PHONOLOGICAL AGREEMENT BY HEADED FEATURE CORRESPONDENCE:

EXTENDING CORRESPONDENCE THEORY TO OUTPUT FEATURES NODES

By

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ABSTRACT OF THE DISSERTATION

Phonological Agreement via Headed Feature Correspondence:

Extending Correspondence Theory to Output Features Nodes

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In the dissertation, I propose a theory of phonological agreement called φ-Correspondence that is a formal extension of Correspondence Theory (McCarthy & Prince 1995). The theory is distinguished from Agreement By Correspondence (ABC, Rose & Walker 2004, Hansson 2001/2010, Bennett 2013/2015) in that it satisfies the following two assumptions.

Hypothesis I (correspondence relation).

I/O-Correspondence and φ-Correspondence relations are the same *kind* of formal relations.

Hypothesis II (Constraints).

I/O-Correspondence and φ-Correspondence constraints have the same definitions.

By analyzing three case studies in Chumash, Kalabari, and Basque, I show that φ-Correspondence solves several empirical and theoretical problems that have been recently pointed out in the literature on harmony, such as the problem of directionality (Bennett 2013/2015), Overlapping harmony (Walker 2016), and Agreement By Proxy (Hansson and McMullin 2016). Counterfeeding opacity is also correctly predicted to arise from the interaction between markedness and faithfulness constraints on heads (Falk 2014).

In the dissertation, I also formulate a generalization on the directionality of dominant-regressive consonant harmonies (Baković 2000, Hansson 2001/2010) and show that in φ-Correspondence it can be analyzed as an effect of the Preservation of the Marked (de Lacy 2002/2006).

Finally, the theory establishes a parallel between feature heads and prosodic heads by showing that they adhere to the same axioms, that they tend to be aligned to right morpho-phonological edges and that they are a target of positional faithfulness constraints.

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This work would not have been successful without the input of some amazing friends, colleagues and members of faculty. I was most fortunate to have worked with a committee whose sole drive was to see me succeed in this study.

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Adam was sincerely the most welcome addition to the department one could expect. His positive energy was a morale boost for anybody who worked with him, and he brought to the department a fresh approach to the discipline. The formal underpinning of my work has substantially improved thanks to his remarkable insights and knowledge of the topic. He is sincere, honest, hardworking and kind with everybody. I am grateful to have had such an amazing member of the faculty as co-chair in my committee.

I am also grateful to my other committee members Bruce and William. I met William the first year I joined the department, when he was about to graduate. This dissertation stems from my qualifying paper, which was inspired by Will's own excellent dissertation. Because of that, I always looked up on him, and sought his advice and support as I would with an older brother. Meeting him (and Allyson) and working with him during all these years has always been a pleasure.

Bruce is an excellent professor. He organized his classes methodically and delivered the content in a rigorous, precise and interesting manner. He asked incisive questions that helped me delve deeper into the subject matter of my dissertation. The meetings I had with him were cordial and went into great depths to explore the various aspects that I needed to cover in my work.

Aside from my committee members, I also wish to take this opportunity to thank some non-committee members whose inputs were instrumental in improving this dissertation. Akin helped me in the initial stages of writing. One of the ideas I got from my collaboration with him is incorporated here. He is a genuine person always willing and ready to help and provide wise advice and suggestions. In my mind he is an honorary member of the committee.

Alan made such a profound impact on my intellectual development. He taught me on the importance of being precise with definitions, thorough with assumptions and mindful of their consequences. His timely advice was also indispensable, as it helped me in the exploration of all the predictions of the theory.

Thanks also to the faculty that directly or indirectly contributed to my dissertation, particular to: Aaron Bravers, Eric Bakovic, Jeremy Perkins, Larry Hyman, Peter Jurgec, Peter Staroverov, Sharon Rose and Viviane Deprez.

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1 Introduction

1.1 Overview

The goal of the dissertation is to outline a theory of phonological agreement called φ-Correspondence that is a formal extension of Correspondence Theory (McCarthy & Prince 1995). The theory is inspired by Agreement By Correspondence (ABC, Rose & Walker 2004, Hansson 2001/2010, Bennett 2013/2015), but it is distinguished from it in that it satisfies the following two hypotheses.

Hypothesis I (correspondence relation).

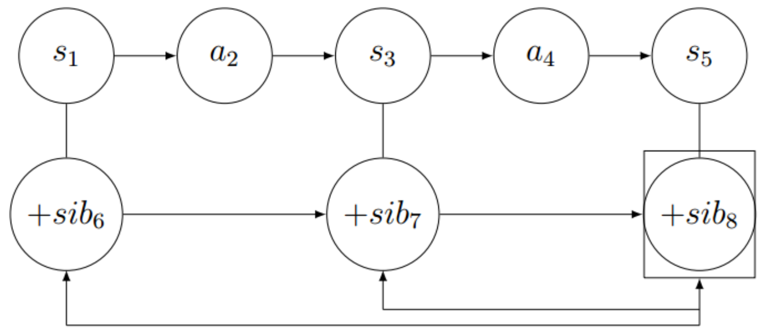
I/O-Correspondence and φ-Correspondence relations are the same *kind* of formal relations.

Hypothesis II (correspondence constraints).

I/O-Correspondence and φ-Correspondence constraints have the same definitions.

I argue that the relations that govern agreement in φ-Correspondence occur between a head and a set of dependent feature nodes on the same feature tier. The diagram below represents an example structure in the model. φ-Correspondence is indicated by a double-headed arrow.

(1) Sibilant feature nodes in φ-Correspondence.



In the representation, the root nodes in the first tier are ordered by a precedence relation, and they are not related by the correspondence relation. The φ-Correspondence relation is instead established between the three sibilants nodes, in particular between the rightmost sibilant (the head) and the other two [+sibilant] feature nodes in the tier. Alignment constraints (among others) determine the position of the feature head, while the (positional) faithfulness constraints determine the outcome of the assimilation.

φ-Correspondence solves several empirical and theoretical problems that have been recently pointed out in the literature on harmony. First, the problem of directionality in ABC is elegantly solved through the use of standard faithfulness constraints on φ-heads (Bennett 2013/2015). Overlapping harmony (Walker 2016) and Agreement By Proxy (Hansson and McMullin 2016) effects are eliminated by moving the correspondence relation to the feature tier. And finally, counterfeeding is correctly predicted to arise from the interaction between markedness and faithfulness constraints on head (Falk 2014).

Another advantage of φ-Correspondence is that it allows us to analyze the generalization that states that in dominant-regressive consonant harmonies the outcome of the harmony is always the marked segment (Baković 2000, Hansson 2001/2010) as an effect of the Preservation of the Marked (de Lacy 2002/2006), while avoiding majority rule effects (Lombardi, 1990, Hansson & McMullin 2016).

Finally, the theory establishes a parallel between feature and prosodic heads: it shows that they adhere to the same axioms, that they tend to be aligned to right morpho-phonological edges, and that they are a target of positional faithfulness constraints.

1.2 Theoretical background

φ-Correspondence is based on three theories: Correspondence Theory (McCarthy & Prince 1995), Agreement By Correspondence (ABC, Rose & Walker 2004, Hansson 2001/2010, Bennett 2013/2015), and headed theories of agreement, such as Span Theory (McCarthy 2004).

This literature review is organized around these theories. φ-Correspondence is an extension of Correspondence Theory. Accordingly, I start in section 1.2.1 by introducing the key concepts of the theory. In section 1.2.2, I introduce ABC and show that despite the obvious similarities, neither its relation nor its correspondence constraints are the same as those of Correspondence Theory. Finally, in section 1.2.3, I compare φ-Correspondence with Span Theory, a theory of agreement that, together with ABC, is the most similar to φ-Correspondence.

Autosegmental theories (Goldsmith 1990, Clements & Hume 1995, Jurgec 2011, among others) will not be discussed in detail, since the main arguments made with reference to ABC also apply to φ-Correspondence (Hansson 2001/2010, Rose & Walker 2004, Jurgec 2011).

1.2.1 Correspondence Theory

Correspondence Theory is based on the definition of a relation and a set of constraints that by applying them to different elements of the phonological representation yield different phonological effects. Correspondence is generally defined as a "special relation between two structures." The authors say:

> Here I will assume that the structural elements in question are just (tokens of) segments but it is a straightforward matter to generalize the approach to higher order units of prosodic structure such as moras, syllables, feet, heads of feet, as well as tones and even distinctive features or *feature nodes* [emphasis added], in support of theories of quantitative transfer, compensatory lengthening, and the effects of floating features (McCarthy & Prince 1995:14).

Much work has been done in Correspondence Theory, such as in its application to other domains such as transderivational identity (Benua 1997), feature nodes (Akinlabi 1996[1]), and reduplication (Inkelas 2008), as well as on the analysis of some specific formal properties of correspondence constraints and relations (Casali 1997, Potts & Pullum 2002, Payne et al. 2017).

In all cases, correspondence relate elements of the same "nature," but with some different "properties"[2] (e.g., input–output or base–reduplicant segments, tone–TBUs, etc.). For this reason, a crucial axiom of correspondence relations is heterogeneity. In this

[1] The suggested relations refer to correspondence between feature nodes and root nodes as opposed to φ-Correspondence, which instead acts on feature node heads and dependents.

[2] These concepts are hard to formulate precisely outside of a formal system (which is one why I adopt one). Clearer and more precise definitions are given in chapter 2.

dissertation, I demonstrate that φ-Correspondence relations have the same formal properties of I/O-Correspondence relations, including heterogeneity.

φ-Correspondence does not have all the properties that heterogenous relations have. However, some of these axioms appear as important constraints on φ-Correspondence relation. For example, an important property of some heterogeneous relations—but not of correspondence—is *totality*. Totality demands that given two disjoint sets of elements X, Y, all elements in X are connected to some elements in Y. Totality is not an axiom of correspondence, but it is implemented as the violable constraints MAX and DEP, defined below.

MAX definition. McCarthy and Prince (1995:16)

Every segment of S_1 has a correspondent in S_2.

MAX is a definition that contains two unbound variables S_1 and S_2. The constraint schema is instantiated as a set of constraints where the value of the two variables is replaced with the domain and the codomain of the correspondence relation (e.g., Input–Output, Base–Reduplicant, etc.). For example, MAX-IO is simply defined as follows:

MAX-IO definition.

Every segment in the *input* has a correspondent in the *output*

1.2.2 Agreement By Correspondence

Agreement By Correspondence (ABC) is a theory developed primarily to deal with consonant (parasitic) harmonies and dissimilation (Walker 2000a, Walker 200b; Rose & Walker 2004; Hansson 2001/2010, Bennett 2013/2015, among others). The theory consists of three main components: a relation called Surface Correspondence, which acts on segments in the output, a set of constraints (CORR) that penalize similar segments that are not in correspondence, and a set of constraints (IDENT-CC) that penalize segments in surface correspondence that differ for some features.

When both some CORR and some IDENT-CC constraints are ranked above the relevant faithfulness constraints, harmony is enforced by the grammar. The tableau below shows a mini-typology of the basic interactions in ABC.

(2) Basic constraints interaction in ABC

Input	Output	ID-IO(+sib)	ID-CC(ant)	CORR-(+sib)	ID-IO(ant)	Comments
ʃ…s	a. $ʃ_x…s_x$		*			Correspondence
	b. $ʃ_x…s_y$			*		No
	d. $ʃ_x…ʃ_x$				*	Harmony
	e. $s_x…s_x$				*	Harmony

In candidate (2a), the two sibilants correspond but do not harmonize, with the result that the constraint that requires identity of the feature anterior ID-CC(ant) is violated. Candidate (2b) is another faithful output obtained by not having the two sibilants in correspondence. Finally, the last two candidates (2c, d) correspond and harmonize, so they do not violate any of the ABC constraints.

It is unclear whether in the original papers (Walker 2000ab, Rose & Walker 2004, Hansson 2001) the authors actually intend for Agreement By Correspondence to be an extension of Correspondence Theory. Hansson (2001) often draws some important parallels between the two theories, specifically in section 4.2.1.2 (Hansson 2001:300). However, the author never makes the claim that the elements of the two theories are formally the same.

Rose and Walker (2004) explicitly establish the relation between the two theories with respect to their constraints in the following passage "IDENT-CC constraints are formulated in accordance with the general IDENT(F) schema given in McCarthy & Prince 1995. But CORR-C↔C constraints are not part of Correspondence Theory."[3] In terms of the correspondence relation, the claim is indirect and perhaps weaker. The authors say (p. 32): "Following the definition given by McCarthy and Prince (1995:262), two structures are in correspondence if a relation is established between their component elements."

This passage, though, expresses a terminological notation rather than a formal equivalence. I take it that the authors are simply stating that they call two segments in correspondence if they are related, not that the relation they use is formally the same correspondence relation as in McCarthy and Prince (1995).

A first formal analysis of Surface Correspondence is in Bennett (2013/2015). Although Bennett (2013/2015) is not proving that any of the properties of Surface Correspondence relations are the same as the ones in Correspondence Theory, the

[3] Although this is formally true only for certain formulations of IDENT-CC, namely for those that do not encode any reference to the directionality of assimilation. See 3.4.1 for a discussion.

analysis is fundamental in that it is the first of its kind to highlight the importance of formally expressing the correspondence relation in ABC.

One property that surface correspondence relations have in common is that they are "homogenous" relations. Correspondence Theory and φ-Correspondence are instead heterogenous relations and have a different set of properties (axioms) than the ones commonly assumed in ABC (see chapter 2).

The latest indication of the absence of references to the original Correspondence Theory in ABC is found in Shih and Inkelas (2017). The authors claim to extend ABC (i.e., one of its possible formulations) to tone–TBU association. The resulting theory, however, is very different from Correspondence Theory applied to tones.[4]

As the examples above show, prose is perhaps the main culprit for the confusion regarding the identity between Agreement By Correspondence and Correspondence Theory, and more generally regarding certain theoretical assertions concerning the definition of (correspondence) relations.

For this reason, I provide a semi-formal axiomatic definition of phonological structures. Similar formalizations have been used for various goals in phonology such as to account for specific properties of a theory (e.g., Coleman & Local 1991, Tesar 2013), to analyze the computational complexity of (part of) phonology (e.g., Eisner 1997, Graf 2010, Rogers et al. 2013, Jardine 2016), or as a tool to provide rigorous descriptions of the components of a theory (e.g., Kornai 1995, Potts & Pullum 2002).

[4] See section 7.1.3 for a brief discussion.

In this dissertation, I use similar tools to define Correspondence Theory and φ-Correspondence to show that they include the same relation and the same set of correspondence constraints in a more rigorous way.

1.2.3 Span Theory

A crucial element that permits the characterization of φ-Correspondence as heterogenous relations and that distinguishes φ-Correspondence from ABC is the φ-head. Headed constituents are pervasive in linguistics. The concept of head is applied to syllable structure (Murray 2006, Smith 2002), element theory (Kaye et al. 1985; and others), stress/tone interaction (de Lacy 2002), and autosegmental assimilation (Halle & Vergnaud 1990, Jurgec 2011), as well as being a central concept in the theory of stress (Prince & Smolensky, 1993/2004) and in syntax (Chomsky, 1965).

McCarthy (2004) is a theory of headed agreement that together with ABC most resembles φ-Correspondence. Span theory is very similar to φ-Correspondence in that the harmonizing feature of these domains is determined by a head, which is freely assigned to some elements by GEN. Nevertheless, two important differences concern the definition of the elements in the agreement relation and the mechanisms that govern the distribution of the heads in the output.

Following Hansson (2001/2010), Span Theory can be subcategorized as a "strict locality" theory of assimilation (Flemming 1995, Gafos 1999). Strict locality theories are defined by two characteristics: a linear span that defines the domain of harmony and the spreading of the harmonizing features to all the segments in the span.

Spans consist of a contiguous segmental string, but in surface correspondence, there is no such strict requirement. Segments in the same domain may be separated by other segments, which can even belong to other correspondence relations (e.g., if there are multiple harmonies). Strict locality has in fact been criticized because all segments between the trigger and the target of assimilation must be permeated by the spreading feature (Hansson 2001/2010: 20–23, 210–221).[5]

Another property of span theory is that all segments in a span are pronounced with the feature value of the head. In contrast, in φ-Correspondence, harmony is only favored by the fact that there are constraints that favor feature identity and that there is a faithfulness constraint that protects the featural content of the head. The head, per se, does not impose any restriction on its domain, it just favors it (more closely resembling O'Keefe 2007).

The other important difference between Span Theory and φ-Correspondence concerns the constraints that determine the head selection. φ-head constraints follow the template of classic positional and alignment constraints. Span theory uses specific constraint schemas.

For example, an important constraint in Span Theory is HEAD([βG, γH, ...], [αF]), which favors [αF] heads, with the set of feature values [βG, γH, ...]. For example, the constraint HEAD([−cont, -son], [−nas]) is violated when a [−continuant, −sonorant] segment does not head a [−nasal] span. HEAD([βG, γH, ...], [αF]) applies only to a subset of segments [βG, γH, ...] with a particular head [αF]. For instance, HEAD([−cont, −son],

[5] Locality is a well-known issue in autosegmental theories, where it has been circumvented using a variety of strategies (Clements & Hume 1995, Jurgec 2011, among others).

[−nas]) contains two conditions: that the segment is an obstruent and that the segment heads an oral span.

In φ-Correspondence, φ-head selection is determined by a positional faithfulness constraint and by an alignment constraint. This approach mimics the head selection mechanisms used to explain other phenomena, such as stress, neutralization, and tones (McCarthy & Prince 1995, Murray 2006, de Lacy 2002) and permits the formulation of simple and well-known constraints. Furthermore, φ-Correspondence constraints penalize unfaithfulness or non-alignment, rather than favoring the presence of a head in a context.

1.3 Outline of the dissertation

The dissertation is roughly organized as follows. In chapter 2, I start with a definition of the theory and establish the equivalence between I/O-Correspondence and φ-Correspondence relations and constraints. I then move on to analyze three case studies, each illustrating a particular aspect of the theory. Chapter 3 deals with directional harmony and focuses on head alignment, chapter 4 concerns feature correspondence in overlapping harmonies, and chapter 5 deals with the interaction of markedness constraints with φ-head faithfulness constraints in counterfeeding patterns. Finally, chapter 6 contains a typology of the theory and a discussion of the empirical generalizations of consonant harmony. A more detailed description of the chapters follows.

1.3.1 Chapter 2 – Theory

In chapter 2, the core chapter of the dissertation, I provide a definition of the elements and properties of the theory. These constitute the fundamental blocks that allow me to formalize correspondence relations and constraints. I then define the correspondence relations and show that I/O-Correspondence and φ-Correspondence both adhere to the same set of axioms. Since no other axiom exists for either I/O-Correspondence or φ-Correspondence, I conclude that the two relations are identical.

I then move to define the φ-Correspondence constraints. I introduced the four constraint schemas RELATE-X, UNIQUE-X, CONTIGUOUS-X, and IDENT-XY and argue that the same definitions apply to both I/O-Correspondence and φ-Correspondence constraints.

A crucial component of φ-Correspondence is the φ-head. I demonstrate that there is only one axiom that defines φ-heads, which is also assumed for phonological heads. I also demonstrate how some theorems derived from this axiom limit the range of φ-Correspondence relations, and I account for its limited generative power compared to I/O-Correspondence.

Finally, I argue that the distribution of heads is governed by two families of constraints that are independently motivated and related to the distribution of other phonological heads, namely Generalized Alignment (§ 2.4.2.1) and Positional Faithfulness constraints (§ 2.4.2.2).

The chapter concludes with a brief exposition of the axioms of other phonological relations (precedence and dominance) and their relevance with respect to Correspondence.

1.3.2 Chapter 3 – Directional harmony in Chumash

In chapter 3, I go through the first analysis of the dissertation. I start with a well-known case of consonant harmony in (Ineseño) Chumash. In Chumash, all sibilants in a word agree in anteriority. The value of the feature [anterior] is determined by the value of the rightmost sibilant in the word. In the example below, the input form /ha-s-xintila-waʃ/ 'his former Indian name' harmonizes for the feature [−ant] giving [haʃxintila-waʃ] based on the fact that the rightmost sibilant in the form is /ʃ/.

(3) Sibilant harmony in Chumash, basic pattern.

a. /ha-s-xintila-waʃ/ → [haʃxintila-waʃ] 'his former Indian name'

cf. /ha-s-xintila/ → [hasxintila] 'his former name'

φ-Correspondence elegantly captures this pattern because of the constraints on φ-head alignment and φ-head faithfulness. The analysis follows from the basic assumptions of the theory. RELATE-[+sib] establishes the correspondence relation among sibilant nodes; ALIGN(φ-head, R) demands alignment of the head to the right edge of the sibilant tier and IDENT-IO(+sib-head) protects the [−ant] sibilant from changing, thus causing the other (non-head) sibilants in the input to harmonize.

This approach is then contrasted with other theories of directionality, where such a pattern requires the formulation of complex constraints, as opposed to the definition of standard positional faithfulness and alignment constraints.

1.3.3 Chapter 4 – Partial overlapping in Kalabari

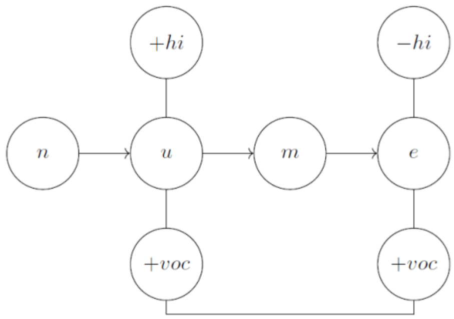
It is common for multiple harmonies to coexist in the same language. Chapter 4 discusses Kalabari, one language in which multiple harmonies end up targeting overlapping sets of segments.

The language has three different harmony patterns: a directional, parasitic back harmony for [+high] vowels, a non-directional parasitic back harmony for [−high] vowels, and a non-parasitic (*aka* system-wide) ATR harmony.

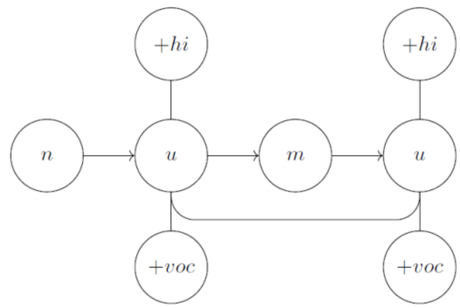
This pattern is unproblematic in φ-Correspondence. Since the correspondence relation occurs at the feature level, the different harmonies are independent one from another. One correspondence relation connects the [+vocalic] node, where ATR harmony is instantiated, while two other different relations are in effect for the [−high] and [+high] tier, as shown in (47a). In theories where the agreement relation is established at the segmental level (47b), the pattern is problematic because the theory predicts that all segments in the relation participate in the harmony. This kind of problem is known as *overlapping harmony* or (Walker 2016) and is very similar to Agreement By Proxy (Hansson 2010, McMullin & Hansson 2016).

(4) Two kinds of correspondence

a. Featural correspondence



b. Segmental correspondence



1.3.4 Chapter 5 – Derived environment effect in Basque

IDENT(φ-head) constraints are standard faithfulness constraints. Even though their predominant function is in establishing directionality of harmony, the constraints interact with standard markedness constraints and predict counterbleeding effects between neutralization and harmonies. In chapter 5, I discuss one of these cases.

In some varieties of Basque, sibilants in most roots agree on the distributed feature. For example, /es̻-ets̺i/ → [es̺-ets̺i] 'persist', as compared with /es/ 'no', /ets̺i/ 'consider'. In addition to harmony, Basque has another process of local assimilation, where laminal sibilants become apical before another consonant.

Derived apicals, however, do not cause other sibilants to harmonize. For example, /s̻is̻ku/ 'bag' maps to disharmonic [s̻is̺ku] and not to [s̺is̺ku]. A simplified analysis of the phenomenon goes as follows: φ-heads on apical sibilants normally act as triggers[6] of

[6] Here trigger and target do not refer to the original meaning of the word. No element 'triggers' a process in OT. In φ-Correspondence, the term refers to an element with the head property for which there is at least one correspondent that is mapped unfaithfully in order to achieve harmony. This is not a formal, precise definition, but it is good enough since I only use the term for the sake of exposition.

sibilant harmony in Basque. However, when the apical sibilant appears before a consonant, a conflict arises. The element either becomes a target of long-distance assimilation or a target of local assimilation.

Neutralization wants to change the second sibilant, while harmony wants the sibilant to remain faithful in order to act as a trigger of harmony. In Basque the conflict is resolved in favor of neutralization, which counterbleeds harmony. The pattern is predicted to occur in φ-Correspondence since heads function as “turbid” elements of the representation (Goldrick, 2000) and interact with other markedness and positional faithfulness constraints.

1.3.5 Chapters 6 and 7 – Typologies and conclusions

In chapter 6, I outline the basic typology of φ-Correspondence. I show that the theory predicts the existence of six directionality patterns, which arise from the combination of three basic directionality types: dominant, directional, and root control.

I then argue that there are three generalizations that restrict the typology of predicted patterns for each of these types. In dominant harmony, the trigger is the marked value, in directional harmony, the trigger is aligned to the right edge of a word (or of the root), and in root control harmony the trigger is in the root. In mixed harmonies, these restrictions apply conjointly.

The last section of chapter 6 focuses on the markedness generalization. I demonstrate that φ-Correspondence is an agnostic theory of directionality and that the markedness generalization can therefore be captured by the theory of faithfulness constraints. In this respect, I provide a general formulation of the theory of faithfulness that accounts for both the markedness generalization and avoid majority rule effects. Finally, chapter 7 concludes, with indications for future work.

2 Theory

In chapter 1, I gave a brief description of φ-Correspondence theory. I showed that the theory includes a head-dependent relation among feature nodes and a set of constraints that define the elements participating in the relation, how heads are assigned, and how harmony is obtained.

In this chapter, I define the theory more rigorously, offer some background and justification of the assumptions made in its formulation, and demonstrate how the identity between I/O and φ-Correspondence is achieved.

The chapter is organized as follows. Section 2.1 starts with a definition of the model, including its elements and relations. Section 2.2 looks more closely at the properties of correspondence relations, while section 2.3 concludes with a definition of correspondence constraints.

In section 2.3.1, I define φ-heads. I introduce the axiom that defines φ heads and show that it applies to other phonological heads (2.4.1). Section 2.4.2 contains the definitions of φ-head constraints.

2.1 Fundamentals

I start with a definition of elements and properties. These definitions are fundamental for arguing for the identity of I/O and φ-Correspondence, and more generally in construing the set of permitted and ill-formed candidates.

2.1.1 Elements

To define a relation, I first need to define the entities the relation acts on. The basic units of representation are the elements.

Definition (element). An element is a unique entity in a model. (i)

Like in Autosegmental Phonology (AP henceforth), an element corresponds to a *node* in a *graph*. Each node in the model is a distinct and unique identity, which is by itself devoid of any property or interpretation. Typographically, each node is assigned a number which uniquely identifies it, and it is represented in text as a bullet followed by a number $\bullet_1$.

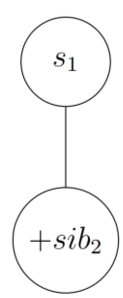
To be well formed, an element needs to have some properties. A complete set of properties for an element, for example, tells us whether the element is in the input or in the output, if it is a syllable or a feature, and so on.

In the example below, the representation has two nodes, a node with the properties output and root node, and a node with the property output, [+sib], and Head. More details are provided in the next section.

(5) A root node connected to a [+sib] head node

$\bullet_1$ = Output, Root

$\bullet_2$ = Output, [+sib], Head



2.1.2 Properties

A property is a unary relation (or a set) that defines the interactions of an element with respect to relations and constraints, and possibly the interpretation of that element at the interfaces. I distinguish three classes of properties: *derivational*, *interpretable*, and *cumulative*.

The *derivational* class specifies whether an element is in the input or in the output. Every element must necessarily be in either one.

An *interpretable* property specifies what type of phonological constituent an element is. In the theory, I postulate the interpretable properties Foot (F), Syllable (σ), Prosodic Word (ω), Root (⨀), and features (one for each feature value, such as [+sib], [−ant], etc.).

Notice that the feature properties specify the feature type and the value of an element. For example, [+sib] is a single property of a node, while [−sib] is another distinct property.

I assume that a root node cannot dominate two feature nodes of the same type (e.g., two [+sib] or a [−sib] and a [+sib] node), and that each root node is fully specified for each feature type (thus also excluding privative features).[7]

[7] In other words, there is no feature underspecification, and complex segments (e.g., affricates, clicks, prenasalized obstruents, etc.) have a dedicated feature value (e.g., delayed_release). None of the assumptions are fundamental for the goal of this dissertation, but they are useful for a concise definition of IDENT constraints.

Finally, *cumulative* properties do not impose any requirement on the presence of any other property in their class.[8] They include the properties *H(ead)*,[9] for head nodes and *R*(*oot*) for nodes contained in a morphological root.

The following table contains a list of all properties used in the model:

Property	Element is…	Type
I	in the input	derivational
O	in the output	derivational
ω	a prosodic word	interpretable
F	a foot	interpretable
σ	a syllable	interpretable
⊙	a root node	interpretable
[+sib]	a feature node [+sib]	interpretable
φ	a feature node φ	interpretable
H	a head	cumulative
R	in the root	cumulative

Now that I defined the elements and the properties of the representation, I can introduce the first axiom of the theory.

[8] In this dissertation, I assume that root nodes are not in φ-Correspondence and therefore cannot have the property Head. I briefly discuss the implications of allowing root node correspondence in section 7.1.1.
[9] I call the sets of non-heads $\overline{H}$ (dependents). $\overline{H}$ is not a canonical property, since there is no axiom that refers to it, and it does not constitute a cohesive set of elements. Nevertheless, it is a useful label that makes some of the definitions and the prose clearer.

$\overline{H} := \{x \mid x \notin H\}$

Axiom I (of properties).

> An element must have one and only derivation property, one and only one interpretable property, and any number of cumulative properties. (ii)

2.1.3 Relations

I now move on to explain how elements are connected through relations. I start with an example illustrating the notation used (§ 2.1.3.1) and then move on to define relations and to distinguish between *kind*, *type*, and *instance* (§ 2.1.3.2). Finally, I reformulate Hypothesis I in light of these new definitions to lay the foundation for the analysis of correspondence relations that is conducted in section 2.2.

2.1.3.1 Notation

For the notation, consider the simple representation in (6a), represented as a diagram in (6b). It contains the set of six elements (universe), indicated by the symbol $\mathbb{D}$. Three elements are in the input, and three are in the output. Four elements are root nodes; two are [+sib] feature nodes.

The symbols $\mathscr{R}$ and < indicate correspondence and precedence, the Symbol ↓ indicates dominance.[10] Subscripts are used to indicate the sets of elements a relation acts on. For example, $\mathscr{R}_{\square\text{-[+sib]}}$ indicates a relation between root nodes and [+sib] nodes, while $<_{\text{O},\,\odot}$ indicates a relation among output root nodes.

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[10] This notation is redundant because the domain and the codomain of any relation never coincide with the codomain and range of another relation. Consequently, given any non-empty set of pairs, it is always possible to determine the type and kind of relation it represents. For example, a relation between I and O or between a feature and a feature head is necessarily a correspondence relation, while a relation among output root nodes is necessarily a precedence relation.

(6) Elements and relations

a. Logic form

$\mathbb{D} = \{\bullet_1, \bullet_2, \bullet_3, \bullet_4, \bullet_5, \bullet_6\}$

$\odot = \{1, \bullet_2, \bullet_3, \bullet_4, \bullet_5, \bullet_6\}$

$\mathrm{I} = \{\bullet_4, \bullet_5, \bullet_6\}$

$\mathrm{O} = \{\bullet_1, \bullet_2, \bullet_3\}$

$[\text{+sib}] = \{\bullet_5, \bullet_6\}$

$\mathscr{R}_{\text{I-O}} = \{\langle\bullet_1, \bullet_3\rangle\}$

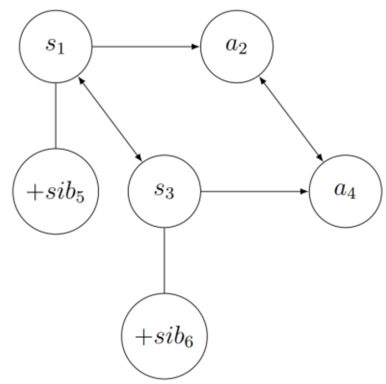
$\mathscr{R}_{\text{O-I}} = \{\langle\bullet_3, \bullet_1\rangle\}$[11]

$<_{\mathrm{I}, \odot} = \{\langle\bullet_1, \bullet_2\rangle\}$

$<_{\mathrm{O}, \odot} = \{\langle\bullet_3, \bullet_4\rangle\}$

$\downarrow_{\square\text{-[+sib]}} = \{\langle\bullet_3, \bullet_5\rangle\}$

b. Diagram



Since φ-Correspondence is always between a head and a dependent of two identical features, I indicate it as $\mathscr{R}_{[\varphi]}$, where φ is the name of the feature value of the elements in correspondence.

[11] $\mathscr{R}_{\text{I-O}}$ and $\mathscr{R}_{\text{O-I}}$ are always the symmetric inverse of one another (see section 2.2). Postulating two distinct relations is required for the axiom II (heterogeneity, see 2.2.1) and for the definition of the constraint RELATE (see 2.3.1.1).

