# Height harmony and nasal vowels: An argument for Agreement by Correspondence*

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## 1. Introduction

A key concern for theoretical accounts of vowel harmony is determining which segments do or do not trigger, block, and undergo harmony, and under which conditions. In this paper, we focus on the harmony system of the Recifense dialect of Brazilian Portuguese, in which vowel nasality determines whether or not tonic (stressed) vowels trigger height harmony. We show that a successful analysis of this phenomenon must make reference to the degree of similarity between a potential trigger and target of harmony, rather than to attributes of the trigger individually. In particular, we adopt Agreement by Correspondence (ABC; Rose and Walker 2004, Rhodes 2012), a constraint-based framework for the analysis of both vowel and consonant harmonies, and provide an analysis of Recifense Brazilian Portuguese (RBP) height harmony within that framework.

In RBP, pretonic mid vowels harmonize in height with tonic oral vowels, but not with tonic nasal vowels. Due to the central role it assigns to segment similarity, ABC is uniquely suited to the analysis of vowel harmony systems in which harmony is dispreferred as the potential trigger and target become more dissimilar. Since ABC constraints only drive harmony between sufficiently similar segments, we propose that in RBP nasal and oral vowels are not similar enough to be compelled to harmonize. We also show that alternative accounts of trigger asymmetries relying on the featural specification of the harmony trigger alone meet with difficulty in accounting for the RBP pattern.

The paper is organized as follows. In section 2, we present an overview of the vowel height harmony system in RBP. Section 3 introduces the core workings of the ABC framework. In Section 4, we provide our analysis of RBP vowel height harmony, situated within the ABC framework. We discuss alternative analyses in section 5. Finally, in section 6, we discuss further implications and directions for further research.

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## 2. Height Harmony in RBP

RBP distinguishes vowels based on height, backness, and nasality. The table in (1) presents an inventory of the surface vowels in RBP (following Vogeley and Da Hora 2013).

(1) *Recifense Brazilian Portuguese surface vowel* inventory

| | | | |
|---|---|---|---|
| High | i ĩ | u ũ | +ATR |
| Mid | e ẽ | o õ | +ATR |
| Mid | ɛ | ɔ | −ATR |
| Low | | a ã | −ATR |

Vowel height in Brazilian Portuguese has been variably analyzed as involving the features [±high], [±low], and [±ATR] (Rochel Madruga 2017, Lee 2003); or four different degrees of aperture (Wetzels 2011). We adopt the former option, though it is not crucial to the analysis we present in section 4.

All of the vowels in (1) are allowed in both pretonic and tonic positions. However, pretonic high-mid vowels [e o] are subject to a distributional restriction: they can only occur as a result of vowel harmony, triggered by a [+ATR] vowel in the tonic syllable, as in (2).

(2)
a. [mo.ˈtoh] ‘motor’
b. [moh.ˈdeh] ‘to bite’
c. [moh.ˈdi.du] ‘bitten’
d. [peh.ˈdeh] ‘to lose’
e. [se.ˈtoh] ‘sector’
f. [peh.ˈdi.du] ‘lost’

Outside of this harmony context, pretonic high-mid vowels may not occur[1], as in (3).

(3)
a. [hɛ.ˈvɛh.su] ‘reverse’ *[he.ˈvɛh.su]
b. [hɛ.ˈdɔh] ‘surroundings’ *[he.ˈdɔh]
c. [sɔw.ˈtah] ‘to let go’ *[sow.ˈtah]

If the tonic vowel is nasal, harmony does not occur, and a low-mid vowel surfaces in pretonic position, as in (4).

(4)
a. [pɛh.ˈdẽ.du] ‘losing’ *[peh.ˈdẽ.du]
b. [mɔh.ˈdõ.mu] ‘butler’ *[moh.ˈdõ.mu]
c. [i.nɔ.ˈsẽ.ti] ‘innocent’ *[i.no.ˈsẽ.ti]
d. [hɛ.ˈdõ.du] ‘round’ *[he.ˈdõ.du]

Height harmony that raises pretonic low-mid vowels, then, is triggered by high and high-mid oral vowels, but not by their nasal counterparts. In the following sections of this paper,

[1]Note that the RBP pattern presented here is distinct from one found in many other Brazilian Portuguese dialects, in which the distributional restriction instead prohibits low-mid [ɛ ɔ] vowels in pretonic position. See Lee and de Oliveira (2003) for an overview of how different dialects pattern in this respect.

we analyze this pattern as being determined by the degree of similarity between a potential trigger and target of harmony. The ABC framework provides for just such an account, and is introduced in the next section.

## 3. Theoretical Background

ABC is a constraint-based framework initially proposed to account for long-distance consonant harmony by Rose and Walker (2004), and later applied to vowel harmony by Rhodes (2012).

