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G[e]LAT[i]NA AND B[ɛ]RNAD[ɛ]TE: ACCOUNTING FOR ADJACENCY IN VOWEL HARMONY IN BRAZILIAN PORTUGUESE

G[e]LAT[i]NA E B[Ɛ]RNAD[Ɛ]TE: UM ESTUDO SOBRE A ADJACÊNCIA NA HARMONIA VOCÁLICA DO PORTUGUÊS BRASILEIRO

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Abstract: This study addresses the issue of vowel harmony in Brazilian Portuguese from the perspective of the Optimality Theory. More specifically, we address the issue of adjacency between vowels which seems to impede vowel harmony of height from taking place (*g[i]lat[i]na), but does not seem to affect vowel harmony of ATR when segments which are not specified for the relevant feature intervene (b[ɛ]rnad[ɛ]te). To account for this difference we propose the re-ordering of the markedness constraints AGREE and NOGAP. Another issue addressed is the optionality of both phenomena which allows non-harmonized outputs. For this, we propose the re-ordering of faithfulness and markedness constraints.
Keywords: Vowel harmony; Adjacency; Optimality Theory; Phonological variation.

Resumo: O presente estudo traz uma análise do processo de harmonia vocálica no Português Brasileiro sob a perspectiva da Teoria da Otimalidade. Mais especificamente, abordaremos a questão da adjacência entre vogais que parece bloquear o fenômeno no caso de harmonia vocálica de altura (*g[i]lat[i]na), mas não parece afetar a harmonia vocálica de ATR quando segmentos não especificados quanto ao traço relevante encontram-se em posição interveniente (b[ɛ]rnad[ɛ]te). Para dar conta dessa diferença, propomos um re-ordenamento das restrições de marca AGREE e NOGAP. Outra questão abordada é a opcionalidade das duas regras permitindo que formas não harmonizadas também sejam produzidas. Para isso, propomos um re-ordenamento entre as restrições de fidelidade e de marca.
Palavras-chave: Harmonia vocálica; Adjacência; Teoria da Otimalidade; Variação fonológica.

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Introduction

The aim of this paper is to present a broad analysis of two processes of vowel harmony in Brazilian Portuguese (BP) – vowel harmony of height and vowel harmony of [ATR] - within the Optimality Theory (OT) model (PRINCE & SMOLENSKY 1993, 2004)[1]. In doing so, we will not only try to determine which constraints are involved in both processes, but we will also try to account for a difference there seems to be between them: the requirement of adjacency. While vowel harmony of height, henceforth VH[high], seems to require that both relevant vowels be in strictly adjacent syllables, vowel harmony of [ATR], henceforth VH[ATR], seems to ignore transparent intervening vowels. One other issue that will be addressed in this analysis is the optionality involved in both vowel harmony processes in the language which allows two optimal surface candidates: a harmonized and a non-harmonized one. The paper is organized as follows: in § 1 we present the vowel system of BP, the phonological neutralization and processes affecting it and the phonological features that specify each vowel according to Lee (2003); in § 2 we discuss the processes of vowel harmony in BP; in § 3 we provide an account for both VH[high] and VH[ATR] within the OT model; and § 4 addresses the problem of variability for these processes within OT and proposes a re-ordering of constraints to surface non-harmonized outputs.

1 The vowel system of BP

Brazilian Portuguese consists of seven vowels which are only fully contrastive when in stressed position:

[1] Considering that these harmony processes are optional in Brazilian Portuguese and vary considerably depending on the dialect, our analysis will make use of the data from Belo Horizonte and Salvador presented by Lee & Oliveira (2003) and data from Minas Gerais, Goiás and Espírito Santo presented by Abaurre & Sândalo (2012). Also, following Lee & Oliveira (2003)'s, Guimarães (2006)'s and Abaurre & Sândalo (2012)'s analysis of vowel lowering in BP as feature spreading, we assume that both processes consist of a regressive assimilation of either height or [ATR] and therefore should be analyzed in tandem, even though they present differences regarding locality as will be shown in the paper. Finally, because it is beyond the scope of this paper, we will not address raising and lowering that do not result from assimilation, such as [pe'kena] ~ [pi'kena], [fo'gãw] ~ [fu'gãw] and [xe'vista] ~ [xɛ'vista], [pos'tuɾa] ~ [pɔs'tuɾa], respectively.
My thanks to Keren Rice and three anonymous reviewers for their valuable comments. Any mistakes and oversights contained herein are entirely my own.