In diagrams, I adopt the following notation:

- Precedence is indicated by an arrow, correspondence by a double-headed arrow, and dominance by a single line.
- Head elements are represented as enclosed in a square ▢.
- Root nodes almost always include an indication of their segmental interpretation, although they do not represent a string.
- Derivational properties are omitted from the diagrams because they are either self-evident in the representation or they are indicated in the example description.

2.1.3.2 Kind, type, and instance

A binary relation (just relation henceforth) is commonly defined as follow.

Definition (relation). A relation is a set of ordered pairs. (iii)

In the discussion of the properties of relations, I need to refer to three levels of abstraction: *kind*, *type*, and *instance*. The least abstract "relations" are called *instances*. Whenever in a candidate (or a structure) two or more elements are connected, we say that they are an *instance* of a relation.

Definition (instance of a relation). An instance of a relation is a pair of elements. (iv)

The most abstract characterization is the *kind*. A *kind* is defined exclusively by the axioms that govern a relation. It defines the set of specific properties that apply to all *instances* of a relation. This is a fundamental concept because I prove the formal identity of the φ-Correspondence and I/O-Correspondence by showing that they are of the same kind, that is, that they adhere to the same set of properties.

Definition (kind of a relation). Two relations are of the same kind of relation if they adhere to the same set of axioms. (v)

In the representation given in (6), there are all three kinds of relations precedence: dominance, and correspondence. No matter what the instances of a relation are for a specific structure, each instance must respect the axioms of the *kind* it belongs to.

Finally, I distinguish different *types* of relations. Types are something between kind and instances, as they are defined by a *kind* and the specification of the domain and the range of the function (i.e., the properties of the elements that participate in the relation).

Definition (type of a relation). Two relations are of the same type if they adhere to the same set of axioms *and* they have the same domain and codomain. (vi)

To give an example, I/O, O/I, B/R, and φ-Correspondence are all different *types* of the same kind (correspondence) of relation.

In (6), there are two types of correspondence ($\mathscr{R}_{\text{I-O}}$ and $\mathscr{R}_{\text{O-I}}$), two types of precedence ($<_{\text{O}, \odot}$ and $<_{\text{I}, \odot}$), and one type of dominance ($\downarrow_{\odot\text{-[+sib]}}$).

2.1.3.3 Hypothesis I (final definition)

Given the definitions above, I can now be more precise with the definition of φ-Correspondence and of Hypothesis I. The first point to make is that φ-Correspondence is not a *kind* of relation *per se*. Instead, φ-Correspondence indicates a set of *types* of correspondence relations. More specifically, the *types* of correspondence relations between a head and a dependent with the same interpretable property φ in {[+sib], [−sib], [+voc], …}.

The terms φ-Correspondence thus indicates the types of correspondence relations extensionally defined as follows:

φ-Correspondence := $\{\mathscr{R}_{[+sib]}, \mathscr{R}_{[+ant]}, \mathscr{R}_{[+voc]}, \ldots\}$. (vii)

Crucially, this set of relation types do not have any property (or axioms) that refer specifically to it, but it is indeed a useful terminology. I thus reformulate Hypothesis I as follows.

Hypothesis I (correspondence relation).

> I/O Correspondence, O/I Correspondence, and all φ-Correspondence relations are different *types* of the same *kind* of correspondence relation. (viii)

2.1.4 Interim summary

In this section, I introduce the building blocks of the model. I define a representation as constituted by a set of unique elements with some properties and their axioms, optionally connected by at least one of three relations: precedence, correspondence, or dominance.

I also show that a representation represents a full OT candidate, since it includes input and output elements, as well as the relation between the two sets of elements.

Finally, I distinguish between instance, type, and kind of relations. This allows us to formulate Hypothesis I more precisely in terms of identity of types among correspondence relations.

2.2 Axioms concerning correspondence

In the previous section, I defined a relation as a set of ordered pairs that adhere to some axioms and illustrated that *kinds* of relations are distinguished entirely by their set of axioms. In this section, I define the axioms that define correspondence to show that the same axioms apply to both I/O-Correspondence and φ-Correspondence. By doing so I demonstrate that the two sets of relation types belong to the same kind of relation (Hypothesis I).

Since most readers are familiar with I/O-Correspondence, I start each subsection with a semi-formal definition of an axiom of I/O-Correspondence and then show that it extends to φ-Correspondence relations. Although I do not provide formal a treatment of Base-Reduplicant and Input-Reduplicant Correspondence, the same definitions apply to these types of correspondence as well, as it was the original intent of McCarthy and Prince (1995) to define a unified theory. Surface Correspondence is discussed with reference to φ-Correspondence whenever relevant, while other less adopted theories based on correspondence, such as transderivational correspondence (Benua 1997) or feature correspondence (Akinlabi 1996), are not discussed.

2.2.1 Heterogeneity

The first axiom is based on the property *heterogeneity*, which is defined as follows:

Definition (heterogeneous relation).

A relation $\mathscr{R}: X \rightarrow Y$ is heterogeneous if the intersection of its domain X with its codomain Y is the empty set ($X \cap Y = \emptyset$). (ix)

A heterogeneous relation (like a function) is thus defined by two sets: a *domain* and a *codomain*, which never overlap. Consider a function that maps a student to a seat in a classroom. The domain of the relation is the set of all students, while the codomain is the set of all seats. The set of students does not contain any seat, and the set of seats does not contain any student. Heterogeneous relations thus connect *elements* that are different in nature (i.e., that have different properties). Correspondence is such a relation.

Axiom II (of correspondence). Correspondence relations are *heterogeneous*.

This axiom is particularly important because it distinguishes φ-Correspondence theory from ABC (§ 1.2.2), it imposes significant restrictions on other properties of the relation, and it restricts the space of the candidate set (§ 2.4.1.2).

In the next section, I show how this axiom applies to the classic formulation of I/O-Correspondence.

2.2.1.1 I/O-Correspondence

In Correspondence Theory, I/O-Correspondence holds between input and output root nodes. In notation, $\mathcal{R}_{\text{I-O}}: X \rightarrow Y$, where X is the set of all elements with the property $\odot$ and O, and Y is the set of all elements with the properties $\odot$ and I.

$X = \{x \mid x \in \odot \wedge x \in \text{I}\}$

$Y = \{x \mid x \in \odot \wedge x \in O\}$

Because of Axiom I, we know that each element must have one and only *derivational* property: an element is either an input element or an output element. As a consequence, the intersection of X and Y of $\mathscr{R}_{\text{I-O}}$ is the empty set, which makes I/O correspondence a heterogeneous relation. *Mutatis mutandis*, O/I correspondence is heterogeneous as well.

This property of correspondence extends to other classic correspondence relations, such as Base/Reduplicant correspondence. For instance, the domain of $\mathscr{R}_{\text{B-R}}$ is the set of output root nodes in the *base*, and the codomain consists of output root nodes in the *reduplicant*.[12] An element cannot be in the base and in the reduplicant in the same representation, and so the two sets are non-intersecting.

2.2.1.2 Heterogeneity in φ-Correspondence

I now move on to φ-Correspondence and show that the relation is also heterogeneous. The argument is straightforward. φ-Correspondence occurs between head feature nodes and non-head feature nodes. An element is either a head or a dependent: it cannot be both, and it cannot be neither (see footnote 9). For this reason, for any φ-Correspondence relation $\mathcal{R}_\varphi$, the intersection of the domain X of $\mathcal{R}_\varphi$, and of the codomain Y of $\mathcal{R}_\varphi$ is always empty.

$$X = \{x \mid x \in \varphi \wedge x \in \mathrm{O} \wedge x \in H\}$$

$$Y = \{x \mid x \in \varphi \wedge x \in \mathrm{O} \wedge x \in \overline{H}\}, \text{ where } \varphi \in \Phi.$$

In fact, φ-Correspondence is very similar to B/R-Correspondence. Both relations act on elements in the output. In the case of B/R-Correspondence, they are output root nodes, in the case of φ-Correspondence they are output feature nodes. In both cases, there is an optional, cumulative, phonetically silent property that creates an asymmetry and allows

[12] Base and Reduplicant are not properties of our model. However, they can be easily formalized as *cumulative* properties, much alike H and $\overline{H}$.

us to distinguish the two sets. In B/R-Correspondence it is the property of being in the base (or in the reduplicant); in φ-Correspondence it is property of being a head.

Heterogeneity is one of the axioms that allow us to establish that φ-Correspondence and I/O-Correspondence are the same kind of relations. In the next two sections, I discuss two further restrictions that heterogeneity imposes on the theory: a reduction on the space of candidates and the constraints correspondence can have on the type of axioms.

2.2.1.3 Candidate space

Heterogeneity reduces the number of possible candidates in GEN.[13] From Axiom II, I can derive the following two theorems of φ-Correspondence:

Theorem I (head correspondence).

A head cannot be in correspondence with another head. (x)

Theorem II (dependent correspondence).

A dependent cannot be in correspondence with another dependent. (xi)

In addition to trivial candidates with just two heads or two dependents in correspondence, candidates with "iterative" spreading of dependents, as represented in the figure below, are also ill-formed. In the structure, $\bullet_6$ and $\bullet_7$ are in correspondence, but neither one is a head.[14]

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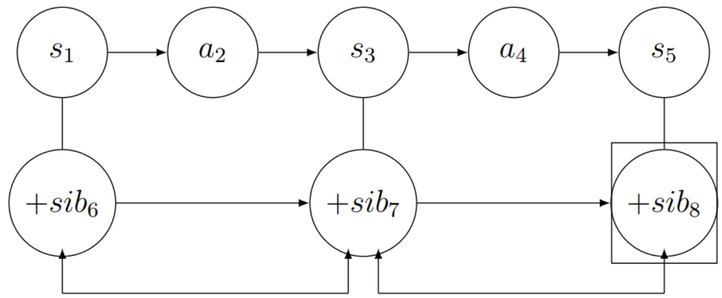
[13] Heterogeneity also defines the properties the relation can have. For example, common properties in the Surface Correspondence literature, such as transitivity, reflexivity, and symmetry, are properties that apply (or can only exist) for non-heterogeneous relations. In other words, a heterogeneous relation can never be transitive, reflexive, or symmetric because the domain and the codomain do not overlap. Some other properties of heterogeneous relations such as interrelational, transitivity, totality, and bijectivity are mentioned in this chapter whenever relevant.

[14] These are only the candidates ruled out by heterogeneity. Other candidates are banned because of the axioms on heads defined in section 2.4.1.

(7) Ill-formed φ-Correspondence relations



The two theorems are easy to prove. φ-Correspondence occurs among feature nodes in the output. Two of the three possible properties (the value of the feature node and output) are already fixed by the definition of the set of relation types themselves.

The only property left is headedness, which distinguishes the sets of non-heads from the set of heads as the domain and range of the relation. As such, any instance of head-to-head and dependent-to-dependent correspondence violates heterogeneity.

Notice that given the current definitions, a head can be in correspondence with multiple dependents, and a dependent can be in correspondence with multiple heads. In section 2.4.1.1, I show that because of an axiom on headedness, the former configuration is possible, while the latter is illicit.

2.2.1.4 Domain and codomain of dominance

In the next two sections, I briefly discuss heterogeneity with respect to dominance and precedence. Of the other two relations in the model, only dominance is heterogeneous. As in the case of φ-Correspondence, dominance is established between pairs of properties that define the domain and the codomain of the relation. Such pairs (excluding the transitively derived ones[15]) are {⟨ω, F⟩, ⟨F, σ⟩, ⟨σ, ⨀⟩, ⟨⨀, φ⟩}, which resembles but never overlaps with correspondence pairs {⟨I, O⟩, ⟨B, R⟩, ⟨φ^H, φ⟩, …}.

The pair of domain sets that dominance acts on varies across *interpretable* elements. An input node cannot dominate an output node, and a head element cannot dominate a non-head element with the same *interpretable* property. A hierarchy is instead established among interpretable properties.

Crucially, the relation is established only among elements with *different* interpretable properties (i.e., I adopt the Strict Layering Hypothesis, Selkirk 1984: 24). Feet dominate syllables, they do not dominate other feet; root nodes dominate feature nodes, not other root nodes.[16] Consider the dominance relation $\downarrow_{F\text{-}\sigma}$ between feet and syllables. We have:

$X = \{x \mid x \in \text{F} \wedge x \in \text{O}\}$

$Y = \{x \mid x \in \sigma \wedge x \in \text{O}\}$

Like the correspondence example, Axiom I prevents an element from having two or more interpretable features, and X and Y never overlap because F ∩ σ = ∅. The same is true for all the pairs in the domain/codomain set, which makes dominance heterogeneous.

2.2.1.5 Domain and codomain of precedence

Unlike dominance and correspondence (and alike surface correspondence in ABC), precedence is a homogeneous relation. This means that only elements from the same set

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[15] Dominance relations are "cross-relationally" transitive (but not themselves transitive). If a foot F_x dominates a syllable σ_y in $\downarrow_{F\text{-}\sigma}$, and the syllable σ_y dominates a root node $\odot_z$ in $\downarrow_{\sigma\text{-}\odot}$, then the relation $\downarrow_{\sigma\text{-}\odot}$ must exist and $\langle F_x, \odot_z\rangle \in \downarrow_{F\text{-}\odot}$. Simply put, if a foot dominates a syllable σ_x, then the foot also dominates all the root nodes $\odot_y$ dominated by σ_x, and all the features dominated by $\odot_y$.

[16] The only exception is in the theories with prosodic node recursion, where a node can dominate another node with the same interpretable properties. In those cases, the different levels are usually distinguished by some labels (Ito & Mester 1992, 2003, Kager 2012, among others).

can participate in the relation. The set of all elements that can participate in a precedence relation is defined by the following axiom.

Axiom III (precedence).

> If a pair of elements ⟨*x*, *y*⟩ are in a precedence relation, then *x* and *y* have the same *derivational* property and the same *interpretable* property. (xii)

This axiom delimits the definition of ALIGN-H and CONTIGUOUS constraints, which are both crucial components of φ-Correspondence. I discuss this issue in § 2.3.2.2 and § 2.4.2.1.

In the model, I do not need to impose any other restriction on the sets of elements that can participate in a precedence relation, as the choice is inconsequential. What is important for the present analysis is that precedence acts on input root nodes, output root nodes, and among like feature nodes.

Precedence among root nodes is necessary for the definition of I/O constraints that refer to the order of the elements in correspondence. I/O-Correspondence occurs among root nodes, and since both CONTIGUITY and LINEARITY (McCarthy & Prince 1995) refer to the order of elements in correspondence, precedence on both input and output root nodes is commonly assumed.

Notice that precedence only exists among feature nodes with the same feature value, as opposed to AP where tiers may contain feature with different values.

Such a relation is incompatible with the proposed model. Since segments have no internal geometry, precedence on feature nodes with different feature values (e.g., [+sib] and [−sib]) would simply replicate the precedence relation at the root node level. Most importantly, such a definition would violate Axiom III (and homogeneity), since there is no interpretable property that relates like features with different values.

2.2.2 Other Properties of Correspondence

I now move to introduce the other two axioms of correspondence, namely Maximal Distance (§ 2.2.2.1) and Symmetric Inverse (§ 2.2.2.2).

2.2.2.1 Maximal Distance

The property of Maximal Distance is an interesting generalization that holds in the theory.

Axiom IV (Maximal Distance)[17]

If x corresponds to y then x differs from y for one and only one property.[18] (xiii)

For instance, I/O-Correspondence is instantiated between root nodes in the input and root nodes in the output. The elements differ for one and only one property: I or O. For $\mathscr{R}_{\text{I-O}}$, I have:

$\text{I} = \{x \mid x \in \odot \wedge x \in \text{I}\}$

$\text{O} = \{x \mid x \in \odot \wedge x \in \text{O}\}$

Likewise, for two elements to be in φ-Correspondence, they must differ for only one and only one property: headedness. A head feature node [+sib] cannot correspond to a dependent [−sib] or [+voc], because the property difference would be higher than one.

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[17] In fact, this axiom expresses both the maximal and minimal distance.
[18] The minimal distance is one since the relation is heterogeneous.

The axiom of Maximal Distance provides an important piece of phonological insight. Correspondence is empirically manifested in input/output domain phenomena, in reduplication, and in agreement. Although apparently different, all these processes can be traced back to one requirement: correspondence is about wanting similar elements to be maximally identical (within the limits imposed by the axioms). The Maximal Distance axiom ensures that only elements that are sufficiently similar *can* be in correspondence.

The axiom intuitively extends to other types of correspondence relations. In B/R-Correspondence, the elements in correspondence are root nodes in the output, and the property that differs concern whether the element is in the reduplicant or not. In Tone/TBU-Correspondence, both elements are in the output, but they differ for their derivational property (tones vs. TBUs).[19]

2.2.2.2 Symmetric Inverse

The other property of correspondence is Symmetric Inverse, which is defined as follows:

Axiom V (Symmetric Inverse).

If *x* corresponds to *y* in $\mathscr{R}_{X\text{-}Y}$, then y corresponds to x in $\mathscr{R}_{Y\text{-}X}$. (xiv)

Symmetric inverse is similar to the definition of the symmetric property of homogeneous relations, which states that if *x* relates to *y* in $\mathscr{R}$, then *y* relates to *x* in $\mathscr{R}$. The difference between the two axioms is that the inverses are not part of the same

[19] The axioms discussed here are necessary and sufficient to describe the current theory in the most restrictive way. Although this characterization of the theory is compatible with some of the fundamental concepts in the field, the aim is not to provide an axiomatic description of the entire phonological module.

relation in correspondence. Instead, pairs of relation types exist that are the inverse of one another.

(8) Symmetric Inverse vs. a symmetric relation

(a) Symmetric Inverse in I/O (b) A homogeneous symmetric relation

$\mathscr{R}_{\text{I-O}} = \{\langle \bullet_1, \bullet_2 \rangle, \langle \bullet_3, \bullet_4 \rangle, \langle \bullet_5, \bullet_6 \rangle\}$ $\mathscr{R}_1 = \{\langle \bullet_1, \bullet_2 \rangle, \langle \bullet_2, \bullet_1 \rangle, \langle \bullet_2, \bullet_3 \rangle, \langle \bullet_3, \bullet_4 \rangle\}$

$\mathscr{R}_{\text{O-I}} = \{\langle \bullet_2, \bullet_1 \rangle, \langle \bullet_4, \bullet_3 \rangle, \langle \bullet_6, \bullet_5 \rangle\}$

The property is straightforward and uncontroversial for I/O-Correspondence. Without symmetric inverse, the theory would predict the existence of candidates where $\bullet_1$ corresponds to $\bullet_2$, but $\bullet_2$ does not correspond to $\bullet_1$.

Likewise, each φ-Correspondence relation entails the existence of an instance of the relation that maps a head to a dependent as well as a relation instance that maps a dependent to a head. Symmetric inverse in φ-Correspondence is not fully realized because of the constraints imposed by the heads on the candidate set and because of Maximal Distance. I further discuss this issue in section 2.3.1.

2.2.3 Interim summary

In this section, I introduced some common axioms that apply to relations. In particular, I argue that I/O-Correspondence and φ-Correspondence are both heterogenous relations that adhere to the axioms of symmetric inverse and minimum distance.

In section 2.1.3.2, I argue that two types of relations are of the same kind if and only if they share the exact same set of axioms. Since I/O-Correspondence and φ-Correspondence adhere to the same set of axioms, and no other axiom exists for either

I/O-Correspondence or φ-Correspondence, I conclude that the model satisfies Hypothesis I, reproduced here:

Hypothesis I (correspondence relation).

> I/O Correspondence, O/I Correspondence, and all φ-Correspondence relations are different *types* of the same *kind* of correspondence relation.

This is a true, but purely theoretical statement that applies to the model defined so far. From chapter 3 on, I show that the proposed theory is empirically adequate and phonologically sound.

2.3 Correspondence constraints

Hypothesis I is about the axioms of correspondence, the purely representational aspects of the relations. In this section, I prove Hypothesis II, which concerns the violable constraints that govern correspondence relations. I define four correspondence constraint schemas RELATE-X (§ 2.3.1.1), UNIQUE-X (§ 2.3.2.1), CONTIGUOUS-X (§ 2.3.2.2), and IDENT-XY (§ 2.3.1.3) and demonstrate that the same constraint definitions apply to Input/Output and φ-Correspondence alike.

I start with the two most important constraints—RELATE-X and IDENT-XY—in section 2.3.1 and then move on to discuss the remaining constraints in section 2.3.2.

2.3.1 *Relate and Ident*

2.3.1.1 *Relate-X*

The first constraint schema corresponds to Max and Dep (and replaces Corr in ABC). Since I extend the definition to feature nodes, and in order to highlight the templatic nature of its definition, I refer to it with the more general name Relate-X.

A Relate-X constraint is satisfied when all elements in the domain of a correspondence relation (e.g., the set of input root nodes) are in a correspondence relation with at least one element in the range (e.g., the set of output root node). It is defined as follows.

Relate-X definition.

> Given a correspondence relation $\mathscr{R}_{X\text{-}Y}$, assign a violation for each element in *X* that is not in $\mathscr{R}_{X\text{-}Y}$.

Relate-X considers a single tier of elements connected by a precedence relation (root nodes or feature nodes) and assigns a violation for each element not in a correspondence relation.

Because of symmetric inverse, correspondence relation types always come in symmetric pairs. Applying the definition of Relate-X to a pair of correspondence relations thus results in two constraints: Relate-I, which corresponds to Max, and Relate-O, which corresponds to Dep.

The same constraints exist for φ-Correspondence. The only parts of the constraint definition that varies are the variables that refer to the range and to the domain of the relation (i.e., the distinguishing factors of the relation types themselves).

Let us start by considering only the φ-Correspondence relations with the dependent as the domain. Because of Hypothesis II, for each φ-Correspondence type there must be a correspondence constraint named RELATE-φ, where φ is the name of the feature nodes in the relation (e.g., RELATE-[+sib], RELATE-[+voc], etc.).

These constraints all impose the same requirement: totality is instantiated at the feature node level.[20] In each case, the domain is the set of non-head feature nodes in the output and the requirement is that each of these nodes corresponds to a head. Examples of RELATE-[+sib] and RELATE-I constraint definitions are given below.

(9) Definition of two RELATE-X constraints.

RELATE-[+sib]

Given the correspondence relation $\mathscr{R}_{[+\text{sib}]}$, assign a violation for each element in the set of output [+sib] that is not in $\mathscr{R}_{[+\text{sib}]}$.

RELATE-I

Given the correspondence relation $\mathscr{R}_{\text{I-O}}$, assign a violation for each element in the set of input root nodes that is not in $\mathscr{R}_{\text{I-O}}$.

[20] Totality means that all elements in the domain or codomain of a relation are in a relation. See section 2.5 for more details.

Recall that $\mathscr{R}_{[+sib]}$ is a shorthand notation that indicates a relation between the two sets [+sib] non-heads and [+sib] heads ($\mathscr{R}_{[+sib]-[+sib\text{-}head]}$), so the two definitions are equivalent except for the domain of the correspondence relation.

Notice that a tier φ with no φ-heads still violates RELATE-φ, since the constraint only considers one element at a time. This is the expected behavior for RELATE-I (or MAX) as well. A candidate may still violate RELATE-I even when there are no output root nodes.

Because of symmetric inverse, I also predict the existence of a constraint RELATE-[+sib-head], where the domain is constituted by φ-heads. Such a constraint, however, is always vacuously satisfied. Simply put, a φ-head is always part of a correspondence domain because of the axiom on the head (xi). I better illustrate this point in § 2.4.1.1.

2.3.1.2 Differences with CORR constraints

A CORR constraint parses each consonant, and once it finds a consonant X with the desired feature [α*f*], it parses each other consonant to check whether (i) it also has the desired feature [α*f*]; (ii) it is in correspondence with X.

The most elegant formulation is probably in Bennett (2013/2015), reproduced below without the additional restriction on the domain of correspondence, which is irrelevant for the current discussion (other definitions may include more complications, such as the directionality of the relations).

(10) Simplified definition of CORR in Bennett (2013:55)

For each distinct pair of output consonants, X & Y, assign a violation if:

a. X & Y both have the feature specification [F], and […]

b. X & Y are not in the same surface correspondence class. […]

RELATE constraints are *simpler* than CORR constraints, in that the constraint only refers to a specific feature tier, and so they refer to a smaller (or equal) set of elements, and do not check for segment similarity. In other words, RELATE simply scans each element with a specific property and checks whether it is in a φ-Correspondence relation.

Additionally, the constraint definition of RELATE constraints only refers to one variable at the time (a feature node), instead of four (the two root nodes and the two feature nodes associated with them),[21] and the number of operations is linear on the size of the domain of the relation.

Another difference between the definitions of the two constraints relates to similarity, a central concept in ABC (Rose & Walker 2004; Hansson 2010). Although the two constraints achieve the same effect of inducing similar segments to interact, in segmental correspondence the similarity effect is due to a conditional statement in the constraint definition (correspond *if* you share a feature value). In contrast, feature correspondence, the similarity effect is more fundamental, since it is the product of the specification of the relation itself (that is, of its domain).

[21] One way of formally determining the complexity of a constraint is to refer to the number of bound variables the constraint refers to. The variables range over nodes on a structure, and the number of nodes a constraint refers to measures the complexity of that constraint (McNaughton & Papert 1971, Jardine 2015). There are CORR constraints that have additional requirements, for example, agreement for an additional feature, or being in the same morphological domain. However, the feature correspondence complexity will always be higher, since it will also have to encode the basic similarity condition and to operate on the set of all segments.

Most importantly, CORR constraint definitions are different from MAX and DEP constraints, while RELATE constraints form a uniform family of constraints that encompasses both I/O- and φ-Correspondence.

2.3.1.3 IDENT-XY[φ]

The second correspondence constraint is IDENT-XY[φ], which is defined as follows:

IDENT-XY(φ) definition.

For each element *x* in X assign a violation if:

a. *x* dominates a feature node *y* in φ or it is dominated by a root node that dominates a feature node *y* in φ,[22] *and*

b. for any of *x*'s correspondents *x′, x′* does not dominate an element in φ.

Let us take for example the constraint IDENT-IO[+sib]. This constraint is violated when an input root node that dominates a sibilant [+sib] corresponds to an output root node that does not dominate a feature [+sib].

Now, let us consider the φ-Correspondence IDENT constraint. In the case of IDENT-IO, the definition assigns a violation for each element in I that is unfaithfully mapped. The set over which φ-Correspondence constraints iterate is instead the set of all non-head features in a tier, such as [+sib].

Non-heads are either not in correspondence—in which case they vacuously satisfy condition (b)—or they correspond to a head. The constraint thus demands that every pair

[22] The first disjoint applie to IO-Correspondence while the second disjoint applies to φ-Correspondence. They express two similar, complementary conditions, but because of the restrictions in the theory they cannot be unified under a single statement. A simplified definition is possible under certain assumptions, as discussed at the end of this section.

of head-dependent in φ-correspondence be dominated by a root node that dominates the same feature φ (i.e., that they agree for a feature φ). For example, the constraint IDENT-[+sib](+ant) is defined as follows:

IDENT-[+sib](+ant) definition.

For each non-head feature node *x* in (the set of feature nodes) [+sib], assign a violation if:

a. *x* dominates a feature node *y* in [+ant] or it is dominated by a root node that dominates a feature node *y* in [+ant], *and*

b. for any of *x*'s correspondents *x', x'* does not dominate an element [+ant].

Simply speaking, the constraint demands that elements in correspondence agree for a specific feature value. φ-Correspondence IDENT constraints are more numerous than I/O-Correspondence IDENT constraints. In the case of I/O-Correspondence, there is only one relation type, which connects input to output root nodes, while for φ-Correspondence, there is an IDENT constraint for each feature for which a φ-Correspondence can be instantiated (e.g., IDENT-[+ant], IDENT-IO[+sib], IDENT-IO[+voc], and so on).

For each of these IDENT classes, the IDENT constraint may demand identity for any specific feature (e.g., IDENT[+sib](ant), IDENT[+sib](retroflex), etc.). Empirically, there is an evident correlation between elements in correspondence and the outcome of the harmony (the X and [ϕ] in the IDENT-XY[ϕ] schema). [+sib] features most often agree on [+ant], but the opposite never occurs; it is common for obstruents to agree in voicing, while the opposite is unattested.

In a geometry where, for example, [+sib] nodes dominate [ant] nodes, one could replace condition (a) of the definition with one that is simply satisfied when elements in correspondence dominate the same node. In addition to constituting a more elegant definition of IDENT, this assumption would predict the relation between features determining which segments agree and their outcome in harmony. However, the introduction of such a geometry would require assumptions and empirical justifications that are irrelevant for the goal of this dissertation.

2.3.2 Other correspondence constraints

This dissertation focuses on RELATE-X and IDENT-XY constraints. However, Correspondence Theory establishes a series of other constraints that encode basic properties of formal relations, such as injection/surjection (UNIQUE-X) and linear ordering among elements in relations (CONTIGUOUS-X).

While I do not discuss any of these constraints in depth, in the following section I provide a definition of the constraints and a description of their empirical effect. In section 7.1, I discuss a series of patterns where these constraints play a fundamental role.

2.3.2.1 UNIQUE-X

While RELATE-X favors elements that are in correspondence, UNIQUE-X is the first of a series of constraints that instead limits correspondence relations. UNIQUE-X penalizes one-to-many correspondence relations and corresponds to UNIFORMITY and INTEGRITY (McCarthy & Prince 1995).

Like RELATE-X, I define UNIQUE-X as a single constraint schema with two variables that ranges over the domain and range of correspondence types. The constraint schema penalizes one-to-many relations (e.g., non-injective relation), and I define it as follows.

UNIQUE-X definition.

> Given the correspondence relation $\mathscr{R}_{X\text{-}Y}$, assign a violation for each element *x* in *X* that corresponds to an element *y* in *Y* if there is another element *z* in *Y* that also corresponds to *x*.

The same constraint schema applies to φ-Correspondence, and as in the case of RELATE-X, a constraint exists for each φ-Correspondence type. An example of a UNIQUE-X constraint applied to φ-Correspondence is given below. I have slightly reworded the formulation to make it clearer for φ-Correspondence, but the constraint definition obtained from the schema above is the same.

UNIQUE-[+sib] definition.

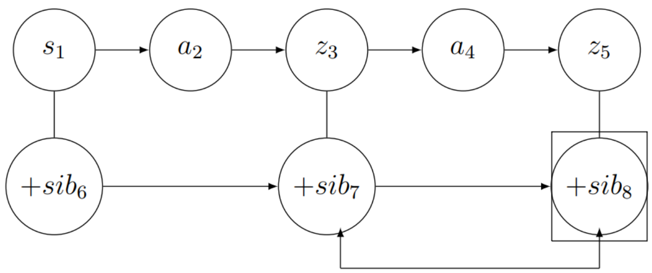
> Given the correspondence relation $\mathscr{R}_{[+\text{sib}]}$, assign a violation for each head *h* in [+sib-head] (*x* in *X*) that corresponds to a non-head *y* in [+sib] (*y* in *Y*) if there is another non-head *z* in [+sib] (*z* in *Y*) that also corresponds to *h*.

In other words, the constraint penalizes heads with multiple dependents. Empirically, UNIQUE-X constraints limit "feature spreading," as in the case of non-iterative assimilation (see Kaplan 2008 and section 7.1).

The three structures in (11) show how UNIQUE-[+sib] is evaluated. In (11), a head is in correspondence with just one dependent (with the first sibilant not being in any φ-

Correspondence relation). The candidate does not violate UNIQUE-[+sib] since there is no other element in addition to •7 that corresponds to the head •8. Empirically, the structure represents a phenomenon of spreading that is limited to a single target and then stops (see 193 for an example).

(11) One-to-one correspondence satisfies UNIQUE-X



The constraint assigns "a violation for each head *h* in [+sib-head] (*x* in *X*)," and so it is vacuously satisfied when no element is in correspondence, since feature heads only exist as part of φ-Correspondence relation.

Finally, a candidate in correspondence with three dependents violates UNIQUE-X only once. The definition could be modified by assigning a constraint for each dependent in addition to the first. However, because of the high number of elements required to create such configurations, it is hard to find a language where such a candidate plays a significant role, and therefore I assume this simpler definition.

As in the case of RELATE-X, we do not observe the presence of two constraints UNIQUE-X that refer to head and non-head feature nodes, and the reason is the same: because of the axiom on heads, a dependent cannot correspond to two heads (see section 2.4.1.1), so no candidate is ever generated that violates UNIQUE-φ constraints.

2.3.2.2 Contiguous-X

Contiguous-X corresponds to Contiguity constraints (McCarthy & Prince 1995), although they have a slightly different definition to adapt them to φ-Correspondence. The concept behind them is the same though: elements in correspondence must form a contiguous sequence. In other words, no gaps between elements in correspondence are allowed. The definition is the following.

Contiguous-X definition.

> For each *x* and *y* in the set of all elements $\bigcup\mathscr{R}_{X\text{-}Y}$[23] in $\mathscr{R}_{X\text{-}Y}$, if *x* precedes *y*, assign a violation for each element *w* not in $\bigcup\mathscr{R}_{X\text{-}Y}$ that follows *x* but precedes *y*.