The central tenet of ABC is that harmony occurs between two segments that are in a surface *correspondence* relation with one another. This correspondence is conditioned upon a high degree of *similarity* between the two segments, as defined by their number of matching feature values. This is based on the observation that, across languages, segments that are more similar are more likely to interact phonologically.

ABC relies on two main types of constraints that work together to drive harmony: CORR-XY and IDENT-XY). Each of these are schematized in (5).

(5) a. CORR-XY: Assign a violation to a pair of segments that share the feature set F but are not in a surface correspondence relation with one another.
b. IDENT-XY[F]: Assign a violation to a pair of segments that are in a surface correspondence relation but do not agree for the feature F.

A CORR-XY constraint refers to two types of segments, X and Y, that share some feature values (those in feature set F) but may disagree in others. The constraint requires segments of these types to be in a surface correspondence relation with one another. IDENT-XY constraints, meanwhile, require segments that are in a surface correspondence relation to agree for the value of some feature F.

A key assumption held within the ABC framework is that there is a family of CORR constraints, each referring to a different set of one or more features, and that the relative ranking of these CORR constraints is fixed across languages. CORR constraints regulating correspondence between more similar segment types (those sharing more feature values in common) are ranked higher than those regulating correspondence between less similar segment types. This is borne out by the typological observation that segments are more likely to harmonize with one another if they are already similar in some way.

Both CORR and IDENT-XY constraints work together to drive harmony: a CORR constraint drives correspondence between two segments that are similar in some way, and a IDENT-XY constraint may then enforce harmony for some feature between these correspondents. Crucially, though, segments may satisfy a IDENT-XY constraint either by agreeing with one another for some feature F, or by failing to enter into a correspondence relation with one another. The degree of similarity between two segments determines which CORR constraints are violated by this failure to correspond. This interaction between CORR and IDENT-XY constraints forms the core of our proposed analysis of RBP height harmony, outlined in the following section.

## 4. Analysis

We analyze the pattern of height harmony triggering in RBP by oral vowels and not nasal vowels as a product of their differing degrees of similarity with oral pretonic vowels, the targets of harmony. Our analysis is situated within the ABC framework, and relies on the constraints in (6).

(6) a. CORR-EĨ: Assign a violation to a pair of vowels sharing the feature [−low] that are not in correspondence with one another.
b. CORR-EI: Assign a violation to a pair of vowels sharing the features [−low, −nasal] that are not in correspondence with one another.
c. IDENT-VV[ATR]: Assign a violation to a pair of corresponding vowels that do not have the same value of the feature [±ATR].
d. *[ĕ]: Assign a violation to a [−high, +ATR] vowel in pretonic position.

The constraints CORR-EĨ and CORR-EI require vowels of different degrees of similarity to be in correspondence with one another. CORR-EĨ is more general, requiring any [−low] vowels to correspond. CORR-EI is more specific, requiring only vowels that are both [−low] and [−nasal] to correspond. Following the assumption of ABC that CORR constraints referring to more similar segments (i.e. those with more features in common) are ranked higher, we assume here that CORR-EI is ranked above CORR-EĨ.

While the CORR constraints determine which vowels in RBP are in a surface correspondence relation with one another, the constraint IDENT-VV[ATR] drives harmony by requiring that any vowels in a surface correspondence relation agree for the feature [±ATR]. We assume that this constraint is high-ranked in RBP.

Finally, the constraint *[ĕ] penalizes high-mid vowels in pretonic position, capturing the distributional restriction illustrated in (3). Crucial for capturing the RBP height harmony pattern is the ranking of *[ĕ] between CORR-EI and CORR-EĨ. This ranking ensures that violations of *[ĕ] are tolerated when ATR harmony occurs between two oral mid vowels, but not when one vowel is oral and the other is nasal.

The ranking of these constraints necessary to generate the height harmony pattern observed in RBP is provided in (7).

(7) IDENT-VV[ATR], CORR-EI ≫ *[ĕ] ≫ CORR-EĨ

The workings of our analysis are illustrated in the following tableaux. In both, underlining of vowels in the candidates indicates that a correspondence relation exists between them. In (8), for [peh.ˈdi.du] ‘lost,’ both the tonic vowel (the harmony trigger) and pretonic vowel (the harmony target) are oral mid vowels, resulting in the application of height harmony.