(1)	[i]	-	**‘sis**.ku	‘dust’
	[e]	-	**‘se**.ku	‘dry-adj’
	[ɛ]	-	**‘sɛ**.ku	‘dry-verb-1st p. sg. pres’
	[a]	-	**‘sa**.ku	‘bag’
	[ɔ]	-	**‘sɔ**.ku	‘punch-verb-1stp. sg. pres’
	[o]	-	**‘so**.ku	‘punch-noun’
	[u]	-	**‘su**.ku	‘juice’

In unstressed position, this system is reduced to 5 vowels in pre-tonic position (2a), 4 in non-final post-tonic position (2b)[2], and 3 in final post-tonic position (2c):

(2a)	[i]	-	**mi**’lita	‘militate-3rdp.sg.pres’
	[e]	-	**me**’ladu	‘sugary’
	[a]	-	**ma**’leta	‘briefcase’
	[o]	-	**mo**’lusku	‘mollusk’
	[u]	-	**mu**’latu	‘dark-skinned man’

(2b)	[i]	-	‘a.**li**bi	‘alibi’
	[e]	-	‘ɔ.**pe**ra	‘opera’
	[a]	-	a’bɔ.**ba**da	‘dome’
	[u]	-	‘ãn.**gu**lu	‘angle’

(2c)	[i]	-	‘ma.**tʃi**	‘kill-3rd p. sg.imp’
	[a]	-	‘ma.**ta**	‘kill-3rd p. sg.pres’
	[u]	-	‘ma.**tu**	‘kill-1st p. sg.pres’

Lee (2003) proposes, according to the Contrastive Feature Hierarchy (DRESHER 2003, 2009), for the BP vowel system to be specified for the following features: Low > Back > High > ATR, as shown in (3) below:

(3)	/a/	-	[+low]
	/i/	-	[-low, -back, +high]
	/e/	-	[-low, -back, -high, +ATR]
	/ɛ/	-	[-low, -back, -high, -ATR]
	/u/	-	[-low, +back, +high]
	/o/	-	[-low, +back, -high, +ATR]
	/ɔ/	-	[-low, +back, -high, -ATR]

[2]According to Câmara Jr. (1970 [1999]), while the contrast between /e/ and /i/ still holds in non-final post-tonic position, the contrast between /o/ and /u/ is neutralized to /u/. Câmara Jr. calls attention to the variation involving the front vowel in this position (‘numeru ~ ‘numiru), which is not attested for the back vowels (a’bɔbura ~ *a’bɔbora).

According to Lee's proposal, [a] is distinguished from all other vowels since it is the only vowel specified as [+low]. The high vowels /i, u/, on the other hand, form a natural class of [+high], and the mid vowels /e, ɛ, o, ɔ/ form a natural class of [-high]. This latter class is also distinguished from one another by [ATR]. The features [high] and [ATR] are relevant in the contrastive hierarchy of vowels because they are active in processes of vowel harmony in the language, a topic which will be discussed in the following section.

2 Vowel Harmony in BP

The phonetic realization of the mid-vowels /e, o/ in pre-tonic position is determined by phonological processes such as Vowel Harmony of Height and Vowel Harmony of [ATR]. Both of these processes are optional in the language and will be discussed in more depth in the subsections that follow.

