggested that BP has seven vowels in prestressed position. I argue that these seven vowels in prestressed position can be explained by the active [ATR] harmony system whose harmonic feature [–ATR] changes the [+ATR] /e/ and /o/ into [–ATR] [ɛ] and [ɔ].

Based on the experimental results and the reanalysis of the two corpora, in Chapter 7 I outlined the proposal of an [ATR] harmony system for BP. In order to defend such a system, I presented arguments based on these main issues: (1) phonology–morphology interaction, whereby I demonstrate that [ATR] harmony is not sensitive to word-formation rules while height harmony is blocked by word-internal morphology; (2) vowel contrastiveness; (3) secondary stress assignment; and (4) locality and cyclicity, which suggest that [ATR] harmony reaches strict local vowels cyclically.

I also argued that [+High] harmony is avoided in BP, and this can be seen in the phonology–morphology interaction, in the analyses with orthographic biases and in the blocking effects of consonants. Evidence of [+high] harmony avoidance is also found in the sociolinguistic literature, which shows a decreasing application of such harmonization according to age and education of speakers. In conclusion, one can consider that height harmony in currently spoken BP is no longer productive, since this kind of harmony has been avoided by younger and highly educated people, as shown in the final chapter.

## 8.2 Limitations and Future Directions

This section presents limitations of the predictions made by this dissertation. Also, it indicates the relevant points of the proposal of an [ATR] harmony that can be further investigated.

### 8.2.1 Vowel Threshold Limitations

Considering that assimilation and coarticulation patterns can be both accounted in native speakers' grammar, this dissertation follows the proposition of Clumek (1976), in which languages show different degrees of coarticulation. With regard to the VT measure proposed in this work, it should be noted that such a method of estimating vowel categories needs detailed investigation on V-to-V sequences in non-harmonic languages. Further research is needed on how vowel categories are affected in languages whose vowel shifts are not imposed by a phonological process that affects adjacent vowels. Another issue that needs to be addressed is the magnitude and range of V-to-V coarticulation in order to examine the extent to which segments can affect each other. This includes, therefore, regressive and progressive coarticulation.

Therefore, VT has to predict degrees of articulation in order to determine the best critical VT value. The criterion to decide on the best critical VT has not been completely explored in this dissertation, hence it remains an open issue. The reason may be explained by the intent to explore intra-speaker VT to examine how the pre-stressed vowels are affected by the surrounding vowel on a speaker-by-speaker basis. Vowel-specific threshold needs to be explored, that is, VT must be based on specific vowels, because different vowels take a different portion of the vowel space. Another limitation is due to the number of participants. There were only six participants in this experiment and data from only four were used to propose the VT. The decision to use only four was based on the imbalance in the number of males and females in the dialects, as discussed in Chapter 3. However, the small number of participants is an important limitation of the VT predictions.

### 8.2.2 Perception Tests

The findings on VT may be explored with the results for the perception tests. One needs to examine how the boundaries predicted by VT in speech production interact with perceptual measures of the vowels. In other words, the question is to determine how speakers map perceptual and acoustic spaces in production. The relationship between perception and production spaces would correspond to the function of premotor mirror systems in which perception of a gesture, such as consonant or a vowel, recalls the premotor simulation of the same gesture (Gallese & Lakoff 2005; Rizzolatti & Arbib 1998). Liberman and Mattingly (1985), in their motor theory of speech perception, argue that perception involves the same cognitive systems found in speech production. This idea was put forward by Tilsen (2007), who proposed boundary areas based on the minimum and maximum formant values of vowel targets – which he referred to as repulsive factors.

### 8.2.3 The Role of Morphology and Secondary Stress Assignment

The role of morphology in [ATR] harmony must be addressed in the future. We have mentioned that [+High] harmony is blocked by word-internal morphology, rather than [ATR] harmony, whose system ignores affix limits. Such a prediction has to take into account whether prediction is true or whether height harmony is not, in fact, an active process. These two phenomena were not detailed experimentally in their interaction with morphology. Schwindt and Quadros (2009) examined height harmony experimentally and the authors suggested that this sort of harmony does not seem to be active in the native speaker's grammar because they did not find replicability of the phenomena in new verbs. Replicability of a pattern in inexistent forms in the language reflects lexicon trends (Becker, 2009). In Becker's model, lexical trends observed in a language create phonological patterns of exceptions that are incorporated into a grammar which applies deterministically to known items, and the same grammar applies stochastically to novel items.

In-depth research is needed on how [ATR] harmony creates allomorphs, for instance. Also, studies should be conducted on how root and word morphemes may trigger harmony or not. Neither possibility has been explored. I have proposed that [ATR] harmony ignores word-internal morphology, but this statement was based only on the corpus of Barbosa da Silva, which may not reflect speakers' knowledge. Moreover, sociolinguistic research can also show differences in the occurrence of [ATR] harmony, hence further research must be performed.

It is not clear how secondary stress interacts with VH. Arantes (2010) observed that *f0* and vowel openness can enhance secondary prominent syllables. I propose that secondary-stressed syllables attract [–ATR] vowels and change the non-high vowels /e, o/ to [ɛ, ɔ], as discussed in Chapter 7. However, further research is needed to examine how secondary stress assignment is established in pre-stressed syllables, as syllables that bear /e, o/ vowels may be preferred. It may be hypothesized that the non-obligatory dactylic foot observed by Sandalo and Abaurre (2007) could be the reason for syllables to select secondary stress assignment, interacting, therefore, with syllable weight and vowel quality.

### 8.2.4 Vowel Dissimilation

The Baiano dialect consistently showed a vowel dissimilation process, as discussed in Chapters 4 and 5. This was a surprising finding, since pre-stressed vowels were expected to agree with the stressed vowel. Rodrigues (2010) found that pre-stressed vowels are more affected in their spectral characteristics than stressed vowels, which corroborates our interpretation of VH. The author found that dissimilatory processes occur only in stressed syllables in BP; however, our results indicate that pre-stressed /e/ and /o/ also undergo dissimilation with stressed vowels. Although vowel categories do not always change as shown by the VT results in Chapter 5, there is a tendency towards lowering in high-vowel environments.

Probably, such dissimilation is characteristic of BA, but more data are needed to determine how dissimilatory effects occur in BP. The dissimilation targets /e/ and /o/ are required to disagree in backness with the stressed vowel; therefore, /e/ tends to be lowered when /u/ is the stressed vowel, while /o/ tends to be lowered when /i/ is the stressed vowel. In the introduction of this dissertation, I formalized this vowel behavior in a phonological rule. However, such formalization is an overgeneralization of the process, because the vowels /e, o/ do not change to low vowels categorically. Although they are affected in their phonetic height, they are not necessarily shifted. In addition to research on this dissimilation itself, investigation is needed of the vowels disagreement involved in the process, not only in Baiano but in the language as a whole.

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# 10 APPENDIX A – PRE-STRESSED VOWEL DURATION IN BAIANO E GAUCHO

## 10.1 A.1 Introduction

The aim of this part is to describe the duration of the pre-stressed and stressed vowels, as well the duration of the surrounding consonants of the target vowels.

## 10.2 A.2 Vowel Durations

### 10.2.1 A.2.1 Pre-stressed Vowels

Although Portuguese does not use vowel length as a phonological feature to distinguish vowels, duration has been reported as a secondary cue for phonological vowel quality (Barbosa, 2006; Escudero et al., 2009). Table A.1 shows the mean, median and standard deviation (SD) of the duration values of all the five pre-stressed vowels produced by Gaucho and Baiano speakers in order to make an exploratory analysis of duration as an important phonetic cue in dialectal differences, for the purpose of assessing the role of duration of pre-stressed vowels in both dialects. The aim is to determine whether we can also draw a line between these dialects for this acoustic parameter.

*Table A.1. Duration of the five BP pre-stressed vowels in the Gaucho and Baiano (in miliseconds).*

| | | *i* | *e* | *a* | *o* | *u* |
|---|---|---|---|---|---|---|
| *Gaucho* | mean | 49 | 69 | 70 | 72 | 53 |
| | median | 43 | 60 | 65 | 63 | 49 |
| | SD | 26 | 32 | 19 | 31 | 26 |
| *Baiano* | mean | 58 | 77 | 86 | 79 | 69 |
| | median | 56 | 75 | 82 | 73 | 66 |
| | SD | 23 | 26 | 27 | 26 | 22 |

A repeated measure analysis of variance returned significant differences between Gaucho and Baiano dialects for duration ($\eta^2$=0.0437; F[1,7787]=1124.34, p<0.001). Considering the whole set of vowels, the geometric mean computed from median values for duration in the Gaucho dialect is 55ms and for the Baiano speakers, 69ms. Baiano's vowels are 1.26 longer (ratio equals to Baiano's geometric mean divided by Gaucho geometric mean).

