Headed Agreement By Correspondence.

Directionality in Consonant Harmony

Abstract

Recent work on harmony has relied on the notion of Surface Correspondence to account for long-distance agreement effects. It is argued that surface correspondence relation holds between a head consonant and its correspondents (HD-Correspondence), rather than between segments with the same status. The head of a correspondence domain (c-head) is selected via constraint interaction and mainly determines the directionality of the assimilation process. A basic factorial typology of the theory is shown to generate attested directionality patterns, a previously unexplained Derived Environment Effect in Basque harmony, and an attested harmony type that is a combination of directional and dominant harmony.

1 Introduction

Consonant harmony is obtained when a set of consonants in the output sharing the same feature value *x* must also have an identical feature *y≠x*. For example, In Ineseño Chumash (Chumash, henceforth), all [+sibilant] segments in the output must agree for the feature value [anterior]. The two inputs in (1) contain sibilants with a different specification of the feature [anterior]. Since all sibilants in the output must agree in anteriority, disharmonic sibilants are mapped unfaithfully in the output.

In Chumash, it is the rightmost sibilant in the prosodic word that determines the feature value of all preceding sibilants. The rightmost sibilant in (1a) is [-anterior], and so the other sibilants are realized as [ʃ]. In (1b), instead, the rightmost sibilant is [+anterior], and so all the other preceding sibilants are realized as [s].

(1) Sibilant harmony in Chumash (Applegate, 1972; McCarthy, 2006)

a. /**s**-wi-**s**-nox**ʃ**-it/	→	[**ʃ**wi**ʃ**nox**ʃ**-it]	‘He hit me in the nose’
b. /**s**-i**ʃ**-ili-uluaqpey-u**s**/	→	[**s**i**s**huleqpey-u**s**]	‘they two want to follow it’
c.f /p-i**ʃ**-al-nan/	→	[pi**ʃ**a-nan]	‘don’t you two go’

A different type of harmony is found in languages like Basque. In Basque, harmony also holds among sibilants, but unlike Chumash, the harmonizing feature is always the [-distributed] sibilant [s̺], regardless of the position of the consonant in the output. In (2a), the rightmost segment in the input is [-distributed], while in (2b) it is [+distributed]. However, in both cases, the sibilants in the output harmonize for the value [-distributed].

(2) Basque coronal harmony in compounds (Hansson, 2010:324)

a. /s̻in-ets̺i/	→	[s̺in-ets̺i]	‘believe’	c.f. /s̻in/ ‘truth’
b. /s̺ats̻uri/	>	/s̺ats̺uri/	‘mole’	

Harmony may be characterized in terms of two feature values (or two sets of feature values). The first one is the feature value that defines the set of segments that harmonize. I call this feature the ***correspondence feature***. In Chumash and Basque, only sibilants harmonize, and so the correspondence feature is [+sibilant].

The second one is the feature value the segments harmonize for. I refer to this feature value as the ***harmonizing feature***. In Basque, the harmonizing feature is [-distributed]. In Chumash, the harmonizing feature is either [+anterior] or [-anterior].

The way the harmonizing feature is chosen is often referred to as *directionality*. Languages like Basque are said to have *dominant harmony* because the harmonizing feature is always a specific feature value. In Chumash, instead, the selection of the harmonizing feature depends on the position in the linear string of the segments with the correspondence feature. Languages like Chumash are said to have *directional harmony*.

This paper proposes a revision of Agreement By Correspondence theory (ABC; Walker 2000a, 2001; Hansson 2001/2010, 2007; Rose and Walker 2004; Bennett, 2013, 2014) in order to provide a better account of directionality in consonant harmonies.

In ABC, harmony is governed by a set of constraints that demand surface correspondence, as well as by a set of constraints that demand featural identity of the segments in correspondence. These two families of constraints play a major role in determining the correspondence feature, the harmonizing feature, and the harmony type of a language.

In the paper, I maintain the basic tenet of ABC that harmony is obtained via surface correspondence and feature identity, but I propose that correspondence holds between Heads and Correspondents (**HD-Correspondence**), rather than between segments with the same status. I argue that this formulation of surface correspondence provides a better treatment of the harmonizing feature selection problem and generates a more comprehensive typology of harmony.

The mapping in (3a) shows an example of HD-Correspondence in a Chumash candidate. In (3a), the set of segments in correspondence (≔ correspondence domain) is formed by three sibilants, all of them [ʃ]. The consonant head (**c-head**) is enclosed in a square, and it corresponds to the other two sibilants in the output (**c-dependents)**. The c-head is the only faithful sibilant in the output, and it determines the harmonizing feature of the correspondence domain it belongs to.

The details of previous formulations of surface correspondence vary, but the underlying assumption has been that each consonant in correspondence has the same status (3b). The sibilant that determines the harmonizing feature is no different from all other sibilants in correspondence. This formulation of surface correspondence is often referred to as CC-Correspondence (Walker 2000a, 2000b, 2009; Rose and Walker, 2004; Hansson 2001/2010, 2007; Rhodes, 2008; Rose, 2000, 2011; Gallagher and Coon, 2009; Bennett, 2013, 2014; McCarthy, 2007; Shih and Inkelas, 2014, etc.).

Similarly to some other phonological heads, such as onset heads (Murray, 2006; Smith, 2002), c-heads are not phonetically distinguished from c-dependents, and the choice of the head consonant is mostly determined by freely rankable constraints.

(3) IO and surface correspondence relations

a.	b.
/**s**-wi-**s**-nox**ʃ**-it/	/**s**-wi-**s**-nox**ʃ**-it/
[**ʃ**-wi-**ʃ**-nox**ʃ**-it]	[**ʃ**-wi-**ʃ**-nox**ʃ**-it]
a. HD-Correspondence	b. CC-Correspondence

1.1 HD-Correspondence

Corr-HD

Previous work in ABC has relied on different definitions of Surface Correspondence (see Bennett, 2013:27–52 for a review). In this paper, I assume that Surface Correspondence is a relation similar to traditional marriage: it is binary (between two individuals), heterogeneous (between individuals of different gender), multiple (one-to-many relations are possible), symmetric (if John is married to Jane, Jane is married to John), non-transitive (if John is married to Jane, and Jane is married to Bob, John is not married to John), and non-reflexive (Jane cannot marry herself).

Heads are special constituents in a domain (for a definition, see §1.2). For example, secondary stress is the head of a foot, and primary stress is the foot head of a prosodic word. The domain of c-heads is called an HD-Correspondence domain. An HD-Correspondence domain is defined by the set of all segments that are in correspondence. The definition in (4) reflects the fact that correspondence domains are always headed.

(4) **Definition of correspondence domain**: A correspondence domain consists of a c-head and of its correspondents.

Example (5) contains an output where all the sibilants are in the same correspondence domain. The rightmost sibilant [**(ʃ)**] is a c-head, and it corresponds with the two other sibilants in the output [ʃ] and [s]. The correspondence domain then consists of the three sibilants {ʃ, s, **(ʃ)**}.