(8) *Tableau: Oral pretonic and tonic vowels*

| Input: /pɛhdidu/ | IDENT-VV[ATR] | CORR-EI | *ĕ | CORR-EĨ |
|---|---|---|---|---|
| a. [pɛ̠h.ˈdi̠.du] | *! | | | |
| b. [pɛh.ˈdi.du] | | *! | | * |
| ☞ c. [pe̠h.ˈdi̠.du] | | | * | |

In (8), candidate (a) exhibits a correspondence relation between pretonic [ɛ] and tonic [i], satisfying both CORR constraints. However, their mismatch for the feature [±ATR] incurs a fatal violation of high-ranked IDENT-VV[ATR]. Candidate (b) avoids this violation of IDENT-VV[ATR] due to the lack of correspondence between these two vowels. However, this violates both CORR constraints. In optimal candidate (c), the vowels are in correspondence and the pretonic vowel undergoes harmony, violating only *[ĕ].

In the tableau for [pɛh.ˈdẽ.du] 'losing' in (9), the tonic vowel is nasal while the pretonic vowel is oral. This results in the selection of an optimal candidate in which harmony has not occurred.

(9) *Tableau: Oral pretonic, nasal tonic vowels*

| Input: /pɛh.ˈdẽ.du/ | IDENT-VV[ATR] | CORR-EI | *ĕ | CORR-EĨ |
|---|---|---|---|---|
| a. [pɛ̠h.ˈdẽ̠.du] | *! | | | |
| ☞ b. [pɛh.ˈdẽ.du] | | | | * |
| c. [pe̠h.ˈdẽ̠.du] | | | *! | |

The candidates in (9) show a very similar violation profile to those in (8) above. The key difference is in candidate (b), in which the lack of correspondence between pretonic [ɛ] and tonic [ẽ] incurs a violation of the more general CORR-EĨ but not the more specific CORR-EI. Because of this, candidate (b)'s violation of low-ranked CORR-EĨ is preferable to candidate (c)'s violation of *[ĕ], resulting in non-harmonizing candidate (b) being chosen as optimal.

These tableau illustrate that the ABC framework successfully captures the height harmony in RBP by appealing to the difference in degree of featural similarity between oral-oral and oral-nasal pairs of vowels. In the following section, we examine alternative analyses of this pattern that do not rely on trigger-target similarity and show that the ABC analysis has significant advantages.

## 5. Alternative Analyses

### 5.1 Trigger Asymmetries

RBP height harmony can be viewed as an example of a harmony system exhibiting a trigger asymmetry: oral vowels may trigger height harmony in environments in which nasal vowels may not. Outside of ABC, analyses of trigger asymmetries are typically based on some attribute of the potential trigger, such as its segmental quality or its position, rather than the similarity between a potential trigger and target. However, such an approach to the height harmony of RBP does not lend itself to an analysis in which it is the oral vowels, and not the nasal vowels, that are preferential triggers of height harmony.

Many analyses of trigger asymmetries in harmony are based on the generalization that 'bad vowels spread' (Kaun 1995). Vowels that are perceptually weak bearers of a feature will be especially compelled to spread that feature in order to ensure that it is correctly perceived by a listener. Perceptual weakness may be the result of a segment's particular combination of features (Kaun 1995, 2004) or by its position (Walker 2005, 2011). In either case, the asymmetry may be accounted for by assuming that a special harmony-driving constraint operates to drive harmony for some feature from a perceptually weak vowel, but not from segments bearing that feature in general.

In RBP, it is the nasality or orality of a potential trigger vowel that determines whether height harmony applies. Nasality has been observed to alter the formant structures of vowels such that height contrasts are more difficult to perceive on nasal vowels relative to oral vowels (Kingston 2007). This suggests that nasal vowels, as perceptually weaker bearers of height features, should be preferred triggers of height harmony relative to oral vowels, in contrast with what is observed in RBP.

The inability of the weak vowel trigger asymmetry approach to account for height harmony in RBP is illustrated by the tableaux in (10) and (11). The constraint SPREAD[+ATR] drives height harmony generally by penalizing segments that do not surface with a trigger's [+ATR] feature. The higher-ranked constraint SPREAD[+ATR]if[+nasal], meanwhile, assigns such penalties only when that harmonizing [+ATR] feature originates on a nasal vowel. The preferential application of height harmony only when a nasal vowel is the trigger is accomplished whenever a constraint that disfavors harmony is ranked between them. We use the familiar constraint *[ĕ] here.

(10) *Tableau: Oral pretonic and tonic vowels*

| Input: /pɛhdidu/ | SPREAD[+ATR]if[+nasal] | *ĕ | SPREAD[+ATR] |
|---|---|---|---|
| ☞ a. [pɛh.ˈdi.du] | | | * |
| b. [peh.ˈdi.du] | | *! | |

In (10), the tonic vowel is oral, and therefore neither candidate violates the high-ranked SPREAD[+ATR]if[+nasal]. Candidate (a), in which harmony has not applied, is chosen as optimal, violating only low-ranked SPREAD[+ATR], while candidate (b) violates *[ĕ].