2.1 Vowel Harmony of Height

Vowel harmony of height is an optional regressive assimilation process triggered by a [+high] vowel /i, u/ and affecting a [-high] vowel /e, o/ in unstressed immediately preceding syllable, as the examples in (4) show (BISOL, 1981):

(4)	a)	/me'ninu/	→	[me'ninʊ]	~	[mi'ninu]	'boy'
	b)	/ko'ɾuʒa/	→	[ko'ɾuʒɐ]	~	[ku'ɾuʒa]	'owl'
	c)	/se'guɾa/	→	[se'guɾɐ]	~	[si'guɾa]	'hold-1stp.pres.'
	d)	/bo'nitu/	→	[bo'nitʊ]	~	[bu'nitu]	'pretty'

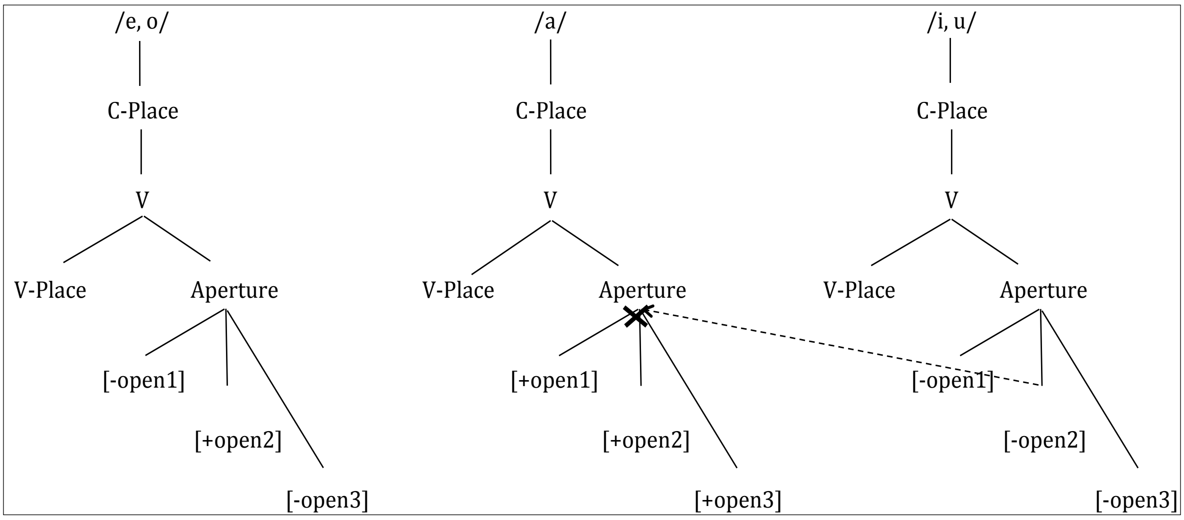
As can been seen in the examples above, both harmonized and non-harmonized forms occur in the language. Also, as shown in (4c-d), a back vowel can affect a front vowel and vice-versa, so there are no restrictions regarding place of articulation.

Also, because VH[high] is optional in the language, many are the studies which have set forth to determine its phonological conditions and phonetic motivation: adjacency and homorganicity between vowels, stress of the high vowel, prosodic domain, and surrounding phonological context. For the sake of conciseness and relevance, only adjacency between vowels will be addressed in this paper.

2.1.1 VH[high] and Adjacency

Previous studies on VH[high] in BP have unanimously considered adjacency between vowels a highly favorable phonological condition for the process. One reason for this is that these studies make use of the Feature Geometry specification for vowels proposed by Clements (1989, 1991) – and applied to BP by Wetzels (1992) – according to which all vowels receive specification for height in terms of the [open] feature. That being so, an intervening vowel which is also specified with the feature being spread becomes opaque and blocks the process:

Figure 1: intervening vowel blocking vowel harmony of height in BP



The examples in (5) below show that when not adjacent, VH[high] between /e, o/ and /i, u/ does not occur, providing strong evidence of adjacency:

(5)	a)	ʒela'tʃina	~	* ʒila'tʃina	'jelly'
	b)	meta'lurʒika	~	* mita'lurʒika	'metalwork'
	c)	melo'dʒia	~	* milo'dʒia	'melody'
	d)	peɾe'sivew	~	* piɾe'sivew	'perishable'

In words with two mid vowels preceding a high vowel, whenever the closest is harmonized, it can spread the feature [high] to the non-adjacent mid-vowel:

(6)	a)	melo'dʒia	~	melu'dʒia	~	milu'dʒia	'melody'
	b)	peɾe'sivew	~	peɾi'sivew	~	piɾi'sivew	'perishable'

Note that if the closest vowel is not raised, the non-adjacent vowel cannot be harmonized, as shown in (5c, d).

However, according to Lee's specification in (3) above, /a/ is specified for [low] only and, therefore, should not impede the spreading of [high]. Thus, considering the specification proposed by Lee, which is adopted in this analysis, cases such as those in (5) and (6) should not be blocked due to intervening vowels but by a strict phonological requirement of the rule: adjacency.

In fact, Nevins (2010:10) argues that vowel harmony is better accounted for by an approach focusing on the target vowel. That is, instead of explaining the process through the spreading of a feature by a trigger vowel, it is better accounted for through the search of a feature by the target vowel, which he calls needy vowel. According to Nevins, as the search starts, the needy vowel may look for a feature exhaustively, ignoring intervening segments which do not present the feature needed. Nevins illustrates this search with RTR Vowel Harmony in Yoruba spoken in Ife. Because this vowel harmony only affects vowels specified for RTR, an intervening vowel which is not specified for this feature is ignored and the search continues until a relevant feature is found. In the examples below, /u/ is not specified for RTR and is, thus, ignored:

(7)	a)	ɔrukɔ	'name'
	b)	ɛlubɔ	'yam flower'
	c)	ɛurɛ	'goat'

However, Nevins shows that, in Standard Yoruba, the same cases shown in (7) above do not undergo vowel harmony:

(8)	a)	orukɔ	'name'
	b)	elubɔ	'yam flower'
	c)	eurɛ	'goat'

The difference between the two systems, according to Nevins, is the definition of distance: in Yoruba spoken in Ife, a vowel assimilates [RTR] from the closest relevant vowel ignoring vowels which are not specified for [RTR]; in Standard Yoruba, the distance is absolute and the search is local: if the closest vowel does not present the relevant feature, the search is interrupted.

Based on Lee's specification of features and Nevins concepts of distance, it seems that VH[high] in BP requires absolute closeness to the relevant vowel. That is, if not immediately adjacent, harmony of height does not take place.

2.2 Vowel Harmony of ATR[3]

Another phonological process in the language is VH[ATR] which tends to occur in some northern and northeastern dialects(MAIA 1986, BARBOSA DA SILVA 1989, LEE & OLIVEIRA 2003, GUIMARÃES 2006, ALVES 2008, SILVA 2009, ABAURRE & SÂNDALO 2012). As a result of this process, an unstressed mid-vowel /e, o/ specified for [+ATR] assimilates to a [-ATR] vowel in subsequent syllable:

(9)	a)	e'lɛtriku	~	ɛ'lɛtriku	'electric'
	b)	bo'kɔ	~	bɔ'kɔ	'silly'
	c)	pɾo'ʒɛtu	~	pɾɔ'ʒɛtu	'project'

As to intervening segments, Abaurre & Sândalo (2012)'s data on the lowering of the pre-tonic position evidences that vowels which are specified for the relevant feature, in this case [ATR], can block the assimilation[4]:

(10)	a)	peɾe'rɛka	~	*pɛre'ɾɛka	'tree frog'

These authors also point out that, similarly to VH[high], whenever the intervening vowel assimilates to the relevant feature, it can, then, spread it to the non-adjacent vowel:

[3]We follow Lee's proposal of specifying /ɛ, ɔ/ as [-ATR] and not [+RTR] to be consistent with his specification.