(5) A correspondence domain consisting of three sibilants

[buʃusu**(ʃ)**upu] sibilant domain = {ʃ, s, **(ʃ)**}

By definition of headedness (17), well-formed correspondence domains have one and only one head. This means that no correspondence domains are generated with two heads in correspondence, with two dependents in correspondence with each other, or without a head, as illustrated in (6).

(6) Possible and impossible correspondence relations

[ʃusuʃu]	[ʃusuʃu]	[ʃusuʃu]	[ʃusuʃu]
a. two heads	b. two dependents	c. no head	d. 1 head → many dependents ✓

One consequence of the fact that correspondence domains are defined entirely in terms of HD-Correspondence is that there is no limit on the number of heads that can appear in a certain output.

Since there is no limit on the number of heads in an output, nor is there a limit on the number of correspondence relations; optima with more than one correspondence domains are possible. Languages like Ndebele have two harmonies co-occurring within the same morphological domain, indicating the co-existence of multiple correspondence domains, each headed by a different segment.

Example (7) is such a case. In the output, in addition to sibilant correspondence, the grammar has also generated correspondence among labials (rendered with a dotted line). The rightmost labial [**(b)**] is a c-head, and corresponds to the word-initial labial stop [p]. Since the two labials are in correspondence, but neither of the two corresponds with one of the sibilants, the two segments form their own correspondence domain, different from that of the sibilants.

(7) An output with two different HD-Correspondence domains

[puʃusu**(ʃ)**u**(b)**u] sibilant domain = {ʃ, s, **(ʃ)**}; labial domain = {p, **(b)**}

There are no other restrictions in GEN in terms of HD-Correspondence. Head status is assigned freely to consonants in the output, and any non-head consonant (dependent) may be in HD-Correspondence with a head.[1] Outputs with HD-Correspondence relations are represented using the following notation: (i) heads are in bolds, and between parentheses; (ii) segments with the same index are in the same correspondence domain.For example, the output [s$_y$…ʃ$_x$…**(ʃ)**$_x$] contains one c-head, indicated as **(ʃ)$_x$**. The two sibilants [ʃ] correspond—as indicated by the fact that they both have the same correspondence index *x*—and therefore constitute a correspondence domain. The [+anterior] sibilant [s] instead has a different, and unique

[1] A more formal definition of HD-Correspondence and of its differences with respect to CC-Correspondence and other correspondence relations (IO, IR, BR) are presented in Iacoponi (2015).

correspondence index *y*. Therefore, it does not correspond with any other sibilants, and does not belong to any correspondence domain.

HD-Correspondence is governed by a family of constraints that penalizes segments with the same feature value that do not correspond. The constraint **Corr-HD(+sibilant)**, for example, assigns a violation for each [+sibilant] segment in the output that is not in the same correspondence domain of any other sibilant. For example, **Corr-HD(+sibilant)** is violated twice in the output $\{ʃ_x…ʃ_y\}_{root}$ because neither sibilant in the domain root is in correspondence. **Corr-HD(+sibilant)** is violated only once in $\{s_y…ʃ_x…ʃ_x\}_{root}$, because only one sibilant in the root is not in correspondence.

Corr-HD is the family of constraints that determines the correspondence features in languages with harmonies.

(8) Definition of **Corr-HD(α*f*, *dom*)**:

Penalize segments with the same feature value αf that are not in the same correspondence domain.

For each consonant in *dom*, assign a violation if:

a. X is [α*f*], &

b. There is a consonant Y [α*f*] in *dom,* &

c. X is not in the same correspondence domain as Y.

Ident-HD

Ident-HD constraints govern the selection of harmonizing features. This family of constraints demands that all segments in HD-Correspondence share the same value of a feature *f*. For example, the constraint **Ident-HD(anterior)** assigns a violation for each pair of segments in correspondence that has a different feature value for the feature [anterior].

Bennett (2014:257–289) proposes that **Ident-CC** can refer to a specific phonological position, namely the onset. Since none of the cases studied here requires **Ident-HD** to make reference to a prosodic or morphological position, I just assume the general formulation in (9) that does not refer to any specific morpho-phonological domain.

(9) Definition of **Ident-HD(*f*)**:

Penalize segments in HD-correspondence that have a different feature value f

For each distinct pair of a consonant X [α*f*] & Y [β*f*] in HD-correspondence,

assign a violation iff α≠β

As an example, let us analyze the input /s…ʃ/. Since there are no examples of epenthesis, deletion, coalescence or splitting in consonant harmony, I only consider candidates with a one-to-one IO-mapping in the paper.

Candidates (10a–c) in the tableau (10) violate one of the two HD-Correspondence constraints. In (10a, b), the two sibilants are in correspondence, thus satisfying **Corr-HD(+sib)**, but their feature value for [anterior] is different. The sibilant [ʃ] is [-anterior] while [s] is [+anterior], and so **Ident-HD(ant)** is violated once.

Constraints requiring feature identity are only violated by segments in correspondence. Therefore, candidate (10c–d) do not violate **Ident-HD(ant)**: the two sibilants have a different specification for the feature [anterior], but they do not correspond. Candidate (10c) only violates **Corr-HD(+sib)**, since the two sibilants are not in correspondence.

Corr-HD(+sib) demands correspondence only between segments that have the feature value [+sibilant]. [-sibilant] segments in the output do not violate the constraint, even if they do not correspond. The candidate (10d) satisfies the two HD-Correspondence constraints by mapping one of the two [+sibilant] segments to [-sibilant]. Since the output [t] is not [+sibilant], it no longer violates **Corr-HD(+sib)**. Consequently, it also does not violate **Ident-HD(+sib)**, because it is not in a correspondence domain. The candidate does however map the segment with the correspondence feature unfaithfully, thus violating the faithfulness constraint **Ident-IO(+sib)**.

The candidate pairs (10a, b) and (10e, f) have the same violation profile. This is because two candidates in the pair differ only in the position of the c-head, but HD-Correspondence constraints do not refer to c-heads in their definition.

Harmonizing candidates like (10e, f) are the main focus of this paper. As shown in the tableau, in terms of HD-Correspondence constraints they both score zero violations. They correspond, agree for the feature [anterior], and harmony is obtained at the cost of violating Ident-IO once.

(10) Basic **HD-Correspondence** constraint interaction

Input	Output	Id-IO(+sib)	Corr-HD(+sib)	Id-HD(ant)	Id-IO(ant)	Comments
ʃ…s	a. **(ʃ)x**…sx			*		Correspondence, but no harmony
	b. ʃx…**(s)**x			*		
	c. ʃx…sy		*			No correspondence
	d. tx…sy	*				
	e. **(ʃ)**x…ʃx				*	Correspondence, and harmony
	f. sx…**(s)**x				*	

As in most OT analyses that make reference to phonological heads (e.g., de Lacy, 2002; Murray, 2001, McCarthy, 2007; and others), the choice of the head is determined by **CON** and **GEN**. The way correspondence relations are generated is discussed in (§2.1) and (§2.3). The rest of this section deals with **CON**.