The constraint looks at the set of all elements in a relation (not at the set of ordered pairs of the relation). Then, for each pair of elements, it assigns a violation if there is an intervening element (within the precedence chain of elements with the same properties) that does not participate in that type of correspondence relation.

To exemplify, consider the definition of Contiguous-[+sib] constraint applied to the structure in (13).

Contiguous-[+sib] definition.

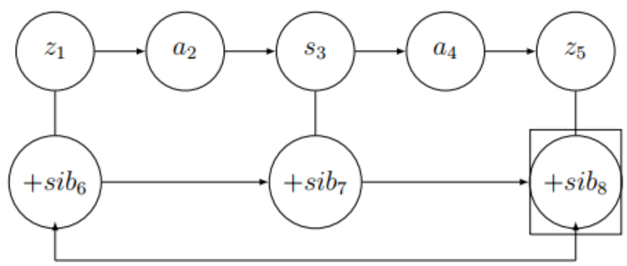
> For each *x* and *y* in the set of all elements $\bigcup\mathscr{R}_{[+\text{sib}]}$ in $\bigcup\mathscr{R}_{[+\text{sib}]}$, if *x* precedes *y*, assign a violation for each element *w* not in $\bigcup\mathscr{R}_{[+\text{sib}]}$ that follows *x* but precedes *y*.

---

[23] I use the notation $\bigcup\mathscr{R}_{X\text{-}Y}$ to indicate the set obtained from the union of each *x*, *y* in the set of pairs $<x_n, y_n>$ in $\mathscr{R}_{X\text{-}Y}$. In notation: $\forall p \in \mathscr{R}_{X\text{-}Y,}\ \pi_1(p) \cup \pi_2(p)$, where π_1 indicates the first coordinate of the pair, and π_2 the second coordinate.

The constraint first iterates over the set of all elements that participate in the relation $\mathscr{R}_{[+sib]}$, namely $\bullet_6$, $\bullet_8$. When $x = \bullet_6$ and $y = \bullet_8$, the constraint assigns a violation mark because there is an element $w = \bullet_7$ that follows x (= $\bullet_6$), precedes y (= $\bullet_8$), and does not belong to $\bigcup\mathscr{R}_{[+sib]}$ (= {$\bullet_6$, $\bullet_8$}). Notice that if $\bullet_7$ were in correspondence with $\bullet_8$, the constraint would not be violated.

(12) CONTIGUOUS-[+sib] violations.



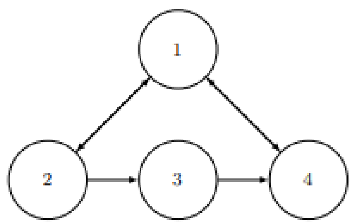
The constraint favors spreading to the nearest target and plays a fundamental role in cases where harmony is limited because of blocking, in non-iterative harmonies and in strictly local spreading (see section 7.1 for a discussion).

Let us now consider the two cases of I/O-Correspondence relations represented below and show how the same definition applies to I/O pairs.

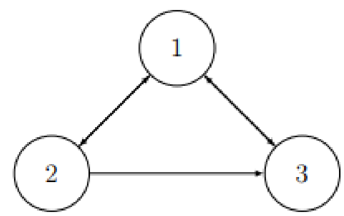
In (13a), the set of elements that participate in the I/O-Correspondence relation includes the three elements {$\bullet_1$, $\bullet_2$, $\bullet_4$}. The constraint binds the variables x and y to each element in this set. Crucially, when one of the variables is $\bullet_1$, the constraint is vacuously satisfied, since there is no precedence relation between $\bullet_1$ and the two other elements $\bullet_2$ and $\bullet_4$. The condition "follows x but precedes y" cannot be satisfied.

(13) CONTIGUOUS in I/O-Correspondence

a. One violation by 2, 4



b. No violation



However, the constraint is violated when $x = \bullet_2$ and $y = \bullet_4$. Like in the case of CONTIGUOUS-[+sib] above, there is an element $w = \bullet_3$ that follows x (= $\bullet_2$), precedes y (= $\bullet_4$), and does not belong to $\bigcup\mathscr{R}_{[+sib]}$ (= $\{\bullet_1, \bullet_2, \bullet_4\}$), so the constraint is violated.

In (13b), there is no precedence relation between 1 and elements 2 and 3. 2 and 3 are related by a precedence relation, but there is no element intervening, and so the constraint is not violated.

2.3.3 Interim summary

In this section, I introduce the four constraint schemas RELATE-X, UNIQUE-X, CONTIGUOUS-X, and IDENT-XY. I argue that the same definitions apply to both I/O-Correspondence and φ-Correspondence constraints, and that different effect on the representation is entirely due to the effects contingent the properties of the elements they act on.

Given these definitions, I conclude that φ-Correspondence also satisfies Hypothesis II, reproduced below.

Hypothesis II (correspondence constraints).

> For each relation type I/O Correspondence, O/I Correspondence, and all φ-Correspondence, there is a proper set of constraints that adhere to the same set of correspondence constraint schemas. (xv)

2.4 φ-heads

A crucial component that distinguishes φ-Correspondence from ABC and I/O-Correspondence is φ-heads. In this section, I define φ-heads with more precision.

I start by looking at the axiom that subsumes all phonological heads and show that it is the only axiom required to define φ-heads (§ 2.4.1.1). I demonstrate how some theorems derived from this axiom limit the range of φ-Correspondence relations and explain its limited generative power as compared to I/O-Correspondence (§ 2.4.1.2).

Finally, in § 2.4.2, I demonstrate that the two constraint classes that govern the distribution of φ-heads in the output are both derived by two well-attested classes of constraints, namely Generalized Alignment (§ 2.4.2.1) and Positional Faithfulness constraints (§ 2.4.2.2).

2.4.1 The property of φ-heads

2.4.1.1 The head axiom

In section 2.1.1, I defined headedness as a *cumulative* property of an element. Unlike *derivational* and *interpretable* properties, the presence of the head property on an element does not impose any restrictions on the other properties of that element. Nevertheless, the distribution of heads is still governed by a single axiom, which applies to all phonological heads in the theory. I define it as follows:

Axiom VI (unique headedness).

> A head defines a unique element among a set of elements with the same interpretable properties connected by a binary relation $\mathscr{R}$. (xvi)

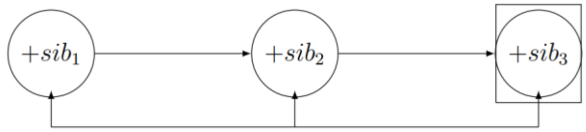
Head elements are parasitic on another *heterogeneous* binary relation (dominance or correspondence). The relation defines a *field* where the head operates. In other words, a head is always a *head of* a set of elements, a *field*, which is defined by a binary relation.

This definition is commonly assumed in definitions of headedness in the literature. Let us consider prosodic heads as an example. A head foot is a foot that is a head of the domain defined by the *dominance* relation of its dominating node (let us say, the prosodic word). Its status as head is defined with respect to other feet that are non-heads and that are dominated by the same node (i.e., are in the same domain).

The same goes with syllables. A head syllable exists as a special syllable in the domain defined by all the syllables dominated by the same foot. There cannot be two head feet dominated by the same prosodic word (i.e., two primary stresses), and there cannot be two head syllables dominated by the same foot.

In the case of φ-Correspondence, the field is defined by correspondence relations. In particular, a φ-head is the head of a correspondence field, which is defined by the set of elements in φ-correspondence. In (14), the head $\bullet_3$ is the head of the field $\{\bullet_2, \bullet_3\}_{[+sib]}$ defined by the correspondence relation $\mathscr{R}_{[+sib]} = \{\{\langle\bullet_3, \bullet_1\rangle, \{\langle\bullet_3, \bullet_2\rangle\}$.

(14) Domain of the φ-head $\bullet_3$



Notice that the axiom does not state which elements can be heads. In fact, I assume that only output feature nodes and output prosodic nodes can have the properties of headedness. Having heads in the input unnecessarily complicates the theory without any evident advantage. The possibility of having head root nodes is instead discussed in section 7.1.1.

Finally, I can derive three theorems (or generalizations) from the axiom on heads. The first one is defined below.

Theorem III (split head). A dependent can be headed by at most one element.[24] (xvii)

The generalization states that a feature node can be headed by one and only one element. In other words, a dependent cannot correspond to two different heads. If that were to occur, the field of the relation would include two heads, which is a violation of the condition on the axiom that states that a head is a "unique" element in the set.

The other theorem states that φ-heads can only exist if they correspond to another feature. To prove it, I introduce the following lemma, which is a reformulation of Axiom VI applied to φ-Correspondence.

[24] I could specify "for each relation type $\mathcal{R}_{X\text{-}Y}$." but it is unnecessary to do so in our model. Because of the distribution of dominance and correspondence relation types, no element can be headed or can be head of two different types of domain. In other words, the domains defined by prosodic heads never overlap with the domains defined by φ-heads.

Lemma (unique headedness).

> A φ-head defines a unique element among a set of elements connected by a φ-Correspondence relation. (xviii)

The argument to prove Theorems VI below goes as follows. To have a head, you need a binary relation. To have a φ-head, you need a φ-Correspondence relation. A φ-Correspondence relation can only exist between a head and a dependent. Therefore, having a head entails having a correspondent. This theorem is fundamental in the case studies, since it allows us to exclude all the problematic candidates that contain heads with no dependents.

Theorem IV (no stranded heads). A φ-head must correspond to a dependent. (xix)

2.4.1.2 Examples

To summarize, a candidate is well formed if and only if:

1. Each instance of a φ-Correspondence relation occurs among nodes with the same feature value, *and*
2. Each instance of a φ-Correspondence relation occurs between one head and one or more dependent (a non-head feature node in a φ-Correspondence relation), *and*
3. Each feature node is in at most one φ-Correspondence relation.

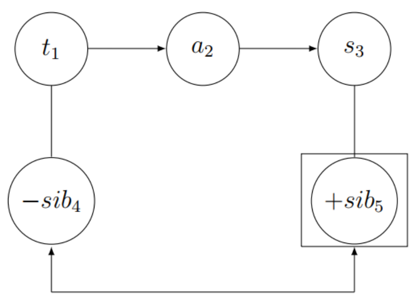
Two dependents in correspondence or two heads in correspondence violate the axiom of heterogeneity of Correspondence and therefore they are not generated as output form of a candidate.

Elements in φ-Correspondence must also be feature nodes of the same value. For instance, the form in (15a) violates the maximal distance axiom, which requires that two elements in correspondence have the same *interpretable* properties.

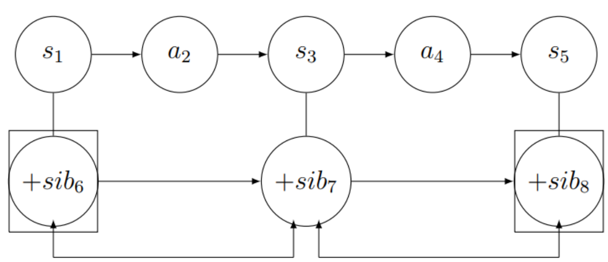
Finally, (15b) violates the split headedness theorem, since a single dependent is related to two heads.

(15) Some examples of ill-formed φ-Correspondence relations

a. An ill-formed structure violates the minimal distance axiom



b. An ill-formed structure violates the split-headedness theorem



2.4.1.3 Cumulativity

Before concluding this section, I briefly discuss why headedness is a *cumulative* property. Headedness is *cumulative* in the sense that it only adds to the existing properties of an element. A foot head has all the properties of a foot, in addition to the property of being a head, and the same applies to syllable heads in prosodic theories and to feature heads.

Being a head cannot deprive an element from its other properties, nor does it create a new "constituent."

This is a fundamental assumption of φ-Correspondence. To make heads constituents, I would have to postulate a different (interpretable) property for each of the properties compatible with headedness (e.g., $[+sib]^{+H}$ vs. $[+sib]^{-H}$, σ^{+H} vs. σ^{-H}, and so on.).

In addition to basically doubling up on the number of interpretable properties, such a theory would have several other consequences: constraints that refer to an element with an interpretable property (e.g., feet or a feature node) refer to all elements with those properties, regardless of their head status. For example, IDENT-IO([+sib]) is violated by heads and non-heads alike. Precedence is also blind to headedness because heads are ordered with respect to elements with the same interpretable and derivational property.

2.4.2 Constraints on φ-heads

2.4.2.1 ALIGN(φ-head)

Now that I have defined where heads can be assigned, I can proceed to define the constraints that determine the distribution of heads in the candidates. Head status is assigned freely to feature nodes in the output within the limit of well-formedness specified in the previous two sections.

I start with ALIGN(φ-head). In chapter 3, I show that in Chumash, the harmonizing feature is always determined by the rightmost sibilant in the word. In Optimality Theory, references to constituents' edges and directionality are predominantly analyzed as an effect of Generalized Alignment constraints. McCarthy and Prince (1993:2) provide the following generalized schema.

(16) ALIGN(Cat1, Edge1, Cat2, Edge2) definition (McCarthy & Prince 1993)

∀ *Cat1* ∃ *Cat2* such that *Edge1* of *Cat1* and *Edge2* of *Cat2* coincide,

where:

Cat1, Cat2 ∈ PCat ∪ GCat

Edge1, *Edge2* ∈ {Right, Left}

The schema defines the set of possible constraints that can be obtained by replacing the variables *GCat* with morphophological categories (root, stem, reduplicant, etc.), the variable *PCat* with phonological constituents (syllable, foot, etc.), and the variables *Edge1* and *Edge2* with the right or left edge of these constituents. An example of an alignment constraint is the following:

(17) Align-PrWd ≔ Align(Ft, R, PrWd, R)

The constraint requires that the two phonological constituents—PrWd (prosodic word) and Ft (foot)—be aligned at their respective right edges.

The φ -head alignment constraint in (14) follows the same schema of Align-PrWd, the only difference being that in ALIGN(φ-head, R), the second *PCat* variable refers to the φ-head instead of the foot. Using McCarthy and Prince's (1993) notation, we have: ALIGN(φ-head, R) ≔ ALIGN(φ-head, R, PrWd, R).

For example, ALIGN([+sib-head], R) is violated once in the output [(ʃ)atyas]$_{\omega}$, since the sibilant head feature node is separated from the right edge of the prosodic word by the only other sibilant node.[25]

The generalized alignment constraint definition refers to properties not introduced in the theory. The following definition follows the Generalized Alignment schema but uses the formalism of the current theory.[26] For example, the constraint that refers to [+sib] nodes can be paraphrased as follows.

ALIGN([+sib-head], R, ω, R) := Align([+sib], R) definition.

> For each [+sib-head] feature node *x* in the output, assign a violation if there is another [+sib] feature[27] node that follows *x* and it is part of the same prosodic word.

For example, in the form [s$_x$o(ʃ)$_x$as]$_{\omega}$ the three [+sib] nodes are all dominated by the same ω. The head (ʃ), which represents a [+sib] head, is not aligned to the right edge of the word, and therefore ALIGN([+sib-head], R) is violated once. Notice that it does not matter whether or not the intervening [+sib] feature node is in correspondence with the head. A precedence relation is established on the [+sib] tier regardless of correspondence.

Instead, the form [ʃ$_x$o(s)$_x$at]$_{\omega}$ does not violate the alignment constraint. The head sibilant feature node is the rightmost feature node in the word, even though it is not the rightmost segment. The constraint evaluates feature nodes in the precedence relation, and

---

[25] Recall that only feature nodes with the same feature value are in the precedence relation.
[26] Notice that the constraint is categorial. It is violated only once, regardless of the number of intervening elements. In my knowledge, there is no theoretical or empirical reason to prefer the gradient or the categorial definition in φ-Correspondence, and so I just assume the simpler categorial formulation.
[27] Or simply an element, since only [+sib] feature nodes can follow a [+sib-head].

only feature nodes with the same value are in the relation. The word-final [t] does not have [+sib] feature node and therefore does not intervene between the second sibilant and the right edge of the word.

2.4.2.2 Ident-IO(φ-head)

The second class of φ-head constraints is comprised by the positional faithfulness constraints of the type IDENT-IO(φ-head). IDENT-IO(φ-head) is violated when a head feature node is not faithful to its input I/O correspondent. More specifically, the constraint is violated by any output node that dominates a head φ-feature and has an input correspondent that does not dominate a matching φ-feature.

(18) **IDENT-IO(φ-head)** definition.

Assign a violation for each output root node *x* that dominates a head feature *h* if:

a. *x* dominates an element *φ*, *and*

b. any correspondent of *x* does not dominate an element *φ′*,

…where *φ* and *φ′* have the same interpretable property.

Positional faithfulness constraints are IDENT-IO faithfulness constraints that refer to specific prosodic positions (e.g., IDENT-IO(Head-σ), in Alderete 1995:14), morphological positions (e.g., IDENT-IO(root), in McCarthy & Prince 1995; Beckman 2013) or phonological constituents (e.g., IDENT-IO(onset), Lombardi 1999; Padgett 2002). IDENT-IO(φ-head) is then a positional faithfulness constraint that refers to a phonological constituent, of the same kind as IDENT-IO(onset).

(19) **IDENT-IO(root)** definition.

Assign a violation for each output node *x* that has the root property if:

a. *x* dominates an element *φ*, *and*

b. any of its *x′* correspondents do not dominate an element *φ′*,

…where *φ* and *φ′* have the same interpretable property.

Tableau (20) shows how IDENT-IO(φ-head) and the other φ-head constraints are evaluated. Candidates (20a–b) have their φ-heads aligned to the right edge of the word and therefore do not violate ALIGN(+sib-head, R).

In both candidates, the head is the rightmost segment in correspondence, and the two segments harmonize. The difference is that in candidate (20a), the φ-head is mapped faithfully, while in (20b) the φ-head is changed to [−anterior] and thus violates IDENT-IO(φ-head).

The output of candidate (20c) is phonetically identical to the output of candidate (20b), since correspondence relations are not phonetically realized. The conditions under which the two candidates are optimal are not the same, though. Candidate (20b) is favored by ALIGN(+sib-head, R), while candidate (20c) is favored IDENT-IO(φ-head) and IDENT-IO(−ant).

(20) Constraints on φ-heads

Input	Output	IDENT-IO(+sib)	RELATE-[+sib]	IDENT-[+sib](ant)	IDENT-IO(φ-head)	ALIGN([+sib-head], R)	IDENT-IO(−ant)	IDENT-IO(+ant)
ʃ…s	a. s$_x$…(s)$_x$						*	
	b. ʃ$_x$…(ʃ)$_x$				*			*
	c. (ʃ)$_x$…ʃ$_x$					*		*
	☠d. (s)$_x$…s$_x$				*	*	*	

Candidate (20d) is harmonically bounded by candidate (20a). The φ-head is not aligned to the right edge of the prosodic word, and it is not faithful. The candidate thus violates both φ-head constraints ALIGN(+sib-head, R) and IDENT-IO(φ-head), as well as the faithfulness constraint IDENT-IO(−ant).

(21) Harmonically bounded candidates for harmonic inputs

Input	Output	IDENT-IO(+sib)	RELATE-[+sib]	IDENT-[+sib](+ant)[28]	IDENT-IO(φ-head)	ALIGN(+sib-head, R)	IDENT-IO(ant)
s…s	a. s$_x$…(s)$_x$						
	☠ b. s$_x$…s$_y$		*				
	☠c. (s)$_x$…s$_x$					*	
	☠ d. t$_x$…s$_y$	*					

[28] I use the feature [+ant] here, but because of the definition of the feature properties (a root node dominates either a [+ant] or a [−ant] node) either feature value penalizes disagreement of the anterior value between the sibilants in correspondence. For a discussion on this issue, see also section 3.4.1.

Notice that because of the asymmetry in the constraint system, even in dominant languages there are no co-optima for candidates that are already harmonic in the input. Since there is only a constraint ALIGN(φ-head, R), and no constraint ALIGN(φ-head, L), except for in dissimilation grammars, the output for harmonic inputs is always harmonic with a right-aligned head.

2.4.3 Interim summary

In this section, I provide a definition of φ-heads. I show that assuming φ-heads does not require the definition of a new property, since prosodic heads are independently postulated. I also argue that the axiom on heads that applies to φ-heads naturally extends to the standard definition of other phonological heads.

I also demonstrate how φ-heads are a main factor in the superficial distinction between I/O-Correspondence and φ-Correspondence and how their existence limits the set of possible structures permitted by the theory.

Finally, I show that the constraints that govern the distribution of φ-heads are Generalized Alignment (§ 2.4.2.1) and Positional Faithfulness constraints (§ 2.4.2.2). Both families of constraints are independently motivated and related to the distribution of other phonological heads in many theories.

2.5 Beyond correspondence

The previous sections were dedicated to correspondence. In this section, I briefly introduce the axioms on dominance and precedence relations to contrast them to φ-Correspondence.

2.5.1 Totality

I briefly touched on totality in section 2.3.1.1, when I defined the constraint RELATE. The axiom of totality requires that all elements in the domain of a relation be related to at least one element in its range. A formal definition is given below.

Definition (totality).

> A relation is total *iff* for each element x in the domain of a relation R is related to at least an element y in the range of R. (xx)

Totality is an axiom of dominance in the theory. This should not be surprising. Under most models of the prosodic hierarchy, each element in the prosodic tier is associated to at least one element on a lower level. In other words, no floating prosodic constituent is allowed in the output.

For example, because of totality every foot dominates at least a syllable. A representation with a floating foot constitutes an ill-formed representation. Notice that the opposite is not true: a syllable never dominates a foot. For this reason, dominance is only right-total. Likewise, floating features nodes are disallowed in the system.

For correspondence relations, totality is not an axiom. In fact, in section 2.3.1.1 I show that RELATE-X constraints favor candidates with left-total relations, in that they only penalize structures where elements in the domain are not in correspondence.

2.5.2 Surjection

Another common property of heterogeneous relation is surjection, which is defined as follows:

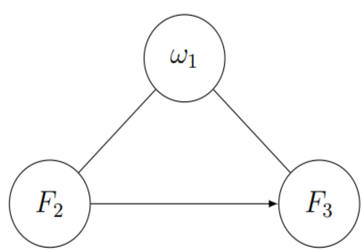
Definition (surjection).

A relation is surjective *iff* each element *x* in the range of a relation R is related to at most one element *y* in the domain of R. (xxi)

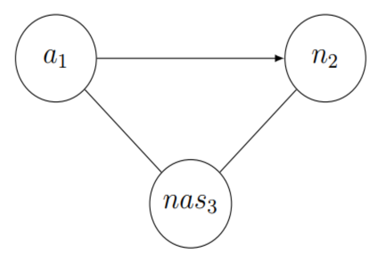
While surjection bans one-to-many mappings from the domain to the range, injective relations do not permit one-to-many mappings from the domain to the codomain. An example of a non-injective (22a) and of a non-surjective (22b) relation are given below.

(22) Example (non-)injection

a. A non-injective relation



b. A non-surjective relation



Non-surjection and injection are axioms of dominance relations. This is also a standard assumption. Let us consider the relation between feet and syllables. A foot can dominate several syllables (22a), but a syllable cannot be dominated by multiple feet. Likewise, a root node is usually assumed to be dominated by only one syllable, although a syllable might dominate multiple segments.[29]

[29] Some theories violate this axiom. For example, ambisyllabicity is a violation of surjection since the same segment belongs to two syllables. In Hyde (2001), a syllable can be parsed into multiple feet.

Autosegmental relations are non-surjective and non-injective at the subsegmental level. Assimilation is obtained when a feature node is associated to two different root nodes (possibly by transitivity via an intermediate C/V-node).

In correspondence theory, non-injective and non-surjective relations are possible but penalized. Whenever there is a disparity between the number of elements in a domain and the number of elements in the codomain a constraint is necessarily violated. If the extra elements are not related, RELATE-X constraints are violated; otherwise, the extra elements must be related to more than one element, in which case UNIQUE-X is violated.

In φ-Correspondence, whenever assimilation causes the spreading of a feature to more than one segment, injection is violated, since the configuration is realized as a head in correspondence with two or more dependents.

2.5.3 Properties of homogeneous relations

As argued in section 2.2.1.5, precedence is a homogeneous relation. The other axiom of precedence is *connectedness*, defined below.

Definition (connectedness).

> A relation *R* is *connected* if each pair of elements in the domain of *R* is joined by a sequence of pairs in *R*. (xxii)

The axiom is quite inconsequential for φ-Correspondence, but notice that like totality for dominance, the axiom is possibly violated by theories with floating feature elements. The introduction of floating elements would thus significantly affect the restrictiveness of the theory, since it requires the relaxation of two axioms of its relations.Precedence in the theory is also irreflexive and transitive, as defined below.

Definition (irreflexivity). A relation R is *irreflexive* if $R_{a,b}$ entails that $a \neq b$.

Definition (transitivity). A relation R is *transitive* if $R_{a,b}$ *and* $R_{b,c}$ entails $R_{a,c}$.

2.5.4 Interim summary

In this section, I briefly discuss some axioms of the other two relations in the model: precedence and dominance. Although the focus of this dissertation is on correspondence, I show that the definition of the relations in the system either sheds some light on the axiom of correspondence, or it has fundamental repercussions on the definition of correspondence relations and correspondence constraints.

I argue that the axioms of dominance are either axioms of correspondence or that they are realized as soft constraints, thus showing that the two relations are underlyingly more similar than previously assumed. I also argue that the definition of precedence has a significant impact on the definition of correspondence relations and constraints. Within the current theory, I can adopt a restrictive definition of precedence, which permits limiting the computational complexity of the theory.

3 Directional harmony in Chumash

3.1 Introduction

In this chapter, I go through the first full analysis of the dissertation. I start with the well-known case of consonant harmony in (Ineseño) Chumash.

In Chumash, all sibilants in a word agree in anteriority, and the value of the feature [anterior] is solely determined by the value of the rightmost sibilant in the word. An example is given below.

(23) Sibilant harmony in Chumash, basic pattern. (Applegate 1972:200; gloss adapted).

a. /ha-s-xintila-waʃ/ → [haʃxintila-waʃ] 'his former Indian name'

cf. /ha-s-xintila/ → [hasxintila] 'his Indian name'

φ-Correspondence elegantly captures this pattern because of the constraints on φ-head alignment and φ-head faithfulness. The analysis is exemplified by the candidate /ha-s-xintila-waʃ/ → [haʃ$_x$xintila-wa(ʃ)$_x$]. In the output form, the two sibilants are in correspondence, and they must agree for the value of [anterior]. The head is right-aligned to the rightmost [+sibilant] feature node, and so it does not violate ALIGN([+sib-head], R).

The positional faithfulness constraint IDENT-IO([+sib-head]) then determines the value of the assimilation, based on the position of the head.

Despite the simplicity of the pattern, standard treatment in ABC is either unsatisfactory or requires the use of constraints that alter fundamental assumptions in OT (see section 3.4.1).

In φ-Correspondence, instead, the analysis does not require the postulation of any non-standard OT constraint or a modification of the theory. Rather, the directionality pattern is captured by the interaction between the independently motivated alignment, positional faithfulness, and standard correspondence constraints.

3.1.1 Chumashan languages

Chumashan languages are a family of languages formerly spoken in Southern California by the Native American Chumashan people. Chumashan languages have been well studied by both descriptive and theoretical phonologists, in particular with reference to the process of sibilant harmony analyzed here (Beeler 1970; Applegate 1972; Harrington 1974; Poser 1982, 2004; Shaw 1991; Hansson 2001/2010; McCarthy 2007; among others).

There are at least three Chumashan languages that show a certain degree of sibilant harmony, Ineseño (or Ynezeño, now Samala), Barbareño, and Ventureño. I focus on Ineseño since it has been the language most discussed in the theoretical literature (Harrington 1974; Poser 1982, 2004; Shaw 1991; Gafos 1996; Hansson 2001/2010; McCarthy 2007; among others) and probably the best documented (Applegate 1972), and because of the three languages it is the one that shows the clearest case of sibilant harmony (Poser 2004).

King (1969) established the number of speakers of speakers of Chumashan languages in pre-contact times at about 10,700 and 17,250. Unfortunately, no first-language speaker remain today

3.1.2 Consonant inventory

Chumashan languages have a rich consonantal system, shared by all languages in the group (Applegate 1972:8). They distinguish plain, glottal, and aspirated consonants, although aspirated consonants seem to be less frequent and more constrained with respect to the contexts in which they can appear (all data in this chapter is converted to IPA).

The same distinction is maintained for the sibilants, which in addition to plain [s, ʃ], can also be aspirated [sʰ, ʃʰ] or glottalized [sˀ, ʃˀ]. The glottal contrast is reduced to plain/glottalized for the series of sonorants.

		Labial	Dental	Palatal	Velar	Uvular	Glottal
Nasal	plain	m	n				
	glottalized	ˀm	ˀn				
Plosive	plain	p	t		k	q	ʔ
	ejective	p’	t’		k’	q’	
	aspirated	pʰ	tʰ		kʰ	qʰ	
Affricate	plain		t͡s	t͡ʃ			
	ejective		t͡s’	t͡ʃ’			
	aspirated		t͡sʰ	t͡ʃʰ			
Fricative	plain		s	ʃ	X		h
	ejective		s’	ʃ’	x’		
	aspirated		sʰ	ʃʰ			
Approx.	plain		l	j	w		
	glottalized		ˀl	ˀj	ˀw		

The table above highlights all 12 sibilants in the language. Recall that within a root, all sibilants agree in anteriority (palatal), but maintain all other features. The sibilants in the column *alveolar* change to match their *palatal* correspondents.

In addition to anteriority, we can distinguish two series of sibilants based on their manner of articulation (fricative and affricate), or three series based on their glottal specification (plain, aspirated, glottalized). The sibilants are not distinguished for voicing.

3.1.3 Directional harmony

All sibilants in a word share the same feature value [anterior] in Chumash, and the harmonizing value is determined by the underlying value of the rightmost sibilant in the output. The generalization is illustrated by the data in (24) below.

(24) Directional harmony in Chumash (data from Applegate 1972, vMcCarthy 2007:2)

/ha-s-xintila-waʃ/ → [haʃxintilawaʃ] 'his former Indian name' (p. 200)

cf. /ha-s-xintila/ → [hasxintila] 'his Indian name' (p. 200)

/s-iʃ-sili-ulu-aq-pej-us/ → [sisʰiluleqpejus] 'they (dual) want to follow it' (p. 333)

cf. /p-iʃ-al-naˀn/ → [piʃanaˀn] 'don't you (dual) go!' (p. 109)

In (24a), the rightmost sibilant has the feature value [−anterior]. The other sibilant in the word is /s/, but because it is followed by a [−anterior] sibilant, it surfaces as [ʃ]. Chumash has directional harmony, because the harmonizing feature is determined by the rightmost sibilant in the prosodic word, regardless of the morphological position or the feature value of the segment. This is shown by (24a), where the target of assimilation is [+anterior], and by (24b), where the target is [−anterior].

As previously mentioned, harmony occurs regardless of the glottal specification. Plain, glottal, and aspirate sibilants all harmonize even if they do not share the same glottal features (aspirated, glottalized). In other words, the only features determining the segments that participate in the harmony is [+sibilant].

(25) Harmony includes aspirated and glottalized affricates (data from Applegate 1972, also cited in Hansson 2001:58-59)

/s-api-tʃʰo-it/ → [ʃapitʃʰolit] 'I have a stroke of good luck' (p. 89)

/s-api-tʃʰo-us/ → [sapitsʰolus] 'He has a stroke of good luck' (p. 118)

Harmony is also independent of the morphology. All data reported in the literature concerns the entire "word" and ignores any morphological boundary. Since there is no process that distinguishes between morphological and phonological words, I can safely assume that morphological and phonological word boundaries align and will simply use the term "word" to refer to either one of them. Unfortunately, there is no data on compounds.

(26) Harmony independent of the morphology (past /-waʃ/) (ibid.)

/s-api-tʃʰo-us/ → [sapitsʰolus] 'he has a stroke of good luck' (p. 118)

/s-api-tʃʰo-us-waʃ/ → [ʃapitʃʰoluʃwaʃ] 'he had a stroke of good luck' (p. 119)

Russell (1993) proposed that harmony in Chumashan languages is phonetic. Poser (2004) shows that the criticisms advanced against the phonological nature of the phenomenon are either not true for Ineseño, are empirically questionable, or are not a diagnostic. McCarthy (2007) further defends the phonological nature of the process by using loanword adaption as evidence of the synchronic nature of the phenomenon. A few exceptions to generalizations are recorded in Applegate (1972:164).

(27) Harmony in loanwords (data from Applegate 1972:164, also see McCarthy 2007:2)

/k-sapatu-Vtʃ/ → [kʃapatutʃ] 'I wear shoes (zapato)' (< Sp. zapato)

/s-kamisa-Vtʃ/ → [ʃkamiʃatʃ] 'he wears a shirt (kamisa)' (< Sp. camisa)

Finally, Chumash has a process that neutralizes [+ant] sibilants to [-ant] when they are immediately preceded by another coronal, such as [s], [l] or [n] (28). This process interacts with long-distance agreement: neutralized sibilants do not undergo but do trigger harmony (29).