[4]Abaurre & Sândalo make use of a different set of features to characterize vowels in BP. In their analysis, they follow Clements & Hume (1995) and represent each vowel by a Vocalic Node which is subdivided into Place Node and Aperture Node. To them, high vowels /i, u/ are specified as [-open] and mid vowels as [+open]. The purpose of their analysis is to argue that /a/ should not be specified for any Aperture Feature because it neither blocks lowering nor triggers it.

(11) a) peɾe'ɾɛka ~ peɾɛ'ɾɛka ~ pɛɾɛ'ɾɛka 'tree frog'

However, differently from VH[high], Abaurre & Sândalo argue that vowels which are not specified for the relevant feature do not block VH[ATR]:

(12) a) berna'dɛtʃi ~ bɛrna'dɛtʃi 'Bernadete'

Therefore, with regard to intervening segments, one difference arises when comparing VH[high] and VH[ATR]: while the former requires strict adjacency – being blocked by vowels which are not even specified for the relevant feature -, the latter does not and is only impeded by intervening vowels specified for the relevant feature. In Nevin's terms, the search in VH[high] stops when the relevant feature is not found in a neighboring vowel, while in VH[ATR] it continues until the vowel's need is satisfied if the neighboring vowel is not opaque.

In the following section we present an analysis of both phenomena within the framework of Optimality Theory (PRINCE & SMOLENSKY 1993, 2004).

3 VH[high] and VH[ATR] in BP: an OT Account

Within the derivational model of the SPE type (CHOMSKY & HALLE, 1968), changing of a phonological feature is obtained by application of rules to underlying forms. Considering the vowel harmony processes presented in the previous sections, we could formulate the following general rule to account for the assimilations affecting the unstressed mid-vowels in BP:

(13) Vowel Harmony Rule in Brazilian Portuguese

$$[e, o] \rightarrow [\alpha \text{ height}] \,/\, \_\_\_\, C \begin{bmatrix} V \\ \alpha \text{ height} \end{bmatrix} + \ldots]\omega$$

(adapted from QUICOLI 1990)

According to the rule in (13), vowel harmony in BP causes a mid-vowel in pre-tonic position to optionally adjust to the height features of a relevant following vowel.

In the OT model, on the other hand, the output of phonological process is not the result of rules being applied to an underlying representation, but the interaction of a set of violable constraints which are ranked in a dominance hierarchy. According to the model, there are two kinds of constraints: markedness (favoring unmarked structures) and faithfulness (favoring preservation of inputs). For each input there is a set of possible outputs – candidates – which are evaluated according to the hierarchy of the constraints of a specific grammar. The winner candidate will be the one which violates the lowest ranked constraints or, in case of a conflict between candidates, the one which makes fewer violations (KAGER 1999). In cases of assimilation, violation of a faithfulness constraint is imposed by a higher-ranked markedness constraint (MAHANTA 2007). That is, assimilation processes such as vowel harmony aim at a less marked output, so a winner candidate is surely to violate such constraints that demand outputs to be faithful to inputs.

In the present analysis of vowel harmony in BP we will make use of two sets of faithfulness and markedness constraints (following MCCARTHY 2011 and KAGER 1999) – one for VH[high] and another for VH[ATR]. Each of these analyses will be presented separately in the subsections that follow.

3.1 An OT account of VH[high]

For VH[high], we propose the use of the following phonological constraints:

(14) Faithfulness Constraints:

IDENT$_{STR}$-H	vowel height must be preserved in stressed position
IDENT-IO	corresponding segments in input and output forms must be identical in feature composition

(15) Markedness Constraints:

AGREE-L[HIGH]	a high vowel on the right must harmonize its [high] Feature to the vowel in a preceding syllable (harmonization is leftwards)

NoGap	gapped configurations are prohibited (ARCHANGELI & PULLEYBLANK 1994)