Given an input /ʃ…s/, there are four candidates that correspond and harmonize. As shown in (11), none of these candidates can be distinguished by HD-Correspondence constraints.

The four candidates (11a–d) differ in the way the relation between head and dependents is established. In candidate (11a, d), the head segment is the rightmost sibilant, and the dependent is the leftmost one. In candidate (11b, c), the roles are reversed: the leftmost sibilant is the head, and the rightmost sibilant is its dependent. The segment features are also different: in (11a, c), the head is [+anterior], in (10b, d) it is [+anterior].

(11) Four harmonizing candidates

Input	Output	Ident-IO(+sib)	Corr-HD(+sib)	Ident-HD(ant)	Ident-IO(-ant)	Ident-IO(+ant)
ʃ…s	a. sx…**(s)x**				*	
	b. **(ʃ)x**…ʃx					*
	c. **(s)x**…sx				*	
	d. ʃx…**(ʃ)**x					*

Align(cHead, R)

The first constraint I am proposing determines the distribution of c-heads in the output. It was shown 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 have been mainly analyzed as an effect of Generalized Alignment constraints (McCarthy and Prince, 1993; Hyde, 2012; Houghton, 2013; and others). McCarthy and Prince (1993:2) provides the following generalized schema.

(12) Generalized Alignment (McCarthy and Prince, 1993)

Align(Cat1, Edge1, Cat2, Edge2) $=_{def}$

∀ 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 (McCarthy and Prince, 1993:15):

Align-PrWd ≔ Align(PrWd, R, Ft, R)

The constraint requires that the two phonological constituents—PrWd (prosodic word), and Ft (foot)—are aligned at their respective right edges. A violation mark is assigned for each syllable that intervenes between the right edge of a foot and the right edge of the prosodic word.

C-heads are phonological constituents, just like feet and prosodic words. The c-head alignment constraint in (13) follows the same schema of **Align-PrWd**, the only difference being that in **Align(c-head, R)**, the second *PCat* variable refers to the c-head instead of the foot.

(13) Definition of **Align(c-head, R)** ≔ Align(PrWrd, R, c-head, R):[2]

Penalize c-heads that are not aligned to the right edge of the prosodic word

For each head H in the output,

assign a violation for each segment C between H and the right edge of the prosodic ω,

where ω is the prosodic word H is contained in, *and*

C is a consonant in correspondence with H.

$*(H, D)$: $\{H\ldots D\}_{\omega}$

For example, **Align(c-head, R)** is violated once in the output $[(\textbf{ʃ})_{\mathbf{x}}\text{at}_{y}\text{as}_{\mathbf{x}}]_{\omega}$, since the head **(ʃ)** is separated from the right edge of the prosodic word by the one sibilant in correspondence [s]. Segments not in correspondence with the head are ignored by the alignment constraint.

Even though the output $[(\textbf{ʃ})_{x}\text{at}_{y}\text{as}_{z}]_{\omega}$ is segmentally identical to $[(\textbf{ʃ})_{\mathbf{x}}\text{at}_{y}\text{as}_{\mathbf{x}}]_{\omega}$, **Align(c-head, R)** is not violated. The sibilant [s] is not in correspondence with the head, and therefore it has the same status of any other segment.[3]

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[2] The definition according to the generalized schema is the following: "∀ PrWd ∃ c-head such that R of PrWd and R of c-head coincide". I use the definition in (13) to keep the format of constraint definitions consistent.

[3] The fact that the sibilant is ignored when not in correspondence follows from the generalized alignment schema. If the separator depended on a feature of the segment, for example [+sibilant], **Align(c-head, R)** would have to include a reference to such feature in its definition. This would not only introduce an unusual additional condition, but

Ident-IO(c-head)

The second c-head constraint proposed in the paper is the positional faithfulness constraint **Ident-IO(c-head)**. **Ident-IO(c-head)** is violated when a consonant head is not faithful to its input correspondent, as per the definition in (14).

(14) Definition of **Ident-IO(c-head)**:

Penalize any unfaithful mapping of c-heads

For each distinct pair of a consonant X in the input, and its correspondent X´ in the output, assign a violation if:

a. if X is [αf], &

b. X´ is not [αf], &

c. X´ is a c-head

For example, **Ident-IO(c-head)** is violated by the mappings s → **(ʃ)**, and ʃ → **(s)**, but not by the mapping to a non-head segment s → ʃ.

It is unclear at the moment whether there is only one **Ident-IO(c-head**) constraint or whether the current formulation generalizes a set of constraints that refer to a single feature, such as **Ident-IO(c-head, nas)**, **Ident-IO(c-head, voi)**, **Ident-IO(c-head, ant)**, etc. The two formulations make different predictions about languages with more than one harmony.[4]

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 and Prince, 1995; Beckman, 1998) or phonological constituents (e.g., **Ident-IO(onset)** Lombardi, 1999; Padgett, 2002). **Ident-IO(c-head)** is then a positional faithfulness constraint that refers to a phonological constituent, of the same kind of **Ident-IO(onset)**.

Tableau (15) shows how **Ident-IO(c-head)** and the other c-head constraints are evaluated. Candidates (15a–b) have their c-heads aligned to the right edge of the word, and therefore do not violate **Align(c-head, R)**.

In both candidates, the head is the rightmost segment of the correspondence domain, and the two segments harmonize. The difference is that in candidate (15a), the c-head is mapped faithfully, while in (15b) the c-head is changed to [-anterior], and thus violates **Ident-IO(c-head)**. The output of candidate (15c) is phonetically identical to the output of candidate (15b), since correspondence relations are not phonetically realized. The condition under which the two candidates are optimal are not the same, though. Candidate (15b) is favored by **Align(c-head, R)**, while candidate (15c) is favored **Ident-IO(c-head)** and **Ident-IO(-ant)**.

Candidate (15d) is harmonically bounded by candidate (15a). The c-head is not aligned to the right edge of the prosodic word, and it is not faithful. The candidate thus violates both c-head constraints **Align(cHead, R)** and **Ident-IO(c-head)**, as well as the faithfulness constraint **Ident-IO(-ant)**.

would also lead to a proliferation of alignment constraints, and as a consequence, to unwarranted typological predictions.

[4] Languages with multiple consonant harmonies are extremely rare, and the analysis of such languages would introduce complications that are not discussed in this paper. So, I will leave this issue aside and assume that there is only one Ident-IO(c-head) constraint.

(15) Constraints on c-heads

Input	Output	**Ident-IO(+sib)**	**Corr-HD(+sib)**	**Ident-HD(ant)**	**Ident-IO(c-head)**	**Align(c-head, R)**	**Ident-IO(-ant)**	**Ident-IO(+ant)**
ʃ…s	a. s$_x$…**(s)**$_{\mathbf{x}}$						*	
	b. ʃ$_x$…**(ʃ)**$_{\mathbf{x}}$				*			*
	c. **(ʃ)**$_{\mathbf{x}}$…ʃ$_x$					*		*
	☠ d. **(s)**$_{\mathbf{x}}$…s$_x$				*	*	*	

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(c-head, R), and no constraint Align(c-head, L), with the exception of dissimilation grammars, the output for harmonic inputs is always harmonic with a right-aligned head.