(28) Sibilant neutralization before coronals (data from Applegate 1972; also see McCarthy 2007:2)

/s-tepuʔ/	→	[ʃtepuʔ]	'he gambles' (p. 117)
/s-lox'-it'/	→	[ʃloxit']	'he surpasses me' (p. 10)

(29) Neutralized sibilants do not undergo but trigger harmony (data from Applegate 1972; also see Poser 1993:318, also cited in Hansson 2001:59)

/s-ti-jep-us/	→	[ʃtijepus]	'he tells him' (p. 120)
/s-is-tɨʔ/	→	[ʃiʃtɨʔ]	'he finds it' (p. 120)

3.2 Background

In the following two sections, I introduce the background for the analysis. These sections follow a template which is maintained throughout the dissertation. I start with a definition of the constraints based on the constraint schemas defined in sections 2.3 and 2.4.2. I then provide a definition of a simplified candidate set, which contains a description of all the permutations of elements I justify as necessary and sufficient for the analysis.

The candidates, the constraints, and the rankings in all the analyses of the dissertation were computed using OT Workplace 64 (Prince et al. 2013).

3.2.1 Constraints

For the analysis of Chumash, I only need the two most fundamental φ-Correspondence constraints: RELATE-X and IDENT-φ. Since harmony occurs among sibilants, I use the constraint RELATE-[+sib] to govern the distribution of sibilant nodes in correspondence. Sibilants in correspondence agree for the feature anterior, so I introduce the IDENT-φ constraint ID-[+sib](ant), which is violated when two sibilants in φ-Correspondence do not agree for the feature anterior. A simplified definition of the two constraints is given below.

(30) φ-Correspondence constraints in Chumash

- **RELATE-[+sib]**
  - Assign a violation for each [+sibilant] feature node that is not in a φ-Correspondence relation.
- **ID-[+sib](ant)**
  - Assign a violation if two nodes in [+sib]-Correspondence have a different specification for the feature [anterior].

Sibilants in Chumash can be mapped unfaithfully to harmonize with other sibilants in the word. The outcome of the harmony is mostly determined by the faithfulness sibilant heads ID-IO(+sib-head), which penalizes sibilant feature heads unfaithfully mapped from the input.

In the analysis, I show how ID-IO(+sib-head) determines the outcome of the harmony by keeping the head faithful and by enforcing all the sibilants to agree.

(31) Positional faithfulness in Chumash

- **ID-IO(+sib-head)**
  - Assign a violation if a segment has a φ-head and an unfaithfully mapped feature.

A φ-head (i.e., a trigger of the harmony) can be either a [+anterior] or a [−anterior] sibilant. Depending on the value of the head, then, harmony may cause an unfaithful mapping of the feature [anterior]. I take this possibility into account by using the constraints IDENT-IO[+ant] or IDENT-IO[−ant].

Additionally, an input sibilant may be realized as a non-sibilant, which allows it to escape the correspondence requirement imposed by RELATE-[+sib]. This is an example of dissimilation candidate in ABC (Rose & Walker 2004, Bennett 2013/2015). To prevent these candidates from winning, I include the IDENT-IO constraint that refer to the feature defining the correspondence domain ID-IO(+sib).

(32) IO-Correspondence constraints in Chumash

- ID-IO(+ant)
- ID-IO(−ant)
- ID-IO(+sib)

Finally, I need the alignment constraint to determine the position of φ-heads in the sibilant tier. I only consider ALIGN([+sib-head], R), since the candidate with the head on the rightmost sibilant is always the winner. I assume that the alignment requirement is on prosodic words, so the extended constraint definition is ALIGN([+sib-head], R, ω, R). The definition of the constraint is given below.

(33) ALIGN in Chumash.

- **ALIGN([+sib-head], R)** := ALIGN(+SIB, R)
  - Assign a violation if there is a head [+sibilant] feature node not aligned to the right edge of the prosodic word.

3.2.2 Candidate set

I now move on to the definition of the candidate set. For the sake of clarity and concision, I abstract only the relevant patterns and elements.

The elements participating in the harmony process are sibilants and non-sibilants. All the sibilants form a homogeneous class, so I do not need to distinguish between place and manner of articulation (except for [anterior]). In the candidate set, then, I only consider the permutations of the elements [s, ʃ] for the potential target of the harmony, and [t] as a general non-sibilant consonant.

The candidate set is represented by the schema in (34) below. The schema indicates the set of all candidates generated by mapping each element defined in the input (left) side to all combinations of elements in the output.

(34) GEN for Chumash

a. Mappings

ʃ → s, ʃ, t

s → s, ʃ, t

* → faithful[30]

b. Other

All combinations of surface correspondence

All possible head positions

One-to-one I/O mapping only

As indicated by the notation "s → s, ʃ, t", the first sibilant in the input /s/ can be mapped to [s], [ʃ], [t]. The candidate set will thus include the output [$ʃ_x$api($tʃ^h$)$_x$oit], where /s/ is mapped to [ʃ]. The second segment is neither /s/ nor /ʃ/, so it is mapped faithfully, as indicated by the statement "* → faithful."

I also assume that each root node in the input is linearly mapped to one root node in the output. In other words, in terms of I/O-Correspondence, I only consider candidates that do not violate any I/O-Correspondence constraint other than IDENT-IO. In other words, input–output mapping is always one-to-one, so no output results from segment epenthesis, deletion, coalescence, or splitting.

[30] The "*" indicates any other segment (i.e., non-sibilants). There is no constraint that favors unfaithfully mapping such segments, so I do not include them in the candidate set.

Let us look at an example. The table below contains all but the dissimilation candidates for the input /s-api-tʃ^{h}o-it/ (I omit the non-informative output where the anteriority of the sibilants is switched).

(35) Non-dissimilation candidates for the input /s-api-tʃ^{h}o-it/

		/s-api-tʃ^{h}o-it/	Correspond	Agree	Head
a.	a.	[s$_x$api(tʃ^h)$_x$oit]	y	n	right
b.	b.	[(s)$_x$apitʃ$^h{}_x$oit]	y	n	left
c.	c.	[ʃ$_x$api(tʃ^h)$_x$oit]	y	y	right
d.	d.	[(ʃ)$_x$apitʃ$^h{}_x$oit]	y	y	left
e.	e.	[s$_x$api(ts^h)$_x$oit]	y	y	right
f.	f.	[(s)$_x$apits$^h{}_x$oit]	y	y	left
g.	g.	[s$_x$apitʃ$^h{}_y$oit]	n	n	N/A
h.	h.	[s$_x$apis$^h{}_y$oit]	n	y	N/A
i.	i.	[ʃ$_x$apitʃ$^h{}_y$oit]	n	y	N/A

The first distinction is between the outputs where the sibilants are in correspondence (35a–f) or not in correspondence (35g–i). Partial correspondence is also possible (e.g., two of three sibilants in correspondence) but not considered. Given the current constraint set, candidates with more than two sibilants do not provide any additional ranking information, since all sibilants always agree, regardless of their number.

At the segmental level, I include the candidates (35a, b, g) where the sibilants are mapped faithfully from the input, candidates (35c, d, h) where they map to [−anterior] sibilants, and candidates (35e, f, i) where they map to [+anterior].

For elements in correspondence, head status may also vary. Given two elements in correspondence, two possible outputs are generated with the head assigned to either the right (35 a, c, e) or the leftmost (35 b, d, f) sibilant. Candidates without a φ-correspondent (35g–i) cannot have heads.

3.3 Analysis

I now move on the actual analysis. I start by discussing the two winning candidates that are necessary and sufficient to obtain the ranking for Chumash (§3.3.1). I then contrast them with the loser candidates with respect to correspondence (§ 3.3.2) and identity (§ 3.3.3). Section 3.3.4 concludes with the full ranking.

3.3.1 Winning candidates

There are two mappings that are necessary and sufficient to obtain a complete ranking for the harmony process in Chumash. The first candidate unfaithfully maps a sibilant to achieve harmony and has a right-aligned [+anterior] sibilant head, /iʃ-tiʃi-jep-us/ → [is$_x$tis$_x$ijepu(s)$_x$]; the second candidate also harmonizes but has a right-aligned [−anterior] head, /s-api-tʃ^{h}o-it/ → [ʃ$_x$api(tʃ^h)$_x$oit].

The following tableau shows the input and the output of each candidate, as well as the constraints they violate. Both candidates satisfy all the constraints, except the two faithfulness constraints that refer to [anterior].

(36) Two winner candidates in Chumash

Input	Output	ID-IO(+sib)	RELATE-[+sib]	ID-[+sib](ant)	ALIGN([+sib], R)	ID-IO(+sib-head)	ID-IO(−ant)	ID-IO(+ant)
a. iʃ-tiʃi-jep-us	is$_x$tis$_x$ijepu(s)$_x$						**	
b. s-api-tʃ^{h}o-it	ʃ$_x$api-(tʃ^h)$_x$oit							*

In both candidates, all the sibilants harmonize for the anterior value of the rightmost sibilant in the word. The candidates do not violate either of the two φ-Correspondence constraints RELATE-[+sib] or ID-[+sib](ant), since all sibilants are in correspondence and agree for the feature [anterior].

ID-[+sib](ant) does not require the segments that are in correspondence to have a particular feature value, so it is equally satisfied if all segments in correspondence are [+ant] or [−ant], as shown by (36).

φ-heads in Chumash are always assigned to the rightmost sibilant in the prosodic word. ALIGN([+sib], R) is thus also never violated by the winners in (36).

Finally, harmony is achieved at the cost of unfaithfully mapping the feature [anterior], regardless of its value. This is a case where alignment of the head overrides the markedness condition that imposes that the outcome of assimilation is a marked feature value (§ 6.2).

3.3.2 Correspondence

I now move on to compare the winning candidates to obtain ranking information. RELATE-φ constraints demand that each feature φ be in a φ-Correspondence relation. However, dispensing with correspondence relations has several advantages. Ident-φ constraints only favor identity among segments in correspondence: it is vacuously satisfied if no feature node is in correspondence. Likewise, since heads can only exist as part of a correspondence relation, IDENT-IO(φ-head) or ALIGN(φ) constraints cannot be violated if there is no φ-correspondence.

The loser candidates in (37a) contain outputs with no φ-Correspondence relations. Since there are no φ-Correspondence relations, there are no heads, and therefore no violation of any constraints referring to them. Notice that unfaithfully mapping the sibilants to achieve harmony would bring no advantage, since the only constraint demanding feature identity is ID-[+sib], which is evaluated with respect to nodes in φ-Correspondence.

(37) Candidates violating Relate-[+sib] in Chumash

ERC	Input	Winner	Loser	ID-IO(+sib)	RELATE-[+sib]	ID-[+sib](ant)	ALIGN([+sib], R)	ID-IO(+sib-head)	ID-IO(−ant)
1	s-api-tʃʰo-it	$ʃ_x$api$(tʃ^h)_x$oit	$s_x$apit$ʃ^h_y$oit		W				L

Nevertheless, the absence of correspondence yields a fatal violation of RELATE-[+sib]. Since there are two [+sibilant] nodes that are not in correspondence, the constraint is violated twice.

3.3.3 Identity

Correspondence is a necessary but insufficient condition for achieving harmony. When correspondence holds among sibilants in the output, IDENT-φ constraints must be ranked above the IDENT-IO constraint that refers to the non-harmonizing feature value.

In Chumash, the harmonizing feature is determined by the rightmost sibilant in the word, which becomes a feature head. Since feature heads are assigned to any [+sibilant] node, regardless of their anteriority, the outcome of the harmony varies depending on the candidate.

The ERCs in (38) show how directional harmony is obtained. The selection of heads can be affected by three factors: alignment, feature value, and morphological affiliation. Chumash has a pure directional harmony, which means that the head is always assigned to the rightmost sibilant of the prosodic word. Alignment is more important than both the feature value of a segment and its morphological affiliation.

Purely directional harmony like Chumash are obtained when an alignment constraint such as ALIGN([+sib], R) dominates both faithfulness constraints that refer to the feature value of the outcome of the harmony, i.e., IDENT-IO(+ant) and IDENT-IO(−ant). Additionally, ALIGN([+sib], R) must be ranked above the relevant positional faithfulness constraints (e.g., IDENT-IO(root), omitted here).

(38) Right-alignment in Chumash

ERC	Input	Winner	Loser	ID-IO(+sib)	RELATE-[+sib]	ID-[+sib](ant)	ALIGN([+sib], R)	ID-IO(+sib-head)	ID-IO(−ant)	ID-IO(+ant)
2	iʃ-tiʃi-jep-us	$is_xtis_xijepu(s)_x$	$iʃ_xti(ʃ)_xijepuʃ_x$				W		L	W
3	s-api-tʃʰo-it	$ʃ_xapi(tʃ^h)_xoit$	$(s)_xapits^h{}_xoit$				W		W	L
2 ∘ 3 [31]							W		L	L

Having the head in the right position is also a necessary but insufficient condition to have directional harmony. The effect of φ-heads in the outcome of harmony is in fact mediated by IDENT-IO(φ-head) constraints.

In the loser candidate in ERC 2 (39), the head (ʃ) is unfaithfully mapped from an input sibilant [s] but is still right-aligned. The opposite mapping is shown in ERC 3, where the head (s) is unfaithfully mapped from [ʃ]. In both cases, the head is aligned to the right, but it is unfaithfully mapped. The losers then violate one of the two IDENT-IO(ant) constraints, as well as the positional faithfulness constraint on φ-heads IDENT-(+sib-head).

[31] The operator ∘ is used to indicate a ranking condition entailed by two ERCs. (Brasoveanu & Prince 2005).

(39) Ident-IO(φ-head)

ERC	Input	Winner	Loser	ID-IO(+sib)	RELATE-[+sib]	ID-[+sib](ant)	ALIGN([+sib], R)	ID-IO(+sib-head)	ID-IO(−ant)	ID-IO(+ant)
4	iʃ-tiʃi-jep-us	$\text{is}_x\text{tis}_x\text{ijepu(s)}_x$	$\text{iʃ}_x\text{tiʃ}_x\text{ijepu(ʃ)}_x$					W	L	W
5	s-api-tʃʰo-it	$\text{ʃ}_x\text{api(tʃ}^h)_x\text{oit}$	$\text{s}_x\text{api(ts}^h)_x\text{oit}$					W	W	L
4 ∘ 5								W	L	L

In the winner of the ERC 5 (40), the harmonizing feature is [+anterior], since the rightmost sibilant in the input is /s/. In the winner of the ERC 5, the harmonizing feature is [−anterior] because the rightmost sibilant is /ʃ/.

Since harmony causes both feature values to be mapped unfaithfully, ID-[+sib](ant) has to be ranked above both IDENT-IO(ant) constraints, as shown by the two ERCs in (40).

(40) Surface identity in Chumash

ERC	Input	Winner	Loser	ID-IO(+sib)	RELATE-[+sib]	ID-[+sib](ant)	ALIGN([+sib], R)	ID-IO(+sib-head)	ID-IO(−ant)	ID-IO(+ant)
6	iʃ-tiʃi-jep-us	$\text{is}_x\text{tis}_x\text{ijepu(s)}_x$	$\text{iʃ}_x\text{tiʃ}_x\text{ijepu(s)}_x$			W			L	
7	s-api-tʃʰo-it	$\text{ʃ}_x\text{api(tʃ}^h)_x\text{oit}$	$\text{s}_x\text{api(tʃ}^h)_x\text{oit}$			W				L

3.3.4 Summary

The support for the skeletal basis of Chumash harmony is given in (41). ERC 1 shows that ID-IO(+sib-head) must be ranked above the faithfulness constraints that refer to [anterior] to avoid dissimilation candidates winning.

(41) Simplified support for the ranking

	Input	Winner	Loser	ID-IO(+sib)	RELATE-[+sib]	ID-[+sib](ant)	ALIGN([+sib], R)	ID-IO(+sib-head)	ID-IO(−ant)	ID-IO(+ant)	Comments
1	ʃ…s	$s_x…(s)_x$	$ʃ_x…s_y$		W				L	L	Correspondence
2	ʃ…s	$s_x…(s)_x$	$ʃ_x…(s)_x$			W			L	L	Agreement
3	ʃ…s	$s_x…(s)_x$	$(ʃ)_x…ʃ_x$				W		L	L	Directionality
4	ʃ…s	$s_x…(s)_x$	$ʃ_x…(ʃ)_x$					W	L	L	No Dominancy

To have harmony, the constraints RELATE-[+sib] and ID-[+sib](ant) also have to be ranked above the faithfulness constraints that refer to [anterior] (ERC 2–3).

ERCs 4 and 5 show how directional harmony is obtained. Because ALIGN([+sib], R) ≫ IDENT-IO(ant), the head of the correspondence relation is always chosen as the rightmost sibilant in the word. Since ID-IO(+sib-head) is ranked above Ident-IO(ant), the head surfaces faithfully, and causes the other sibilants in the domain to harmonize for its [anterior] feature value.

3.3.5 *Blocking*

The dissimilation cases (Poser 1993:137, McCarthy 2007) do not pose any issue for the analysis. The dissimilation is between two adjacent root-nodes in the assimilation. In our model, it means it can be targeted by a markedness constraint that refers to the precedence relation.

As in the case for Basque, I postulate a generic markedness constraint that targets the banned sequence of adjacent root nodes. Also notice that the previous analysis is unaffected by the introduction of this constraint because it can only be violated for /sn/ sequences, and in the examples above that was never the case.

Derived sibilants do not undergo, but trigger harmony. Let us consider the two cases separately. Recall that in Chumash, harmony is from right-to-left. In the tableau below, the [+anterior] sibilant would normally induce regressive assimilation of all preceding sibilants. However, this requirement conflicts with the effect of local assimilation, which prefers candidates with the [−anterior] sibilant.

ERC	Input	Winner	Loser	*sn	ID-IO(+sib)	RELATE-[+sib]	ID-[+sib](ant)	ALIGN([+sib], R)	ID-IO(+sib-head)	ID-IO(-ant)	ID-IO(+ant)
8	sn…s	ʃn…s	s_xn…(s)$_x$	W		L	L			L	W
9	sn…s	ʃn…s	(ʃ)$_x$n…ʃ$_x$	W		L	L	W		W	L

Derived sibilants, instead, trigger harmony. This is because in this case, local assimilation is not in conflict with long-distance agreement, in fact, it feeds it. Since there is no longer a conflict to be resolved, the optimal candidate is the one that displays both local and long-distance agreement.

ERC	Input	Winner	Loser	*sn	ID-IO(+sib)	RELATE-[+sib]	ID-[+sib](ant)	ALIGN([+sib], R)	ID-IO(+sib-head)	ID-IO(-ant)	ID-IO(+ant)
10	s…sn	ʃ$_x$…(ʃ)$_x$n	s$_x$…(s)n$_x$	W					L		
11	s…sn	ʃ$_x$…(ʃ)$_x$n	(s)$_x$…ʃn$_x$				W	W	W	W	L
12	s…sn	ʃ$_x$…(ʃ)$_x$n	s…ʃn			W			L	W	L
13	s…sn	ʃ$_x$…(ʃ)$_x$n	s$_x$…(ʃ)$_x$n				W				L

McCarthy (2007) uses the example of neutralization in Chumash argues that the local assimilatory process does not interfere with correspondence because a CRISPEDGE constraint is violated. CRISPEDGE constraints (Ito & Mester 1994, Walker 2001:852) are violated when some nodes are linked across a domain and therefore are different from correspondence.

I believe a more general and accurate argument McCarthy (2007) makes is that local and long-distance interactions are governed by two different kinds of relations. ϕ-Correspondence theory makes this insight explicit and more evident: ϕ-Correspondence constraints induce harmony among similar elements at a distance, local markedness constraints, instead, refer to the precedence relation, and so do not necessarily to similarity.

Since they are two different relations, correspondence and precedence do not interact at the representation level (one may nonetheless postulate a constraint that refers to both relations).

3.4 Discussion

3.4.1 Directionality in ABC

A simple solution to the problem of directionality is the one proposed in Rose and Walker (2005). A definition can be paraphrased as follows.

(42) IDENT-CC(−ant) definition.

Assign a violation for each pair of segments in the output that

1. are in a correspondence relation, *and*
2. C1 is [−ant] and C2 is [+ant].

The purpose of this constraint is to enforce harmony to [−ant]. However, as pointed out in Bennett (2013/2015), the constraint does not favor a specific value. Neither of the outputs [$ʃ_x$…$ʃ_x$] and [s_x…s_x] violates the constraint, so the constraint cannot distinguish between them.

The above formulation fails because IDENT-CC is a markedness constraint, and therefore evaluates only the output in the candidate. IDENT-CC will need to prefer the output [ʃ…ʃ] to the output [s…s] only when there is a disjoint input specification for the segments; otherwise, neutralization to the marked will be predicted. IDENT-CC will then necessarily have to refer to the input to obtain such an effect. The only way of formulating such a constraint is then to use targeted constraints or have a hybrid faithfulness/markedness constraint such as this one:

(43) Ident-CC(−ant) definition.

Assign a violation for each segment in the output

1. if the two segments are in correspondence *and*
2. have a different specification for the feature [ant]
3. if in the input one of the two segments is [+ant].

However, such constraints are overly complex, both in terms of conditions to be satisfied and formally, since it is simultaneously a markedness constraint and a faithfulness constraint.

Other approaches to the problem of directionality (Hansson 2001/2010, Baković & Rose, 2014) have relied on "targeted" constraints. To illustrate, I use Hansson's (2010:265) targeted constraints as an example. Hansson (2001/2010) uses two constraints of the type in (44) to account for the harmonizing feature selection problem in Chumash directional harmony.

(44) →IDENT[ant]-CC definition.

Candidate *x´* is preferred over *x* (*x´*> *x*) *iff x* contains a consonant C_i which is marked with respect to CC/Ant, and *x´* is exactly like *x* except in that the same C_i is unmarked with respect to CC/Ant.

Targeted constraints such as →IDENT[ant]-CC can hardly be connected to any well-studied constraint type. They are evaluated by comparing different candidate forms, and they resemble neither conventional markedness constraints nor faithfulness constraints.

Targeted constraints are also structurally complex. For example, →IDENT[ant]-CC contains two conjunctive conditions ("is marked… and it is exactly like…") and an exception ("except in that the same C_i is unmarked with respect to CC/Ant").

Specifically related to →IDENT[ant]-CC is the fact that such constraints are evaluated based on the relative markedness of segments. However, directionality is usually captured by alignment constraints in Optimality Theory. Markedness is a crucial component of dominant harmony, but it plays no role in directional harmony.

Another advantage of φ-heads and φ-Correspondence constraints is that each constraint fulfills a specific function. IDENT-IO constraints only require featural identity, as opposed to targeted CC-IDENT constraints, which also specify the conditions under which identity should occur. This property is fundamental for the analysis of the typological asymmetry in the typology of dominant-recessive harmony discussed in chapter 6.

Finally, in φ-Correspondence directionality constraints follows the generalized schema of IDENT constraints, thus satisfying Hypothesis II.

3.4.2 Directionality in dissimilation

As it is, φ-Correspondence does not significantly differ from ABC with respect to dissimilation. However, the existence of heads in φ-Correspondence makes it possible to formulate constraints that penalize the position of *φ-head based on the feature value of a segment.

Now, suppose we introduce a constraint *φ-HEAD[+ant],[32] which assigns a violation for each [+anterior] sibilant head. The constraint can, under certain rankings, cause the dissimilation mappings /s…s/ ⟶ [s… ʃ] to be optimal. The tableau below exemplifies the process.

(45) Dissimilation in φ-Correspondence

/s…s/	*φ-HEAD[+ant]	ID-IO(+sib)	RELATE-[+sib]	ID-[+sib](ant)	ALIGN([+sib], R)	ID-IO(+sib-head)	ID-IO(−ant)	ID-IO(+ant)
a. s_x…$(s)_x$	!*							
b. s…t		!*						
c. s_x…$(ʃ)_x$				*				*

In candidate (**Error! Reference source not found.**a), the two sibilant feature nodes are in correspondence and agree. φ-Correspondence relations, however, always require a head. In the candidate, there are two [+ant] sibilants, so a head is assigned to the rightmost one. This violates *φ-HEAD[+ant], which penalizes marked [+ant] heads.

[32] The constraint can be functionally justified by claiming that heads prefer to be assigned to marked values. Such postulation relates to the generalization discussed in section 6.2 which states that that in dominant harmonies the outcome of the harmony is always determined by the marked value of a feature. The generalization in 6.2 relates to faithfulness constraints, but it could be adapted to dissimilation and markedness alike.

There are three possible solutions to avoid a violation of the constraint. The ABCD mechanism consists in escaping correspondence altogether by mapping the sibilant to a [−sibilant],[33] as illustrated by candidate (**Error! Reference source not found.**b).

However, *φ-HEAD[+ant] is also not violated if the head is assigned a different value for the feature [anterior]. The unfaithful dissimilation mapping [s_x…($ʃ$)$_x$] does not violate *φ-HEAD[+ant] because the head is no longer [+anterior].

Directionality is then established the same way as for harmony depending on the ranking of IDENT-IO and ALIGN(φ-head) constraints, in this case by aligning the head to the right edge of the word and causing the corresponding segment to dissimilate.

Notice that in this case dissimilation is within elements in correspondence. The theory thus also predicts that directional dissimilation is typologically different in terms of targets to non-directional dissimilation, which instead is thought as a way of escaping correspondence.

Given the complicated nature of the interaction of these constraints with the other constraints of the theory, and since the model without φ-heads constraints is quasi-identical to ABCD with respect to dissimilation, I leave the issue of dissimilation aside.

3.4.3 Summary of the chapter

In this chapter, I show how a simple process of directional harmony can be analyzed using φ-Correspondence. The analysis follows from basic assumptions of the theory, such

[33] Notice that unlike CORR in ABC, RELATE-[+sib] is violated when there is a single element not in correspondence, since the constraint does not evaluate two segments at the same time. Since you need at least two elements to form a correspondence relation in φ-Correspondence, there is no candidate that can satisfy the constraint without banning that specific segment.

as that correspondence is headed, that heads like to align to edges, and that heads mark privileged positions.

There is also a clear division of labor between different types of constraints: ALIGN constraints require alignment to an edge; φ-Correspondence constraints determine the set of elements that participate in the harmony; I/O-Correspondence constraints target input/output faithfulness. Not only do the constraints do only “one thing,” but the general nature of the constraint definitions allows us to relate them to general classes of constraints (Generalized Alignment, Positional Faithfulness, and Correspondence).

The atomization of constraint function is important in OT. Simple, specialized constraints are preferred over complex, heterogeneous ones. One advantage of simpler constraints is that they yield a richer set of predictions. While one could define small sets of constraints that descriptively account for a phenomenon, the most interesting predictions emerge from the interaction of the simple ones. The advantages of this approach over ABC are then discussed. Rose and Walker (2004)’s constraints cannot account for such cases of directional harmony, even when directionality is specified in the constraint definition, while Hansson (2001)’s analysis requires an alteration of the EVAL procedure. φ-Correspondence, instead, can elegantly account for directionality by using constraints that adhere to independently justified constraint schemas.

4 Partial Overlapping in Kalabari

4.1 Introduction

It is not uncommon for two different harmonies to coexist in the same language, especially in the domain of vowel harmonies. Possibly because of the limited number of vocalic features (as compared to consonantal features), different harmonies tend to share the same segmental targets. For example, the vowel [e] may be target of both a [−high] parasitic harmony and of a harmony that targets all vowels. Following Walker (2017), I call these types of harmonies *overlapping harmonies*.

Classic formulations of ABC predict a high degree of interaction among overlapping harmonies. Since correspondence is established at the segmental level, if two harmonies overlap, the theory predicts (depending on how the agreement constraints are defined) that all segments in the correspondence participate in all harmonies. Continuing with the example above, suppose that there is a sequence [e] … [u]. The two vowels are in correspondence because of the system-wide ATR harmony. However, in ABC the correspondence relation will also induce the unwanted parasitic harmony that supposedly targets only [−high] vowels. Empirically, I am not aware of the existence of such a case of induced harmony. In contrast, overlapping harmonies are always independent from one another.

This prediction is borne out in feature correspondence: since the correspondence relation occurs at the feature level, the existence of a correspondence relation on a feature does not entail the existence of any other correspondence relation on other features.

Kalabari presents an interesting example of overlapping harmonies. Three harmonies are enforced in its roots: a system-wide ATR harmony and two different back harmonies parasitic on height.

Kalabari is also an interesting case, because unlike Hansson's (2010) and Walker's (2017) examples, the lack of interaction can be shown to occur at the paradigmatic level between roots with only two syllables. Therefore, intransitive correspondence does not resolve the problem.

Finally, Kalabari high vowel harmony – unlike the other two – is dominant-directional and limited to two vowels. This pattern is not only predicted by basic φ-Correspondence constraint interaction, but it also shows that headedness is a property of feature nodes, and not of roots.

The chapter is organized as follows. In section 4.1, I start with an overview of Kalabari's harmonies (§ 4.1.1) to briefly show how overlapping harmonies are problematic for classic ABC, but not for φ-Correspondence (§ 4.1.2). Section 4.2 lays down the theoretical and empirical basis for the analysis in section 0. Section 4.4 concludes with a comparison of the analysis with other relevant theories.

4.1.1 Overview of Kalabari's harmony

Kalabari is an East Ijaw language spoken in Nigeria (Williamson 1969; Jenewari 1977, 1980, 1985; Akinlabi 1997). It is characterized by three co-occurring vowel harmonies: a directional, parasitic back harmony for [+high] vowels, a non-directional parasitic back harmony for [−high] vowels, and a non-parasitic (*aka* system-wide) ATR harmony. The harmonies manifest themselves as a set of co-occurrence restrictions operating in the root.

For example, [−high] vowels agree for the feature [back] with other [−high] vowels. Sequences like *[e] … [o] are unattested, but a [+high] and a [−high] vowel can co-occur even if they do not agree for the feature [back], as in the word [númé] 'song'.

The back harmony for high vowels bans root containing sequences[34] of [+high, +back] … [+high, −back] like [u…i]. This harmony is "directional": the sequence *[u … i] is disallowed, while the sequence [i … u] is well formed.

Vowels in the same word must also agree in ATR, regardless of their height. So, a sequence like *[e…ʊ] is also banned, even though the two vowels do not have the same height specification.

The vowel [a] behaves marginally differently from other vowels. [a] cannot occur with the front non-high vowels [e] and [ɛ], but can occur with any high vowel, as one would expect from the [−high] back harmony restriction. I take this generalization to indicate that the dominant feature in back harmonies is [+back], and thus that sequences like [a]… [e] are mapped to a harmonic root.

The vowel [a] also does not participate in [ATR] harmony. I argue that [a] is neutral in ATR harmony because it has a [−ATR] specification, and because in Kalabari there is no [+ATR, +low] vowel. Since [−ATR] is the recessive feature, the vowel cannot trigger

[34] A sequence is constituted by two or more vowels in the same word separated by one or more consonants.

harmony by itself, and because of the inventory gap, it cannot be the target of the harmony either.

To summarize, all vowels are included in, or constitute, the domain of ATR harmony, while back harmonies are parasitic on height. [−high] vowels harmonize in backness regardless of their order, while for [+high] vowels the harmony is directional and restricted to adjacent targets. There is no backness co-occurrence restriction between vowels with a different value for the feature [high]. Finally, the low vowel [a] harmonizes for backness, but not for ATR.

(46) Harmonies in Kalabari

	Low	Mid	High
Low	NA	[+ATR] only	[+ATR]
Mid	[+ATR] only	[+ATR] and [+back]	[+ATR]
High	[+ATR] only	[+ATR] only	[+ATR] and dir. [+back]

4.1.2 Overlapping harmonies

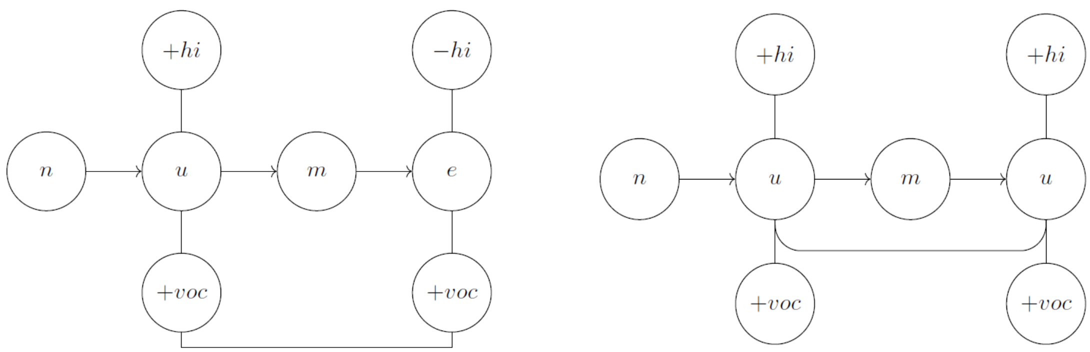
As anticipated in the introduction, Kalabari exhibits a case of *overlapping harmonies*. The overlapping sequences in Kalabari include a mid vowel and high vowel that are disharmonic in backness but agree in ATR, as in the word [númé] “song”. The existence of these sequences, together with the absence of comparable words disharmonic in ATR (i.e., [u] … [e]), shows that vowels with a different height specification need only agree in ATR, not in [back].

In the feature correspondence analysis, the correspondence relation only connects the [+vocalic] node (47a). No correspondence is instantiated at the level of [high] feature, since the [+high] and [−high] features are distinct, and therefore no back harmony is demanded (47b).

Classic ABC predicts that in these sequences either both ATR and back harmony occur, or neither. This is because there is only one *type* of correspondence relation (2b), one which causes both the ATR harmony and the unwanted back harmony to apply to the same segments (see also Hansson 2010, Walker 2016).