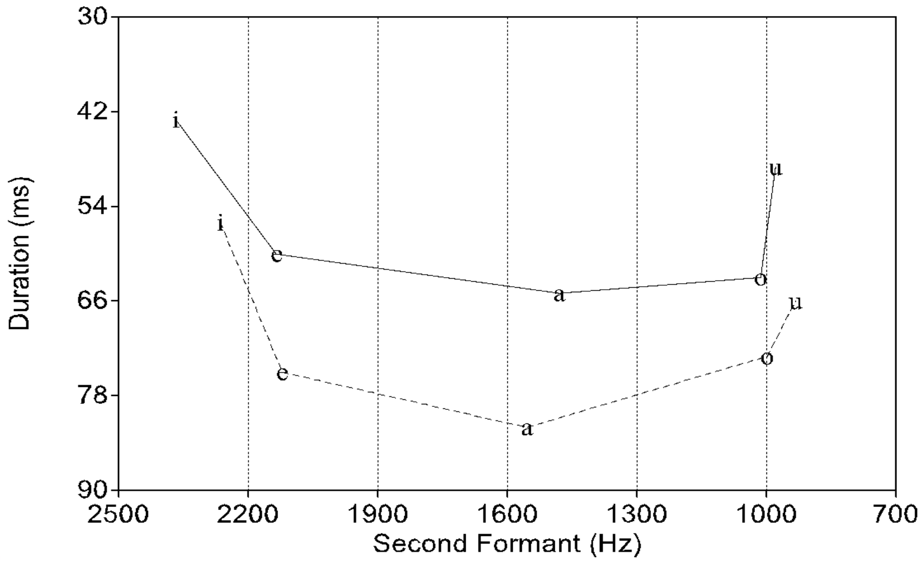



Figure A.1. Median duration for pre-stressed vowels as a function of vowel category. The values of F2 are the median of each vowel category in the dialects and the purpose is only to provide vowel space shapes. Solid lines stand for Gaucho; dashed lines stand for Baiano.

There were also more four significant results with small-to-moderate effect size. Gender returned ($\eta^2$=0.2809; F[1,7787]=7229.58, p<0.001) and the role of C1 was equal to ($\eta^2$=0.0667; F[1,7787]=571.99, p<0.001) while that of C2 was equal to ($\eta^2$=0.2353; F[1,7787]=866.31, p<0.001). The fact that C2 and gender are the only variables with strong effect size is expected because duration has been reported as a gender-dependent parameter (Escudero et al., 2009; Simpson, 2009); also, the difference in C2 can be tracked to contrast yielded in the corpus between obstruents and sonorants in C2. It is well-known that vowels followed by voiced consonants are longer than their voiceless counterparts (Luce & Charles-Luce, 1985). This hypothesis may be confirmed when it is analyzed the explicit interaction between duration and Class-C2 ($\eta^2$=0.1005; F[1,7883]=1617.18, p<0.001).

### 10.2.2 A.2.2 Stressed Vowels

It is well-known in the literature that Portuguese does not use vowel length as a phonological cue (Camara Jr., 1962; Bisol, 2005; Mateus & D'Andrade, 2000); however it does not mean that dialects use different duration values in stressed position (Barbosa, 2007 - for duration and stress in BP). Table A.2 shows the mean, median and standard deviation (SD) of duration values for all the seven stressed vowels produced by Gaucho and Baiano speakers.

*Table A.2. Duration (in ms) of Gaucho and Baiano dialects for the seven BP stressed vowels.*

| | | *i* | *e* | *ɛ* | *a* | *ɔ* | *o* | *u* |
|---|---|---|---|---|---|---|---|---|
| | mean | 60 | 75 | 93 | 96 | 95 | 79 | 66 |
| *Gaucho* | median | 60 | 72 | 89 | 94 | 92 | 75 | 61 |
| | SD | 18 | 22 | 24 | 22 | 25 | 24 | 23 |
| | mean | 105 | 112 | 120 | 126 | 122 | 114 | 100 |
| *Baiano* | median | 103 | 111 | 119 | 124 | 119 | 104 | 101 |
| | SD | 36 | 33 | 35 | 34 | 37 | 38 | 42 |

Duration mean is significantly different according to the second vowel ($\eta^2$=0.0878; F[6,7906]=368.1, p<0.001), dialect ($\eta^2$=0.2218; F[1,7906]=5160.1, p<0.001) and gender ($\eta^2$=0.3751; F[1,7906]=9172.4, p<0.001). These results seem very reliable, as the difference between these three characteristics can be easily seen in the next plot. Gaucho stressed vowels are shorter than Baino's, and women's vowels are longer than men's. This finding supports the study by Escudero et al. (2009), which indicates that women produce vowels longer than man for both European and Brazilian Portuguese.

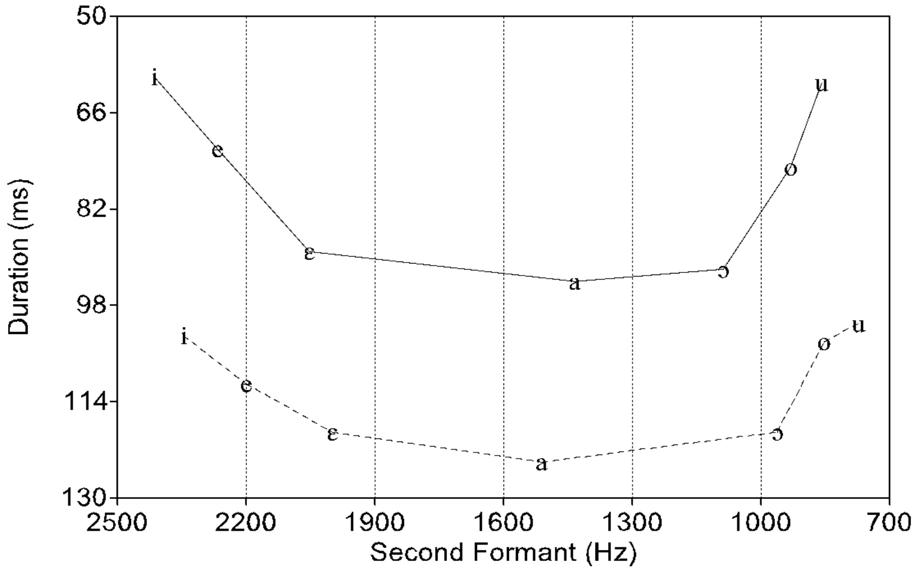



Figure A.2. Median duration for stressed vowels as a function of vowel category. The values of F2 are the median of each vowel category in the dialects and the purpose is to provide vowel space shapes. Solid lines stand for Gaucho; dashed lines stand for Baiano.

Considering the whole set of vowels, the geometric mean computed from median values for duration is about 76ms for Gaucho and 111ms for Baiano, which implies that Baiano vowels are 1.45 longer (ratio equals to Baiano's geometric mean divided by Gaucho's geometric mean). As Kenstowicz and Sandalo (2016) pointed out, duration can be predicted by syllable position within the word, confirming Major's (1981, 1986) findings. The relation between vowel duration and syllable position can be ordered from the longest to the shortest vowels as follows: stressed > pre-stressed > post-stressed. In this respect, we compute the ratio between stressed and pre-stressed vowels to determine how different these vowels are. Baiano stressed vowels are 1.59 longer than the pre-stressed, while in the Gaucho dialect, the ratio between V1 and V2 is 1.38.

## 10.3 A.3 Consonant Durations

### 10.3.1 A.3.1 C1 – The Preceding Consonant

Duration in stop consonants has been reported to be sensitive to the place of articulation (e.g. Repp 1984). One might expect that duration in stops is a cue for distinction between voiced and voiceless segments and different places of articulation. In general, voiced consonants are longer than their voiceless counterparts, and it is assumed that labials are longer than coronals, which are longer than velars. The mean, median and standard deviations for the three stop phonemes and for the allophone [tʃ] are given in the table below.

*Table A.3.* Duration for Gaucho and Baiano dialects (in milliseconds) for the three sets of BP stops phonemes and the affricate allophone.

| | p | t | k | tʃ |
|---|---|---|---|---|
| mean | 127 | 122 | 130 | 158 |
| median | 123 | 117 | 125 | 152 |
| SD | 31 | 30 | 30 | 36 |

In order to check how duration interacts with vowels that undergo vowel harmony, a Generalized Linear Model was run to test if C1-Duration may be predicted by dialect, gender, C1 place of articulation and also by the target vowel (V1). The results may be seen in Table A.4 below.

*Table A.4. GLM Regression model for duration of the first consonants (C1).*

| | $\chi^2$ | df | p-value |
|---|---|---|---|
| (Intercept) | 0.012 | 1 | 0.911 |
| Dialect | 1.110 | 1 | 0.292 |
| Gender | 8793.48 | 1 | >0.001 |
| C1 – Place | 519.34 | 3 | >0.001 |
| V1 | 541.58 | 4 | >0.001 |

The most interesting fact is that dialect is not a significant variable to explain C1 duration. This result is interesting because it indicates that the difference between the dialects lies more in vowels than in consonants. C1 duration mean is significantly different according to gender, C1 place of articulation and V1. It can be noted that the longest consonant is the affricate, whereas the duration of the three stops lies within ≈120ms each. Tukey's post-hoc test does not return any significant value for the comparisons, which suggests that the mean duration of C1 is not different among the four consonants in C1. This result is seen as follows.