(16) Harmonically bounded candidates for harmonic inputs

Input	Output	**Ident-IO(+sib)**	**Corr-HD(+sib)**	**Ident-HD(ant)**	**Ident-IO(c-head)**	**Align(c-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$_y$	*				*	*

Template for CON subsets

The analyses and the typology discussed in this paper only use constraints derivable from the template in (17). The only exception is Basque, whose analysis includes a process of neutralization that requires the use of the constraint ***s̥C**.

Individual CON subsets are obtained by replacing the variable *c* with the correspondence feature of the harmony discussed and the variable *h* with the harmonizing feature.

For example, in Chumash the correspondence feature is [+sibilant], and the harmonizing feature is [anterior]. Therefore, the subset of CON includes constraints such as **Corr(+sib)**, derived from **Corr(*c*)**, and **Ident-HD(ant)**, derived from **Ident-HD(*h*)**.

The formal definition of the constraints in (17) is the one given in § 2.1 and 2.2.

(17) CON template

$\text{CON}_{\text{HD-Corr}}$

Corr-HD(*c*): "*Penalize segments with the same feature value c that do not correspond*"

Ident-HD(*h*): "*Penalize correspondents that have a different feature value for h*"

$\text{CON}_{\text{c-head}}$

Align(c-head, R): "*Penalize c-heads that are not aligned to the right edge of the prosodic word*"

Ident-IO(c-head): "*Penalize any unfaithful mapping of c-heads*"

$\text{CON}_{\text{m/f}}$

Ident-IO(*c*): "*Penalize any unfaithful mapping of the feature value c*"

Ident-IO(+*h*): "*Penalize any unfaithful mapping of the feature +h*"

Ident-IO(-*h*): "*Penalize any unfaithful mapping of the feature -h*"

Ident-IO(root): "*Penalize any unfaithful mapping of a segment in the root*"

***s̺C**: "*Assign a violation for each s̺C sequence in the output*" (only Basque)

1.2 Definitions and Assumptions

Heads

Headed constituents are pervasive in linguistics. The concept of head has been applied to syllable structure (Smith, 2002; Murray, 2001), element theory (Kaye et al., 1985; and others), stress/tone interaction (de Lacy, 2002), autosegmental assimilation (Halle and Vergnaud, 1998; Jurgec, 2012), as well as being a central concept in the theory of stress (Prince and Smolensky, 1993/2004) and in syntax (Chomsky, 1967). All linguistic heads obey the **uniqueness axiom**, which is defined as follows:

(18) **The uniqueness axiom.** A domain D has one and only one head (of that domain D).

A syntactic phrase in X-Bar theory (Chomsky, 1967; Jackendoff, 1977) can only have one head, but any number of dependents (one complement, plus any number of adjuncts). In a phonological word, there can be any number of feet, but only one of them is the head,[5] the primary stress. Uniqueness can be considered part of the definition of headedness itself.

No configuration is possible other than a c-head in relation with one or more dependents, because of the three properties of HD-Correspondence defined in (19).

(19) The three properties of HD-Correspondence

Property of S(aturation): Two c-heads cannot be in correspondence.

Property of G(overnment): Two dependents cannot be in correspondence.

Property of E(xistence): There must be one c-head in a correspondence domain.

The three properties of HD-Correspondence are all derived from the properties of headedness and correspondence.

Property S says that two heads cannot be in correspondence with each other. If two segments are in correspondence, they constitute a domain, but because of *uniqueness*, domains can contain exactly one head. The configuration with two heads in (20a) is thus impossible, as it violates **Property S**.

The second property is different from the other two as it does not follow from **uniqueness**. There is in fact nothing in the **uniqueness axiom** that prevents two dependents from being in correspondence. Dependents are not even phonological constituents. They are defined negatively as consonants that are not heads.

[5] Trivially, there must be a foot in a prosodic domain to have a foot head. Unstressed parses are headless prosodic words because there is no foot that can serve as a head in the first place. Similarly, if a segment is not in correspondence, it cannot be a c-head.

Nevertheless, correspondence between dependents is ill-formed because no constraint favors it, while at the same time it is penalized by correspondence constraints. Any candidate with two segments in dependent-dependent correspondence is harmonically bounded by a candidate with an HD (head–dependent) correspondence, or a candidate lacking correspondence altogether. The proof that such candidates are ill-formed is given in another paper, where the formal properties of HD-Correspondence are analyzed in more detail. In the rest of the paper, I assume **Property G**, since it significantly reduces the size of the candidate sets considered in the analyses.

Property E says that for each domain, there must be at least one head. This means that whenever there is an HD-Correspondence relation between two segments, the correspondence domain the segments belong to must be headed. This property follows straightforwardly from **uniqueness**. It is formally a conjecture since it is obtained by simply replacing the generic terms *head* and *domain* from the *uniqueness axiom*, with the specific HD-Correspondence terms *c-head* and correspondence domain. Candidates such as (20c) are thus not generated.

Example (20) shows three correspondence configurations that violate Property S (20a), G (20b) and E (20c) respectively. Example (20d) is a legitimate configuration since it does not violate any of the three properties. There is one head in the correspondence domain, each dependent corresponds to the head, and no correspondence is established among dependents.

(20) Possible and impossible correspondence relations

[ʃusuʃu]	[ʃusuʃu]	[ʃusuʃu]	[ʃusuʃu]
a. two heads (S)	b. two dependents (G)	c. no head: (E)	d. 1 head → many dependents. ✓

Heads in Autosegmental Approaches

This paper proposes a revision of ABC's correspondence mechanism, and therefore the focus has been on the comparison between HD-Correspondence and CC-Correspondence. The proposal, though, can be related to two autosegmental theories of assimilation that make use of heads: McCarthy (2004) and Jurgec (2012).

Autosegmental theories of spreading (Clements, 1980, Clements and Sezer, 1982, Archangeli and Pulleyblank 1989, 1994; Shaw, 1991; Odden, 1994; Clements and Hume, 1995) have been the predominant theory in dealing with assimilation, especially before the 21th century (Schein and Steriade, 1986; Shaw, 1991; McCarthy, 1989; Yip, 1989; Bradshaw, 1999; Gafos, 1998, 1999; Padgett, 2002; McCarthy, 2004; Jurgec, 2012).

In autosegmental theory, consonant harmony is mainly determined by three variables: the trigger, which determines the feature value that is spreading, the target, which determines the segment that assimilates to the trigger, and an optional parameter that determines the direction of the spreading.

A principle shared by all autosegmental theories is the ban against association lines crossing. The segments undergoing assimilation must be adjacent on some level to the trigger. The problem of locality is evident in long distance assimilation, where intervening consonants often come between the assimilating consonants without interacting with the assimilation process.