We propose the positional faithfulness constraint [Ident$_{STR}$-H] be ranked the highest to preserve height features of vowels in stressed position; this constraint is followed by NoGap which prevents non-adjacent vowels from harmonizing; next is Agree-L[high] requiring that vowels harmonize in height regressively, that is, from right to left; and, finally, Ident-IO requiring that output and input be identical regarding all features.[5]

(16) Ranking of constraints for VH[high]:

Ident$_{STR}$-H >> NoGap >> Agree-L[high] >> Ident-IO

The result of this ranking is illustrated below:

Tableau 1

/pe'ɾigu/	Ident$_{STR}$-H	NoGap	Agree-L[high]	Ident-IO
a. pe'ɾigu			*!	
☞ b. pi'ɾigu				*
c. pe'regu	*!		*	*

In the tableau above, candidate (a) is ruled out because the high vowel fails to harmonize to a preceding vowel which surfaces as a mid-vowel; candidate (c) is also ruled out because it violates a positional faithfulness constraint which protects stressed vowels from changing features; candidate (b) is, therefore, the winner candidate because it only violates the lowest ranking constraint – a faithfulness constraint against harmonized outputs. However, this tableau raises a problem in the language: even though candidate (b) is the optimal candidate in the language, candidate (a) should not be completely ruled out because it is also a possible output in BP. The problem is that in standard OT view there is just one winner against a group of losing candidates. In this

[5] The ordering between the suggested markedness constraints is relevant to prevent assimilation between non-adjacent vowels, as it is shown in Tableau 3.

view, only candidate (b) in the tableau above is indeed optimal. In order not to rule out possible optimal candidates, Coetzee (2004) proposes that instead of having a two-level ordering of candidates (winner vs. losers), we have a rank-ordering of candidates, that is, candidates are ranked from the most optimal to the least optimal, an approach which fully accounts for non-categorical phenomena such as variation and phonological processing[6]. However, Coetzee limits the rank-ordering of candidates by proposing a *critical cut-off point* which divides the constraint set into those constraints that a language is willing to violate and those that a language is not willing to violate (p. 17). As a consequence, candidates which violate constraints ranked higher than the critical cut-off point will never be accessed as variable outputs in the language. With regard to Tableau 1 above, the fact that both candidates (a) and (b) are accessed as variant outputs means that AGREE-L[HIGH]and IDENT-IO rank lower than the critical cut-off point. On the other hand, candidate (c) is never accessed as a possible variant, meaning that it violates constraints ranked higher than the cut-off point:

Tableau 1b

			critical cut-off	
/pe'ɾigu/	IDENT$_{STR}$-H	NOGAP	AGREE-L[HIGH]	IDENT-IO
a. pe'ɾigu			*	
☞ b. pi'ɾigu				*
c. pe'regu	*!		*	*

In the next tableau, we show an effect of iterative rules, as in the derivational model, which apply to their own output proceeding directionally until no further changes can be made in the word. As we have seen in (6), a harmonized mid-vowel can serve as trigger to harmonize one other mid-vowel preceding it:

[6] Kager (1999:405) had already pointed out the problem of *non-unique outputs* in OT and argued that this is not a problem of this model only reoccurring in derivational theory as well.

Tableau 2

			critical cut-off	
/meɾe'sidʊ/	IDENTSTR-H	NOGAP	AGREE-L[HIGH]	IDENT-IO
a. meɾe'sidʊ			*	
b. meɾi'sidʊ			*	*
☞c. miɾi'sidʊ				**
d. miɾe'sidʊ		*!	*	*
e. meɾe'sedʊ	*!			*

In the tableau above, candidate (c) is the most optimal output because it does not fail to satisfy AGREE-L[HIGH]and only violates a faithfulness constraint which is ranked very low in the hierarchy. Candidate (d), on the other hand, violates adjacency skipping an intervening vowel which could have undergone harmony, and is, thus, ruled out; candidate (e) also violates the highest-ranked candidate when it changes feature of a stressed vowel surfacing with three mid-vowels; candidates (a) and (b) are within the limits of the critical cut-off point which correctly predicts them as possible outputs in the language.