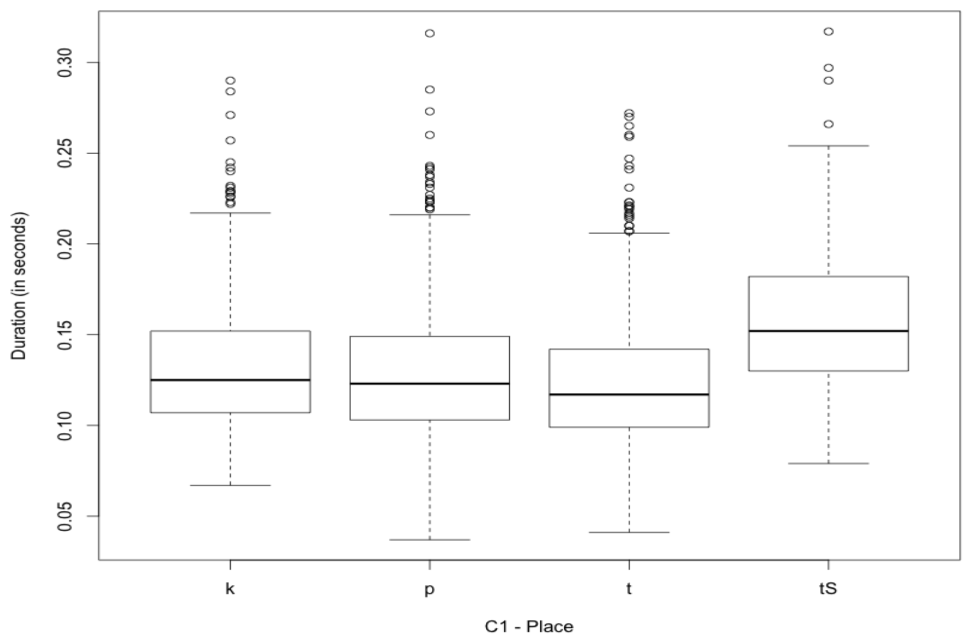



Figure A.3. Duration of the pre-stressed vowels according to the four consonants in C1.

Duration is also a cue in many languages to discriminate voiced from voiceless stops in the context of final voice neutralization. In such cases, vowels tend to be longer before voiced consonants than before voiceless ones. As the duration of stops may be explained by the quality of the next vowel that immediately follows the consonant, it is interesting to investigate how vowels influence duration when they are in the syllable onset.

To visualize how stop duration and vowels are linked to each other, Figure A.4 shows duration as a function of the second formant of each pre-stressed vowel. The goal of the figure is to show as clearly as possible how duration is affected by the quality of the next vowel and by dialect in the same plot.

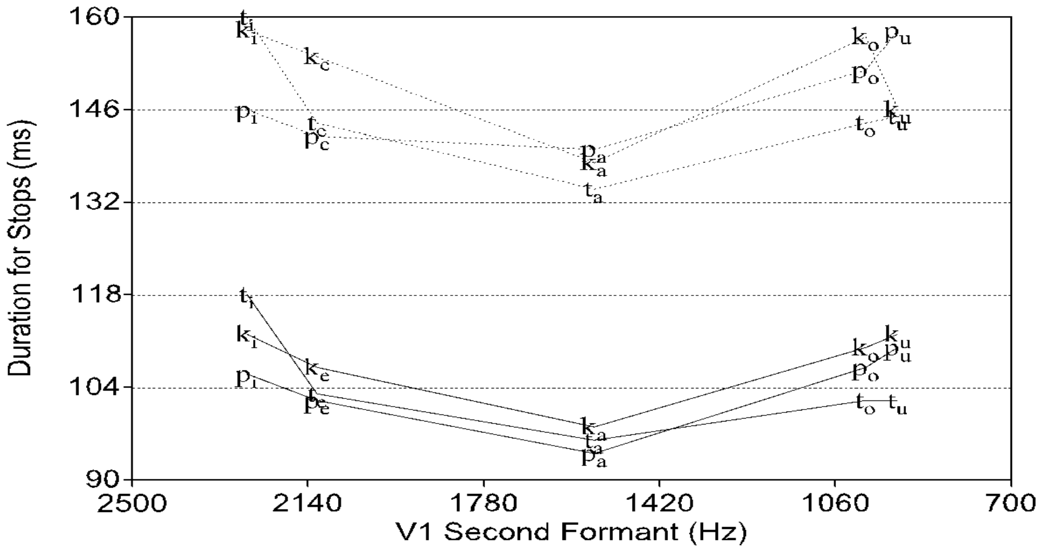



*Figure A.4. Median duration for C1 consonants as a function of vowel category. The values of F2 are the median of each vowel category in the dialects. The purpose of inserting F2 information is to provide vowel space shape. Solid lines stand for Gaucho; dashed stand for Baiano.*

As far as gender is concerned, female speakers produce longer consonants than male speakers, and the ratio of their geometric mean is 1.41. However, regardless of the gender difference, one might notice that both genders present the same tendency for C-to-V association: consonant duration decreases directly with the height of the next vowel. Therefore, one can notice in the plot that consonant duration is directly proportional to vowel height, i.e., the higher the vowel, the greater the consonant duration. In a certain way, one can speculate whether there is a sort of compensation between consonants and vowels within a syllable. As previously known, vowels have intrinsic duration (inversely proportional to height), which means that low vowels are longer than high vowels (see Fowler 1992). Therefore, one might hypothesize that in order to keep the same syllable timing the longest vowels should associate with the shortest consonant. As our goal is to describe C1 duration, this issue will not be discussed but it is a hypothesis of how a syllable as a phonological unit distributes its timing within constituents.

### 10.3.2 A.3.2 C2 – The Intervening Consonant

The duration results for consonants in C2 position reveal statically significant results of duration predicted by the four factors Class C2, V2, dialect and gender. For this reason, a single plot will be presented for stops, separated by dialect; and for liquids, the results will be presented for each consonant. The factorial ANOVA yielded main effect for dialect ($\eta^2$=0.0088, F[1,7885]=198.41; $p<0.001$), gender ($\eta^2$=0.2830, F[1,7885]=9058.30; $p<0.001$), Class C2 ($\eta^2$=0.3360, F[7,7885]=1512.75; $p<0.001$), V2 ($\eta^2$=0.0051,F[6,7885]=26.06;$p<0.001$). The multiple interaction analysis of variance showed significant results for interactions between gender and C2 ($\eta^2$=0.0806, F[7,7885]=366.31; $p<0.001$), and dialect and Class C2 ($\eta^2$=0.0212, F[7,7885]=94.46; $p<0.001$).

Figure A.5 shows results for stops duration, with information about the duration of all stops as a function of the following stressed vowel (V2). The pattern found for pre-stressed consonants and their relation with the next vowel within the same syllables seem to remain in stressed position, but the effect size is not strong ($\eta^2$=0.0051).

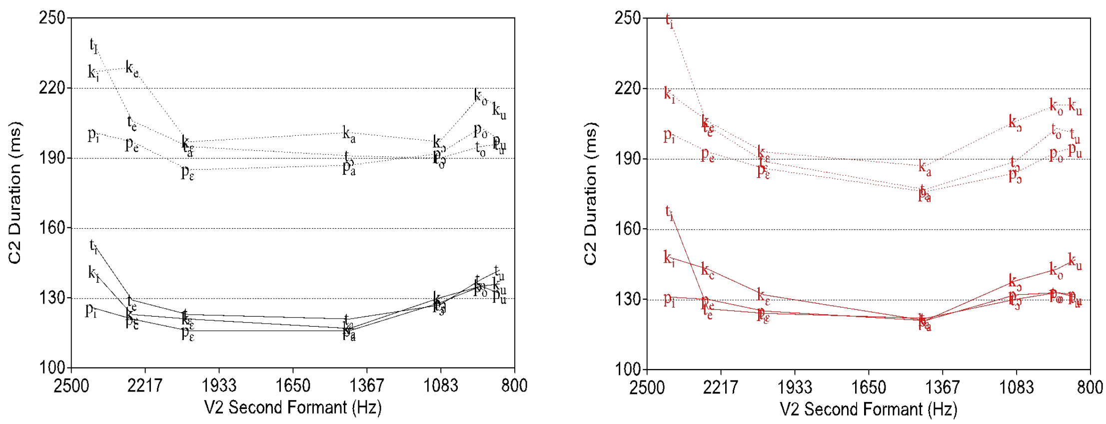



*Figure A.5. Median duration for C2 consonants as a function of vowel category. The values of F2 are the median of each vowel category in the dialects. Black lines in the left panel stand for Gaucho; red lines in the right panel stand for Baiano; dotted lines=females, solid lines=males.*

As shown in the plots above, males and females have significant different duration values (c.i.=-1.1010, -1.0566; $p<0.001$), and this result has been consistent through all durational analysis. However, although dialect has returned significant difference, a Tukey's HSD post-hoc revealed no significant interactions among the pairs for cross-dialect analysis.