Locality has been circumvented using a variety of strategies, such as feature geometry (Halle, 1995; Steriade, 1986; Odden, 1994), underspecification (Shaw, 1991), relativized locality (Kiparsky, 1981; Clements and Sezer, 1982; Steriade, 1986, 1987, 1995; Odden, 1994), suprasegmental foot constituents (Piggott, 1996), violable spreading constraints (O'Keefe, 2007), and inter-tier association (Jurgec, 2012).

Jurgec (2012) and McCarthy (2004) are relevant to the present discussion because they both make use of headedness. However, the function of headedness in the two theories is fairly different.

Span theory is very similar to HD-Correspondence in that domains (spans) are freely created by GEN, and in that the harmonizing feature of these domains is determined by a head. Nevertheless, the mechanisms underlying the creation of the domains and the selection of the heads are rather different.

Two important differences concern the definition of the domains and the mechanisms that govern the distribution of heads in the output.

Following Hansson (2001/2010), span theory can be subcategorized as a "strict locality" theory of assimilation (Flemming 1995; Ní Chiosáin and Padgett, 1997, 2001; 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. In surface correspondence, instead, there is no such a strict requirement. Segments in the same domain may be separated by other segments, which can even belong to other correspondence domains (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 have to be permeated by the spreading feature. This assumption raises some empirical and theoretical issues, as discussed in Hansson (2001/2010: 20–23, 210–221). Recent work, though, has addressed the problem of strict locality. For example, O'Keefe (2007) is a revision of span theory that accounts for segment transparency. The problem of multiple harmonies, though, seems to be left unaddressed.

Another property of span theory is that all segments in a span are pronounced with the feature value of the head. In contrast, in HD-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 HD-Correspondence concerns the constraints that determine the head selection. C-head constraints follow the template of classic positional and alignment constraints. Span theory uses specific constraint schemas. An important constraint 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 example **HEAD([-cont, -son], [-nas])** contains two conditions: that the segment is an obstruent, and that the segment heads an oral span.

Another difference is that in HD-Correspondence head selection is determined by a positional faitfhulness 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 and Prince, 1993; Murray, 2001; de Lacy, 2002). In these approaches, CON contains constraints that penalize unfaithfulness or demand alignment, rather than favoring the presence of a head in a particular context.

The other constraint that governs head selection in span theory is **FtHdSp(αF)**, defined as follows:

(21) Definition of **FtHdSp(αF)**

If an input segment ς_I is [αF] and it has an output correspondent ς_O, then ς_O is the head of an [αF] span.

According to the constraint definition, headedness is demanded depending on the feature specification of the input and the output. In HD-Correspondence no such constraint exists. Head selection is governed by one alignment constraint and by the positional faithfulness constraint **Ident-IO(c-head)**.

Jurgec (2012)'s heads are rather different from both HD-Correspondence and span theory heads, so I do not compare the two approaches. Suffice it to say that the main function of heads in Jurgec (2012) is to propagate the spreading of a feature. In Jurgec (2012) assimilation occurs within maximally binary, headed and recursive feature domains. Some targets can be associated with a spreading feature, but when a particular target cannot be a head, it terminates the spreading. For a more detailed comparison between autosegmental theory and ABC, see Hansson (2001/2010), Rose and Walker (2004), Sasa (2009), Jurgec (2014), and others.

1.3 Advantages

Theoretical advantages

Classic and more recent approaches to the problem of directionality in ABC (Rose and Walker, 2004; Hannson 2001/2010; Bakovic and Rose, 2014) have relied on so called “targeted” constraints.

Bennett (2013) dismisses targeted constraints, but it only partially explores alternative solutions to the problem. The author’s conclusion is that “directionality is an unresolved issue in surface correspondence theory” (2013:98).

HD-Correspondence allows the dismissal of targeted constraints—as in Bennett (2013)—and at the same time provides a solution to the problem of directionality by using conventional constraints.

To illustrate this point, I use Hansson’s (2010:265) targeted constraints as an example. Hansson (2001/2010) uses two constraints of the type in (22) to account for the harmonizing feature selection problem in Chumash directional harmony.

(22) →**IDENT[ant]-CC**

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.

In HD-Correspondence, directionality is mainly governed by the generalized alignment constraint **Align(c-head, R)**, and the faithfulness constraint **Ident-IO(c-head)**. Compared to targeted constraints, c-head constraints are more conventional. **Align(c-head, R)** formally follows from the generalized alignment schema, and **Ident-IO(c-head)** is a positional faithfulness constraint. In contrast, 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 c-head and HD-Correspondence constraints is that each constraint fulfills a specific function. **Ident-HD** constraints only require featural identity, as opposed to targeted **CC-Ident** constraints, which also specify the conditions under which identity should occur.

Finally, the introduction of c-heads makes surface correspondence more similar to other correspondence relations, such as Input/Output, Base/Reduplicant, and Input/Reduplicant. Since **Ident-HD** just demands featural identity (as in Bennett, 2014), the constraint follows the generalized schema of **Ident** constraints in (23).

(23) Definition of **Ident-*AB*(*f*)**:

Penalize segments in correspondence that have a different feature value f
For each distinct pair of a consonant X [α*f*] & Y [β*f*] in *AB*-correspondence,
assign a violation iff α≠β

In §2.1, it was noted that surface identity constraints that refer to a prosodic position (i.e., the onset) have been proposed in the literature (see Bennett, 2014). In this case, **Ident-HD** is the HD-Correspondence version of IO positional faithfulness constraints, with **Ident-HD(f, Onset)** using the same schema of other well-studied positional faithfulness constraints, such as **Ident-IO(f, Onset)**.

Derived Environment Effect

An empirical advantage of HD-Correspondence is that it predicts a type of blocking in harmony that is not straightforwardly analyzable in ABC.

For instance, sibilant harmony in Basque interacts with a process of neutralization (Hualde, 1994), whereby laminal sibilants are neutralized when followed by another consonant. Neutralized sibilants do not agree with other sibilants in the root. For example, the word for “bag” is the disharmonic [s̺is̻ku], not [s̻is̻ku] or [s̺is̺ku].

Headless ABC cannot capture the mapping /s̺is̺ku/ → [s̺is̻ku] (Falk, 2014). **CC-Ident (**which requires agreement of segments in correspondence) has to be ranked above **Ident-IO(+dist)** in order to obtain assimilation, but below the same constraint **Ident-IO(+dist)** to avoid overapplication in neutralized forms. In ABC, there is no other constraint that distinguishes the two segments in correspondence, and therefore no ranking exists that can select the right optima.

In HD-Correspondence, when the candidate with neutralization harmonizes, it also violates **Ident-IO(c-head)**, since the c-head is mapped unfaithfully. The ranking **Ident-IO(c-head)** ≫ **Corr-HD(+sib)**, then, ensures that the candidate with the neutralized segment wins, resulting in the “harmony blocking” effect. A complete analysis of harmony blocking in Basque is given in §3.2.

Dominant-directional languages

HD-Correspondence predicts the existence of dominant-directional harmonies. In dominant-directional languages, harmony takes places only when there is a segment in the correspondence domain that is both marked and right-aligned. If the right-aligned segment is unmarked, harmony does not occur. Empirically, these languages have been known in the theoretical literature of consonant harmony at least since Hansson (2010:368), but to my knowledge, no analysis has ever been attempted.