(47) Two kinds of correspondence

a. Featural correspondence b. Segmental correspondence



4.2 Background

In this section, I provide some background for the analysis carried out in section 0. The section describes the vowel inventory of the language (§ 4.2.1), as well as the exception to the harmonies generalizations (§ 4.2.3). Sections 4.2.4 and 4.2.2 introduce the constraint set and the candidate set assumed in the analysis.

4.2.1 Vowel inventory

On the surface, Kalabari has nine oral vowels—[a, i, ɪ, e, ɛ, ɔ, o, ʊ, u]—and nine corresponding nasal vowels (Jenewari 1977, 1985), which may be split into [+ATR] and [−ATR] sets. The same vowels may also be split into [+back] and [−back] sets as in (4).[35]

(48) Kalabari vowels (Williamson 1969; Jenewari 1977, 1980, 1985).

a. ATR Split	b. Back Split
[+ATR] vowels: [i, e, o, u]	[+back] vowels: [u, o, ʊ, ɔ, a]
[−ATR] vowels: [ɪ, ɛ, ɔ, ʊ, a]	[−back] vowels: [i, e, ɪ, ɛ]

The nasal vowel vowels behave like the oral ones, so I do not further distinguish between the two sets. Tones also do not interact with the harmony patterns, so they are omitted from the tableaux.

From the vowel inventory, schematized in (5) below, one can observe that every vowel has a [±ATR] counterpart and a [±back] counterpart, except for the low vowel /a/. In 4.3.2.2, I argue that this inventory gap provides evidence for the dominance status of [+ATR] and [+back] features and that it also explains the apparent absence of ATR harmony for the low vowel.

[35] The +/− split here is not to be construed as recognition of +/− specification, but should rather be viewed merely as a useful descriptive tag for advanced tongue root versus retracted tongue root vowels, on the one hand, and back versus front vowels, on the other. To simplify the description our focus will be on oral vowels, but the statements made here are true for the nasal vowels as well.

(49) Kalabari vowel inventory

	[−back]		[+back]	
	[+ATR]	[−ATR]	[−ATR]	[+ATR]
[+high]	i	ɪ	ʊ	u
[−high]	e	ɛ	ɔ	o
[+low]			a	

4.2.2 Exceptions

The patterns introduced in the previous sections were previously described in the literature (e.g., Akinlabi 1997). A search for exceptions in Blench (2008) reveals only the terms listed in (48). In addition to being small in number, all the exceptions are either loanwords (48f), compounds (18a–d), or exceptional (48e).

(50) Some loanwords and compounds do not harmonize (Blench, 2008)

a. tʊmg + bákɪ 'sowr (fruit)' (p. 343)

b. tʊ́ḿg + balí 'single (e.g., single fruit, single digit)' (p. 343)

c. kʊ́rɔ́ + tánjí 'catfish' (p. 212)

d. kʊrɔ + kɔ́njɪ 'a proud person' (p. 212)

e. kʊ́lʊ́kʊ́lʊ́kalíka 'a war drumical name for the Kalabaris' (p. 211)

f. egúsí 'melon' (p. 99)

4.2.3 Constraints

In the analysis, I include the following constraints based on the schemas defined in sections 2.3 and 2.4.2:

- RELATE-[−hi]
- RELATE-[+hi]
- RELATE-[+voc]
- ID-[+hi](bk)
- ID-[−hi](bk)
- ID-[+voc](ATR)
- ALIGN([+high], R)

The other constraints included in the analysis are standard faithfulness and markedness constraints. Recall that [−back] and [+ATR] low vowels never surface in Kalabari. In other words, while for mid and high vowels there are [±back] and [±ATR] pairs of vowels, the only low vowel in the system is [a].

To account for this generalization, I use the markedness constraint *æ, which assigns a violation for each [+ATR] or [−back] low vowel in the output.[36]

Finally, I use the four IDENT-IO constraints that refer to the two harmonizing feature values of [back] and [ATR], and the meta-constraint IDENT-IO(height), which assigns a violation for each vowel in the output that has a different value for either [±low] or [±high] from its input correspondent. All the constraints used in the analysis are listed below. From this point forth, I use the abbreviated constraint names in (23).

[36] In both the candidate set and in the constraint name, I use the symbol æ to indicate any low vowel that it is [+ATR] or [−back]. Since the vocalic inventory of Kalabari only has the single [−ATR, +back] vowel "a", this notation does not have any substantial effect on the analysis.

(51) Other constraints for Kalabari.

- ID-IO[+bk]
- ID-IO[−bk]
- ID-IO[+ATR]
- ID-IO[−ATR]
- ID-IO[height]
- *æ

4.2.4 Candidate set

The candidate set includes all combinations of vowels in bisyllabic roots for both the input and the output forms. Outputs are further distinguished depending on whether two features correspond or not. The schema in (52) defines the candidate set.

(52) Candidate set generation schema

input	utput
V…V	$V\ldots V_{\{\pm\varphi,\ \ldots\}}$

where V = [æ, a, i, ɪ, e, ɛ, ɔ, o, ʊ, u]

For the purpose of this analysis, it is sufficient to only consider roots with two vowels and correspondence on three feature domains [+high, −high, +vocalic]. I ignore [−vocalic] segments for simplicity, and I assume that no consonant has these features. Since there are only two segments, they can correspond or not correspond for a given feature. I indicate the features in correspondence by placing them between curly brackets. Some examples are given below:

(53) Examples of candidates

- ε…o $_{\{-H\}}$ = a root containing the vowels [ε] and [o]. The two [−high] feature nodes are in correspondence.
- ε…o $_{\{\}}$ = a root containing the vowels [ε] and [o]. No feature node is in correspondence.
- ε…o $_{\{-H, V\}}$ = a root containing the vowels [ε] and [o]. The two [−high] feature nodes, and the two features [+vocalic] correspond.
- ☹ ε…i $_{\{+H\}}$ = a root containing the vowels [ε] and [o]. Ill-formed because there is only one [+high] node in the output.

I assume that harmony in Kalabari is always obtained via featural unfaithfulness, so vowels are always in a one-to-one relation with their input (no epenthesis, deletion, coalescence, or splitting) and in the same order (no metathesis). Candidates where a vowel is mapped to a consonant are also not included in the candidate set.

4.3 Analysis

4.3.1 The three basic harmonies

In this section, I provide a formal analysis of Kalabari's harmonies. The data is mostly from Akinlabi (1997). I demonstrate that feature correspondence permits a fairly simple analysis of the system as the combination of three harmonies (§§ 4.1–4.3).

I then show that the behavior of [a], which acts as a trigger for back harmony, but which is opaque to ATR harmony (§ 4.2), is also elegantly captured by the theory. I conclude by showing why classic segmental correspondence cannot account for the data and briefly discuss an alternative analysis based on feature-specific IDENT constraints (§ 4.3).

4.3.1.1 Back harmony in [−high] vowels

There are two distinct types of parasitic back harmonies in Kalabari: one concerns [+high] vowels, and the other [−high] vowels. I start with [−high] vowels. The set of [−high] vowels include all the mid vowels [e, ɛ, o, ɔ] and the low vowel [a]. Because of the special behavior of [a], I only discuss mid vowels in this section. The analysis of [a] is illustrated in section 4.3.2.2.

Mid vowels fall out neatly into two [+ATR] and [−ATR] sets and into two [+back] and [−back] sets. Since back harmony is not directional in [−high] vowels, and [−high] vowels must also agree for ATR, in forms with only mid vowels, all the vowels must be *identical* (11) (Williamson 1969:107; Jenewari 1973:63, Akinlabi 1997:100). The only sequences allowed are [o…o], [e…e], [ɛ…ɛ] or [ɔ…ɔ]. All other combinations are ruled out (12).

(54) Mid vowel sequences are identical (Akinlabi 1997:100)

[+ATR]	[−ATR]
éré ‘female’	ɛ́rɛ́ ‘name’
béle ‘light’	ḅɛ́rɛ́ ‘case/trouble’
énéme ‘oil palm’	ɛ́tɛ́rɛ̄ ‘mat’
póló ‘compound’	ɔ́lɔ́ ‘cough’
ólóló ‘bottle’	ɔḅɔ́kɔ̄ ‘fowl’

(55) Non-occurring mid vowel sequences

ATR violation	back violation	ATR and back violations
*e … ɛ	*o … e	*o … ɛ
*ɛ … e	*ɔ … ɛ	*ɔ … e
*o … ɔ	*e … o	*e … ɔ
*ɔ … o	*ɛ … ɔ	*ɛ … o

The tableau below shows the relevant candidates. I exclude the constraints referring to [+high] and those specific to [a] because they do not apply to any the candidate in the tableau.

(56) Back harmony in Kalabari (mid vowels)

Input	Winner	Loser	RELATE-[−hi]	RELATE-[+hi]	ID-[+hi](bk)	ID-[−hi](bk)	ID-IO[+bk]	ID-IO[−bk]
e…o	o…o {-H, V}	a. e…o {V}	W					L
		b. e…o{-H, V}				W		L
		c. e…e {-H, V}					W	L

In terms of OT ranking, harmony is obtained as usual when the relevant RELATE and ID-[*f*](g) constraints dominate ID-IO[−bk] or ID-IO[+ATR].[37] In the case of high vowel

[37] I assume for now that [+back] are [+ATR] are the dominant features. I justify this assumption in section 4.3.2.2.

back harmony, RELATE-[+hi] and ID-[+hi](bk) dominate ID-IO[bk]. Likewise, for [−high] vowels, the ranking is RELATE-[−hi], ID-[−hi](bk) ≫ ID-IO[−bk].

4.3.1.2 Back harmony in [+high] vowels

For high vowels, if the first high vowel of the root is [+back], then the immediately following high vowel must be [+back] as well. Therefore, the disharmonic sequences [u…i] and [ʊ…ɪ] are not attested.

The trisyllabic forms show that in a sequence of high vowels, once a [+back] occurs, the following high vowel must also be [+back].

(57) High vowels, directional back harmony (Akinlabi 1997:101)

[+ATR]	[−ATR]
ḅuru 'yam'	ḅʊrʊ 'become rotten'
kúrúsu 'cannon'	ḅʊkʊrʊ 'crayfish trap'
kírī 'ground'	fɪrɪ 'work/message'
íkú 'louse'	íkʊ́ 'rock'

(58) Attested and non-attested roots (back-harmony)

Attested	Not attested (*[+back] … [−back])
i … u	*u … i
ɪ … ʊ	*ʊ … ɪ
i … u … u	*u … i … u *, u … u … i, *u … i … i
ɪ … ʊ … ʊ	*ʊ … ɪ … ʊ, *ʊ … ʊ … ɪ, *ʊ … ɪ … ɪ

For the sake of exposition, I set aside the issue of directionality and assume that [+high] vowels always agree in backness. By doing so, the analysis of [+high] vowel back harmony parallels the analysis of [−high] vowels, as shown in the tableau below.

(59) Back harmony in Kalabari (high vowels)

Input	Winner	Loser	RELATE-[−hi]	RELATE-[+hi]	ID-[+hi](bk)	ID-[−hi](bk)	ID-IO[+bk]	ID-IO[−bk]
u…i	u…u {+H, V}	a. u…i {V}		W				L
		b. u…i{-H, V}			W			L
		c. i…i {-H, V}					W	L

Notice how the two constraints RELATE-[−hi] and RELATE-[+hi] refer to two complementary sets of pairs of feature nodes, so they cannot ever be violated by the same element. As a result, the two harmonies are completely independent in terms of basic feature correspondence constraints and relations, even though their rankings “overlap” in that both pairs of correspondence constraints dominate ID-IO([bk]).

For this reason, sequences of mid and high vowels do not have to be harmonic for the feature [back].

(60) Mid and high roots disharmonic for back (Akinlabi 1997:118)

[+ATR]	[−ATR]
ékulé ‘hawk’	fɛ́rʊ́ ‘wind’
pókī ‘listen’	dɔ́kī ‘burn (intr.)’
ímō ‘sweat’	píkɔ́ ‘feather’

4.3.1.3 ATR harmony

I now move on to ATR harmony. Using the traditional terminology, ATR harmony is *system-wide* or non-parasitic, in the sense that the harmonizing vowels do not need to share any feature value in addition to the one specifying that they are vowels.[38]

The data below show that if two high vowels co-occur in the root, they have identical ATR feature.

(61) High vowels, ATR harmony (Akinlabi 1997)

[+ATR]	[−ATR]	
ḅuru 'yam'	ḅʊrʊ 'become rotten'	(p. 101)
kírī 'ground'	fɪrɪ 'work/message'	(p. 111)
íkú 'louse'	íkʊ́ 'rock'	(p. 101)

(62) Unattested sequences of high vowels disharmonic for ATR

*u … ʊ, *ɪ ... i

*ʊ … u, *i … ɪ

Despite having a different height feature value, mid and high vowels agree for [ATR] (63), as demonstrated by the absence of [ATR] disharmonic roots such as the ones listed in (64).

[38] [a] is neutral to [ATR] harmony, so this statement is biased by our working analysis. I justify this assertion in 5.2.2.1.

(63) Mid and high vowel agree for ATR (Akinlabi 1997:101)

[+ATR]	[−ATR]
fíyé ‘food’	bɪtɛ ‘cloth’
féní ‘bird’	dɛrɪ ‘laugh’
poku ‘bat’	tɔ́rʊ́mgbɔ́ ‘eye’
fúrō ‘belly/stomach’	dʊ́rɔ́ ‘barracuda’

(64) Sequences of mid and high vowels disharmonic in [ATR]

Same Back		Different Back		Unattested	
[+ATR]	[−ATR]	[+ATR]	[−ATR]	[+ATR]	[−ATR]
i … e	ɪ … ɛ	e … u	ɛ … ʊ	*i … ɛ	*ɪ … e
e … i	ɛ … ɪ	u … e	ʊ …ɛ	*ɛ ... i	*e … ɪ
o … u	ɔ … ʊ	o … i	ɪ … ɔ	*o … ʊ	*ɔ … o
u … o	ʊ … ɔ	i … o	ɔ …ɪ	*ʊ … o	*o … ɔ

Feature correspondence is straightforwardly applied to general harmonies by assuming that correspondence acts on the vocalic feature nodes [+voc]. The subranking for ATR harmony thus also parallels that of the two parasitic harmonies, with RELATE([+voc]), ID-[+voc]([ATR]), and ID-IO([+ATR]) ≫ ID-IO([−ATR]).[39] Notice that

[39] See (4.2) for a justification of the subranking ID-IO([+ATR]) ≫ ID-IO([−ATR]).

no constraint refers to the height of the vowels, so a quasi-identical analysis applies to mid vowel ATR harmony as well.

(65) ATR harmony for [+high] vowels

Input	Winner	Loser	RELATE([−hi])	RELATE([+voc])	ID-[−hi](bk)	ID-[+voc](ATR)	ID-IO[+ATR]	ID-IO[+bk]	ID-IO[−ATR]	ID-IO[−bk]
i…ʊ	i … u {+H, V}	a. i … ʊ {+H}		W					L	
		b. i … ʊ {+H, V}				W			L	
		c. ɪ … ʊ {+H, V}					W		L	

4.3.2 *Harmony interactions*

In the previous section, I discussed the three basic harmonies and showed that because of feature correspondence, it is natural to treat three harmonies independently as very simple and common cases of harmony.

In this section, I discuss the complications of the system and demonstrate that φ-Correspondence can account for them naturally. I start with the case where two harmonies interact, resulting in the overlapping harmony pattern. I then move on to the analysis of the behavior of [a] and show how it naturally emerges from the system.

4.3.2.1 Overlapping harmonies

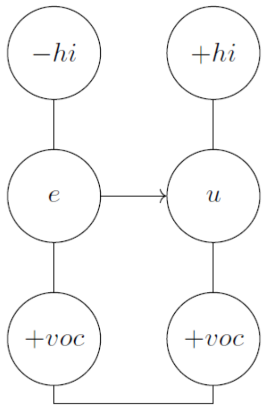
Roots containing a mid and a high vowel agree only for [ATR], but not for [back]. For example, the sequence [e…u] is well attested. Given the current analysis, [e…u] maps from both the faithful input /e…u/ and the disharmonic /ɛ…u/. Let us consider the unfaithful candidate.

The winning candidate /ɛ…u/ → [e…u]{V} has one correspondence relation on the vocalic tier, but no correspondence on either the [+high] or [−high] tier (67). Since [e] is [−high] and [u] is [+high], the winner does not violate either of the correspondence constraints RELATE([−hi]) or RELATE([+hi]). Because neither their [+high] nor [−high] feature are in correspondence, there is no constraint that favors agreement for backness (66d). However, both vowels have the [+voc] feature, so they must correspond, as in (66a), and agree for the feature ATR, as in (66b). Finally, the relative ranking of the IDENT-IO(ATR) (66c) determines the dominance of the [+ATR] feature.

(66) Tableau for the mapping /ɛ…u/ → [e…u]

Input	Winner	Loser	RELATE([−hi])	RELATE([+hi])	RELATE([+voc])	ID-[−hi](bk)	ID-[+voc](ATR)	ID-IO[+ATR]	ID-IO[+bk]	ID-IO[−ATR]	ID-IO[−bk]
ɛ…u	e…u {V}	a. ɛ…u {}			W					L	
		b. ɛ…u {V}					W			L	
		c. ɛ…ʊ {V}						W		L	
		d. ɛ…i {V}							W	L	

(67) Representation of the output [e…u] with feature correspondence in Kalabari



4.3.2.2 [a] and the active features

In the previous section, I assumed that the "active," dominant features were [+ATR] and [+back]. In this section, I show that the currently analysis elegantly captures the behavior of [a] and provides justifications for the assumptions previously made on the directionality of the harmony.

Low and mid vowels agree in [+back], because both have the same [−high] specification for height. This is without regard to whether the same sequences agree in [ATR]. The following examples of occurring and non-occurring sequences illustrate the point.

(68) Low and mid agree for [back], since they are both [−high] (Akinlabi 1997:103)

Back agreement	Back violation	
[+ATR]	[−ATR]	Non-occurring
ḍáwó 'kola nut'	ḍawɔ 'dream'	*a … e
áyō 'onion'	awɔ 'children'	*ɛ … a

As noted earlier, only the vowel [a] has no [−ATR] counterpart. It does not undergo ATR harmony because of this inventory gap. Interestingly however, though [a] does not have a [−back] counterpart, it does participate in back harmony.

(69) Low and high vowels can combine without restriction (Akinlabi 1997:103)

[+ATR]	[−ATR]
niná ‘urine’	pɪnā ‘be white’
ati ‘ten’	wárɪ ‘house’
fúrā ‘be pregnant’	ḍʊḅa ‘be (come) fat/big’
awuwán ‘yawn’	árʊ́ ‘canoe’

The low vowel [a] can co-occur with both [+ATR] and [−ATR] vowels, so even disharmonic roots like [a…o] are attested. If we exclude harmonically bounded candidates, we are left with four competing candidates: the winner, which has the faithful mapping, and the three losers, which achieve harmony by means of one of the following three mechanisms.

(70) ATR disharmonic roots

Input	Winner	Loser	*æ	ID-IO[height]	RELATE-[−hi]	ID-[−hi](bk)	ID-[+voc](ATR)	ID-IO[+ATR]	ID-IO[+bk]	RELATE-[+voc]	ID-IO[−ATR]	ID-IO[−bk]
a…o	a…o $_{\{-H\}}$	a. æ…o $_{\{-H, V\}}$	W							L		
		b. o…o $_{\{-H, V\}}$		W						L		
		c. a… ɔ $_{\{-H, V\}}$						W		L		
		d. a…o $_{\{-H, V\}}$					W			L		

The first option is to change the ATR value of the /a/ to [+ATR] (70b). The output is harmonic but does not win because low [+ATR] vowels do not ever surface in Kalabari. This generalization is captured by ranking the constraint *æ in the first stratum of the ranking. The second option, (b), is to change the height of the low vowel, an option that is ruled out by mean of the constraint ID-IO(height).

The third candidate (c) is the most interesting, which changes the mid vowel to [−ATR]. However, using the standard phonological terminology, [−ATR] is the regressive feature, and it cannot trigger harmony.[40]

Notice that when harmony is achieved and the dominant value determines the outcome of the harmony, dominance is established by the relative ranking of the two faithfulness constraints IDENT-IO[+ATR] and IDENT-IO[−ATR]. Here harmony is blocked, and so the ranking is between RELATE and the faithfulness constraint that refer to the regressive value IDENT-IO[−ATR].

[a] is neutral to ATR harmony, but it participates in back harmony. The absence of disharmonic output shows the exact opposite of what was observed concerning ATR harmony: [+back] is the active dominant feature for the [−high] harmony. [a] can co-occur with back vowels (e.g., [a…o] and [a… ɔ]), but not with front vowels, because front non-high vowels are mapped unfaithfully to harmonize for backness with [a].

To summarize, [a] is the only low vowel in Kalabari, so phonotactically no ATR or back alternation is possible without changing the vowel height. The fact that [a]

[40] The dominance of the [+ATR] value also conforms to Casali's (2003) generalization, which states that "[+ATR] is normally dominant in languages with an [ATR] contrast among high vowels."

harmonizes with non-high back vowels shows that [+back] is the dominant feature: since [a] is [+back], it causes other low vowels to agree for backness. In contrast, the neutral status of [a] with respect to ATR harmony shows that [+ATR] is the dominant feature value.

4.4 Discussion

4.4.1 Independence of directionality

Vowels of the same height participate in both ATR and back harmonies. For example, I assume that the input /e…ɔ/ harmonizes for both ATR and backness and that it thus maps to [o…o] (again, the explanation for the choice of the active features is given in section 4.3.2.2). The winner thus has two correspondence relations, one on the vocalic tier and another on the [−high] tier. Both relations are targeted by the respective IDENT constraints, which, – like in previous examples – cause the two segments to harmonize.

For example, candidate (a) does not violate ID-[−high](bk), even though it corresponds and harmonizes for ATR, because the constraint only targets [−high] feature nodes in correspondence. The candidate contains two [−high] feature nodes, but they are not in correspondence, only the [+voc] nodes are (see 4.3 for a diagrammatic representation).

Notice that the two harmonies are also independent in terms of directionality: the first segment changes to harmonize for backness, while the second changes to harmonize for ATR. This shows that directionality cannot be enforced on the segmental level via RELATE/CORR constraints.

(71) Back and ATR harmony for mid vowels

Input	Winner	Loser	RELATE([−hi])	RELATE([+voc])	ID-[−hi](bk)	ID-[+voc](ATR)	ID-IO[+ATR]	ID-IO[+bk]	ID-IO[−ATR]	ID-IO[−bk]
e…ɔ	o…o {-H, V}	a. e…ɔ {V}	W							L
		b. o…ɔ {-H}		W					L	
		c. e…o {-H, V}			W					L
		d. o…ɔ {-H, V}				W			L	
		e. ɔ…ɔ {-H, V}					W		L	L
		f. e…e {-H, V}						W	L	L

4.4.2 Independence of interaction

Traditional ABC cannot account for such cases of partially overlapping harmonies. An analysis using *segmental* correspondence largely parallels the analysis described in the previous sections. However, as the tableau below shows,[41] in the standard ABC analysis an input like /e…u/ containing mid and high vowel is incorrectly predicted to harmonize for the feature back.[42] RELATE-[−hi], RELATE-[+hi], and ID-VV[bk] must dominate ID-IO[bk] to obtain the back harmonies (a), while RELATE-[+voc] and ID-VV[ATR] must dominate ID-IO[ATR] to account for the ATR harmony (b). Given these ranking conditions, the faithful candidate cannot win (c).

[41] I use a classic tableau here because it better shows the wrong prediction.
[42] I assume that there are no anti-faithfulness constraints in CON, and therefore that if the /e…u/ does not map to its faithful output [e…u], then nothing else does (Tesar, 2013).

Mid and high vowels must be in correspondence, since they participate in the ATR harmony. However, for both mid and high vowels to participate in back harmony, ID-VV[bk] must dominate ID-VV[bk]. The two conditions for harmony are thus satisfied: the two segments correspond, and the ID-VV constraint that refers to the harmonizing feature dominates the corresponding ID-IO constraint. If you alter this relative ranking, you lose the parasitic harmonies; conversely, if you do not, back harmony over-applies to mid–high vowel combinations as well.

(72) Ranking contradiction for mid–high sequences in ABC: /e…u/ → [o…u]

Input	Output	*æ	ID-IO[height]	CORR-[hi]	Corr-VV	ID-IO[+ATR]	ID-VV[bk]	ID-IO[+bk]	ID-VV[ATR]	ID-IO[−ATR]	ID-IO[−bk]
e…u	a. e_x…u_y				!*						
	☹ b. e_x…u_x						!*				
	c. e_x…i_x							!*			
	💣 d.o_x…u_x										*

The tableau also makes clear why intransitive correspondence does not work in this case. The problem occurs even with only two segments, where by definition, transitivity cannot play a role at the syntagmatic level.

A solution to this problem is to have ID-VV selectively apply to vowels with specific features, that is, to make ID-VV parasitic on a specific set of features (Walker 2016). Nonetheless, a central tenet of ABC is the distinction between correspondence and identity constraints. IDENT-VV constraints determine the feature value for which the segments in correspondence must agree, while correspondence constraints determine the set of segments that participate in the harmony. By making ID-VV parasitic, one could in principle eliminate Surface Correspondence altogether,[43] since the function of establishing the segments that participate in harmony is taken over by IDENT constraints.

The resulting constraints are also quite descriptive, since they specify both the target and the outcome of the harmony ("two segments with the feature φ must agree for the feature φ′").

In the analysis I am proposing, I maintain the basic mechanism of ABC as correspondence plus identity, and I address the issue of overlapping harmony by simply moving the correspondence relation from the root tier to the feature tier.

The main advantage of this model is that multiple harmonies are now representationally independent. For example, the diagram below[44] shows the correspondence relations for the mapping /o…e…ɪ/ ⟶ [o…o…i] in feature correspondence.

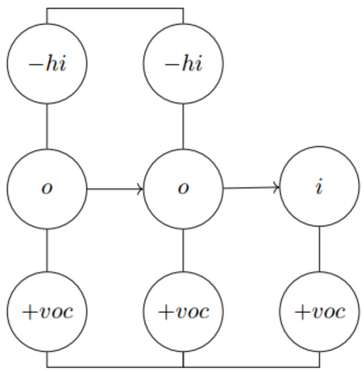
There are two domains for the surface correspondence relations. The domain of the first relation is the set of all [+high] nodes, while the domain of the second is the set of all [+vocalic] nodes. Both relations are total, in the sense that all elements in a domain are in correspondence.

However, in terms of segments, only the first two vowels are related by the [−high] correspondence relation, since the last vowel is not associated with a [−high] feature

[43] Similarly, in McCarthy (2010), CORR constraints are eliminated, but not Surface Correspondence.
[44] From now on, I omit all the consonants from the diagrams, since they do not interact with the vowels and since their features never overlap.

node. For this reason, the high vowel is correctly excluded from participating in the [back] harmony with the other mid vowels, while still participating in the ATR harmony.

(73) Multiple, non-overlapping harmonies in feature correspondence



To obtain a similar effect using Bennett's (2013/2015) model, one has to postulate two overlapping relations: one for the general ATR harmony and another limited to the first two vowels for the non-directional back harmony. However, such a set of relations is impossible in ABC, fundamentally because the same segment cannot be in two different surface correspondence relations, like [m] and [p] in (72).

(74) [m] and [p] are in two different correspondence relations (Bennett 2015:31)

[$s_1am_{1,2}p_{1,2}el_1a$]

Intransitive correspondence formulations (Walker, 2017) do not solve the problem either. This is most evident in cases like Kalabari bysillabic root, where the relation occurs between two segments, and so transitivity cannot play a role (the definition of transitivity itself requires the existence of at least three elements).

5 Derived environment effects in Basque

5.1 Introduction

IDENT(φ-head) constraints are standard faithfulness constraints, and φ-heads are normal phonological heads. Their role in harmony phenomena is a by-product of the assumption that φ-heads only exist as part of a φ-Correspondence relation, which usually causes harmonic processes, while faithfulness to a head is predicted to interact with other markedness constraints as well. Specifically, φ-Correspondence predicts that neutralization may block harmony and that harmony may block neutralization.

The former is what happens in Basque. In some varieties of the language, sibilants in most roots agree on the distributed feature, which distinguishes between laminal and apical sibilants. For example, /es̻-ets̺i/ → [es̺-ets̺i] ‘persist’, cf. /es/ ‘no’, /ets̺i/ ‘consider’.

In addition to harmony, Basque has another process of neutralization, where sibilants neutralize apical before another consonant.

Derived apicals, however, do not cause other sibilants to harmonize. For example, /s̻is̻ku/ ‘bag’ maps to disharmonic [s̻is̺ku] rather than to [s̺is̺ku]. The second sibilant [s̺] normally triggers long-distance assimilation, but it is transparent to harmony if it is in a neutralization context. The three processes are summarized below.

(75) Abstract set of mappings in Basque

a. Sibilant harmony

/s̻…s̺/ → [s̺… s̺]

b. Neutralization

s̻C→ s̺C

c. Neutralization bleeds harmony (DEE)

/s̻…s̻C/ → [s̻… s̺C]

This is the pattern that φ-Correspondence predicts to arise from the interaction between IDENT-IO(φ-head) and markedness constraints on segment clusters.

A simplified analysis of the phenomenon goes as follows: φ-heads on apical sibilants normally act as triggers[45] of sibilant harmony in Basque. However, when the apical sibilant appears before a consonant, a conflict arises. The element either becomes a target of long-distance assimilation or a target of local assimilation. On the one hand, neutralization wants to change the second sibilant, while on the other hand, harmony wants the sibilant to remain faithful in order to act as a trigger of harmony.

There are four possible solutions to this conflict: (i) the element is not assigned the status of a φ-head in the first place, so it does not act as a trigger of the harmony (neutralization bleeds harmony); (ii) harmony bleeds neutralization, which results in a violation of the constraint that demands local assimilation; or (iii) neutralization feeds

[45] Here trigger and target do not refer to the original meaning of the word. No element 'triggers' a process in OT. In φ-Correspondence, the term refers to an element with the head property for which there is at least a correspondent that is mapped unfaithfully in order to achieve harmony. This is not a formal, precise definition, but it is good enough since I only use the term for the sake of exposition.

harmony (which results in a violation of an IDENT-IO(φ-head) constraints).[46] There is a fourth logical case, namely the case where harmony feeds neutralization. However, this case requires a different configuration where the trigger of harmony is not the neutralized segment. In this case, the theory always predicts (iv) to occur, since the *targets* of φ-correspondence assimilations are not protected by any positional faithfulness constraint (see 5.2.4).

Basque belongs to the first class of languages, where neutralization prevents harmony from occurring. As pointed out in Falk (2014), such a process cannot be analyzed in ABC. The reason is that all the segments in correspondence are representationally identical. Even in the theories that encode directionality in special IDENT-CC/VV constraints (Hansson 2001, Rose & Walker 2004), the difference between "triggers" and "targets" is encoded in the IDENT-CC/VV constraint and is opaque to other constraints. In contrast, in φ-Correspondence, heads are explicitly "marked" in the representation, and making them susceptible to targeting by standard faithfulness constraints and interact with other processes.

In the rest of the section, I start with an introduction of Basque consonant inventory (§ 5.1.1). I then describe more thoroughly the pattern of harmony, the neutralization process, and how the two processes interact (§ 5.1.2). I subsequently proceed to introduce the constraints (§ 5.1.3) and the candidate sets (§5.1.4).

[46] See Chapter 6 for a typology of these patterns.

5.1.1 Consonant inventory

Most dialects of Basque distinguish three series of sibilants: laminal [s̻, ts̻], apical [s̺, ts̺], and palatal [ʃ, tʃ], as indicated in the table above. However, the majority of the dialects (e.g., Vizcaya, much of Guipu’zcoa) have lost the distinction between laminal and apical sibilants, so that in these varieties the anterior harmony process (Trask 1997) has no visible effect.

The distinction between laminal and apical sibilants is orthographically expressed via the distinction between <s> for the apical and <z> for the laminal sibilants, which makes data written in the standard orthography amenable to analysis (Falk n.d.).[47]

With the exception of the distinction between laminal and apical sibilants, Basque has a fairly unmarked consonant system, shown in the table below.

(76) Consonants in Standard Basque

	Labial	Laminal	Apical	Palatal	Velar	Glottal
Nasal	m		n	ɲ		
Plosive	p, b	t, d		c, ɟ	k, g	
Affricate		ts̻	ts̺	tʃ		
Fricative	f	s̻	s̺	ʃ		h
Approximant				j		
Lateral			l	ʎ		
Rhotic			r			
Rhotic Tap			ɾ			

[47] The data contained in this chapter is from the “Lexikoa Atzo eta Gaur” (LAG) (https://www.ehu.eus/eu/web/eins/lexikoa-atzo-eta-gaur-lag-). A parser-friendly version of this dictionary was kindly provided by Joshua Falk.

5.1.2 Harmony

In the dialects that maintain the distinction between laminal and apical sibilants, underlying sibilants in the root agree in the distributed feature. For example, disharmonic sequences like [s̺…s̻] or [s̻… ts̺] are not attested.