Finally, we present an input which does not undergo VH[HIGH] because the unstressed mid-vowel is not strictly adjacent to a high vowel:

Tableau 3

			critical cut-off	
/ʒela'tʃinɐ/	IDENT$_{STR}$-H	NOGAP	AGREE-L[HIGH]	IDENT-IO
☞ a. ʒela'tʃinɐ			*	
b. ʒila'tʃinɐ		*!		*

In Tableau 3 above, Candidate (b) is ruled out because it violates NOGAP, a constraint ranked higher than the critical cut-off point. Note, however, that had the ordering of markedness constraints been different, the wrong optimal candidate would have been selected:

Tableau 3(b)- different ordering of markedness constraints

/ʒela'tʃinɐ/	IDENT$_{STR}$-H	AGREE-L[HIGH]	NOGAP	IDENT-IO
a. ʒela'tʃinɐ		*!		
☹ b. ʒila'tʃinɐ			*	*

In this subsection we have briefly presented an OT analysis of vowel harmony of [high] in BP. We have shown that a faithfulness constraint must be ranked higher than any other constraint in order to protect any feature changing in stressed vowels; we have also shown that the ordering of markedness constraints is relevant to select the optimal candidate when relevant vowels are not in adjacent position; as to the ordering of candidates, we have seen that a two-level ordering as proposed by standard OT rules out possible outputs which could also surface in the language.

In the following subsection we will perform a similar analysis of ATR vowel harmony in BP.

3.2 An OT account of VH[ATR]

For VH[ATR], we propose the use of the following phonological constraints:

(17) Faithfulness Constraints:

IDENT$_{STR}$-ATR	ATR vowel specification must be preserved in stressed position.
IDENT-IO	corresponding segments in input and output forms must be identical in feature composition

(18) Markedness Constraints:

AGREE-L[ATR]	a mid-vowel on the right must harmonize its [ATR] feature to a mid-vowel in a preceding syllable (harmonization is leftwards)

NOGAP — gapped configurations are prohibited (ARCHANGELI & PULLEYBLANK 1994)

As seen, the main difference between VH[high] and VH[ATR] is that the latter does not require absolute adjacency between relevant vowels. We propose that this difference is achieved by re-ordering both markedness constraints. In doing so, VH[ATR] will favor assimilation regardless of adjacency:

(19) Ranking of constraints for VH[ATR]:

IDENT$_{STR}$-ATR >> AGREE-L[ATR] >> NOGAP >> IDENT-IO

We also propose a critical cut-off point which, as in VH[high], must be placed before AGREE-L[ATR].

The tableaux below illustrate how this ranking of constraints applies in the grammar.[7]

Tableau 4

/e'lɛtɾikʊ/	IDENT$_{STR}$-ATR	**critical cut-off** AGREE-L[ATR]	NOGAP	IDENT-IO
a. e'lɛtɾikʊ		*		
☞ b. ɛ'lɛtɾikʊ				*
c. e'letɾikʊ	*!	*		*

In Tableau 4 above candidate (b) is the most optimal candidate for violating only the lowest ranked constraints; candidate (a) fails to surface with a [+ATR] mid-vowel in pre-tonic position, but it is within the limits of the critical cut-off; candidate (c), however, does not satisfy the highest-ranked constraint for it changes the feature specification of a stressed vowel, so it must be ruled out.

[7]The winner candidate in Tableaux 4, 5 and 6 that follow applies to certain dialects in the northern and northeastern regions of Brazil, including the ones analyzed by Lee & Oliveira (2003), Guimarães (2006) and Abaurre & Sândalo (2012). In the south and southeastern regions, candidate (a) is most likely to be the most optimal one.

In Tableau 5 below harmony takes place in the optimal candidate (b) because VH[ATR] does not require absolute adjacency and, thus, ignores vowels not specified for ATR. Note that if we assumed the process involved height feature [low] or [open], we would also have to assume /a/ is underspecified for this feature in order for it to be ignored in the process.