For instance, in Pengo, coronals harmonize for the feature [distr_release]. However, while the input /t…tʃ/ surfaces with the harmonic output [tʃ…tʃ] (64a–c), the input /t…tʃ/ does not harmonize. If the [+dist_release] segment is not to the right of the other coronal, harmony does not occur (64e–f).

A standard constraint set in ABC that includes Corr and CC-Ident constraints cannot account for this type of languages.

(24) Dominant-directional harmony in Pengo (Burrow and Bhattacharya, 1970; Hansson, 2010:368)

a. titʃ ~ tʃitʃ	‘to eat (past stem)’	
b. toːtʃ ~ tʃoːtʃ	‘to show’	
c. taːnd͡ʒ~ tʃaːnd͡ʒ	‘to appear’	
e. t͡ʃeta man	‘to be awake’	*tʃetʃa man
f. d͡ʒaːti	‘castle’	*dʒaːtʃi

2 Analyses

2.1 Chumash Directional Harmony

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 hereby analyzed (Applegate, 1972; Beeler, 1970; Gafos, 1996; Hansson, 2001/2010; Harrington, 1974; Lieber, 1987; Poser, 1982, 1993, 2004; McCarthy, 2007; Shaw, 1991).

There are at least three Chumashan languages that show a certain degree of sibilant harmony, Ineseño (now called Samala), Barbareño, and Ventureño. I focus on Ineseño since it has been the most discussed language in the theoretical literature (Gafos, 1996; Hansson, 2001/2010; Harrington, 1974; Lieber, 1987; Poser, 1982, 1993, 2004; McCarthy, 2007; Shaw, 1991), probably the best documented (Applegate, 1972) and the one that shows the clearest case of sibilant harmony of the three languages (Poser, 2004).

Chumashan languages have a rich consonantal system, shared by all languages in the group (Applegate, 1976:8). 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.

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.

In Ineseño Chumash (Chumash henceforth), all sibilants in a word share the same feature value [anterior], which is determined by the underlying value of the rightmost sibilant in the output.[6]

Russell (1993) proposed that harmony in Chumashan languages is phonetic. This position was challenged by Poser (2004), who showed that the criticisms advanced are either not true for Ineseño, are empirically questionable, or are not a diagnostic. McCarthy (2007) also defended the phonological nature of the process by providing evidence from loanword adaptation. Following McCarthy (2007) and Poser (2004), I consider Chumash harmony an actual phonological process, as illustrated by the data in (25a).

(25) Sibilant harmony in Chumash (Applegate, 1976:239; Hansson, 2010:45,146; McCarthy, 2007)

a. Unbounded right-to-left harmony.

/ha-**s**-xintila-wa**ʃ**/	→ [ha**ʃ**xintila-wa**ʃ**]	'his former gentile'
c.f. /ha-**s**-xintila/	→ [ha**s**xintila]	'his gentile'
/**s**-i**ʃ**-ili-uluaqpey-u**s**/	→ [**sis**huleqpey-u**s**]	'they too want to follow it'
c.f /p-i**ʃ**-al-nan/	→ [pi**ʃ**a-nan]	'don't you two go'
/**s**-wi-**s**-nox**ʃ**-it/	→ [**ʃ**wi**ʃ**nox**ʃ**-it]	'He hit me in the nose'

b. Harmony includes aspirated affricates.

/**s**-api-**tʃʰ**-o-it/	→ [**ʃ**-api-**tʃʰ**-o-it]	'I have a stroke of good luck'
/**s**-api-**tʃʰ**-o-u**s**/	→ [**s**-api-**sʰ**-o-**us**]	'He has a stroke of good luck'

c. Harmony independent of the morphology (past /-waʃ/; 3.SG /-us/).

/**s**-api-**tʃʰ**o-u**s**/	→ [**s**apitsʰol-u**s**]	'he has a stroke of good luck'
/**s**-api-**tʃʰ**o-u**s**-wa**ʃ**/	→ [**ʃ**api**tʃʰ**ol-u**ʃ**-wa**ʃ**]	'he had a stroke of good luck'
/**s**-i**ʃ**-ti**ʃ**i-jep-u**s**/	→ [**sis**ti**s**ijep-u**s**]	'they (two) show him'

d. Harmony in loanwords.

/k-**s**apatu-V**tʃ**/	→ [k**ʃ**apatu**tʃ**]	'I wear shoes' (< Sp. zapato)
/**s**-kamis**a**-V**tʃ**/	→ [**ʃ**kami**ʃ**a**tʃ**]	'he wears a shirt' (< Sp. camisa)

In (25a), 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 (25a), where the target of assimilation is [+anterior], and by (25b) where the target is [-anterior].

No blocking effect is observed, and the harmony may cause more than one segment to be mapped unfaithfully (25c, d). There are few exceptions to this generalization (Applegate 1972:119), but as noted in McCarthy (2007), the process is robustly attested and has applied in loanword adaption (25d).

The following table summarizes the properties of harmony in Chumash.

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[6] Chumash harmony has been argued to interact with a process of palatalization and of dissimilation (McCarthy, 2007). Due to the scarcity of the data, and the dubious existence of such process, I will only analyze the basic phenomenon, which is robustly attested.

(26) Harmony in Chumash

Correspondence feature	[+sibilant]
Harmonizing feature	[anterior]
Harmony type	directional
Domain	unbounded

GEN and CON

The set of constraints and their prose definitions are listed in (27). All constraints are from the template in (17).

(27) Constraint set $CON_{sib\text{-}ant}$

$CON_{HD\text{-}Corr}$

Corr-HD(+sib): "*Penalize [+sib] segments that do not correspond*"
Ident-HD(ant): "*Penalize correspondents with a different feature value [anterior]*"

$CON_{c\text{-}head}$

align(c-head, R): "*Penalize c-heads that are not aligned to the right edge of the prosodic word*"
Ident-IO(c-head): "*Penalize any unfaithful mapping of c-heads*"

$CON_{m/f}$

Ident-IO(+sib): "*Penalize any unfaithful mapping of the feature value [+sibilant]*"
Ident-IO(+anterior): "*Penalize any unfaithful mapping of the feature value [+anterior]*"
Ident-IO(-anterior): "*Penalize any unfaithful mapping of the feature value [–anterior]*"

The set of inputs is the one that appears in the data in (25). The outputs were generated using the schema in (28). The schema indicates the set of all candidates generated by mapping each segment in the input set to all combinations of segments indicated in the schema. For example, given an input /**s**-api-**tʃʰ**-o-it/, a candidate is generated including such input, as well as the output [**ʃ**$_x$-api-**tʃʰ**$_x$-o-it]. 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-**tʃʰ**$_x$-o-it], where /s/ is mapped to [ʃ]. The second segment is neither /s/ or /ʃ/, and so it is mapped faithfully, as indicated by the statement '* → faithful'.