(11) *Tableau: Oral pretonic vowel and nasal tonic vowel*

| Input: /pɛhdẽdu/ | SPREAD[+ATR]if[+nasal] | *ĕ | SPREAD[+ATR] |
|---|---|---|---|
| a. [pɛh.ˈdẽ.du] | *! | | * |
| ☞ b. [peh.ˈdẽ.du] | | *! | |

In (11), the tonic vowel is nasal and therefore a preferred trigger of height harmony. As a result, non-harmonizing candidate (a) fatally violates SPREAD[+ATR]if[+nasal], and harmonizing candidate (b) is chosen as optimal.

Taken together, these tableau illustrate that an approach in which preference is given to triggering by perceptually weak bearers of a harmonizing feature does not generate the triggering asymmetry observed in RBP height harmony. Instead, under this constraint ranking the opposite pattern is generated: one in which nasal vowels are preferred as the triggers of height harmony over oral vowels. We do not claim that this is an unwanted or pathological prediction of this constraint set, but crucially, there is no ranking of these constraints that favors an oral vowel over a nasal vowel as a height harmony trigger, as is observed in RBP.

## 5.2 Trigger Underspecification

Another alternative analysis for the trigger asymmetry between oral and nasal vowels in RBP height harmony relies on the lack of an ATR contrast among nasal mid vowels. Under this approach, vowels that are [−high, −low, +nasal] would not be specified for [±ATR] because there is no contrast that would make such a specification necessary. As a result, nasal mid vowels would be unable to act as triggers of height harmony and spread the feature [±ATR] to other vowels. However, there are several factors that lead us to disfavor this approach to the non-trigger status of nasal mid vowels.

One possibility is that this underspecification for the feature [±ATR] persists from the phonological input to the output. The phonological grammar would be permitted to produce underspecified output forms such as [pɛh.ˈdẼ.du]. The fact that nasal mid vowels in RBP are produced as high-mid (Wetzels 2011, Bisol and Veloso 2016) would then need to be attributed to a later phonetic implementation model that operates on a language-specific basis to insert feature specifications, such as [+ATR], after the phonological grammar has produced an output form (see Rice (1996) for an example of such a proposal). This introduces a level of complexity to the model of the phonology-phonetics interface that is not necessary in the ABC analysis. Furthermore, other analyses of Brazilian Portuguese phonology, such as that proposed by Quicoli (1990), rely on the phonological grammar having access to fully specified vowels.

Alternatively, the [+ATR] specification on nasal mid vowels could be supplied not by a post-phonological phonetic implementation mechanism but instead by a process that applies late within the phonological derivation. Crucially, this feature-filling process would apply after height harmony has applied (or failed to apply, in the case of tonic nasal mid vowels). The derivation in (12) illustrates.

(12) *Ordering of height harmony and feature-filling phonological processes*

| Input: | /pɛhdidu/ | /pɛhdẼdu/ |
|---|---|---|
| Height Harmony | pehdidu | – |
| Feature Filling | – | pɛhdẽdu |
| Output: | [peh.ˈdi.du] | [pɛh.ˈdẽ.du] |

However, this approach casts the non-application of height harmony as a case of underapplication (or counterfeeding) opacity, rendering it incompatible with many output-oriented, constraint-based theories of phonological grammar. The ABC analysis proposed in this paper, by contrast, does not rely on the derivationally opaque ordering of phonological processes.

## 6. Conclusion

The analysis presented here relies on a phonological framework in which the application of harmony is determined by segment similarity. In RBP, segment similarity is determined by the feature [±nasal]: two oral vowels are considered sufficiently similar to harmonize, but an oral and a nasal vowels are not.

Since the height harmony system of RBP is conditioned upon the feature [±nasal], a broader question that this analysis introduces is whether there is something unique about the feature [±nasal], or whether all phonological features are equally able to determine (dis)similarity with respect to vowel harmony. The preliminary answer appears to be that [±nasal] is not unique in this regard. Many Bantu languages, for instance, exhibit a front/back asymmetry in the application of height harmony. Hyman (1999) cites Nyamwezi (Tanzania) as an example: in that language, high front vowels lower following all mid vowels, but high back vowels lower only after mid back vowels. It appears, then, that a trigger and target's sharing of the feature [+back] is necessary for height harmony to occur in Nyamwezi. Similarly, in many rounding harmony systems, harmony prefers or is fully restricted to applying only among vowels of the same height (Kaun 1995, 2004). This typological observation forms the basis of the analysis of rounding harmony in Halh Mongolian presented by Rhodes (2012), in which harmony holds only among non-low vowels.

Therefore, while RBP height harmony provides further support for ABC's assumption that CORR constraints are in a fixed ranking based on the number of shared features they refer to, it does not appear that some features are more active in determining similarity than others. However, further study of similarity-dependent vowel harmony phenomena is warranted to help answer this question.

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