Tableau 5

/beɾna'dɛtʃi/	IDENT$_{STR}$-ATR	**critical cut-off** AGREE-L[ATR]	NOGAP	IDENT-IO
a. beɾna'dɛtʃi		*		
☞ b. bɛɾna'dɛtʃi			*	*

Finally, Tableau 6 below shows how VH[ATR] can apply iteratively. The most optimal candidate, and thus the winner (c), violates only faithfulness between input and output forms, while (a) and (b) are also accessed as possible outputs for violating constraints which are ranked below the critical cut-off point:

Tableau 6

/peɾe'ɾɛka/	IDENTSTR-ATR	**critical cut-off** AGREE-L[ATR]	NOGAP	IDENT-IO
a. peɾe'ɾɛka		*		
b. peɾɛ'ɾɛka		*		*
☞c. pɛɾɛ'ɾɛka				**
d. peɾe'ɾeka	*!	*		*

It is important to note that both of these processes, VH[high] and VH[ATR], are optional in the language and this should be considered in the analysis. The following section is, thus, dedicated to an account via OT for the variability involved in these processes.

4 An OT account of the variability of VH[high] and VH[ATR]

In order to account for differences between grammars, the choice and order of constraints in OT is not rigid and can vary from language to language. Likewise, variability within a system has been treated in this model by varying constraint orders (GUY 1997, KAGER 1999). According to Kiparsky (1994), individual speakers can have competing grammars with different constraint orderings, and variation arises from choosing one grammar over the other. Nagy and Reynolds (1997) also postulate different constraint orderings, but instead of assuming different grammars, they propose that a constraint ordering can vary within the same grammar. In both cases, it is the different order of constraints that will license different output surfaces[8]. In this view, unstressed vowels in pre-tonic position do not undergo VH[high] and VH[ATR] in BP if a faithfulness constraint requiring input-output correspondence is ranked higher than the markedness constraints which motivate feature changing. We propose, thus, the following re-ranking for non-harmonized outputs:

(20) Ranking for non-harmonized outputs – VH[high]

IDENTSTR-H >> IDENT-IO >> NOGAP >> AGREE-L[HIGH]

(21) Ranking for non-harmonized outputs – VH[ATR]

IDENTSTR-ATR >> IDENT-IO >> AGREE-L[ATR] >> NOGAP

Tableaux 7 and 8 below illustrate how the new order of constraints exhibited in (20) and (21) correctly selects a non-harmonized output:

[8] The re-ordering of constraints to account for variability within a grammar is equivalent to the concept of optional rules in derivational models (KAGER, 1999: 405).

Tableau 7

/pe'ɾigu/	IDENTSTR-H	critical cut-off IDENT-IO	NOGAP	AGREE-L[HIGH]
☞ a. pe'ɾigu				*
b. pi'ɾigu		*		
c. pe'regu	*!	*		*

Tableau 8

/e'lɛtɾikʊ/	IDENTSTR-ATR	critical cut-off IDENT-IO	AGREE[ATR]	NOGAP
☞ a. e'lɛtɾikʊ			*	
b. ɛ'lɛtɾikʊ		*		
c. e'letɾikʊ	*!	*	*	

Because both candidates (b) in the tableaux (7) and (8) above violate IDENT-IO, they are no longer the most optimal outputs.

Conclusion

We have shown in this paper that both processes of VH[high] and VH[ATR] can be accounted by the same set of constraints in BP. The main difference between these two processes, that is, adjacency, is easily represented in the OT model by a re-arranging of constraints ordering. We have also shown that for non-categorical processes such as those in BP, a rank-ordering of candidates better accounts for the surface of non-optimal candidates in which the VH applies but not iteratively. With regard to variability, re-ordering faithfulness constraints higher than markedness constraints within the same grammar makes it possible for non-harmonized outputs to surface.

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