In addition to the segmental variation, outputs also vary for their correspondence relations. In the output [**ʃ**$_x$-api-**tʃʰ**$_x$-o-it] the two sibilants are in correspondence, but another segmentally identical output [**ʃ**$_x$-api-**tʃʰ**$_y$-o-it] also exists, where the two sibilants are not in correspondence. Finally, as stated in §1.1, input–output mapping is always one-to-one, and so no output results from segment epenthesis, deletion, coalescence, or splitting.

(28) GEN for Chumash

a. Mappings
ʃ → s, ʃ, t
s → s, ʃ, t
* → faithful

b. Other
All combinations of surface correspondence among sibilants
one-to-one I/O mapping only

The constraints in $CON_{sib\text{-}ant}$ (27) were used to determine the ranking of Chumash based on the set of mappings in (25). The generator, the constraints, and the rankings for the analyses were computed using OT Workplace 54 (Prince et al., 2013). The skeletal basis is given in (29). The first column of each tableau contains the ERCs (Entailment Ranking Condition); the operator ∘ is used to indicate the fusion of two ERCs. (Brasoveanu and Prince, 2005)

(29) Skeletal basis for Chumash

#ERCs	Id-IO(+sib)	Corr-HD(+sib)	Id-HD(ant)	Align(c-head, R)	Id-IO(c-head)	Id-IO(-ant)	Id-IO(+ant)	Comments
1 ∘ 2	W					L	L	No dissimilation
3 ∘ 4		W				L	L	Correspondence
5 ∘ 6			W			L	L	Agreement
7 ∘ 8				W		L	L	Directionality
9 ∘ 10					W	L	L	No Dominancy

Analysis
The two mappings sufficient to obtain a ranking for Chumash are /i**ʃ**-ti**ʃ**i-jep-u**s/** → [i**s**$_x$ti**s**$_x$ijep-u**(s)**$_x$] and /**s**-api-**tʃ**^{h}-o-it/ → [**ʃ**$_x$-api-**(tʃ**^{h}**)**$_x$-o-it]. The violation tableau for the two winner candidates is in (30).

As shown by the candidate /**s**-api-**tʃ**^{h}-o-it/ → [i**s**$_x$ti**s**$_x$ijep-u**(s)**$_x$], all the sibilants harmonize for the feature value of the rightmost sibilant in the prosodic word, which in this case is the c-head **(s)**. The winner does not violate either of the two HD-Correspondence constraints **Corr-HD(+sib)** and **Id-HD(ant)**, since all sibilants are in correspondence and agree for the feature [anterior].

C-heads in Chumash are always assigned to the rightmost sibilant in the prosodic word. **Align(c-head, R)** is thus never violated by the winners (30a, b). Harmony is achieved at the cost of unfaithfully mapping the feature [anterior]. Candidate (30a) violates **Id-IO(-ant)** by unfaithfully mapping the feature [-ant] (ʃ → s). Candidate (30b) violates **Id-IO(+ant)**, because it maps the feature [+ant] unfaithfully (s → ʃ).

Since the winners always harmonize, they never violate **Id-HD(ant)**, which requires that the segments in correspondence have the same feature value [anterior].

Id-HD(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 (30a, b)

(30) Two winner candidates in Chumash

Input	Output	Id-IO(+sib)	Corr-HD(+sib)	Id-HD(ant)	Align(c-head, R)	Id-IO(c-head)	Id-IO(-ant)	Id-IO(+ant)
a. i**ʃ**-ti**ʃ**i-jep-u**s**	i**s**$_x$ti**s**$_x$ijep-u**(s)**$_x$						**	
b. **s**-api-**tʃ**^{h}-o-it	**ʃ**$_x$-api-**(tʃ**^{h}**)**$_x$-o-it							*

Correspondence is not the sole way to satisfy **Corr-HD(+sib)**. The correspondence constraint is violated only when a **[+sibilant]** segment is not in a correspondence domain. If a segment is [-sibilant], **Corr-HD(+sib)** is not violated, regardless of correspondence.

The winners in dissimilation languages are candidates that escape the correspondence requirement by unfaithfully mapping the correspondence feature. The losers in ERC 1 and 2 (31) map the non-rightmost sibilant to a [-sibilant] segment.[7] With respect to **Corr-HD(+sib)**, both candidates are as good as the winners, since correspondence is only required among sibilants, and the crucial segments are no longer sibilants in the output.

Dispensing with correspondence relations has several advantages. Id-HD constraints only favor harmony for segments in correspondence, so the feature [anterior] can be mapped faithfully without violating any faithfulness constraint. As shown in ERC 1 ∘ 2, then, **Id-IO(+sib)** has to be ranked above both constraints that refer to [anterior], since they are both violated by the winners.

Furthermore, since heads can only exist as part of a correspondence domain, no c-head or HD-Correspondence constraint is ever violated by the dissimilating candidates.

The loser candidates, however, do worse on the two Ident-IO constraints that refer to the feature [anterior], since harmony is achieved at the cost of unfaithfully mapping the harmonizing feature. As shown in the support for the skeletal basis further below in (36), there is a constraint in each ERC that dominates either **Ident-IO(-ant)** or **Ident-IO(+ant)**. For the sake of concisiveness, I will henceforth refer to such constraint as **F.harm**.

It was shown that dispensing with correspondence has its advantages in terms of constraint violations. In (32), the candidate with no correspondence does not violate **Corr-HD(+sib)**, because all sibilants except one are mapped to [-sibilant] segments.

(31) Dissimilation candidates in Chumash

ERC	Input	Winner	Loser	Id-IO(+sib)	Corr-HD(+sib)	Id-HD(ant)	Align(c-head, R)	Id-IO(c-head)	Id-IO(-ant)	Id-IO(+ant)
1	i**ʃ**-ti**ʃ**i-jep-u**s**	i**s**$_x$ti**s**$_x$ijep-u**(s)**$_x$	i**t**ti**t**ijep-u**s**	W					L	
2	**s**-api-**tʃ**^{h}-o-it	**ʃ**$_x$-api-**(tʃ**^{h}**)**$_x$-o-it	**t**-api-**tʃ**^{h}-o-it	W						L
Fusion 1 ∘ 2				W					L	L

The loser candidates in (32) contain outputs with disharmonic segments that are not in correspondence. However, unlike the losers in (31), the segments are mapped faithfully for the feature sibilants. The difference is that in (32), the sibilants do not correspond when they disagree in anteriority. Since the segments are [+sibilant] in the output, the absence of correspondence yields a fatal violation of **Corr-HD(+sib)**.

As in the case of dissimilation, the losers do not violate faithfulness constraints that refer to the feature [anterior], and so **Corr-HD(+sib)** has to be ranked above **F.harm** (ERC 3 ∘ 4).

Notice that only disharmonic sibilants do not correspond. In ERC 3, the two [+anterior] sibilants are already featurally identical in the input, and so they can be mapped faithfully, and correspond, without violating any constraint. The loser in ERC 3 actually harmonically bounds the segmentally identical candidates without correspondence.