The same stop phoneme tended to present the same duration in both dialects. Comparisons between Gaucho and Baiano /p/ returned no significant results (c.i.=-0.0448, 0.1650; p=0.84); /t/ had a similar result (c.i.=-0.0085, 0.2210; p=0.10); and also did /k/ (c.i.=-0.0980, 0.1147, p=1.0), which means that the difference lies in gender and vowels.

The duration pattern of liquids is totally different for each segment and dialect. Within the group of liquids, laterals are vowel-like segments, hence it was expected that these consonants would be more affected by the following vowel than rhotics. For liquids, Tukey's HSD post-hoc test revealed significant (only at 0.05 level) difference in dialect (c.i.=-0.1998, -0.0005; p=0.047) while there was a more reliable interaction with gender (c.i.=-1.2012,-1.0016, p<0.001).

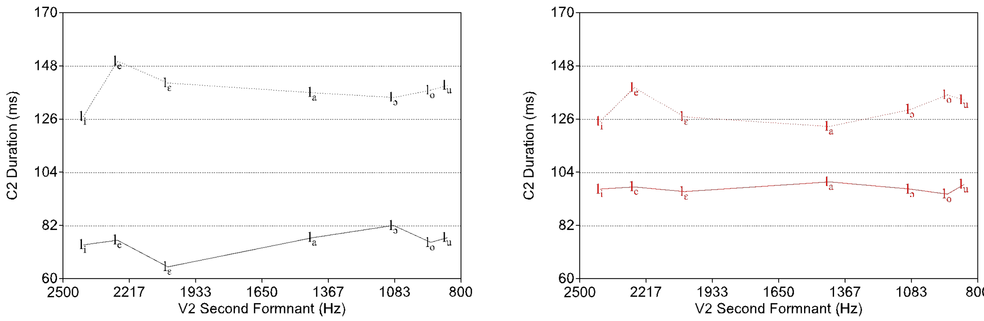



*Figure A.6.* Median duration for the lateral /l/ in C2 as a function of vowel category. The values of F2 are the median of each vowel category in the dialects. Black lines in the left panel stand for Gaucho; red lines in right panel stand for Baiano; dotted lines=males, solid lines=females.

Regarding the palatal phoneme /ʎ/, the duration pattern is different not only for dialect but also for gender, as can be seen in the plots below. It seems that Gaucho has the same duration pattern presented in /l/, while for Baiano speakers there is no difference in terms of gender. (see Silva 2002, for discussion on liquids duration)

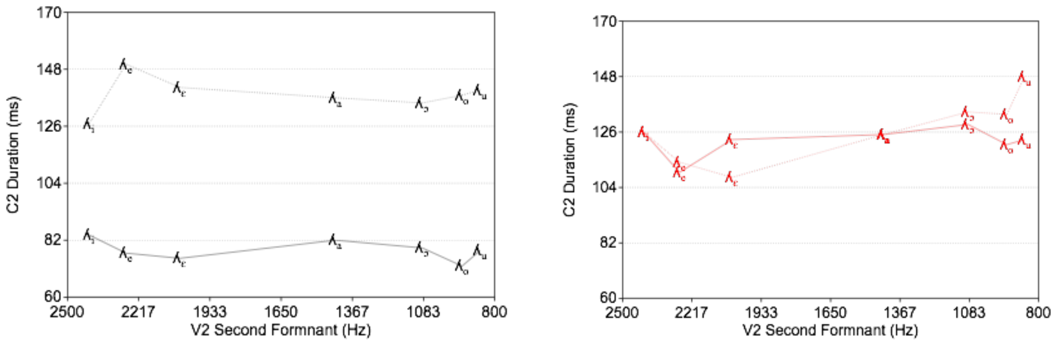


*Figure A.7.* Median duration for the lateral /ʎ/ in C2 as a function of vowel category. The values of F2 are the median of each vowel category in the dialects. Black lines in the left panel stand for Gaucho; red lines in right panel stand for Baiano; dotted lines=females, solid lines=males.

Tukey's HSD post-hoc test revealed a significant difference between Baiano and Gaucho /ʎ/ (c.i.=-0.4288,-0.2248; p<0.001). However, Baiano's /ʎ/ did not show a significant difference for duration in interactions with gender (c.i.=-0.2123, 0.0555; p=0.8220).

These findings about /ʎ/ could be tracked on the large difference reported cross-dialect on the production of this lateral phoneme. Many studies have reported that /ʎ/ presents a large variation, and is freely produced as [lʲ] and [ʎ] (Cristófaro-Silva, 1999:148). This variation could explain the different patterns between the dialects and be the reason why Gaucho's /ʎ/ shows duration values similar to those of /l/ for the same dialect. A pairwise comparison for Gaucho /l-ʎ/ does not suggest any difference at all (c.i.=-0.0706, 0.1311; p=0.999). This issue will not be discussed deeply, but it is a suggestion for further research on the variation of these segments.

A similar pattern is seen for tap in both dialects, which do not show a significant difference in a pairwise comparison for the variables dialect (c.i.=-0.0401, 0.1594; p=0.797) and gender (c.i.=-0.140, 0.0589; p=0.991). As can be seen in the plots below, tap shows duration near ≈40ms in Gaucho and Baiano for male and female speakers.

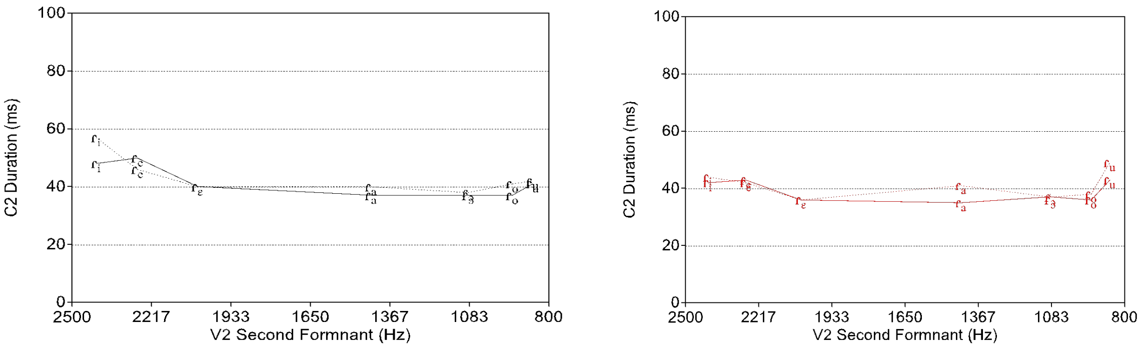



*Figure A.8.* Median duration for the tap /ɾ/ in C2 as a function of vowel category. The values of F2 are the median of each vowel category in the dialects. Black lines in the left panel stand for Gaucho; red lines in the right panel stand for Baiano; dotted lines=females, solid lines=males.

This result confirms what is found in many languages about tap duration (Ladefoged, 2001). Previous studies in Brazilian Portuguese suggest that the duration of /ɾ/ is close to 23ms and its duration is not dependent on the quality of the next vowel (Silva 2002:72).

Based on the family of rothic consonants, some researchers assume that BP has an opposition between /ɾ/ and the trill /r/ (Camara Jr., 1962, 1970). The trill production is not productive and in many BP dialects this segment is debucalized, being realized as the glottal voiced fricative. Many proposals have appeared, including germination (Monaretto, 1992), Abaurre and Sandalo (2003), Harris (2002). The status of the underlying phoneme[39] is not on debate here, but rather its realization in our data, which is the velar or glottal voiced fricative.

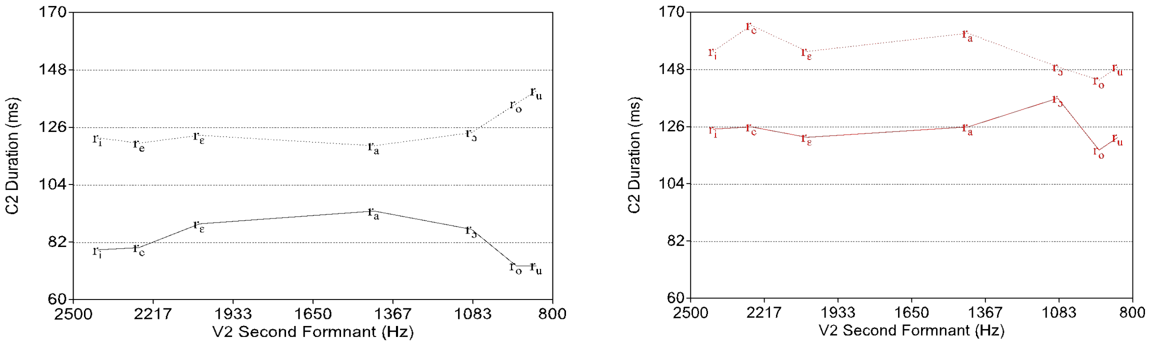



*Figure A.9.* Median duration for the phoneme /r/ in C2 as a function of vowel category. The values of F2 are the median of each vowel category in the dialects. Black lines in the left panel stand for Gaucho; red lines in right panel stand for Baiano; dotted lines=females, solid lines=males.