Palatal sibilants behave like laminals, so roots contain apical sibilants and palatal sibilants, but no root contains a laminal and a palatal sibilant (e.g., *[ʃ…s̻]).

Even though harmony is manifested as a co-occurrence restriction in the root, it is still possible to determine its directionality by observing compounds and loanword adaptation patterns (39a, b). The alternations show that in most dialects the outcome of the harmony is always the apical coronals [s̺, ts̺] as opposed to the laminal [s̻, ts̻].

(77) Basque coronal harmony (LAG, also cited in Hansson 2010:53)

a. Compounds

/s̻in-ets̺i/ → [s̺in-ets̺i] ‘believe’ cf. /s̻in/ ‘truth’

/es̻-ets̺i/ → [es̺-ets̺i] ‘persist’ cf. /es/ ‘no’, /ets̺i/ ‘consider’

b. Sound change and loanwords

frants̻es̺ > frants̺es̺ ‘French’, from Spanish *francés* (Trask 1997:138)

s̺as̻oi > s̺as̺oi(n) ‘season’, from Spanish Sazón (Hualde et al. 1996:113)

The harmony does not extend to suffixes, so disharmonic pairs are attested so long as one of the sibilants is in an affix.

(78) Affixes do not harmonize (LAG, also cited in Hansson 2010:53)

hots̺es̻ 'noise *instrumental*' cf. hots̺ 'noise'

its̺as̺os̻ 'sea *instrumental*' cf. its̺as̺ 'sea'

s̺arts̻e 'enter *gerund*' cf. s̺ar- 'enter *stem*'

What makes these varieties of Basque interesting is the generalization that neutralized sibilants have ever trigger harmony (Falk, 2014). In other words, disharmonic roots are allowed so long as one of the sibilants is neutralized.

Laminal sibilants neutralize before another consonant, so the sequence [s̻C] never surfaces. The resulting [s̺] in neutralization contexts, though, does not cause other sibilants to harmonize. For example, the input /s̻is̻ku/ (77c) maps to the disharmonic [s̻is̺ku], rather than to [s̺is̺ku].[48]

(79) Laminal neutralization in disharmonic roots (Falk 2014:1)

/s̻is̻ku/ → [s̻is̺ku], *[s̺is̺ku] 'bag'

espacio (sp.) > es̺pas̻io, *es̺pas̺io Spanish 'space'

5.1.3 Constraint set

In the analysis, I include the following constraints based on the schemas defined in sections 2.3 and 2.4.2. They include the relate constraint RELATE-[+sib], which governs the distribution of the sibilant nodes in correspondence, the constraint that enforces feature identity among sibilants for the feature distributed ID-[+sib](dist), and the

48 This neutralization process is no longer active in the grammar of Basque (Hualde, p.c.), as demonstrated, for example, by the words [gus̺ti] 'all' and [bes̺te] 'other'.

alignment constraint on sibilant heads ALIGN([+sib-head], R). Finally, there is the faithfulness constraint on φ-head ID-IO(+sib-head).

(80) Constraints related to φ-Correspondence in Basque

- RELATE-[+sib]
  - Assign a violation for each [+sibilant] feature node that is not in a φ-Correspondence relation.
- ID-[+sib](dist)
  - Assign a violation if two nodes in [+sib]-Correspondence have a different specification for the feature [distributed].
- ALIGN([+sib-head], R), *alias* ALIGN([+sib], R)
  - Assign a violation if there is a head [+sibilant] feature node not aligned to the right edge of the prosodic word.
- ID-IO(+sib-head)
  - Assign a violation if a segment has a φ-head and an unfaithfully mapped feature.

I also consider the two IDENT-IO constraints that refer to the harmonizing feature values of [dist], and the IDENT-IO constraint that refers to the feature nodes in correspondence ID-IO(+sib).

(81) IO-Correspondence constraints in Basque

- ID-IO[+dist]
- ID-IO[−dist]
- ID-IO[+sib]

I assume that a constraint *s̻C stands for a set of markedness constraints that favors the mapping /s̻C/ → [s̪C] over /s̻C/ → [s̻C]. The constraint can potentially be derived either from the interaction of other markedness constraints or from constraints that favor local assimilation.

However, even in the case that local assimilation is governed by correspondence (e.g., Shih & Inkelas, 2014), due to their independence of correspondence relations on different tiers (see chapter 4), the specific mechanism of assimilation has no repercussions on the current analysis. I thus assume the following simple definition:

(82) ***s̻C** definition.

Assign a violation for each s̻C cluster in the output.

Finally, I use the constraint φ-EDGE[+sib](root) to account for the fact that harmony only occurs within the root. The constraints appear in the ABC literature as CC-EDGE(root) and prohibits correspondence between two segments that do not belong to the same morphological or prosodic domain (Bennett 2015:73–80).

(83) φ-EDGE[+sib](root) definition.

Penalize φ-Correspondence across root boundaries

For each pair of elements X, Y in φ-Correspondence, assign a violation if X is in the root and Y is not in the root.

In the output [ʃ$_{x}$…{s$_{y}$…ʃ$_{x}$}$_{root}$], Edge-HD(root) is violated once, because the two sibilants [ʃ] are in correspondence, while the leftmost [ʃ] is not in the root. No violation is assigned, because the sibilant [s] is not in correspondence, since the constraint is only violated by segments that correspond. Segments not in correspondence are ignored, no matter what their morphological position or their featural specification is. The set of all constraints used in the analysis is listed below.

- RELATE-[+sib]
- ID-[+sib](dist)
- ID-IO(+sib-head)
- ALIGN([+sib-head], R)
- ID-IO[+dist]
- ID-IO[−dist]
- ID-IO[+sib]
- *s̻C

5.1.4 Candidate set

The set of inputs consists of the forms defined in the schema (77). The candidate set includes three critical segments: the apical [s̺], the laminal [s̻], and the non-sibilant [t] for the dissimilation candidate.

Since sibilants preceding a consonant are neutralized for the apical/laminal distinction, I include the non-sibilant consonant C. C always follows the sibilant, since it is the only relevant neutralization context, and it is always mapped faithfully since it never neutralizes.

(84) GEN for Basque

a. Mapping rules

s̻ → s̺, s̻, t

s̺ → s̺, s̻, t

C → C

b. Others

- All combinations of surface correspondence among sibilants
- One-to-one I/O mapping only

To exemplify, given an input /s̻… s̺C/, there is the following possible subset of outputs: [s̻… s̺C], [s̺$_x$… (s̺)$_x$C], [s̻$_x$… (s̻$_x$)C]. Notice that no segment is ever inserted or deleted, so the consonant C must be specified underlyingly to appear in the output. Also, C is never part of a correspondence relation. This is justified by the phonotactics of Basque, since a sibilant never follow another sibilant in a coda.

5.2 Analysis

I now move to illustrate the analysis of these two phenomena and of their interaction. I start with an overview of the support candidates in section 5.2.1. Section 5.2.2 contains the analysis of the basic harmony pattern, while section 5.2.3 shows how blocking occurs in the case of neutralized segments. Finally, 5.2.5 shows how root-bound harmony is captured in the same way as in classic ABC by banning correspondence that crosses a specific morphological domain.

5.2.1 Overview

Three candidates are sufficient to determine the ranking of Basque: the harmonic candidate with a left-aligned dominant feature (/s̺olas̻/ → [(s̺)$_x$olas̺$_x$]), the candidate that shows the Derived Environment Effect (/s̻is̻ku/ → [s̻$_x$is̺$_y$ku]), and the candidate with the disharmonic sibilant in the root (/its̺as̺o+s̻/ → [its̺$_x$a(s̺)$_x$os̻$_y$]).

The violation tableau for the three winners is shown in (85). In candidate (85a), the output is harmonic, has all the sibilants in correspondence, and agrees in the head's feature value [−distributed]. Since the input is disharmonic, the non-head, [+distributed] segment [s̻] is mapped unfaithfully, resulting in a violation of ID-IO[+dist].

Basque has dominant harmony, so the head is determined by the feature value of the segments in correspondence, rather than by their position. In candidate (85a), the [−distributed] sibilant is aligned to the left of the word. Since the head is not right-aligned, the candidate violates ALIGN([+sib], R).

Candidate (85b) is not harmonic. A disharmonic candidate violates either the RELATE or IDENT-[sib] constraint. If the segments with the correspondence feature do not correspond, they violate RELATE. Alternatively, the segments may correspond, but not agree. In this case, the candidate violates IDENT-[sib]. Finally, because it is adjacent to another consonant, the [+distributed] sibilant is mapped unfaithfully in this candidate as well, resulting in a violation of ID-IO[+dist].

(85) Violation tableau for the three winners

Input	Output	ID-[+sib](dist)	*s̻C	ID-IO(−dist)	ID-IO(+sib-head)	RELATE-[+sib]	ID-IO(+dist)	AL([+sib], R)
a. s̺olas̻	(s̺)ₓolas̺ₓ						*	*
b. s̻is̻ku	s̻ₓis̺ᵧku					*	*	
c. its̺ₓa(s̺)ₓos̻ᵧ	its̺ₓa(s̺)ₓos̻ᵧ					*		

5.2.2 Basic interaction

To have harmony, the RELATE-φ constraint and the corresponding IDENT-φ constraint must dominate at least one IDENT-IO constraint that refers to a harmonizing feature (86a, b). Since harmony is established among sibilants for the feature [−distributed], we have the two ranking conditions: RELATE-[+sib] ≫ IDENT-IO[−distributed] and ID-[+sib](dist) ≫ ID-IO[−distributed].

(86) Harmony in Basque

s̺olas̻ ⟶ (s̺)ₓolas̺ₓ	ID-[+sib](dist)	*s̻C	ID-IO(−dist)	ID-IO(+sib-head)	RELATE-[+sib]	ID-IO(+dist)	AL([+sib], R)
a. s̺ₓolas̻ᵧ					W	L	L
b. s̺ₓolas̻ₓ			W			L	L
c. s̻ₓolas̻ₓ				W		L	L

The varieties of Basque under consideration display a dominant harmony. Purely dominant harmonies are obtained by ranking ID-IO[+dist] above ALIGN([+sib], R). In the ERC (86c), the candidate with the head on the dominant feature wins, even if the φ-head it is not the rightmost feature on the tier.

ERC (86c) also shows that dominant feature is determined by the relative ranking of IDENT-IO constraints, and it is independent of φ-Correspondence.

This is an important point that it is expanded in chapter 6: because dominant directionality is governed by IDENT-IO constraints, markedness effects apply, creating an asymmetry in the typology. The dominant feature is [−distributed], and it is imposed by the ranking ID-IO[−dist] ≫ ID-IO[+dist].

5.2.3 Derived environment effect

The interaction between neutralization and harmony can be observed in the mapping /s̻is̻ku/ → [s̻$_x$is̺$_y$ku]. In the winning candidate, the second sibilant neutralizes [s̺] because of the constraint on s̻C clusters. The two sibilants do not correspond. For this reason, the first sibilant does not violate ID-[+sib](dist), even though the resulting root is disharmonic. The second sibilant is a [s̺], which normally acts as a trigger of harmony. However, in this case harmony is blocked.

(87) DEE in Basque

s̻is̻ku ⟶ s̻$_{x}$is̪$_{y}$ku	*s̻C	ID-[+sib](dist)	ID-IO(+sib)	ID-IO(+sib-head)	ID-IO(−dist)	RELATE-[+sib]	ID-IO(+dist)	AL(φ-head, R)
a. s̻$_{x}$i(s̻)$_{x}$ku	W					L		
b. s̻$_{x}$is̻$_{y}$ku	W							
c. s̪$_{x}$i(s̪)$_{x}$ku				W		L	W	
d. s̻$_{x}$i(s̪)$_{x}$ku		W				L		

The first two candidates have identical output forms, although (87a) harmonically bounds (87b), since it does not violate RELATE-[+sib]. In both candidates, the second sibilants do not neutralize, so they violate the constraint on local assimilation *s̻C. Since the two output sibilants are identical, corresponding and agreeing does not violate any other constraint.

In the introduction, I said that if there is an interaction between neutralization and harmony I consider four relevant outcomes: (i) neutralization bleeds harmony; (ii) harmony bleeds neutralization; (iii) neutralization feeds harmony; and (iv) harmony feeds neutralization. I said that (i) is the winner candidate in Basque. (87a) instead represents the second case. The candidate corresponds and harmonizes, and so it does not violate either RELATE-[+sib] or ID-[+sib](dist). However, by doing so, it violates the constraint on local assimilation *s̻C. Because of φ-Correspondence, neutralization is blocked.

Candidate (87c) represents the case where neutralization feeds harmony.[49] The second sibilant assimilates and becomes a trigger, causing the first sibilant to assimilate.

The outcome of the harmony is thus by the head, which is considered a privileged position and protected by IDENT-IO(+sib-head). But a head is not just a privileged position with respect to harmony. As a harmony trigger, a feature head has a privileged status even with respect to other markedness constraints. ID-IO(+sib-head) is thus violated in this candidate. Without φ-heads and the constraint ID-IO(+sib-head) the winning candidate without harmony would lose to this candidate (see 5.2.7).

Finally, candidate (87d) is an alternative valid representation of the winning candidate in Basque. If we look at the segmental information, the output is identical to the winning candidate. The root is disharmonic, with the first sibilant mapped faithfully and the second neutralized. Since the winning candidate and the loser are phonetically identical, there is no way to tell which one is the actual winner.

The only difference is in the correspondence relation. To have harmony, both the RELATE-X and the IDENT-φ constraints need to outrank the relevant faithfulness constraints. If a faithfulness constraint outranks RELATE-X but not IDENT-φ, then we have correspondence without harmony; if it outranks both, we have no correspondence. The same prediction is made in ABC. This means that some of the candidates generated are

[49] Again, I use a "derivational" terminology to elucidate the process. Here "harmonize" means that a segment is mapped unfaithfully to achieve harmony. If two sibilants are identical and are mapped faithfully in the input, in φ-Correspondence they "harmonize" the same way as in candidates where there is an alternation. So, neutralization does not really feed harmony, because harmony would be achieved anyway, although not via an unfaithful mapping.

phonetically identical and that different rankings are compatible with the same set of data.

Notice that for disharmonic roots the input with two apicals must be assumed, unlike harmony, where I show that no output with disharmonic candidate exists. The goal of this analysis is to show that some candidates fail to harmonize and that there is a ranking that generates disharmonic candidates as optimal in the otherwise harmonizing grammar of Basque. The assumption is that these candidates have an underlying apical in a neutralization context.

5.2.4 Other predictions

Unfortunately, I could not find any root with three syllables in the lexicon. Nevertheless, extending the analysis to roots with three sibilants, the prediction is that an input with both a neutralized and a non-neutralized [−distributed] sibilant is harmonic. For example, the input /s̺…s̻…s̻k/ maps to [(s̺)$_x$…s̺$_x$…s̺$_x$k]. Since now there is a non-neutralized [−distributed] sibilant in the input (the first s̺), the head does not need to be assigned to the sibilant in the neutralization context. Instead, the first sibilant becomes the head and causes the second sibilant to assimilate, while the neutralized sibilant inconsequentially corresponds and agrees with the rest of the sibilants.

(88) Input with three sibilants harmonize

s̪is̪is̪ku	*s̪C	Id-[+sib](dist)	Id-IO(+sib)	Id-IO(+sib-head)	Id-IO(−dist)	Relate-[+sib]	Id-IO(+dist)	Al(φ-head, R)
a. (s̪)$_x$is̪$_y$is̪$_x$ku						!*	*	*
b. (s̪)$_x$is̪$_x$is̪$_x$ku							**	*
c. s̪$_x$i(s̪)$_x$is̪$_x$ku	!*				*			*

The theory also makes the prediction that a DEE cannot occur if the affected segment is a target instead of a trigger of the assimilation (see the tableau in (89) below). Since only heads are targeted by Ident-φ constraints, targets are predicted to not interact with other processes given the current constraint set, since only heads are marked with the property H, and only H nodes are targeted by constraints. This is prediction (iv), where harmony feeds neutralization.

Imagine a language like Basque, where the neutralization causes the sibilants to map to the regressive feature [s̪]. Since [s̪] is not the dominant feature, there is no demand for it to be a head. In case of disharmonic input, then, the head would be assigned to the [s̪] segment. This segment, though, does not interact with the neutralization process. It can be a head, stay faithful, and trigger harmony as if there were no neutralization.

(89) Neutralization of the regressive feature has no effect

s̪is̪ku ⟶ (s̪)$_x$is̪$_x$ku	*s̪C	ID-[+sib](dist)	ID-IO(+sib)	ID-IO(+sib-head)	ID-IO(−dist)	RELATE-[+sib]	ID-IO(+dist)
s̻$_x$i(s̻)$_x$ku	W					L	L
s̻$_x$i(s̪)$_x$ku		W				L	
s̻$_x$is$_y$ku						W	L

5.2.5 Domain restrictions

The last issue that is still left unaddressed is the fact that suffixes do not harmonize with the root. The instrumental suffix /-s̻/ for example, never surfaces as [s̪], even if an apical sibilant is present in the root, nor does it cause the sibilant in the root to become [−distributed]. The input /its̪as̪o+s̻/ maps faihtfully to [its̪a s̪os̻] rather than to *[its̪as̪os̪] or *[its̻as̻os̻].

This phenomenon has little to do with headedness or feature correspondence. Rather, it is due to the presence of an undominated φ-EDGE constraint that penalizes correspondence across root boundaries. The analysis is identical to a standard ABC analysis for this pattern.

Candidates (90a, b) select the rightmost [−distributed] segment as the head. It is a perfect head since it does not violate any c-head constraint. However, it fatally violates φ-EDGE[+sib](root). The only way to avoid the final dental from being a head is to not have the segment in correspondence, as shown in (90c).

(90) Domain restriction in Basque

Input	Winner	Loser	φ-EDGE[+sib](root)	*s̻C	ID-[+sib](dist)	ID-IO(+sib)	ID-IO(+sib-head)	ID-IO(−dist)	RELATE-[+sib]	ID-IO(+dist)	AL(φ-Head, R)
its̺as̺o+s̻	its̺$_{x}$a(s̺)$_{x}$os̻$_{y}$	its̺$_{x}$as̺$_{x}$o(s̺)$_{x}$	W						L	W	
s̺olas̻	(s̺)$_{x}$olas̺$_{x}$	s̺$_{x}$olas̻$_{y}$							W	L	L

5.2.6 Summary

The tableau in (91) shows the three strata of the grammar. At the top stratum, there are all the undominated constraints. Harmony across root-boundary is always banned by Φ-EDGE[+sib](root). The constraint *s̻C is also undominated, since neutralization applies across the board.

ID-[+sib](dist) is also undominated, even though not all output harmonizes. This is because elements not in correspondence vacuously satisfy the constraint. In the case where harmony is not achieved, the elements are not in correspondence, so the constraint is not violated.

Next, there are the three faithfulness constraints. ID-IO(+sib) is undominated, so candidates do not ever map a sibilant into a non-sibilant to escape correspondence. ID-IO(+sib-head) is also undominated. Because a φ-head cannot be mapped unfaithfully, disharmonic candidates vacuously satisfy the constraint by having the sibilants not in correspondence.

Finally, ID-IO(−dist) determines the directionality of both the local assimilation and of the long-distance assimilation process. Harmony in Basque is dominant-regressive, and the dominant value is always [−distributed] and never [+distributed].

The only constraint in the second stratum is RELATE-[+sib]. The constraint is sandwiched between two other strata. On the one hand, it dominates ID-IO(+dist), so that harmony can be achieved when neutralization does not interfere or when correspondence does not cross the root boundaries. On the other hand, correspondence, and thus harmony, is restricted in Basque by both morphological factors and by the neutralization process. In these contexts, correspondence is not instantiated, and the constraint RELATE-[+sib] is violated. Finally, in the bottom stratum are the constraints ID-IO[+dist] and ALIGN([+sib], R). ID-IO[+dist] is violated by all unfaithful mappings of sibilants. If a sibilant must change because of neutralization or because of harmony, then it is always the [+dist] feature value that is changed. ALIGN([+sib], R) is also on the bottom stratum, since Basque is a purely directional harmony, and alignment to an edge does not play any role in the assignment of the φ-heads in the output.

(91) Support tableau for Basque

ERC	Input	Winner	Loser	Φ-EDGE[+sib](root)	*s̻C	ID-[+sib](dist)	ID-IO(+sib)	ID-IO(+sib-head)	ID-IO(−dist)	RELATE-[+sib]	ID-IO(+dist)	AL(φ-head, R)
1	its̺as̺o+s̻	its̺$_x$a(s̺)$_x$os̻$_y$	its̺$_x$as̺$_x$o(s̺)$_x$	W						L	W	
2	s̻is̻ku	s̻$_x$is̺$_y$ku	s̻$_x$i(s̻)$_x$ku		W					L	L	
3	s̻is̻ku	s̻$_x$is̺$_y$ku	s̻$_x$i(s̺)$_x$ku			W				L		W
4	s̻is̻ku	s̻$_x$is̺$_y$ku	s̻$_x$it$_y$ku				W			L	L	
5	s̻is̻ku	s̻$_x$is̺$_y$ku	s̺$_x$i(s̺)$_x$ku					W		L	W	
6	s̺olas̻	(s̺)$_x$olas̺$_x$	s̻$_x$ola(s̻)$_x$						W		L	L
7	s̺olas̻	(s̺)$_x$olas̺$_x$	s̺$_x$olas̻$_y$							W	L	L

5.2.7 Basque in ABC

As previously reiterated, ABC cannot capture the interaction between harmony and neutralization. I show that a crucial role in blocking the harmony is played by φ-heads via the constraint IDENT-IO(+sib-head). Since ABC does not have any head, it cannot capture either the asymmetry between trigger and target in Basque or the interaction of elements in a correspondence relation with other phenomena. The analysis of ABC of the harmony pattern follows the lines of the analysis in φ-Correspondence. To have harmony, IDENT-CC(ant) and CORR(+sib) must be ranked above ID-IO(+dist). Neutralization is also obtained by ranking *s̻C above ID-IO(+dist).

This ranking works well when the two processes do not interact. However, when the two processes co-occur, a ranking contradiction arises. As illustrated in (92), CORR(+sib) has to be ranked above IDENT-IO[−dist] in order to have harmony (92e), while at the same time it must be ranked lower than the same IDENT-IO[+dist] to avoid overapplication in neutralized forms (92b).

(92) Basque in ABC

Winner	Losers	*s̻C	ID-CC(dist)	ID-IO(−dist)	CORR(sib)	ID-IO(+dist)
s̻is̻ku → s̺$_x$is̻$_y$ku	a. s̺$_x$is$_x$ku		W		L	
	b. s̺$_x$is̺$_x$ku	W		W	L	
	c. s̻$_x$is̻$_x$ku				L	W
s̺olas̻ → s̺olas̺	d. s̺$_x$olas̻$_x$		W			L
	e. s̺$_x$olas̻$_y$				W	L
	f. s̺$_x$olas̺$_x$			W		L

In φ-Correspondence, ID-IO(+sib-head) favored the candidate without harmony. However, in ABC the absence of heads (or any other marking on the trigger of harmony) does not permit a distinction between the two sibilants in correspondence. In fact, there is not even a way to refer to elements in correspondence outside of the domain of Surface Correspondence constraints.

5.3 Chapter summary

In this chapter, I discussed a rare case of interaction between harmony and neutralization in Basque, which is a direct consequence of the introduction of φ-heads.

In general, I showed that φ-heads play different roles in φ-Correspondence. First, I demonstrate that φ-heads are essential in the proof of Hypothesis I, since they allow us to formulate φ-Correspondence as a type of correspondence relation (chapter 2).

I also showed that φ-heads play a major role in determining the directionality of the harmony (chapter 3). Directional harmonies (like in Chumash) are argued to have a right-aligned φ-heads. In other languages (see Dominant-Directional harmony in section 6.1.2.3), the alignments of φ heads interacts with other IDENT-IO constraint either to determine the directionality of the harmony or limit the domain of the correspondence relations.

In this chapter, I have shown a yet another effect of φ-heads. Feature nodes are marked with a head feature, and the positional faithfulness constraints IDENT-IO(φ-head) directly refer to the property in their evaluation of an element as a privileged position.

The general nature of headedness and of the positional faithfulness constraints yields to the interaction with other local markedness constraints. In particular, the theory predicts that harmony may non-trivially interact with neutralization process affecting the trigger of a harmony process in various ways.

In Basque, we see an example of neutralization counterbleeding harmony. When a potential trigger occurs in a neutralization context, it cannot act as the head of the harmonic domain. If the neutralized segment is the only possible trigger, harmony does not occur, which explains the disharmonic roots observed in the language.

In the previous sections, I showed that cases where Kalabari can be analyzed in classic ABC by introducing a somewhat complex set of constraints. Interactions between neutralization and harmony require non-trivial alteration either of the correspondence relation or of the constraint evaluation mechanism. These interactions are predicted to occur in φ-correspondence because of the general definition of headedness and positional faithfulness constraint.

ABC does not have heads and does not distinguish between triggers and targets. Any phenomenon that presents an asymmetry between the two types of elements is therefore problematic for the theory (see also Walker 2016 for a clear example of trigger–target asymmetry).

6 Typologies

In this chapter, I discuss the typological predictions of the theory. In section 6.1, I discuss the basic typology of directionality in φ-Correspondence. In section 6.2, I introduce a set of generalizations that restricts the types of attested directionality patterns, and the consequences one of these restrictions have on theories of markedness.

6.1 Base typology

I start with the basic typology of φ-Correspondence. This typology defines the basic patterns of directionality predicted by the theory by focusing on the interaction between the basic φ-Correspondence constraints RELATE-X and IDENT-φ.

6.1.1 Formal typology

6.1.1.1 Features

In section 2.3, I explain that the number of φ-Correspondence constraints grows linearly with the number of features postulated. A model with five features has five RELATE-φ constraints and five IDENT-φ constraints, while a model with ten features has double that number. This proliferation of constraints raises two issues.

The first issue is practical: more constraints generate bigger typologies, which in turn are harder to analyze. In this chapter, I only consider one harmony at the time (i.e., set of φ-Correspondence constraints that refer to a single feature). This move is justified because φ-Correspondence relations are mostly independent from one another, as illustrated in the analysis of Kalabari in chapter 4. In other words, harmony may interact with other processes and other harmonies, but not directly via correspondence.

The second issue concerns the raw number of constraints themselves. However, the constraints are all derived from the same schemas (i.e., have the same definition), so the number of features (and consequently the number of postulated constraints) is less important.

Thus, one can study the structure of the typology for one harmony and generalize it to all other features. The actual typology comprises different languages in terms of features, but they can all be linked back to one of the abstract patterns described in the rest of this section.

For the sake of readability, instead of using an abstract feature, I use the feature [+sibilant] to refer to the tier of correspondence and the feature [anterior] for the harmonizing feature.

6.1.1.2 Candidate set

Candidates include a root with two consonants and two vowels, and an optional suffix with a sibilant. The segments considered include the sibilants [s, ʃ], which represent the segments with the correspondence feature, and the segment without the correspondence feature [t]. The vowel [a] is used to separate the consonants but does not play any role under the current constraint set. An example of a possible candidate is as follows: /ʃasa+s/ → [s_xas_xa+s_x]. The complete characterization of the candidates is provided in (93), in the usual format.

(93) Candidate set

a. Inputs

[s, ʃ, t] a [s, ʃ, t] a + ([s, ʃ, t])

b. Mappings

ʃ → s, ʃ, t

s → s, ʃ, t

t → t

c. Other

All combinations of surface correspondence among sibilants

One-to-one I/O mapping only

There is no deletion or epenthesis in the candidates, so the input and output always contain the input segments. The last consonant is considered morphologically an affix to the root, and there is no morphological rephrasing, so the structure of both input and output is always CVCV+(C).

The output follows the same format used in chapter 3. It may contain one and only one head, the indices indicate correspondence, and it contains the same set of segments [s, ʃ, t] included in the input.

6.1.1.3 Constraints

The constraint set used is like the one used for Chumash in chapter 3. It includes constraint RELATE-[+sib] to govern the distribution of nodes in correspondence, and the

IDENT-φ constraint ID-[+sib](ant), which favors elements in correspondence that agree for the feature anterior.

(94) φ-Correspondence constraints in Chumash

- RELATE-[+sib]
  - Assign a violation for each [+sibilant] feature node that is not in a φ-Correspondence relation.
- ID-[+sib](ant)
  - Assign a violation if two nodes in [+sib]-Correspondence have a different specification for the feature [anterior].

The other two constraints refer to φ-heads. ID-IO(+sib-head) is the faithfulness constraint that penalizes φ-heads from being mapped unfaithfully, and ALIGN([+sib-head], R) penalizes the misalignment of the heads to an edge.

- ID-IO(+sib-head)
  - Assign a violation if a segment has a φ-head and an unfaithfully mapped feature.
- ALIGN([+sib-head], R)
  - Assign a violation if there is a head [+sibilant] feature node not aligned to the right edge of the prosodic word.

Finally, there are the IDENT-IO constraints that refer to the features in correspondence (+sib) and to the features for which agreement is demanded (anterior), and one constraint that refers to segments in the root ID-IO(root) (see (19) for a definition).

(95) IDENT-IO Constraints in the typology

- ID-IO(+ant)
- ID-IO(−ant)
- ID-IO(+sib)
- ID-IO(root)

The constraint set contains two justified simplifying assumptions. First, I assume that ID-IO(−ant) always dominates IO(+ant). The typology that does not impose this restriction includes the same patterns but with the feature values switched. Furthermore, this move is empirically justified, as discussed in section 6.2.2.

Likewise, I do not include the mirror image of ALIGN([+sib-head], R) that would refer to the left edge. The absence of this constraint is justified empirically, as discussed in 6.2.1.2.

6.1.1.4 The typology

The list of language types generated by the typology is given in (96). Since there is no phonetic realization of headedness or of correspondence, grammars with the same segmental mapping are merged together and considered as a single language.

For example, although the faithful mapping with no elements in correspondence is structurally different from the output with some elements in correspondence, the candidates are considered the same when classifying the language.

The tables below contain the languages of the typology. Most languages can be obtained by simply looking at the candidates with two segments in the root. These languages are included in (96). Including an affix allows us to further distinguish one type of language, indicated in (97).

The mappings reported always concerns sibilant harmony, while the languages reported refer to the general pattern description. Descriptions of the patterns for each attested type of harmony can be found in section 6.1.2.

(96) Typology within the root (CVCV).

/ʃasa/	/saʃa/	Language description	Example languages
$(ʃ)_x aʃ_x a$	$ʃ_x a(ʃ)_x a$	*Pure dominant harmony.* Outcome determined by a feature.	Malto, Basque, Moroccan Arabic
$s_x a(s)_x a$	$ʃ_x a(ʃ)_x a$	*Pure directional harmony.* Outcome determined by alignment to an edge.	Tsilhqot'in, Chumash, Saisiyat, Thao
$ʃ_x as_y a$	$ʃ_x a(ʃ)_x a$	*Dominant-directional harmony.* Harmony only if aligned and dominant.	Ngizim, Pengo, Kera
$ʃ_x at_y a$	$ʃ_x a(ʃ)_x a$	*Dominant-directional dissimilation.* Harmony if aligned and dominant, otherwise.	unattested?
$ʃ_x at_y a$	$ʃ_x at_y a$	*Dissimilation.* Dissimilation for disharmonic inputs.	Chol
$ʃ_x as_y a$	$s_X aʃ_y a$	*Faithful.* No harmony or dissimilation.	All other languages

In addition to the faithful and dissimilation languages, the typology includes three well-known types of harmonies: dominant harmonies, where the target is determined by a specific feature value; directional harmonies, where the target is determined by the position of the feature in the string (leftmost or rightmost); root control harmonies, where the target is in a *privileged morphological position* (discussed in the next section).[50] The harmonies can be either exclusively of one type (i.e., "pure") or mixed.

Mixed types (such as dominant-directional) are classified as a combination of base types. Mixed types impose a restriction on the application of harmony based on their base type. For example, in dominant-directional harmony, only dominant-right aligned segments act as triggers. If the rightmost sibilant does not have the dominant feature, harmony is blocked. Likewise, in dominant-root control harmonies, only segments with the dominant feature in the root can act as triggers.

6.1.1.5 Root control

Including an affix simply extends the typology above with two additional languages. In dominant-root control harmony, the outcome is determined by a segment in the root with the dominant feature.

There are two subtypes of languages that belong to this type. These differ in whether the root segments harmonize or not. For example, in /saʃa+s/ → [s_xa$(ʃ)_x$a+$ʃ_x$] the sibilants in the root do not harmonize, while in the candidate /saʃa+s/ → [$ʃ_x$a$(ʃ)_x$a+$ʃ_x$], harmony includes the suffix and the segments in the root.

[50] In this dissertation, I only discuss the distinction between root (privileged) vs. affixes (non-privileged). (Beckman, 1998:191–209). In Obolo, harmony goes from onset (privileged) to coda, but such cases are scarce.

(97) Typology with an affix (CVCV+C)

/ʃasa+s/	/saʃa+s/	Language description	Example languages
$(\int)_x$as_xa+$\int_x$	s_xa$(\int)_x$a+$\int_x$	*Dominant-root control.* Outcome determined by a feature in the root.	Bemba, Yaka (Bantu)
$\int_x$as_xa+s_x	$\int_x$a$(\int)_x$a+$\int_x$	*Dominant-directional-root control harmony.* Harmony if aligned, dominant, and in the root.	Unattested

Both language subtypes are attested. However, since the question as to whether or not harmony extends to the root is not relevant for the typology of directionality (see also section 6.1.2.5), I consider the two languages as belonging to the same directionality type.

Dominant-directional-root control harmonies seem to be unattested. However, these patterns, much like the dominant-directional dissimilation class (see previous section) are also subtle, so they are easy to miss in a cursory description of a language.

Notice that no directional-root control languages are not generated, in which, the outcome of the harmony would be determined by the rightmost segment in the root.

However, whether or not these languages are generated or depends not on φ-Correspondence, but rather on the definition of ALIGN(φ-head) constraints. In section

2.4.2.1, I assume that the alignment constraints have a categorical definition rather than a gradient one.

The categorical definition does not generate these languages because it cannot distinguish between candidates like ʃ$_x$a(ʃ)$_x$a+s and (ʃ)$_x$aʃ$_x$a+s. The sibilant is not right-aligned in either candidate, so it violates the categorical definition is violated once.[51]

(98) Language not generated.

/ʃasa+s/	/saʃa+s/	Language description	Example languages
s$_x$a(s)$_x$a+s	ʃ$_x$a(ʃ)$_x$a+ʃ	*Directional-root control.* Outcome determined by alignment to the root.	Unattested

6.1.2 Empirical survey

I now review the empirical attestation of the types generated by the typology. The focus is on the basic directionality types, and so the details of the harmony processes, eventual alternative analyses, and the interaction of harmony with other processes are not discussed.

[51] If we consider prefixes, then such languages are predicted by the typology even with the categorial definition. Having an ALIGN(φ-head) that refers to the root edge as opposed to the prosodic word edge also yields the same outcome. More evidence is required to assess the most appropriate definition of ALIGN(φ-head) and of its effect on directionality.

6.1.2.1 Dominant harmony

I start with dominant harmonies. In those harmonies, the outcome of the assimilation is determined by specific value of a feaure, such as [+ant] as opposed to [−ant].

While in many varieties of Arabic, sibilant assimilation is directional, in Moroccan harmony, it is argued to be pure dominant (99). Heath (1987) provides the following data:

(99) Sibilant harmony in Moroccan Arabic (Heath 1987)

	Classical Arabic		Moroccan	
a.	zadʒ	→	ʒaʒ	‘glass’
b.	zulajdʒ	→	ʒlliʒ	‘tiles’
c.	sardʒ	→	ʃarʒ	‘saddle’
d.	ʃams	→	ʃomʃ	‘sun’

Another example of a pure dominant harmony is Basque (§ 3.2). In this language, coronal harmony manifests itself as a co-occurrence restriction in roots, in compounds, and in loanword adaptations. In some dialects, harmony is always to the apical coronals /s̺, ts̺/ and never the alveolar coronals /s, ts/ (Trask 1997).

The examples in (100) show that the assimilation target is independent of directionality, since it goes from left to right. It is also independent of root control, since the assimilation also occurs within roots, as also seen in (100).

(100) Basque coronal harmony

a. /sin-etṣ̻i/ → [ṣ̻in-etṣ̻i] 'believe', cf. /sin/ 'truth'

b. /es-etṣ̻i/ → [eṣ̻-etṣ̻i] 'persist', cf. /es/ 'no', /etṣ̻i/ 'consider'

c. /frantseṣ̻/ > /frantṣ̻eṣ̻/ 'French', from Spanish *francés*

d. /ṣ̻atsuri/ > /ṣ̻atṣ̻uri/ 'mole'

e. /ṣ̻asoi/ > /ṣ̻aṣ̻oi(n)/ 'flavor'

In Tlachichilco Tepehua (Hansson 2010:88-94), dorsalized /p, t/ harmonizes with uvular /q, q'/ (e.g., /q'ut-łi/ → [ʔoq-łi]).[52]

Place harmony is different from other types of harmony in that it is parasitic on other features. For example, in Gojri two plosives have to be identical if they are aspirated. A similar requirement is active in Aymara and Tzutujil (and other Mayan languages), the difference being that the features are ejectives. In Hausa two glottalic consonants must identical.

In Kera, the prefix /ka/ is realized as [ga] if there is a voiced segment in the root (although see Pearce 2005 for an alternative analysis). This harmony is of type dominant-root control in that the trigger is in the root, and only the marked feature value can be the harmonizing feature. Directionality is irrelevant, as assimilation occurs in both prefixes

[52] Watters (1998) notes two exceptions: /ʔaq-lukut/ → [ʔaq-qloquti] 'horn', cf. /ʔaq-/ 'head' and /lukut/ 'bone'; and [ʔaqlaqawa:nan] from /lakaw/ 'dream'. The exceptions are sporadic, but they cannot be derived from directionality, since the target is the leftmost sibilant, nor they can be derived from root-orientedness, since the uvular is in a prefix.

and suffixes. Similarly, several Coptic dialects (Sahidic, Akhminic, Assiutic) underwent a sound change where /s/ > /ʃ/, via assimilation to tautomorphemic /ʃ, tʃ/.

(101) Voicing harmony in Kera

a. Voicing harmony in feminine suffix /-ka/

sar-ka ‘black (fem.)’

d͡ʒar-ga ‘colorful (fem.)’

b. Voicing harmony in nominal prefix /k-/

kə-maanə ‘woman’

kə-taːta-w ‘cooking pot (pl.)’

kə-kamma-w ‘chief (pl.)’

gə-daːrə ‘friend’

gə-dajka-w ‘jug (pl.)’

c. Bidirectional voicing harmony (collective /-kaŋ/, masculine /-ki/)

kə-sar-kaŋ ‘black (coll.)’

ki-sir-ki ‘black (masc.)’

gə-d͡ʒar-gaʌ ‘colorful (coll.)’

gi-d͡ʒir-gi ‘colorful (masc.)’

Most cases of nasal harmony are of the *dominant-root control* type. A sonorant in a suffix becomes a nasal if there is a nasal at a certain distance in the root. For example, in

Yaka and in many Bantu languages, harmony is always obtained via nasalization of a segment in an affix.

(102) Nasal harmony in Yaka (Hyman, 1996)

a. Perfective suffix /-idi/ → [-idi]:

tsub-idi 'to wander (perf.)'

kud-idi 'to chase (perf.)'

kik-idi 'to block (perf.)'

kas-idi 'to lie (perf.)'

b. Nasal harmony in /-idi/ → [-ini]

tsum-ini 'to sew (perf.)'

kun-ini 'to plant (perf.)'

wun-ini 'to whisper (perf.)'

b. Nasal harmony must be triggered in the root

kud-ana 'to chase (caus.)'

kik-ana 'to block (caus.)'

(103) Nasal harmony in Lamba (data from Odden, 1994)

a. Perfective suffix /-ile/:

-pat-ile 'scold (perf.)'

-uum-ine 'dry (perf.)'

-mas-ile 'plaster (perf.)' *[-mas-ine]

b. Intransitive reversive suffix /-uluk-/:

-fis-uluk-a 'get revealed'

-min-unuk-a 'get unswallowed'

-mas-uluk-a 'get unplastered' *[-mas-unuk-a]

Hansson (2001/2010), citing Greenberg (1951), notes that in some Teke dialects (Kukuya), in a sequence CVCVCV, only the second and the third velar consonants harmonize for nasality.

6.1.2.2 Directional

In directional harmonies, the outcome of the assimilation is determined by a segment that is aligned to a specific edge of the word. An example of pure directional harmony is Chumash (§ 3.1), where the rightmost sibilant in the word determines the [ant] value of all other sibilants.

Several Formosan languages also show the effect of pure directional harmony in sound change, although there are some exceptions. All the reconstructions are from Blust's (1995) analysis, and the original forms are from Proto-Austronesian. The two clearest cases (Blust 1995; Hansson 2010:56) are Saisiyat (NW Taiwan) and Thao (Central Taiwan). In Saisiyat, there are words that display anteriority assimilation. Similarly, Thao also has continuant harmony, and anteriority harmony in sibilants, as well as a very peculiar case of harmony with the lateral fricatives.

Another case of pure directional harmony is the Northern Athapaskan language Tsilhqot'in (Chilcotin). In Tsilhqot'in, pharyngealized alveolar sibilants /sˤ, zˤ, tsˤ, ts'ˤ, dzˤ/ (−RTR) contrast with plain alveolar sibilants /s, z, ts, ts', dz/ (Cook 1993; Hansson 2007; 2010). The two alveolar sibilant series harmonize for [RTR], and the harmonizing feature is determined by the rightmost segment in the word.

In various Niger-Congo and Afro-Asiatic languages, such as Shambaa, Izere, Rwanda, and Rundi, harmony is directional, often from suffix to root, as shown in (104). In (104a) the root-final sibilants [s, z] fuse with the palatal glide of the perfective suffix /-je/ and become [ʂ, ʐ]. The data in (55b) shows that the harmonizing feature is always determined by the rightmost segment, even when it appears in a suffix. Given the data available, it is unclear if the harmony is dominant, since the harmonizing feature always seems to be the retroflex. If that is the case, then these languages are of the type dominant-directional (see below).

(104) Directional harmony in Rwanda

a. Root harmony

/ba-ra-saːz-je/ → [baraʂaːʐe] 'they are old'

/a-sas-je/ → [aʂaʂe] 'he just made the bed'

/a-sokoz-je/ → [aʂokoʐe] 'he just combed'

b. Suffix to root harmony

/ku-sas-iːʂ-a/ → [ku-ʂaʂiːʂa] 'to cause to make the bed'

/ku-saːz-iːʂ-a/ → [ku-ʂaːʐiːʂa] 'to cause to get old'

/ku-uzaz-iːʂ-a/ → [ku-uʐaʐiːʂa] 'to cause to fill'

Both Tsuut'ina (Sarcee) (105) and Navajo (106) have directional harmony, with the harmonizing feature determined by the rightmost sibilant in the root. Wiyot (Algic; Teeter 1959) and Rumsen (Costanoan) are also argued to have directional harmony.

(105) Sibilant harmony in Tsuut'ina

/si-tʃiz-aʔ/ → [ʃitʃidza] 'my duck'

/si-tʃogo/ → [ʃitʃogo] 'my flank'

/na-s-ɣatʃ/ → [naʃɣatʃ] 'I killed them again'

(106) Sibilant harmony in Navajo (data from McDonough, 1991)[53]

/j-iʃ-mas/ → [j-is-mas] ‘I am rolling along’

/ʃ-is-na/ → [s-is-na] ‘he carried me’

/si-d͡ʒeːʔ/ → [ʃi-d͡ʒeːʔ] ‘they lie (slender stiff objects)’

/dʒ-i-zda/ → [dzizda] ‘he sat down’

/dz-isʃ-l-haːl/ → [dʒiʃhaːl] ‘I tumble into water’

6.1.2.3 Dominant-directional

In dominant-directional languages, harmony occurs only when a marked segment is the rightmost correspondence segment in the word. This happens in Bolivian Aymara and in the West Chadic language Kera. In Kera, there is optional root-internal harmony if /tʃ/ follows a /t/. The only two examples given involve the mapping /t…tʃ/ → [tʃ... tʃ], but according to Hansson’s (2010) description, the sequence /tʃ…t/ does not trigger harmony. The two examples are reported below.

(107) Kera coronal harmony

a. tutʃi ~ tʃutʃi ‘tamarind’

b. tʃe tʃerke ‘backbone’

In Basaa, the velar stop /k/ nasalizes if the previous consonant is a nasal. Another dominant-directional language is Pengo. In Pengo, coronals harmonize for [distr_release], for example /t…tʃ/ → [tʃ…tʃ] (108). However, as in the case of Kera and Aymara,

[53] Navajo also has been argued to have a process of RtoL consonant harmony between the perfective /si-/ and 1st singular subject prefixes (McDonough 1991).

harmony is blocked if a [+distr_release] coronal is not the rightmost segment in the correspondence. The reverse mapping never happens, regardless of the position of the segments, so the input /ʃ…t/ is mapped faithfully [ʃ…t], as shown in (108).

(108) Dominant coronal harmony in Pengo (data from Burrow & Bhattacharya 1970)

a. titʃ ~ tʃitʃ ‘to eat (past stem)’

b. to:tʃ ~ tʃo:tʃ ‘to show’

c. ta:nd͡ʒ~ tʃa:nd͡ʒ ‘to appear’

e. tʃeta man ‘to be awake’, *tʃetʃa, *teta

f. d͡ʒa:ti ‘castle’, *dʒa:tʃi

6.1.2.4 Non-harmonic types

In addition to three types of harmony, there are several grammars with non-harmonic candidates. As in ABC, the typology of φ-Correspondence includes faithful grammars that differ on whether the segments with the correspondence feature are in correspondence or not.

The dissimilation language is the same predicted by ABC (e.g., Bennett 2013): a segment may escape the requirement to correspond by unfaithfully mapping the feature for which correspondence is demanded.

Finally, the dominant-dissimilation grammar is a combination of the dissimilation type and the dominant-directional one. In this grammar, disharmonic roots harmonize when the rightmost segment in the correspondence is marked; otherwise, disharmonic roots dissimilate. To my knowledge, such grammars are unattested. Nevertheless, the directional-dissimilation grammar is a combination of two already rare language types. The fact that the language is unattested might then be because the conditions for such a grammar to come about are very unlikely to occur in a language.

6.1.2.5 Domain restrictions

The generalizations and the properties discussed in this section apply to the harmonizing feature component and should not be confounded with other correspondence effects, such as harmony domain restriction.

An example of domain restriction was shown for Basque, where harmony does not extend to suffixes (§ 2.3). There are other languages where affixes do not trigger harmony or participate in harmony. In Rwanda retroflex harmony only holds within the stem (a). Sibilant in the affixes do not participate in the harmony (b).

(109) Rwanda domain restriction (Mpiranya & Walker 2006, cited in Bennett 2015:78)

a. /ku-sas-iiʂ-a/ → [gu<ʂaʂiiʂa>] 'to cause to make the bed'

b. /zi-saaʂ-e/ → [zi<ʂaaʂa>] 'it became old (perf.)'

In Athapaskan languages, harmony goes from the root to the prefix, and it is right-to-left, as in Chumash. Hansson (2010:148) citing (Sapir & Hoijer, 1967:16) notes that enclitics are never affected by harmony. In both languages the harmonizing feature is determined by the rightmost sibilant in the root. Enclitics that follow the root do not participate in the harmony.

These languages still fall under the generalizations discussed in this section. Basque and Rwanda have agreement to the marked feature value, while Sarcee and Navajo are directional. Nonetheless, the properties and the generalizations discussed have nothing to say about the domain restriction, they are just limited by it in their application.

6.2 Trigger asymmetries

There are several patterns that concern the directionality of the outcome of the harmony and are attested in an asymmetric way. In section 6.2.1, I formulate three parameters that account for these asymmetries. Each parameter encodes a generalization on a macro-type of directionality (*dominant, directional, root control*). I then illustrate how the combination of these parameters limit the typology of directionality introduced in the previous section only to the attested patterns.

Sections 6.2.2 focus on the generalization on markedness. This generalization is particularly important because it allows us to distinguish between general theories of markedness. I show that the typology of consonant harmony provides evidence for the hypothesis that a subset of faithfulness constraints are in a fixed ranking relation as opposed to a stringent relation.

6.2.1 The three generalizations

In this section, I argue that for each of the three macro-types of harmonies (dominant, directional, and root control) there is a bias towards a specific direction of assimilation.

6.2.1.1 Dominancy

The first generalization concerns dominant harmonies. Hansson (2010) and Bennett (2013/2015) noted a tendency or a strong preference for “marked” (see 6.2.2.1 for a working definition of markedness) feature values to be the target of assimilation.

Although in most cases the generalization is rendered opaque by alignment and root control effect, an analysis of all the languages reported in Hansson (2001/2010) confirms that in dominant harmony the target of assimilation is always the marked value. The following generalization states that if there is harmony in a dominant harmony, the outcome of the harmony is the marked feature value, given that no other process affects the harmonizing segments (e.g., neutralization).

(110) **Generalization** (Harmony to the Marked)

Given a sequence ψ of consonant segments $<s_1, s_2, \ldots s_n>$ in the input with different specifications −φ, +φ of a feature, if a sequence Ψ of corresponding segments in the output $<S_1, S_2, \ldots S_n>$ harmonizes in a *dominant harmony* grammar $\mathcal{G}$, then the segments in Ψ will have a *marked* feature specification +φ, and not the *unmarked* −ϕ, unless $S \in \Psi$ cannot be +φ in $\mathcal{G}$.

For example, if a set of consonants harmonizes for nasality, dominant harmony is always obtained by changing [−nasal] segment to [+nasal], but never the opposite ([+nasal] → [−nasal]).

Phonotactic restriction may give the impression of a violation of the generalization. For example, in Tiene, in $C_1VC_2VC_3$ stems, C2 and C3 are required to agree in nasality via dominant harmony (111a, b). However, when the coronal continuant segment /s/ is the affix segment, the target if agreement is [−nasal] (111c).

(111) Nasalization and denasalization in Tiene

a. Nasalization in infixed applicative /-lV-/

bak-a ‘reach’, ba-la-k-a ‘reach for’

jɔb-ɔ ‘bathe’, jɔ-lɔ-b-ɔ ‘bathe for’

duma ‘run fast’, du-ne-m-e ‘run fast for’

b. Nasalization in stative /-Vk-/

jaat-a ‘split’, jat-ak-a ‘be split’

sɔn-ɔ ‘write’, sɔn-ɔɳ-ɔ ‘be written’

c. Denasalization with infixed causative /-sV-/

lab-a ‘walk’, la=sa=b-a ‘cause to walk’

kuk-a ‘be sufficient’, ku=si=k-e ‘make sufficient’

tóm-a ‘send’, tó-se=b=e ‘‘cause to send’

dím-a ‘get extinguished’, dí-se=b=e ‘extinguish’

The correspondence pair [$n_x \ldots s_x$] can agree in nasality by either nasalizing the /s/, or to the coronal nasal, (violating IDENT-IO(+sibilant) or *NASFRIC), or by denasalization (thus violating IDENT-IO(+nasal)). The generalization is then compatible with this analysis, since there is no need in any IDENT-IO constraint to refer to an unmarked value of a feature (e.g., IDENT-IO(−nasal)).

There is another apparent violation of the markedness generalization. In Bukusu, the applicative /-il/ assimilate to a rhotic in the stem (110). However, in Sundanese, the opposite relation holds between rhotics and laterals: the plural /-ar/ assimilates to a lateral in the stem (111). Unlike the other cases discussed in 1.3 where the asymmetry was due to the markedness hierarchy between two values of the same feature (e.g., [+nasal] vs. [−nasal]), the symmetry in these examples is due to the fact that both [+lateral] and [+rhotic] are marked for coronals (as opposed to [−lateral] and [−rhotic]). In section 1.3 it was shown that the marked value for the coronals /s/ can either be dental /s̪/ or palatal /ʃ/ (or even retroflex). Since both are marked in sibilant ([+distributed], [−anterior]), either can be the trigger in dominant harmony.

(112) rhotic > lateral harmony in Bukusu.

a. /il/ is faithful

xam-il-a ‘milk for’

but-il-a ‘pick/gather for’

teːx-el-a ‘cook for’

b. /il/ → [ir] if preceded by a [+rhotic]

/bir-il-a/ → [bir-ir-a] ‘pass for’

/ir-il-a/ → [ir-ir-a] ‘die for’

/kar-il-a/ → [kar-ir-a] ‘twist’

(113) lateral > rhotic harmony in Sundanese

a. infix /il/ is faithful

litik l-al-itik 'little (plural)'

ləga l-al-əga 'wide (plural)'

b. /il/ → [ir] if preceded by a [+rhotic]

kusut k-ar-usut 'messy (plural)'

poho p-ar-oho 'forget (plural)'

riwat r-ar-iwat 'startled (plural)'

6.2.1.2 Alignment

The second generalization states that in directional harmonies, the trigger of the assimilation is always right-aligned, never left-aligned. As in the case of markedness, mixed types and other independent processes may make the alignment imperfect. The interaction with other factors is accounted for as an effect of the violability of OT constraints, as show in the typology. A descriptive generalization is given below.

(114) **Generalization** (Harmony to the Right).

Given a sequence ψ of consonant segments $<s_1, s_2, \ldots s_n>$ in the input with different specifications φ, φ' of a feature, if a sequence Ψ of corresponding segments in the output $<S_1, S_2, \ldots S_n>$ harmonizes in a *direction harmony* grammar $\mathcal{G}$, then the segments in Ψ will have the feature specification φ' of the rightmost segment $s_n \in \psi$, and never the value ϕ, unless $S \in \Psi$ cannot be φ', or an independent process changes $\varphi' \rightarrow \varphi$.

The classic example of directional harmony in Chumash was discussed in chapter 3. In Chumash, it is always the rightmost sibilant that determines the target of harmony, regardless of markedness and morphological constituency. Chumash thus constitutes an example of *pure directional* harmony. The generalization states that languages like Chumash, where it is the leftmost sibilant that determines the outcome of the harmony, do not exist.

Hansson (2001/2010) has a long discussion about this asymmetry. He accounts for it in terms of functional bias for anticipatory coarticulation effects in consonant production. Analytically, the typological gaps are either caused by the absence of constraints like ALIGN(φ-head, L) or simply that the patterns never arise for functional reasons.

Notice that the former option has no relation with Hypothesis II, since ALIGN(φ-head) constraints are not φ-Correspondence constraints. Either choice is thus quite inconsequential for the goal of this dissertation.

6.2.1.3 Privileged Position

The fact that root control harmony is always inside-out is a generalization that can be derived from related work on harmony (Baković 1999), and more general work on positional faithfulness (Prince & Smolensky 1993/2004; Beckman 1998, among others).

(115) **Generalization** (Harmony from the Privileged).

> Given a sequence ψ of consonant segments $<s_1, s_2, \ldots s_n>$ in the input with different specifications φ, φ' of a feature, if a sequence Ψ of corresponding segments in the output $<S_1, S_2, \ldots S_n>$ harmonizes in a *root-controlled harmony* grammar $\mathcal{G}$, then the segments in Ψ will have the feature specification φ′ of the segment(s) in a privileged position, and never the value ϕ, unless S ∈ ψ cannot be φ′ in $\mathcal{G}$.

One characteristic of root control harmony is that it cannot be a pure type, unlike dominant and directional harmonies. For example, Navajo is described as *root control* harmony in Hansson (2001/2010).

Harmony can be obtained via assimilation of the marked /ʃ/ and the unmarked value /s/ of the sibilant. The value is determined by the feature value in the root.

(116) Root-controlled sibilant harmony in Navajo (data from McDonough 1991)

> /j-iʃ-mas/ → [j-is-mas] ‘I am rolling along’
>
> /ʃ-is-na/ → [s-is-na] ‘he carried me’
>
> /si-d͡ʒeːʔ/ → [ʃi-d͡ʒeːʔ] ‘they lie (slender stiff objects)’

Root control directionality tells you that the outcome of the assimilation is determined by a segment in the root. However, any root control harmony still has to resolve the conflict that arises when two targets appear in the root.

Consider for example the disharmonic input /s+aʃaso/, where the first sibilant is in an affix. Assuming there is no harmony among sibilants in the root, the grammar needs to decide which of the two sibilants determines the outcome of the harmony in the affix. Even if the harmony is only within root, as in /ʃaso/, the grammar still has to decide which of the two sibilants acts as the trigger.

Given the generalizations on directionality so far discussed, if the [−ant] sibilant is picked, the harmony is also directional, if the [+ant] /s/ segment acts as trigger it is a directional harmony. Either way, the grammar must determine a trigger, and morphological affiliation alone cannot decide. Both sibilants are in the root, and therefore the harmony type must at least be dominant-root control or directional-root control. Cases where only one consonant appears in the root are undetermined, not pure root control.

The asymmetry is obviously an effect of the privileged status of root segments as opposed to segments in affixes. Evidence is conspicuous across different phonological patterns, and in OT is analyzed as an effect of the well-justified constraint IDENT-IO(root). The data from consonant harmony supports the theory.

6.2.1.4 Mixed types

Each harmony type is associated with a generalization. Thus, for example, the markedness generalization is always valid in dominant harmony, even in mixed-type languages. A dominant-root control does not show agreement to the unmarked if not for phonotactic reasons. The agreement to the marked is limited to affixes or segments to the left of the dominant feature.

For example, recall that in Yaka, the perfective suffix /-idi/ is realized as [-ini] when preceded by a nasal in the root. If the nasal is in the affix, the obstruents in the root do not harmonize.

Yaka is a dominant-root control language, so two generalizations hold: it is always a segment in the affix that is changed, and the target of assimilation is always [+nasal], never [−nasal] (i.e., nasalization rather than denasalization).

Notice that both conditions must be true. A nasal in the affix does not trigger harmony because of the generalization on root control, and [−nasal] segment in the root does not denasalize nasal affixes because of the generalizations on dominant harmony.

The table below shows the effect of the generalization on each of the different harmony types obtained by combining the three macro-types.

(117) Combinations of harmony types

Harmony type	**Outcome determined**
pure dominant	the marked feature value
dominant-directional	marked *and* rightmost segment
dominant-root control	marked segment in the root
pure directional	rightmost segment
directional-root control	rightmost segment in the root
pure root control	segment in the root
restricted	marked rightmost segment in the root

6.2.2 Markedness generalization

In this section, I show that the typology of consonant harmony not only provides evidence for the preservation of the marked, but that it also crucially distinguishes between the two most important theories of faithfulness ranking restriction: To capture the markendness generalization, preservation of the marked must be implemented as a fixed ranking condition on faithfulness constraint, as opposed to a stringency formulation of the constraints.

I start with a working definition of markedness and illustrate the result of the empirical investigation (6.2.2.1). I then define the set of mappings and languages that the typology must include to adhere to the MG (6.2.2.4) and subsequently define a unique candidate set that allows us to compare the theories of markedness to test (6.2.2.6).

In section 6.2.2.7, I define the two constraint sets for the stringency typologies and for the fixed ranking typologies. Section 6.2.2.8 and 6.2.3.1 show that only the fixed ranking restriction can account for the MG. Finally, section 6.2.3.1 provides more evidence for the fixed ranking hypothesis by showing that stringency also yields majority rule effects, while fixed ranking does not.

6.2.2.1 Markedness

I start with by introducing an operational definition of markedness. The definition below is limited to a specific type of markedness effects, and the only purpose is to provide a simple definition of markedness for the sake of exposition. For a similar definition of markedness also see Prince's (2000:3).

Definition (markedness). Given two features φ and ∫ in a context C, +φ $\rangle_m$ φ (φ *more marked* than +φ) if /+φ/ → [φ] but not /φ/ → /+φ/ in C. (operational definition)

The definition only refers to markedness in targets. For example, in Sri Lankan Portuguese Creole, marked place of articulation (labials and dorsals) undergo assimilation, while the unmarked coronals do not. Markedness is also typically argued to determine the form of epenthetic segments (de Lacy 2002/2006), so the definition does not apply to these cases.

Markedness scales depend on the prosodic position. For example, [+nasal] is more marked than [−nasal] in onset position, but less marked in coda. In the proposal I will only consider assimilation of segments in onset position, since they constitute almost all cases.[54] Table 2 summarizes the findings. In the first group of columns the total number of language surveyed for each type of harmony is indicated. The second group includes all the languages that show a dominant harmony pattern (not necessarily *pure dominant*).

Two kinds of languages were not included: (i) purely root-controlled and purely directional languages where assimilation is entirely dependent on the morphological affiliation or the position in the string of the target segments (and therefore both values are found); (ii) languages where it is impossible to determine the input–output mapping because there is no asymmetry in the co-occurrence restrictions.

(118) Asymmetries in dominant harmony

Type	Total Number	Map	Languages
laryngeal	16	[−voice] → [+voice] d…t → d…d	Ngizim, Kera, Malto
nasal	23	[−nasal] → [+nasal] n…l → n…n	Kikongo, Lamba, Bemba, Yaka…
dorsal	8	[−high] → [+high] q…k → q…q	Tlachichilco Tepehua, Misantla Totonac, …
coronal	42	[+ant] → [−ant] [–dist] → [+dist]	Aari, Flemish, Gimira…

[54] A case of onset–coda assimilation is found in Malto.

6.2.2.2 Agnostic directionality

I now discuss the theoretical implication of the MG for the theories of markedness. I start by distinguishing two types of theories of directionality of agreement: those where the outcome of the harmony is determined by agreement constraints (*intrinsic directionality*) and those where the outcome of the harmony is entirely determined by faithfulness constraints (*agnostic directionality*).

φ-Correspondence is an example of a theory *agnostic* to directionality. RELATE-φ, IDENT-φ, and ALIGN(φ-head) constraints do not determine what the outcome of the harmony is. Take for example the candidates in the tableau below.

(119) Harmonic outputs never violate φ-Correspondence constraints

Input	Output	RELATE (+sib)	IDENT-[sib](ant)	ALIGN(+sib-head, R)
ʃ…s	s_x…$(s)_x$			
	$ʃ_x$…$(ʃ)_x$			

The input contains two disharmonic sibilants, while the two outputs are harmonic. In the first candidate, the sibilants agree for the feature [+ant], in the second for the feature [−ant]. The candidates have identical violation profiles. If we only consider φ-Correspondence constraints, the outcome of the harmony is undefined.

Directionality is governed by standard IDENT-IO constraints such as IDENT-IO(φ) (e.g., IDENT-IO(−ant)), IDENT-IO(φ-head), and IDENT-IO(root). In ABC, Bennett (2013/2015) is an example of a theory where agreement constraints are also agnostic to directionality.

For example, Bennett (2013/2015) has the following definition of CC·IDENT.

(120) **CC·IDENT-[F]** definition.

For each distinct pair of consonants X & Y, assign a violation if:

a. X & Y are in the same surface correspondence class, *and*

b. X is [αF], *and*

c. Y is [βF]

… where F is some feature, [αF] & [βF] are its possible values and α != β.

Again, in previous tableaux, (see 2.3.1.1 for a definition of CORR), the two candidates are not distinguished (as also discussed in Bennett 2013/2015).

(121) CORR and CC·IDENT are agnostic to directionality in Bennett (2013/2015).

Input	Output	CORR(+sib)	CC·Ident(ant)
ʃ…s	s_x…s_x		
	$ʃ_x$…$ʃ_x$		

There are other theories which are agnostic to directionality. For example, directionality in Span Theory (McCarthy 2004; O'Keefe 2007) is very similar to directionality in φ-Correspondence. A span is assigned a head, and then the head determines the outcome of the harmony via a positional faithfulness constraint.

Theories of *intrinsic* directionality include autosegmental theories where the directionality of the spreading is encoded in the rules/constraints that define the agreement target (e.g., Clements 1976, Goldsmith 1990, Jurgec 2011). With the most notable exception being Bennett (2013/2015), most formulations of ABC are also of this type (e.g., Rose & Walker 2004, Hansson 2001/2010). For a discussion on intrinsic directionality in ABC, see section 3.4.1.

6.2.2.3 Markedness theory

Markedness generalization states that the trigger in dominant harmony is always the marked segment. In φ-Correspondence, the trigger feature value is the node that is faithfully preserved. By combining the generalization with the definition of trigger in φ-Correspondence, you get the result that in dominant harmonies*, the marked feature value is faithful*. This effect falls under the definition of one of the most important generalizations in the theories of markedness, known as the Preservation of the Marked (de Lacy, 2002/2006). The effect is observed across phonological domains such as neutralization, local assimilation, and epenthesis, among others.

PoM is a generalization on candidate forms: it does not necessarily say anything about how the generalization is implemented in a theory. De Lacy (2002/2006) shows that PoM in OT is best implemented as part of a theory of faithfulness constraints. This approach has the advantage of applying across different phonological domains, since faithfulness constraints play a crucial role in all unfaithful mappings.

Thus, optimally the typological effects on the preservation of the marked should arise from the interaction between a general theory of agreement and the general theories of markedness.

6.2.2.4 Typology conditions

A theory that accounts for MG should answer the following question: Given a disharmonic correspondence pair ⟨s, ʃ⟩, where s and ʃ represent two segments in correspondence, with different feature values—ʃ (marked) and s (unmarked)—that are required to harmonize, what set of constraints should be in CON so that the mapping in (122a) is possible, but not the mapping in (122b)?

(122) Possible and impossible mappings

a. /s…ʃ/ → [ʃ…ʃ]

b. /s…ʃ/ → [s…s]

The fact that a theory generates both the mapping to the unmarked and the mapping to the marked is not sufficient to demonstrate that such a theory cannot account for MG.

The unmarked mapping may in fact result from neutralization. Imagine a language where /ʃ/ → [s]. Then, it is obvious that for independent reasons (i.e., neutralization) it would also map /ʃ…s/ → [s…s] in the system above. The following conditions must then hold:

(123) Given a pair of segments ⟨s, ʃ⟩ in correspondence, where s and ʃ have different feature values—s (marked) and ʃ (unmarked)—a set of constraints can account for MG if:

a. that the mapping (i) is possible, *and*

b. the mapping (ii) entails the mapping (iii), i.e., it is due to neutralization.

i. /s…ʃ/ → [ʃ, ʃ]

ii. /s…ʃ/ → [s, s]

iii. /ʃ/ → [s]

In other words, the only way to obtain the mapping /s…ʃ/ → [ʃ, ʃ] should be via a ranking that also neutralizes the marked value /ʃ/ → [s] in any context.