The phoneme /r/ shows a significant difference for gender (c.i.=-0.9433, -0.7403; $p<0.001$) and dialect (c.i.=-0.8708, -0.6680; $p<0.001$). As can be seen in the plots, duration of /r/ can be split into two ranges, from ≈60ms to ≈128ms in Gaucho and from ≈128ms to ≈170ms in Baiano. A possible explanation for this pattern could lie in the place of articulation, which is not under investigation here, but it could be an important cue for distinguishing these phonetic realizations of the BP rhotic phoneme.

[39]For the sake of simplification of report results, I assume that the phoneme is the trill /r/.

## 11 APPENDIX B – PRAAT SCRIPT: ADD FORMANTS

```
# Praat script AddFormants.praat
# Paul Boersma, April 25, 2006
# Modified in September, 2010

Read Table from table file... tableNova.txt
numberOfRows = Get number of rows
assert numberOfRows = 14
previousSpeaker$ = ""
for row to numberOfRows
	speaker$ = Get value... row speaker
	gender$ = Get value... row gender
	start = Get value... row start
	end = Get value... row end
	#
	# Seja econômico com espaço na memória.
	#
	if speaker$ <> previousSpeaker$
		if previousSpeaker$ <> ""
			select Sound 'previousSpeaker$'
			Remove
		endif
		Read from file... 'speaker$'.wav
		previousSpeaker$ = speaker$
	else
		select Sound 'speaker$'
	endif
	#
	# Formant analysis.
	#
	formantCeiling = if gender$ = "M" then 5000 else 5500 fi
	duration = end - start
	mid = start + duration / 2
	startpart = mid - duration / 5
	endpart = mid + duration / 5
	Extract part... startpart endpart Rectangular 1.0 no
	Rename... segment
	windowLength = Get total duration
	To Formant (burg)... 0 5 formantCeiling windowLength 50
	for iformant to 3
		f'iformant' = Get value at time... iformant windowLength/2 Hertz Linear
		b'iformant' = Get bandwidth at time... iformant windowLength/2 Hertz Linear
	endfor
	plus Sound segment
	Remove
	#
	# Save results in tableNova.
	#
```

```
        select Table tableNova
        for iformant to 3
                formant = if f'iformant' = undefined then 0 else f'iformant' fi
                bandwidth = if b'iformant' = undefined then 0 else b'iformant' fi
                Set string value... row F'iformant' 'formant:0'
                Set string value... row B'iformant' 'bandwidth:0'
        endfor
endfor
Write to table file... tableNova.txt
select Sound 'previousSpeaker$'
Remove
```

# 12 APPENDIX C – QUESTIONNAIRE

**Questionário para selecionar participantes para um estudo sobre o português brasileiro**

Data: _____/_____/_____
Nome: ____________________________________________________________
Fone: ____________________________________________________________
E-mail: ____________________________________________________
Idade: ________________ Local e data de nascimento: ____________________
Profissão: __________________________________________________________
Se estudante universitário, em que fase está: _____________________________
Nome do curso: __________________

1) Relacione as cidades e países para os quais você tenha viajado ou nos quais tenha morado por mais de quatro semanas desde que nasceu:
Cidade e país: _____________________, Duração da estadia: __________________
Cidade e país: _____________________, Duração da estadia: __________________
Cidade e país: _____________________, Duração da estadia: __________________

2) Onde os seus pais nasceram? Mencione a cidade.
a) Mãe: ______________________ b) Pai: ________________________

3) Na sua casa se fala outro(s) idioma(s) além do português? ___________
Especifique qual(is) idioma(s): ___________________________________________________

4) No momento, você estuda algum idioma?
Especifique o(s) idioma(s) e nível (iniciante, intermediário, avançado):
Idioma: ________________, Nível: _____________
Idioma: ________________, Nível: _____________

Se você não respondeu as questões 3 e 4, pule para a questão 9.

5) Onde estuda o(s) idioma(s)? (Por exemplo: colégio, cursinho de idiomas, aulas particulares, etc.)
Idioma: ________________, Lugar: ________________________________________
Idioma: ________________, Lugar: ________________________________________

6) Quantas horas por semana você estuda o(s) idioma(s)?

Idioma: ________________, Horas por semana: _____________

Idioma: ________________, Horas por semana: _____________

7) Já estudou outro(s) idioma(s) anteriormente? ______________

Especifique qual(is) idioma(s): __________________________________________________

8) Que idade tinha quando começou a estudar outro(s) idioma(s)?

Idioma: ________________, Idade: _____________

Idioma: ________________, Idade: _____________

Idioma: ________________, Idade: _____________

9) Você identifica o seu sotaque com a sua cidade natal? Se não, especifique o local.

__________________________________________________

10) Você reside atualmente em sua cidade natal? Se não, especifique a cidade e estime quanto tempo você mora na sua residência atual.

__________________________________________________

# 13 APPENDIX C – INFORMED CONSENT FORM

UNIVERSIDADE ESTADUAL DE CAMPINAS
INSTITUTO DE ESTUDOS DA LINGUAGEM
TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Nome do(a) Participante:________________________________________________________
Endereço: ______________________________________________________________________
Cidade: _______ Estado: ___ CEP: _______________ Telefone: (____)________
Nome do Pesquisador Principal: Magnun Rochel Madruga
Orientador: Maria Bernadete Marques Abaurre
Instituição: Instituto de Estudos da Linguagem, Universidade Estadual de Campinas

Prezado Voluntário,

Convidamos o(a) Sr.(a) para participar da pesquisa "**A produção e a percepção da harmonia e da redução vocálica no Português Brasileiro: o papel das pistas fonéticas em gramáticas baseadas em restrições**", sob a responsabilidade do pesquisador Magnun Rochel Madruga, doutorando em Linguística/IEL/UNICAMP. O estudo tem como objetivo geral investigar o papel das pistas fonéticas na organização gramática do falante, especialmente na produção e a percepção de palavras em que ocorrem o processo de Harmonia Vocálica. Sua participação na pesquisa é voluntária e sua tarefa consistirá na leitura de frases e também no julgamento de dados linguísticos através de testes de percepção. Como nessas duas tarefas não se utiliza nenhum método invasivo e o material utilizado é de seu uso cotidiano – computador, fones de ouvido e microfone –, os riscos decorrentes de sua participação na pesquisa são mínimos. A sessão de coleta de dados não ultrapassará 30 minutos. Ainda, caso considere algum desconforto e risco mínimo para o(a) Sr(a), é soberana sua decisão em desistir de participar da pesquisa a qualquer tempo. Se aceitar participar, estará contribuindo para o melhor entendimento da relação produção/percepção da fala, bem como para o avanço das pesquisas em Linguística. Ressalta-se, porém, que não haverá qualquer forma de reembolso em virtude de sua participação na pesquisa, visto que as sessões de coleta de dados ocorrerão nos dias e horários em que o Sr(a) já estiver na UNICAMP para a realização alguma atividade no *campus*, local em que será realizada a pesquisa. Se depois de consentir em sua participação, o Sr(a). desistir de continuar participando, tem o direito e a liberdade de retirar seu consentimento em qualquer fase da pesquisa, seja antes ou depois da coleta dos dados, independente do motivo e sem nenhum prejuízo a sua pessoa. Os resultados da pesquisa serão analisados e publicados, mas sua identidade não será divulgada, sendo guardada em sigilo. Esses resultados serão armazenados pelo pesquisador e poderão ser requeridos pelo Sr(a) a qualquer tempo, independente do término ou não da pesquisa. Para quaisquer denúncias ou reclamações, o(a) Sr(a) poderá entrar em contato com o pesquisador no endereço Rua Antonio Augusto de Almeida, 578, ou pelo telefone (19) 981940374, ou poderá entrar em contato com o Comitê de Ética em Pesquisa/FCM/UNICAMP, cujos dados para contato são: Rua: Tessália Vieira de Camargo, 126 – CEP 13083-887 Campinas – SP; Fone (019) 3521-8936 ou 3521-7187 e-mail: cep@fcm.unicamp.br.