6.2.2.5 Candidate set

To evaluate the conditions under which MG is realized, one only needs to consider the following candidate set.

(124) Candidate set for the typology

a. /s…ʃ/ → [ʃ…ʃ] or [s…s]

b. /ʃ/ → [s] or [ʃ]

c. /s/ → [s] or [ʃ]

The goal of the typologies is to evaluate the outcome of harmony. For this reason, I only include candidates where the two segments interact to yield harmony. The segments considered are only /s/ and /ʃ/.

Because of the condition on neutralization, I also include the mapping of single segments to their faithful and non-faithful output, so both /s/ and /ʃ/ can map to [s] and [ʃ].

Directionality effects are manifested only in disharmonic inputs that harmonize, so the mappings <s, ʃ> → <s, s> and <s, ʃ> → <ʃ, ʃ> are both crucial.

Candidates with the input with the reverse ordering of the sibilants /ʃ…s/ are not included. Dominant harmony is myopic to linear ordering, so all generalizations hold equally regardless of the order of the sibilants.

6.2.2.6 Constraints

In the candidate set, I assumed only candidates with one segment or those with the segments in correspondence and in agreement. In terms of constraints, this equates to saying that RELATE-[+sib] and IDENT-[+sib](ant) are never violated (or undominated).

As stated in the previous section, markedness and harmony operate in a modular fashion, with limited overlap: the theory of harmony determines what segments correspond and what features agree, while the theory of markedness determines the outcome of the harmony.

In φ-Correspondence (and in agnostic directionality theories) this translates into faithfulness constraints (and partially markedness) governing the outcome of the harmony.

For the typology, I thus consider the constraints IDENT-IO(+ant), and IDENT-IO(−ant). IDENT-IO(+ant) is violated only when a [+ant] segment in the input is mapped to [−ant], IDENT-IO(−ant) when a [−ant] segment is mapped to [+ant]. The third and last constraint is *[−ant], which assigns a violation for each segment in the output with the feature [−ant].

Finally, the fixed ranking hypothesis imposes that for any ranking IDENT-IO(−ant) dominates IDENT-IO(+ant). I do not impose any ranking restriction on the markedness constraints since both the stringency and the fixed ranking restriction on markedness constraints make the same prediction with respect to MG.

6.2.2.7 *Fixed ranking*

To check whether the fixed ranking condition predicts MG, I check that in the typology generated by the candidate set and the constraints described in the previous sections all the conditions are met.

There are three conditions, which are reproduced and formalized below:

1. There is a ranking (i.e., a language) where the sibilants harmonize to the marked value, and at the same time the unmarked sibilants do not neutralize to its marked value.

   ∃ rank | /ʃ…s/ → [ʃ…ʃ] and /s/ → [s]

2. There is a ranking where the marked value neutralizes to the unmarked value

   ∃ rank | /ʃ/ → [s]

3. There is no ranking where the sibilants harmonize to the unmarked value, and at the same time the marked sibilants remain faithful.

   ∄ rank | /ʃ…s/ → [s…s] and /ʃ/ → [ʃ]

The conditions are verified against the typology in the tableau below. The first condition says that harmony to the marked should be possible, even in languages when there is no neutralization of the unmarked value. In other words, the typology must contain a language where harmony to the marked is not the result of neutralization. Such ranking exists and is obtained when IDENT-IO(−ant) dominates *[−ant] and IDENT-IO(+ant).

(125) Fixed ranking: harmony to the marked

ERC	Input	Winner	Loser	*[−ant]	ID(−ant)	ID(+ant)
∃ rank | /ʃ…s/ → [ʃ…ʃ] and /s/ → [s]						
a.	ʃ…s	ʃ…ʃ	s…s	L	W	L
c.	s	s	ʃ			L

The second condition, which requires that neutralization to the unmarked also be possible, is attested as well in languages where *[−ant] dominates IDENT-IO(+ant).

(126) Fixed ranking: neutralization to the unmarked

ERC	Input	Winner	Loser	*[−ant]	ID(−ant)	ID(+ant)
∃ *rank* | /ʃ/ → [s]						
c.	ʃ	s	ʃ	W		L

Finally, the last requirement ensures that there is no language in the typology where harmony to the unmarked occurs while the marked value maps faithfully. The stringency restriction correctly predicts this ranking to be impossible.

(127) Fixed ranking: harmony to the unmarked.

ERC	Input	Winner	Loser	*[−ant]	ID(−ant)	ID(+ant)
∄ *rank* | /ʃ…s/ → [s…s] *and* /ʃ/ → [ʃ]						
d.	ʃ…s	s…s	ʃ… ʃ	W	L	(W)
f.	ʃ	ʃ	s	L	W	

The last two ERCs show that harmony to the unmarked not possible in this grammar. The ERC (d) states that either *[−ant] dominates IDENT-IO(−ant) or IDENT-IO(+ant) dominates IDENT-IO(−ant). However, the second condition is ruled out by the fixed ranking relation between the two faithfulness constraints, which leave only the first condition as available.

The ERC (f) contains the contradictory condition. ERC (d) states that *[−ant] must dominate IDENT-IO(−ant), while ERC (f) states that IDENT-IO(−ant) must dominate *[−ant]. Thus, no ranking is possible in the grammar that generates harmony to the unmarked and does not neutralize the marked segment in all other contexts. This is the right prediction, because we do not want a theory to generate such language.

6.2.2.8 Stringency

An alternative to fixed ranking is to assume that faithfulness constraints are stringently defined. This means that there is no restriction on the ranking of faithfulness constraints, but that instead there is no IDENT-IO constraint in CON that only refers to the unmarked value of a feature. A formal definition is given below, adapted from de Lacy (2006:54).

(128) Stringency restriction on CON.

- For a binary feature φ, there are only the constraints *+φ, Ident-IO(+φ), and Ident-IO(±φ), where +φ is the marked value of φ.
- The constraints IDENT-IO(−φ) and *−φ do exist.

IDENT-IO(−ant) and IDENT-IO(+ant) are violated only when the input has a specific feature value. IDENT-IO(±ant) is violated when a segment is mapped unfaithfully for the feature [ant] regardless of its input feature specification. It is sufficient to violate only one ranking condition to prove that stringency cannot account for MG. The condition violated is the one that states that there no language is possible that has harmony to the unmarked and faithful mapping of the marked feature value in isolation.

The tableau below contains the ranking for this language. Its interpretation parallels the one in the previous section. ERC (d) states that to have harmony to the unmarked, either *[−ant] dominates IDENT-IO(−ant) or IDENT-IO(+ant) dominates IDENT-IO(−ant). Since there are no fixed ranking conditions, both options are open.

Likewise, the ERC (f) requires that IDENT-IO(−ant) dominate *[−ant]. This condition now only partially conflicts with the ones in ERC (e), since it only affects one of the disjuncts. The ranking for the grammar with assimilation to the unmarked and no neutralization is thus possible when the stringent faithfulness constraint dominates ID(−ant) and ID(ant) dominates *[−ant]. For those familiar with ERC fusion (Brasoveanu and Prince, 2011), the last row of the tableau shows that the fused ERC contains at least a W.

(129) Stringency and the MG

ERC	Input	Winner	Loser	*[−ant]	ID(−ant)	ID(±ant)
💣 ∄ *rank* | /ʃ…s/ → [s…s] *and* /ʃ/ → [ʃ]						
d.	ʃ…s	s…s	ʃ…s	W	L	W
f.	ʃ	ʃ	s	L	W	
				L	L	W

6.2.2.9 Stringency and fixed ranking

A logical possibility is to make both assumptions about CON, that is, to postulate that there are two faithfulness constraints in a fixed ranking and stringent relation. This gives us two additional sensible ranking restrictions:

1. IDENT-IO(−ant) ⋙ IDENT-IO(±ant)
2. IDENT-IO(±ant) ⋙ IDENT-IO(−ant)

As can be seen from tableau below, the first condition is very similar to the case where there is fixed ranking and no stringency, the only difference being in the ERC (e) in the third condition.

The ERC (e) states that either ID(±ant) or ID(−ant) must dominate *[−ant]. Thus, *[−ant] ≫ ID(−ant) from ERC (d) and ID(±ant) ≫ *[−ant] from ERC (d). The final ranking is therefore ID(±ant) ≫ *[−ant] ≫ ID(−ant).

(130) IDENT-IO(−ant) ⋙ IDENT-IO(±ant)

ER	Input	Winner	Loser	*[−ant]	ID(−ant)	ID(±ant)
∃ *rank* | /ʃ…s/ → [ʃ…ʃ] *and* /s/ → [s]						
a.	ʃ…s	ʃ…ʃ	s…s	L	W	L
b.	S	s	ʃ			L
∃ *rank* | /ʃ/ → [s]						
c.	ʃ	s	ʃ	W		L
💣 ∄ *rank* | /ʃ…s/ → [s…s] *and* /ʃ/ → [ʃ]						
d.	ʃ…s	s…s	ʃ… ʃ	W	L	
e.	ʃ	ʃ	s	L	W	W
				L	L	W

This is the only possible ranking to have harmony to the unmarked. However, as shown in the final ranking, ID(±ant) dominates ID(−ant) by transitivity, which violates the fixed ranking condition. Therefore, the condition IDENT-IO(−ant) ⋙ IDENT-IO(±ant) also correctly predicts that harmony to the unmarked is not possible.

The tableau for the other fixed ranking order IDENT-IO(±ant) ⋙ IDENT-IO(−ant) is identical to the one above (same constraints me entails same violations). Therefore, ranking to get assimilation to the unmarked is also ID(±ant) ≫ *[−ant] ≫ ID(−ant).

However, now the fixed ordering relation is reversed. IDENT-IO(±ant) must dominate IDENT-IO(−ant), which is compatible with the ranking that yields harmony to the unmarked. To sum up, either one of these two following restrictions accounts for the markedness generalization.

1. IDENT-IO(−ant) ⋙ IDENT-IO(±ant)
2. IDENT-IO(−ant) ⋙ IDENT-IO(+ant)

Theorem IV (faithfulness in MG).

> A theory is compatible with the MG if a faithfulness constraint referring to the marked value of a feature always dominates the other faithfulness constraint that refers to the unmarked value of the same feature.

The theorem only refers to the MG. A stronger formulation would involve generally defining the faithfulness restriction over all domains as follows.

Hypothesis III (faithfulness ranking condition).

> Faithfulness constraints referring to the marked value of a feature always dominate the other faithfulness constraint that refers to the unmarked value of the same feature.

6.2.3 Open issues

A potential problem is cases where the unmarked value survives in coalescence. De Lacy (2002/2006) claims that Pali is such a case. To (overly) simplify, in the markedness hierarchy for places of articulation, dorsal is the most marked, followed by labials and coronals. However, in Pali, coronals are preserved as faithful over labials. Since the output of coalescence is determined by the relative ranking of faithfulness constraints, the hypothesis incorrectly predicts that such a pattern is impossible.

There are two considerations to be made. In the analysis of the typology of coalescence, de Haas (1988) claims that in coalescence the output is always the marked value. Pali might thus be an exception for which an alternative analysis is possible.

The other issue concerns markedness in place of articulations. The phenomenon in Pali concerns major places of articulation. However, there is only one potential case of harmony to major place of articulation in Ngbaka (Danis 2017),[55] and it respects the expected markedness hierarchy. The hypothesis may thus just be valid for features other than major places of articulation.

[55] Rose and Walker (2004) and Hansson (2001/2010) both observed the lack of empirical evidence for such cases.

Whether the restriction on faithfulness constraint ordering is a valid generalization in all phonology is beyond the scope of this dissertation. The MG, though, is an important new generalization both for theories of harmony and for theories of markedness.

Another potential problem with the generalization is the observation in Baković (2000) that in vowel harmony the reverse effect is observed. In dominant harmonies, the unmarked value acts as the dominant feature value, and the marked value as the regressive one. This generalization is not only contrary to the MG, but more generally to the PoM. However, it must be noted that Baković (2000) refer to the feature ATR, for which the markedness relation is not as clear as for other features.

Directionality in dominant vowel harmonies is also often complicated by the effect of other apparently unrelated factors, such as the phonotactic of the language. For example, Casali (2003) observes that [+ATR] is normally dominant in languages with an [ATR] contrast among high vowels, while [−ATR] is dominant in languages without the contrast.

6.2.3.1 Majority rule

Another pair of mappings that should not be generated by any grammar assigns the outcome of the harmony based on which feature is most numerous in the input. For example, a language may map /ʃ…ʃ…s/ → [ʃ…ʃ…ʃ] because the majority of the sibilants in the input are [−ant], but /ʃ…s…s/ → [s…s…s] since the majority of sibilants are [+ant].

Such mapping is known as majority rule (Lombardi 1999, among others) and as in the case of local assimilation it is never observed in long distance harmony patterns. This adds a fourth condition to the typology.

4. There is no ranking where the outcome of the harmony is determined by the majority rule.

∄ rank | /ʃ…ʃ…s/ → [ʃ…ʃ…ʃ] and /ʃ…s…s/ → [s…s…s]

It has been well known since Lombardi (1990) that the majority rule effect emerges when a general faithfulness constraint such Id(±ant) dominates the specific ones such as ID(−ant), but also ID-IO(onset) or ID-IO(φ-head).

To give an example, the tableau below shows that only when ID(±ant) is ranked above any of the other two faithfulness constraints the majority rule mappings win.

ERC	Input	Winner	Loser	ID(±ant)	ID(−ant)	ID(+ant)
💣 ∄ *rank* | /ʃ…ʃ…s/ → [ʃ…ʃ…ʃ] *and* /ʃ…s…s/ → [s…s…s]						
a.	ʃ...s...s	s...s...s	ʃ...s...s	W	L	W
b.	ʃ...ʃ...s	ʃ...ʃ...ʃ	ʃ...ʃ...s	W	W	L

Stringency without fixed ranking, or the fixed ranking IDENT-IO(±ant) ⋙ IDENT-IO(−ant), thus also incorrectly predicts majority rule patterns.

This condition is already entailed by the more specific one that accounts for the MG. In other words, the theorem (see the previous section) already excludes majority rule patterns and does not need to be amended.

Theorem V (MG and majority effect).

> A theory is compatible with the markedness generalization and does not predict *majority rule effects* if a faithfulness constraint referring to the marked value of a feature always dominates the other faithfulness constraint that refers to the unmarked value of the same feature.

Finally, this section also shows that the existence of majority rule effect is external to φ-Correspondence itself. The concerns expressed on (certain formulations of) ABC in McMullin and Hansson (2015) thus do not apply to φ-Correspondence or to similar agnostic theories of directionality.

6.3 Chapter summary

In this chapter, I describe the basic typology of φ-Correspondence. I show that the theory predicts the existence of several directionality patterns, which arise from the combination of the basic directionality types: dominant, directional, and root control.

I also provide empirical support for the various types of harmony and for the fact that the mixed types directional-root control and pure root control are neither generated nor attested.

I then describe the three generalizations that operate on the directionality types previously introduced. For dominant harmony, the trigger is always the marked value; for directional harmony, the trigger is always aligned to the right edge of a prosodic word or of the root; for root control harmony the trigger is in the root. The three generalizations are schematized below.

(131) *Properties of consonant harmony*

dominant		directional		root-controlled	
marked	~~unmarked~~	R	~~L~~	inside-out	~~outside-in~~
$/\alpha\ldots\beta/ \rightarrow *[\alpha\ldots\alpha], [\beta\ldots\beta]$		$/\alpha\ldots\beta/ \rightarrow [\beta\ldots\beta], *[\alpha\ldots\alpha]$		$/\alpha\ldots\beta/ \rightarrow [\beta\ldots\langle\beta\rangle_{m}], [\alpha\ldots\langle\alpha\rangle_{m}]$	
Target β is marked.		Target β is on the right.		Target β is in a privileged p.	

I also show that the generalizations extend and hold conjointly in mixed types. For example, in a dominant-directional harmony the trigger is both marked and right-aligned to an edge.

The generalization on root control effect is analyzed as an effect of positional faithfulness constraints (or more generally it is due to the status of the root as a privileged position). The generalization on alignment is less straightforward and may be due to a functional bias. Analytically, it can easily be mimicked by omitting the constraint ALIGN(φ-head, L).

The generalization on dominance is the most interesting one, because it is incompatible with the theory of markedness, where the faithfulness constraints are in a stringent relation.

Finally, I argue that φ-Correspondence is an agnostic theory of directionality and that the markedness generalization ought therefore to be captured by the theory of markedness. In this respect, I provide a general formulation of the theory of faithfulness that accounts for both the MG and avoid majority rule effect. The generalization crucially concerns fixed ranking as opposed to stringency.

7 Conclusions

7.1 Open issues

Before concluding, in this section I discuss three issues that were not investigated in the dissertation because they were not central to the goal of the thesis. I briefly investigate the consequences of the assumption that φ-Correspondence acts on feature nodes (7.1.1) and on tones (7.1.2) and then conclude with some phenomena that arise from the interaction of the constraints UNIQUE and CONTIGUOUS (7.1.2).

7.1.1 Root–node correspondence

In the dissertation, I defined the domain and codomain of φ-Correspondence as consisting of output feature nodes. However, a more general definition of the domain of φ-Correspondence could include all output-interpretable features, and therefore root nodes as well.[56]

When applied to root nodes, the effects of φ-Correspondence become very close to theories of strictly local spreading (Ní Chiosáin & Padgett 1993, Gafos 1996, Flemming 1995, among others). The empirical domain of these patterns includes all languages where a feature spreads across a string of consecutive segments (see Walker 2008 for an extensive review).

To give an example, in the Applecross dialect of Irish Gaelic (Ternes 1973, cited in Walker 2008:35), nasality spreads from a stressed nasal vowel until it reaches a voiceless

[56] This assumption would also require a redefinition of the axiom of Maximal Distance (or the assumption that all input root nodes are heads), since head root nodes would differ of two properties with respect to input root node.

obstruent and then stops. The description of the phenomenon is simplified, but it expresses a pattern that is quite common.

(132) Scottish Gaelic nasal spreading

a. /mãhar/ → [mãh̃ãr̃] ‘mother’

b. /tʲiãnu/ → [tʲiãnũ] ‘to do, to make’

c. /ʃɛ̃nɛvar/ → [ʃɛ̃nɛ̃ṽãr̃] ‘grandmother’

d. /tʰãhusk/ → [tʰãh̃ũsk] ‘senseless person, fool’

e. /kʰɔ̃ispaxk/ → [kʰɔ̃ĩspaxk] ‘wasp’

φ-Correspondence captures this kind of assimilation without further assumptions when the domain of correspondence is the set of root nodes. Let me start with the example without blocking. In the mapping /mãhar/ → [mãh̃ãr̃] ‘mother’, nasality spreads from the first nasal to all other segments in the word. The basic constraints we need are RELATE-R, IDENT-[⊙](nasal), CONTIGUOUS-⊙, IDENT-IO(+nasal), and IDENT-IO(−nasal), defined the usual schemas in chapter 2.

The tableau below shows how the spreading candidates win: RELATE-⊙ demands all segments (root nodes) to be in correspondence, IDENT demands that they agree for nasality, and finally, ID-[⊙](nasal) determines that nasality spreads.

(133) Nasal spread in root correspondence

/mãhar/	ID-[⊙](nas)	CONTIG-R	RELATE-R	ID-IO[nas]
a. ☞				***
b. $m_x(\tilde{a})_x h_x a_x r_x$	***			
c. mãhar			****	

Adding a markedness constraint against voiceless nasal obstruents (*[t̃]) yields the blocking mapping. The crucial candidates are illustrated in the tableau below. RELATE-⊙ favors candidates with all segments in correspondence. One of the segments, though, cannot nasalize without fatally violating *[t̃].

(134) Blocking in root correspondence

/kʰɔ̃ispaxk/	ID-[⊙](nas)	*[t̃]	CONTIG-⊙	RELATE-⊙	ID-IO-nas]	Comments
a. ☞ kʰ(ɔ̃)$_x$ĩ$_x$spaxk				6	1	spreading
b. kʰɔ̃ispaxk[57]				7		no
c. k̃ʰ$_x$		3			7	spreading
d. kʰ(ɔ̃) $_x$ĩ$_x$spã$_x$xk			1		3	obstruents

There are two candidates that harmonize and do not violate the phonotactic constraints, the one where the obstruent is transparent and nasalization simply skips it (d), and the candidate where the obstruent blocks the spreading of the feature (a). The winner in Gaelic is the latter, since it does not violate CONTIGUOUS-⊙.

This simplified analysis shows that the basic mechanism of φ-Correspondence can account for basic cases of local spreading by extending the correspondence relation to root nodes. Further work is necessary to verify whether this approach is viable as a general theory of the phenomenon.

[57] Notice that the sour grape candidate (Padgett 1995) is harmonically bounded.

7.1.2 Contiguous, unique, and proximity

In the dissertation, I mainly focused on the two core constraints that drive assimilation: RELATE and IDENT. However, in chapter 2 I also briefly discussed two additional constraints of correspondence UNIQUE and CONTIGUOUS, which are defined here:

CONTIGUOUS-XY definition.

For each *x* and *y* elements members of the relation $\mathcal{R}_{X\text{-}Y}$, if *x* precedes *y*, assign a violation for each element *w* in *Y* that follows *x* but precedes *y.*

UNIQUE-X definition.

Given the correspondence relation $\mathcal{R}_{X\text{-}Y}$, assign a violation for each element *x* in *X* that corresponds to an element *y* in *Y* if there is another element *z* in *Y* that also corresponds to *x*.

As mentioned in section 7.1.1, CONTIGUOUS constraints play a crucial role in blocking. Consider the following case of blocking in consonant harmony in Kinyarwanda. In this language, root-final palatal sibilants [s, z] triggers regressive harmony to the preceding sibilant. Note that the perfective suffix [-i, -e] and the agentive [-i] cause the sibilant to become retroflex in the first place (Walker & Mpiranya 2006).

(135) Coronal harmony in Kinyarwanda

-saaz + i-e → [s̺aaz̺e] 'become old + perfective'

-uzuz + i-e → [uz̺uz̺e] 'fill + perfective'

-sakuz + i-e → [s̺akuz̺e] 'shout + perfective'

Crucially, harmony is blocked by intervening coronals.

(136) Harmony blocking with coronals

siitaaz + i-e → [siitaaẓe], *[ʂiitaẓe] 'make stub + perfective'

saandaaz- + i-e → [saandaẓe], *[ʂaandaẓe] 'become warm (liquid) + perfective'

sodook + iẓe → [sodookeẓe], *[ʂodookeẓe] 'make move slowly + perfective'

The basic analysis is straightforward, and it is the same as in the case of unbounded harmony illustrated in the previous section. The blocking segment cannot assimilate, so the potential target is separated by one feature node from the head, thus violating CONTIGUOUS-[cor].

In the tableau below, candidate (b) violates IDENT-[cor][rtfl] because the coronal [t] does not assimilate in [+rtfl] with the head, while candidate (c) has the skipped feature node.

(137) Blocking in Kinyarwanda

/s…t…ʐ/	ID-[sib](rtfl)	CONTIG-[cor]	ID-IO[−rtfl]	RELATE-[cor]
a. ☞ [s…t…ʐ]				**
b. [ʂ1…t1…(ʐ)1]	*			
c. [ʂ1…t…(ʐ)1]		*	*	

A diagrammatic representation of candidate (c) is given below. The head is in correspondence with the first coronal [ʂ]. However, to do so it has to skip over [t], which also has a coronal feature node, thus fatally violating CONTIGUOUS-[cor].

Relevant phenomena that involve the constraints Contiguous and Unique concern languages where harmony extends to one target (non-iterative harmony).[58] In Lango (Nilotic, Uganda), [+ATR] spreads from the suffix vowel to the last vowel of the root.

(138) ATR harmony in Lango (Woock & Noonan 1979, cited in Kaplan 2008)

a. /bɔŋɔ+ni/ → [bɔŋo+ni] 'your dress'

b. /cɔŋɔ+ni/ → [cɔŋo+ni] 'your beer'

c. /amʊk+ni/ → [amuk+ni] 'your shoe'

d. /mɔtɔka+e/ → [mɔtok+æ] 'cars'

Cases of non-iterative harmony can be captured by ranking both Unique and Contiguous above the relevant Relate constraint. As the tableau below exemplifies, Unique prevents correspondence from relating more than two elements (c), while Contiguous ensures that the target is the one adjacent to the head[59] (d).

(139) Non-iterative harmony in Lango

/bɔŋɔ+ni/	Id-[+voc](ATR)	Unique-[+voc]	Contig-[+voc]	Relate-[+voc]	Id-IO[ATR]	Comments
a. ☞ bɔŋo$_x$n(i)$_x$				*	*	one head, one dependent
b. bɔŋɔni				!**		faithful
c. bo$_x$ŋo$_x$n(i)$_x$		!*			**	unbounded spreading
d. boŋɔni			!*	*	*	non-contiguous spreading

[58] See Kaplan (2008) for a critical analysis of non-iterative processes.
[59] Harmony is also limited to the syllable adjacent to the suffix. To restrict the harmony to this condition, a Proximity constraint is required (e.g., Rose & Walker 2004).

In this section, I only show some phenomena that UNIQUE and CONTIGUOUS can account for. I leave the investigation of the full range of predictions and a more detailed analysis of the examples discussed for future work.

7.1.3 Tones

As mentioned in chapter 1, a natural expansion of the theory is in the domain of the tonology. McCarthy and Prince (1995:18) already suggest an extension of Correspondence Theory in the following passage:

> Then MAX-ET requires that every tone-bearing element have a correspondent tone, and DEP-ET requires that every tone have a correspondent tone-bearing element. These are equivalent to two clauses in Goldsmith's (1976) "Well-Formedness Condition" for autosegmental phonology: every tone-bearing element is associated with some tone; and every tone is associated with some tone-bearing element. The other constraints on correspondence laid out in Appendix A, such as LINEARITY, CONTIGUITY, and ANCHORING, also have clear analogues in principles of auto-segmental association, such as the line-crossing prohibition, the requirement of directional one-to-one linking and the Initial Tone Association Rule (Clements & Ford 1979).

In terms of Hypothesis I, the relation respects all the three axioms of correspondence. It is heterogeneous (between a TBU and a tone), the elements in correspondence differ with respect to one property (output TBUs vs. output tone elements), and the relation has symmetric closure (tone corresponds to TBUs and TBUs correspond to tone, as demonstrated by the constraints below).

Many well-known tonal constraints parallel the φ-Correspondence constraint definitions. RELATE-T demands that all tones be related to a TBU, and it is therefore violated by floating tones. The idea of floating tones and their tendency to get related to a TBU has been fundamental in autosegmental phonology since its inception, and it was first formalized as the OT constraint *FLOAT in Myers (1997).

The other RELATE constraint is RELATE- TBU, which has the same definition of RELATE-T but with the mapping going from TBUs to tones (see symmetric closure above). The constraint demands that each TBU be in correspondence with at least a tone. As in the case of RELATE-T, this is a well-known constraint in tonology under the name of SPEC-T (Yip 2002).

The constraints UNIQUE-T and UNIQUE-TBU penalize contour tones and tone spreading, respectively. As in the case of RELATE, these phenomena are natural and widespread in tonology, and so are the constraints that refer to them (Yip 2002).

The CONTIGUOUS constraints penalize skipping in tone spreading, while as pointed out in McCarthy and Prince (1995:18), LINEARITY is a violable version of the no-crossing constraint in autosegmental theory, and it has been postulated in the tonal literature by Zoll (2013).

There is only one constraint class that does not seem to have any effect or correspondent in the tonal literature, namely IDENT-XY. Recall that Hypothesis II demands that all constraints be instantiated for a specific relation, but it does not require that those constraints have an effect. I have shown an example of UNIQUE constraints that refer to heads. It is possible to postulate such a constraint, but it would have no effect in the grammar because a dependent can never correspond to two heads. In other words, while some constraint definitions can be formulated, it is not the case that within the theory they always have an effect. IDENT-TBUT is such a constraint. Following the schema in section 2.3.1, the constraint is defined as follows:

IDENT-TBUT definition.

For each TBU *x* assign a violation if:

a. *x* dominates an element *φ*, *and*

b. any of its *x′* correspondents (tone) do not dominate an element *φ′*,

… where *φ* and *φ′* have the same interpretable property.

The problem with this constraint is that while TBUs directly dominate some features (e.g., a syllable dominates a root node, which in turn dominates some feature nodes via transitivity of dominance), tones are not in a dominance relation with either the root or feature nodes (they are connected by correspondence). Therefore, the constraint is always vacuously satisfied and has no effect on the typology.

In this section, I only briefly touched on the possibility and plausibility of extending Corresponding Theory to tonology. Nevertheless, I show that there is a transparent relation between correspondence constraints and well-attested constraints in autosegmental tonology. The current formalism and resources should also make it easy to compile a typology of basic tonal constraint interaction and to conduct a valuable, rigorous comparison between tonal correspondence, autosegmental theory, and other forms of correspondence (such as B/R or φ-Correspondence).

7.2 Conclusion

The goal of the dissertation was to demonstrate that φ-Correspondence is empirically and theoretically desirable. The first step consisted in applying the tools of logic and model theory to provide a rigorous definition of correspondence and of correspondence constraints to show that the same definitions apply to both Correspondence Theory and φ-Correspondence. These definitions constitute the basis of φ-Correspondence and allowed me to test the following two main hypotheses of the dissertation:

Hypothesis I (correspondence relation).

> I/O Correspondence, O/I Correspondence, and all φ-Correspondence relations are different *types* of the same *kind* of correspondence relation.

Hypothesis II (constraints).

> For each relation type I/O Correspondence, O/I Correspondence, and all φ-Correspondence there is a proper set of constraints that adhere to the same set of correspondence constraint schemas.

Concerning Hypothesis I, I identified three axioms of correspondence—heterogeneity, symmetric closure, and minimal distance—and showed that they hold for both the I/O-Correspondence and φ-Correspondence relation.

For the constraints, I introduced the four schemas RELATE-X, UNIQUE-X, CONTIGUOUS-X, and IDENT-XY and demonstrated that a definition of the each of the constraints exists for both I/O and φ-Correspondence relation. The focus was on RELATE-

X and IDENT-XY, but I presented some examples of patterns where the other constraints distinguish crucial candidates.

I postulated that a fundamental component of φ-Correspondence is the φ-head. Without heads, φ-Correspondence cannot be defined as a correspondence relation and the constraints cannot be formulated using the correspondence constraint schemas.

The theory highlights a new parallel between segmental (harmony) and prosodic phenomena. It shows that φ-heads obey the same fundamental axioms of other linguistic heads and tend to be right aligned and positionally faithful like other prosodic heads.

Headedness also plays a crucial role in the directionality of harmony. I argued that head–dependent agreement relations are currently the best configuration to express well-known asymmetries in agreement patterns.

Directional harmonies, such as in Chumash, are elegantly captured by assuming that the trigger of the harmony is marked with a head status (see chapter 3). By doing so, no special directionality constraints need be postulated, and the parallel between prosodic and feature heads is established.

φ-heads also allow us to naturally capture the counterfeeding opacity effects observed in the typology of harmony (see chapter 5). In fact, the patterns are naturally predicted by the theory as the result of the interaction of the independently motivated positional faithfulness constraint on φ-heads and basic markedness constraints.

The other crucial notion of φ-Correspondence is feature correspondence. This assumption is crucial in providing a unified definition of the correspondence constraints and allows us to formulate constraints on head-alignment using standard Generalized Alignment constraints.

Empirically, I showed that feature correspondence solves the problems of overlapping harmonies (and Agreement by Proxy), where harmony between to elements cannot be established by virtue of the presence of another intervening harmony (chapter 4).

Finally, I identified a parametric system of directionality types and argued that each of the basic type is asymmetric in its typological attestation (chapter 6). Since directionality is obtained via φ-head faithfulness, I also showed that the markedness generalization is optimally analyzed as an effect of the Preservation of the Marked, for which I provided a formulation that avoids majority rule effects.

The dissertation leaves open two major issues that can pursued in the future. φ-Correspondence is established at the feature node level. However, the model suggests the possibility of having a head-dependent relation on root nodes as well. This would make a theory more alike span theory that accounts for cases of "unbounded" harmony such as nasal spreading. Since all root nodes are in the domain of the relation, parasitic effects are not expected to occur, and the CONTIGUOUS and UNIQUE constraints will favor candidates with a span of segments in correspondence (section 7.1.1).

I also briefly touched on UNIQUE-X and CONTIGUOUS-X schemas, showing that such constraints express some important restrictions on agreement relations, but neither their predictions nor the empirical evidence were analyzed sufficiently. Of particular interest were the cases where harmony is limited to a contiguous sequence of target segments, such as in Oroqen, Teke dialects, or Yabem, or to account for non-iterative harmony and blocking (section 7.1.2). Finally, I suggested that φ-Correspondence (or Correspondence Theory in general) could be extended to tones using the methodology of discussing formal properties and the constraint schemas described in this dissertation (7.1.3)

Theoretically, the most interesting contribution of phi-Correspondence Theory is to highlight the "economical" nature of phonology, with a few axioms and elements accounting for a diverse number of phenomena.

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