**Consentimento Pós–Informação** Eu,_____________________________________________________________, fui informado sobre a finalidade e a necessidade da minha colaboração na pesquisa e entendi a explicação. Por isso, concordo em participar do projeto, sabendo que não perceberei qualquer auxílio financeiro e que posso desistir a qualquer tempo. Este documento é emitido em duas vias, que serão ambas assinadas por mim e pelo pesquisador, ficando uma via com o pesquisador e outra com o participante.

_____________________________ Data: ___/ ____/

Assinatura do participante Assinatura do Pesquisador ResponsáveL

# 14 APPENDIX D – VGLM RESULTS

## 14.1 Results on Bisol (1891) Dataset

The models presented in this appendix were ran with the VGAM package in R (Thomas and Yee 2013; Thomas, Yee, Stoklosa and Huggins 2015) .

### 14.1.1 Baselines for each variable in the model

| V1 | V2 | Place C1 | Place C2 | Class C1 | Class C2 |
|---|---|---|---|---|---|
| i | a | Labial | Labial | Stop | Stop |

**Baseline 1** V1 = u
**Baseline 2** V1 = e
**Baseline 3** V1 = o

### 14.1.2 Formula

Call:

*vglm(formula = V1 ~ V2 + PlaceC1 + PlaceC2 + ClassC1 + ClassC2, family = "multinomial", data = bisol81)*

### 14.1.3 Summary

Coefficients:

| | Estimate | Std. Error | z value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept):1 | 2,78658 | 0,42665 | 6,531 | 6,52e-11 *** |
| (Intercept):2 | -1.295.665 | 341,28131 | -0,038 | 0,969716 |
| (Intercept):3 | 2,45842 | 0,35106 | 7,003 | 2,51e-12 *** |
| V2e:1 | 4,66034 | 1,08387 | 4,3 | 1,71e-05 *** |
| V2e:2 | 18,4179 | 341,28286 | 0,054 | 0,956962 |
| V2e:3 | 2,73719 | 1,03579 | 2,643 | 0,008227 ** |
| V2.E:1 | 2,17841 | 0,36514 | 5,966 | 2,43e-09 *** |
| V2.E:2 | 12,96071 | 341,28157 | 0,038 | 0,969706 |
| V2.E:3 | 1,55005 | 0,26831 | 5,777 | 7,60e-09 *** |
| V2.O:1 | 1,59657 | 0,33694 | 4,738 | 2,15e-06 *** |
| V2.O:2 | 13,91794 | 341,28127 | 0,041 | 0,96747 |
| V2.O:3 | 0,47387 | 0,22156 | 2,139 | 0,032450 * |
| V2o:1 | 0,73832 | 0,32728 | 2,256 | 0,024075 * |
| V2o:2 | 15,8199 | 341,28116 | 0,046 | 0,963028 |
| V2o:3 | -0,48029 | 0,21397 | -2,245 | 0,024792 * |

| | | | | |
|---|---|---|---|---|
| V2u:1 | 4,9716 | 1,05571 | 4,709 | 2,49e-06 *** |
| V2u:2 | 17,45401 | 341,28282 | 0,051 | 0,959212 |
| V2u:3 | 3,54084 | 1,02343 | 3,46 | 0,000541 *** |
| V2i:1 | 0,56528 | 0,36049 | 1,568 | 0,116861 |
| V2i:2 | 14,49893 | 341,28125 | 0,042 | 0,966113 |
| V2i:3 | -0,7157 | 0,24372 | -2,937 | 0,003319 ** |
| PlaceC1Coronal:1 | -4,53536 | 0,26525 | -17.099 | < 2e-16 *** |
| PlaceC1Coronal:2 | -3,79152 | 0,39681 | -9,555 | < 2e-16 *** |
| PlaceC1Coronal:3 | -0,75204 | 0,21222 | -3,544 | 0,000395 *** |
| PlaceC1Palatal:1 | -1,21523 | 0,20879 | -5,82 | 5,88e-09 *** |
| PlaceC1Palatal:2 | -1,04564 | 0,24565 | -4,257 | 2,08e-05 *** |
| PlaceC1Palatal:3 | -0,85312 | 0,21188 | -4,026 | 5,66e-05 *** |
| PlaceC1Dorsal:1 | -0,16863 | 0,63402 | -0,266 | 0,790265 |
| PlaceC1Dorsal:2 | -0,63284 | 0,73097 | -0,866 | 0,386619 |
| PlaceC1Dorsal:3 | 0,23445 | 0,63825 | 0,367 | 0,713371 |
| PlaceC2Coronal:1 | -0,43239 | 0,25074 | -1,724 | 0,084621 , |
| PlaceC2Coronal:2 | 0,08261 | 0,3025 | 0,273 | 0,784773 |
| PlaceC2Coronal:3 | -0,50096 | 0,24575 | -2,038 | 0,041501 * |
| PlaceC2Palatal:1 | -0,5881 | 0,1702 | -3,455 | 0,000550 *** |
| PlaceC2Palatal:2 | -1,33291 | 0,26382 | -5,052 | 4,36e-07 *** |
| PlaceC2Palatal:3 | -0,35959 | 0,15325 | -2,346 | 0,018956 * |
| PlaceC2Dorsal:1 | -0,5034 | 0,29037 | -1,734 | 0,082976 , |
| PlaceC2Dorsal:2 | -0,14532 | 0,4028 | -0,361 | 0,718262 |
| PlaceC2Dorsal:3 | -0,89425 | 0,23399 | -3,822 | 0,000132 *** |
| ClassC1Fricative:1 | -0,35337 | 0,63905 | -0,553 | 0,580296 |
| ClassC1Fricative:2 | -0,51686 | 0,68438 | -0,755 | 0,450117 |
| ClassC1Fricative:3 | -0,21337 | 0,65118 | -0,328 | 0,743168 |
| ClassC1Nasal:1 | -0,97406 | 0,27517 | -3,54 | 0,000400 *** |
| ClassC1Nasal:2 | -0,99685 | 0,31687 | -3,146 | 0,001656 ** |
| ClassC1Nasal:3 | -0,29986 | 0,27688 | -1,083 | 0,278808 |
| ClassC1Lateral:1 | 4,81962 | 0,58878 | 8,186 | 2,71e-16 *** |
| ClassC1Lateral:2 | 3,44613 | 0,68054 | 5,064 | 4,11e-07 *** |
| ClassC1Lateral:3 | 0,67872 | 0,57911 | 1,172 | 0,241193 |
| ClassC1Rhotics:1 | -0,84002 | 0,21713 | -3,869 | 0,000109 *** |
| ClassC1Rhotics:2 | -1,51719 | 0,25425 | -5,967 | 2,41e-09 *** |
| ClassC1Rhotics:3 | -0,6733 | 0,22265 | -3,024 | 0,002494 ** |
| ClassC2Fricative:1 | -0,64776 | 0,26408 | -2,453 | 0,014173 * |
| ClassC2Fricative:2 | -0,47939 | 0,35547 | -1,349 | 0,177464 |
| ClassC2Fricative:3 | 0,04339 | 0,24286 | 0,179 | 0,858194 |
| ClassC2Nasal:1 | -1,68215 | 0,20339 | -8,271 | < 2e-16 *** |
| ClassC2Nasal:2 | -0,80658 | 0,29806 | -2,706 | 0,006808 ** |
| ClassC2Nasal:3 | -0,57718 | 0,17785 | -3,245 | 0,001173 ** |
| ClassC2Lateral:1 | 0,53955 | 0,30224 | 1,785 | 0,074234 , |
| ClassC2Lateral:2 | 0,5716 | 0,3693 | 1,548 | 0,121673 |
| ClassC2Lateral:3 | 0,97729 | 0,29179 | 3,349 | 0,000810 *** |

| | | | | |
|---|---|---|---|---|
| ClassC2Rhotics:1 | -0,17567 | 0,17881 | -0,982 | 0,32586 |
| ClassC2Rhotics:2 | 0,32922 | 0,24389 | 1,35 | 0,177048 |
| ClassC2Rhotics:3 | 0,18169 | 0,16457 | 1,104 | 0,269582 |

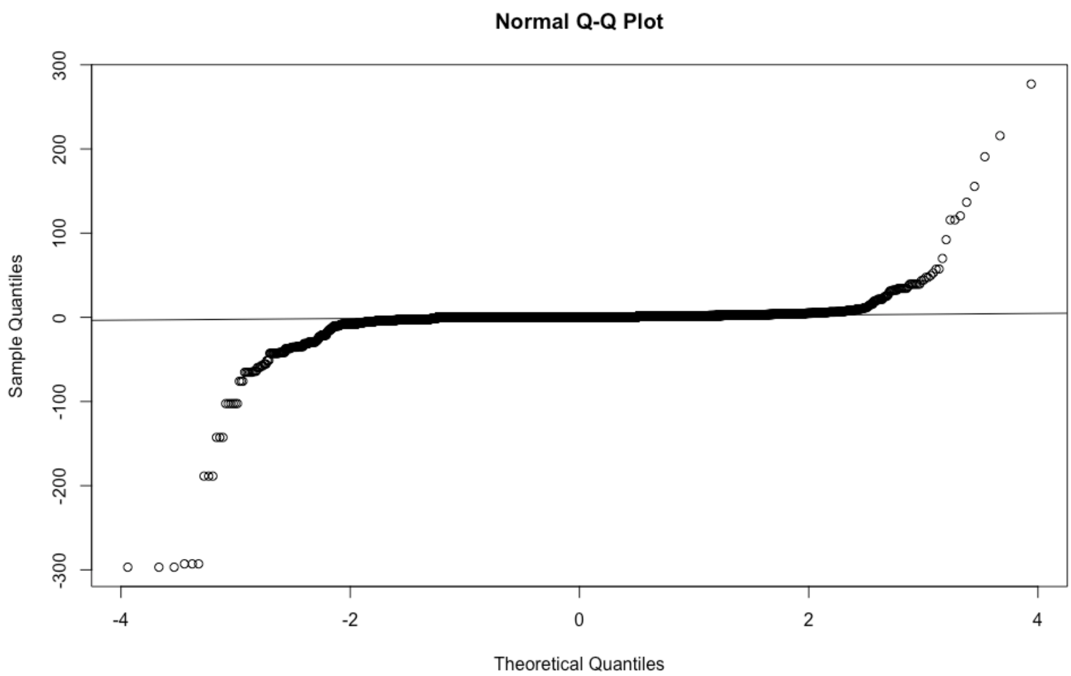
Number of linear predictors: 3
Residual deviance: 7125.868 on 12258 degrees of freedom
Log-likelihood: -3562.934 on 12258 degrees of freedom
Number of iterations: 16
Reference group is level 4 of the response

### 14.1.4 Analysis of Deviance

Analysis of Deviance Table (Type II tests)

| | Df | Chisq | Pr(>Chisq) |
|---|---|---|---|
| Stressed Vowel | 18 | 412.48 | <2.2e-16 |
| Place C1 | 9 | 459.49 | <2.2e-16 |
| Place C2 | 9 | 53.96 | 1.92e-08 |
| Class C1 | 12 | 424.88 | <2.2e-16 |
| Class C2 | 12 | 117.79 | <2.2e-16 |

### 14.1.5 QQ Plot for Residuals




## 14.2 Results on Barbosa da Silva (1989) Dataset

### 14.2.1 Baselines for each variable in the model

| V1 | V2 | Place C1 | Place C2 | Class C1 | Class C2 |
|---|---|---|---|---|---|
| i | a | Labial | Labial | Stop | Stop |

**Baseline 1** V1 = e
**Baseline 2** V1 = ɛ (= .E)
**Baseline 3** V1 = ɔ (= .O)
**Baseline 4** V1 = o
**Baseline 5** V1 = u

### 14.2.2 Formula

Call:

*vglm(formula = V1 ~ V2 + PlaceC1 + PlaceC2 + ClassC1 + ClassC2, family = "multinomial", data = bdasilva89)*

### 14.2.3 Summary

| | Estimate | Std. Error | z value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept):1 | 3.02908 | 0.84969 | 3.565 | 0.000364 *** |
| (Intercept):2 | 1.67221 | 0.86217 | 1.94 | 0.052436 . |
| (Intercept):3 | 0.31067 | 1.31309 | 0.237 | 0.812974 |
| (Intercept):4 | 0.59536 | 1.32793 | 0.448 | 0.653908 |
| (Intercept):5 | 1.17056 | 0.97584 | 1.2 | 0.230322 |
| V2e:1 | 17.32921 | 1761.3743 | 0.01 | 0.99215 |
| V2e:2 | 17.44422 | 1761.37428 | 0.01 | 0.992098 |
| V2e:3 | 0.55375 | 3283.69869 | 0 | 0.999865 |
| V2e:4 | 0,71886 | 3256,8907 | 0 | 0.999824 |
| V2e:5 | 16,16188 | 1761,37457 | 0.009 | 0.992679 |
| V2.E:1 | 0,58234 | 0,78044 | 0,746 | 0,455566 |
| V2.E:2 | 1,62461 | 0,76367 | 2,127 | 0,033389 * |
| V2.E:3 | 1,40995 | 1,27849 | 1,103 | 0,270104 |
| V2.E:4 | -15,25714 | 667,77825 | -0,023 | 0,981772 |
| V2.E:5 | -0,1587 | 0,92522 | -0,172 | 0,863807 |
| V2.O:1 | -0,3233 | 0,76871 | -0,421 | 0,674066 |
| V2.O:2 | -0,41272 | 0,76305 | -0,541 | 0,58859 |
| V2.O:3 | 2,70614 | 1,24944 | 2,166 | 0,030320 * |
| V2.O:4 | 0,83729 | 1,30617 | 0,641 | 0,521503 |
| V2.O:5 | 0,48841 | 0,86683 | 0,563 | 0,573131 |
| V2o:1 | -1,99345 | 0,71531 | -2,787 | 0,005323 ** |
| V2o:2 | -1,60128 | 0,71163 | -2,25 | 0,024440 * |
| V2o:3 | 0,20092 | 1,22205 | 0,164 | 0,869404 |
| V2o:4 | 0,97774 | 1,22965 | 0,795 | 0,426536 |
| V2o:5 | -0,98158 | 0,82092 | -1,196 | 0,23181 |
| V2u:1 | 0,34921 | 1,24489 | 0,281 | 0,779079 |
| V2u:2 | 0,56289 | 1,25262 | 0,449 | 0,653166 |
| V2u:3 | 3,10727 | 1,59272 | 1,951 | 0,051066 , |
| V2u:4 | -14,40148 | 1251,34357 | -0,012 | 0,990817 |
| V2u:5 | 2,65676 | 1,27724 | 2,08 | 0,037518 * |
| V2i:1 | -2,09545 | 0,79414 | -2,639 | 0,008324 ** |

| | | | | |
|---|---|---|---|---|
| V2i:2 | -1,00506 | 0,76101 | -1,321 | 0,186605 |
| V2i:3 | -0,72093 | 1,37204 | -0,525 | 0,599276 |
| V2i:4 | -0,0814 | 1,32117 | -0,062 | 0,950869 |
| V2i:5 | -0,38894 | 0,88786 | -0,438 | 0,66134 |
| PlaceC1Coronal:1 | -3,73235 | 0,5509 | -6,775 | 1,24e-11 *** |
| PlaceC1Coronal:2 | -0,83803 | 0,512 | -1,637 | 0,101679 |
| PlaceC1Coronal:3 | -4,04923 | 0,66518 | -6,087 | 1,15e-09 *** |
| PlaceC1Coronal:4 | -3,25566 | 0,76852 | -4,236 | 2,27e-05 *** |
| PlaceC1Coronal:5 | -1,01347 | 0,5625 | -1,802 | 0,071589 , |
| PlaceC1Palatal:1 | -0,30662 | 0,37239 | -0,823 | 0,410285 |
| PlaceC1Palatal:2 | -0,27731 | 0,39404 | -0,704 | 0,481576 |
| PlaceC1Palatal:3 | -0,53704 | 0,41013 | -1,309 | 0,190381 |
| PlaceC1Palatal:4 | -0,37441 | 0,43756 | -0,856 | 0,39218 |
| PlaceC1Palatal:5 | -0,1138 | 0,43387 | -0,262 | 0,79309 |
| PlaceC1Dorsal:1 | -1,41148 | 0,91006 | -1,551 | 0,120909 |
| PlaceC1Dorsal:2 | -1,16245 | 0,94712 | -1,227 | 0,21969 |
| PlaceC1Dorsal:3 | -1,85396 | 1,06848 | -1,735 | 0,082717 , |
| PlaceC1Dorsal:4 | -1,85811 | 1,33282 | -1,394 | 0,163283 |
| PlaceC1Dorsal:5 | -1,0724 | 1,1513 | -0,931 | 0,351612 |
| PlaceC2Coronal:1 | 0,01917 | 0,47761 | 0,04 | 0,967977 |
| PlaceC2Coronal:2 | -0,50621 | 0,49809 | -1,016 | 0,30948 |
| PlaceC2Coronal:3 | 0,08521 | 0,54844 | 0,155 | 0,876533 |
| PlaceC2Coronal:4 | 1,10581 | 0,56701 | 1,95 | 0,051147 , |
| PlaceC2Coronal:5 | -0,30916 | 0,54384 | -0,568 | 0,569715 |
| PlaceC2Palatal:1 | 0,97119 | 0,44198 | 2,197 | 0,027994 * |
| PlaceC2Palatal:2 | 0,73486 | 0,45482 | 1,616 | 0,106158 |
| PlaceC2Palatal:3 | 0,97893 | 0,47497 | 2,061 | 0,039297 * |
| PlaceC2Palatal:4 | 0,22005 | 0,54822 | 0,401 | 0,688127 |
| PlaceC2Palatal:5 | -0,39446 | 0,51823 | -0,761 | 0,446557 |
| PlaceC2Dorsal:1 | 0,48606 | 0,74038 | 0,657 | 0,511498 |
| PlaceC2Dorsal:2 | -1,41488 | 0,88813 | -1,593 | 0,111136 |
| PlaceC2Dorsal:3 | 0,89752 | 0,8026 | 1,118 | 0,263452 |
| PlaceC2Dorsal:4 | 0,47634 | 1,02924 | 0,463 | 0,6435 |
| PlaceC2Dorsal:5 | -0,44308 | 0,83326 | -0,532 | 0,594908 |
| ClassC1Fricative:1 | 0,31074 | 1,14591 | 0,271 | 0,786257 |
| ClassC1Fricative:2 | -0,8242 | 1,2843 | -0,642 | 0,521037 |
| ClassC1Fricative:3 | 0,09501 | 1,19981 | 0,079 | 0,936882 |
| ClassC1Fricative:4 | -17,42381 | 1640,30122 | -0,011 | 0,991525 |
| ClassC1Fricative:5 | 0,95846 | 1,22919 | 0,78 | 0,435539 |
| ClassC1Nasal:1 | -2,27015 | 0,54382 | -4,174 | 2,99e-05 *** |
| ClassC1Nasal:2 | -1,13135 | 0,54768 | -2,066 | 0,038856 * |
| ClassC1Nasal:3 | -1,69383 | 0,60709 | -2,79 | 0,005270 ** |

| | | | | |
|---|---|---|---|---|
| ClassC1Nasal:4 | -1,9285 | 0,63989 | -3,014 | 0,002580 ** |
| ClassC1Nasal:5 | -0,54176 | 0,59771 | -0,906 | 0,364722 |
| ClassC1Lateral:1 | 1,92881 | 1,00276 | 1,924 | 0,054417 , |
| ClassC1Lateral:2 | -0,26644 | 1,04154 | -0,256 | 0,798093 |
| ClassC1Lateral:3 | 2,08895 | 1,08602 | 1,923 | 0,054418 , |
| ClassC1Lateral:4 | 2,26302 | 1,12732 | 2,007 | 0,044704 * |
| ClassC1Lateral:5 | 0,96633 | 1,08586 | 0,89 | 0,373511 |
| ClassC1Rhotics:1 | -0,6335 | 0,45473 | -1,393 | 0,163578 |
| ClassC1Rhotics:2 | -0,92358 | 0,48293 | -1,912 | 0,055821 , |
| ClassC1Rhotics:3 | -0,27283 | 0,49259 | -0,554 | 0,579661 |
| ClassC1Rhotics:4 | -0,96227 | 0,50458 | -1,907 | 0,056514 , |
| ClassC1Rhotics:5 | -0,66128 | 0,5341 | -1,238 | 0,215672 |
| ClassC2Fricative:1 | 0,5462 | 0,53508 | 1,021 | 0,307358 |
| ClassC2Fricative:2 | 0,91645 | 0,56039 | 1,635 | 0,101965 |
| ClassC2Fricative:3 | -0,66874 | 0,69089 | -0,968 | 0,333078 |
| ClassC2Fricative:4 | -0,32411 | 0,66727 | -0,486 | 0,627163 |
| ClassC2Fricative:5 | -0,23054 | 0,63483 | -0,363 | 0,716496 |
| ClassC2Nasal:1 | -0,28234 | 0,58985 | -0,479 | 0,63218 |
| ClassC2Nasal:2 | 0,76647 | 0,61017 | 1,256 | 0,209059 |
| ClassC2Nasal:3 | -0,74416 | 0,64238 | -1,158 | 0,246682 |
| ClassC2Nasal:4 | -1,03091 | 0,84247 | -1,224 | 0,221074 |
| ClassC2Nasal:5 | 0,74147 | 0,63889 | 1,161 | 0,245827 |
| ClassC2Lateral:1 | 1,63189 | 0,56049 | 2,912 | 0,003596 ** |
| ClassC2Lateral:2 | 1,15005 | 0,59583 | 1,93 | 0,053585 |
| ClassC2Lateral:3 | 1,09659 | 0,614 | 1,786 | 0,074102 |
| ClassC2Lateral:4 | 0,7173 | 0,6454 | 1,111 | 0,266397 |
| ClassC2Lateral:5 | 1,25715 | 0,60698 | 2,071 | 0,038342 * |
| ClassC2Rhotics:1 | 0,5794 | 0,40963 | 1,414 | 0,15723 |
| ClassC2Rhotics:2 | 0,76925 | 0,43444 | 1,771 | 0,076617 |
| ClassC2Rhotics:3 | 0,22329 | 0,44766 | 0,499 | 0,617932 |
| ClassC2Rhotics:4 | -0,17363 | 0,49446 | -0,351 | 0,725475 |
| ClassC2Rhotics:5 | -0,22754 | 0,47925 | -0,475 | 0,634942 |

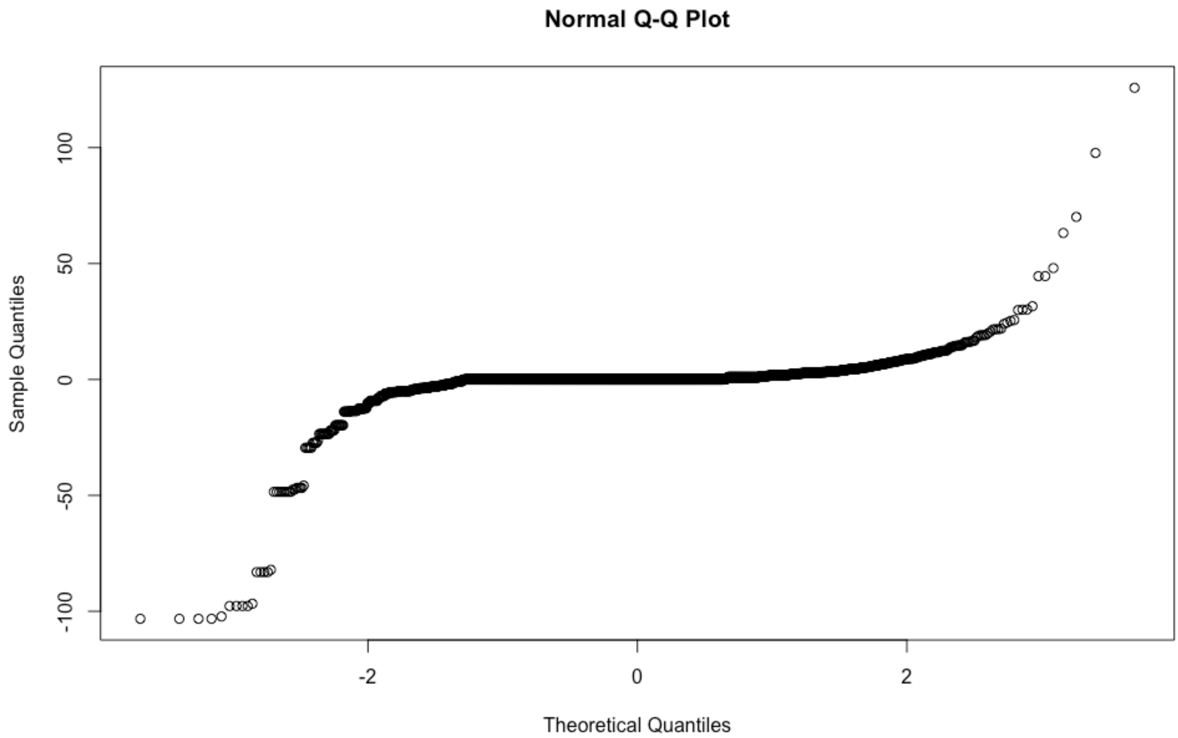
Residual deviance: 2308.979 on 4350 degrees of freedom
Log-likelihood: -1154.49 on 4350 degrees of freedom
Number of iterations: 17
Reference group is level 6 of the response

### 14.2.4 Analysis of Deviance

Analysis of Deviance Table (Type II tests)

| | Df | Chisq | Pr(>Chisq) |
|---|---|---|---|
| Stressed Vowel | 30 | 210.407 | <2.2e-16 |
| Place C1 | 15 | 93.850 | 1.887e-13 |
| Place C2 | 15 | 36.605 | 0.0014448 |
| Class C1 | 20 | 66.198 | 7.510e-07 |
| Class C2 | 20 | 45.394 | 0.0009755 |

### 14.2.5 QQ Plot for Residuals

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Thomas W. Yee, Jakub Stoklosa, Richard M. Huggins (2015). The VGAM Package for Capture-Recapture Data Using the Conditional Likelihood. Journal of Statistical Software, 65(5), 1-33. URL http://www.jstatsoft.org/v65/i05/.