[7] The dissimilation segment is simplified as [t] throughout the paper. An unfaithful segment [t] represents a segment that has only the correspondence feature unfaithfully mapped, but satisfies all other Ident-IO constraints.

(32) Candidates violating **Corr-HD(+sib)** in Chumash

ERC	Input	Winne*r*	Loser	**Id-IO(+sib)**	**Corr-HD(+sib)**	**Id-HD(ant)**	**Align(c-head, R)**	**Id-IO(c-head)**	**Id-IO(-ant)**
3	i**ʃ**-ti**ʃ**i-jep-u**s**	i**s**$_x$ti**s**$_x$ijep-u**(s)**$_x$	i**ʃ**$_x$ti**(ʃ)**$_x$ijep-u**s**$_y$		W				L
4	**s**-api-**tʃ^h**-o-it	**ʃ**$_x$-api-**(tʃ^h)**$_x$-o-it	**s**$_x$-api-**tʃ^h**$_y$-o-it		W				
Fusion 3 ∘ 4					**W**				**L**

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

In Chumash, the harmonizing feature is determined by the rightmost sibilant in the prosodic word, so it varies depending on the candidate. In the winner of the ERC 5 (33), the harmonizing feature is [+anterior], since all sibilants in correspondence are mapped to [s]. In the winner of the ERC 6, the harmonizing feature is [-anterior].

Since harmony causes both feature values to be mapped unfaithfully, **Id-HD(ant)** has to be ranked above **F.harm**, as shown by the ERCs 5 and 6 in (33).

(33) Surface identity in Chumash

ERC	Input	Winner	Loser	**Id-IO(+sib)**	**Corr-HD(+sib)**	**Id-HD(ant)**	**Align(c-head, R)**	**Id-IO(c-head)**	**Id-IO(-ant)**	**Id-IO(+ant)**
5	i**ʃ**-ti**ʃ**i-jep-u**s**	i**s**$_x$ti**s**$_x$ijep-u**(s)**$_x$	i**ʃ**$_x$ti**ʃ**$_x$ijep-u**(s)**$_x$			W			L	
6	**s**-api-**tʃ^h**-o-it	**ʃ**$_x$-api-**(tʃ^h)**$_x$-o-it	**s**$_x$-api-**(tʃ^h)**$_x$-o-it			W				L
ERC 5 ∘ 6						**W**			**L**	**L**

The ERCs in (34) show how directional harmony is obtained. As mentioned in the introduction, the selection of the head 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. Directionality is favored over dominancy because of the ranking **Align(c-head, R) ≫ F.harm**, which always favors right-aligned heads.

(34) Directional harmony in Chumash

ERC	Input	Winner	Loser	**Id-IO(+sib)**	**Corr-HD(+sib)**	**Id-HD(ant)**	**Align(c-head, R)**	**Id-IO(c-head)**	**Id-IO(-ant)**	**Id-IO(+ant)**
7	i**ʃ**-ti**ʃ**i-jep-u**s**	is$_x$ti**s**$_x$ijep-u**(s)**$_x$	i**ʃ**$_x$ti**(ʃ)**$_x$ijep-u**ʃ**$_x$				W		L	W
8	**s**-api-**tʃ**^{h}-o-it	**ʃ**$_x$-api-**(tʃ^h)**$_x$-o-it	**(s)**$_x$-api-**ts**$^h{}_x$-o-it				W		W	L
ERC 7 ∘ 8							**W**		**L**	**L**

In the loser candidate in ERC 9 (35), the head **(ʃ)** is unfaithfully mapped from an input sibilant [s], but is still right-aligned. The opposite mapping is shown in ERC 10, 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 **F.harm**, as well as **Id-IO(c-head)**.

(35) Ident-IO(c-head)

ERC	Input	Winner	Loser	**Id-IO(+sib)**	**Corr-HD(+sib)**	**Id-HD(ant)**	**Align(c-head, R)**	**Id-IO(c-head)**	**Id-IO(-ant)**	**Id-IO(+ant)**
9	i**ʃ**-ti**ʃ**i-jep-u**s**	is$_x$ti**s**$_x$ijep-u**(s)**$_x$	i**ʃ**$_x$ti**ʃ**$_x$ijep-u**(ʃ)**$_x$					W	L	W
10	**s**-api-**tʃ**^{h}-o-it	**ʃ**$_x$-api-**(tʃ^h)**$_x$-o-it	**s**$_x$-api-**(ts^h)**$_x$-o-it					W	W	L
ERC 9 ∘ 10								**W**	**L**	**L**

The support for the skeletal basis of Chumash harmony is given in (36). ERC 1 and 2 show that **Id-IO(+sib)** has to be ranked above the faithfulness constraints that refer to [anterior] to avoid dissimilation candidates winning.

To have harmony, the HD-Correspondence constraints **Corr-HD(+sib)** and **Id-HD(ant)** also have to be ranked above the faithfulness constraints that refer to [anterior] (ERCs 3–6).

ERCs 7 and 8 show how directional harmony is obtained. Because **Align(c-head, R) ≫ F.harm**, the head of the correspondence domain is always chosen as the rightmost sibilant in the word. Since **Id-IO(c-head)** is ranked above **F.harm**, the head surfaces faithfully, and causes the other sibilants in the domain to harmonize for its [anterior] feature value.

(36) Support for the skeletal basis

ERC	Input	Winner	Loser	**Id-IO(+sib)**	**Corr-HD(+sib)**	**Id-HD(ant)**	**Align(c-head, R)**	**Id-IO(c-head)**	**Id-IO(-ant)**	**Id-IO(+ant)**
1	i**ʃ**-ti**ʃ**i-jep-u**s**	i**s**$_x$ti**s**$_x$ijep-u**(s)**$_x$	i**t**ti**t**ijep-u**s**	W					L	
2	**s**-api-**tʃ**^{h}-o-it	ʃ$_x$-api-**(tʃ^h)**$_x$-o-it	**t**-api-**tʃ**^{h}-o-it	W						L
3	i**ʃ**-ti**ʃ**i-jep-u**s**	i**s**$_x$ti**s**$_x$ijep-u**(s)**$_x$	iʃ$_x$ti**(ʃ)**$_x$ijep-u**s**$_y$		W				L	
4	**s**-api-**tʃ**^{h}-o-it	ʃ$_x$-api-**(tʃ^h)**$_x$-o-it	s$_x$-api-**tʃ**$^h{}_y$-o-it		W					L
5	i**ʃ**-ti**ʃ**i-jep-u**s**	i**s**$_x$ti**s**$_x$ijep-u**(s)**$_x$	iʃ$_x$ti**ʃ**$_x$ijep-u**(s)**$_x$			W			L	
6	**s**-api-**tʃ**^{h}-o-it	ʃ$_x$-api-**(tʃ^h)**$_x$-o-it	s$_x$-api-**(tʃ^h)**$_x$-o-it			W				L
7	i**ʃ**-ti**ʃ**i-jep-u**s**	i**s**$_x$ti**s**$_x$ijep-u**(s)**$_x$	iʃ$_x$ti**(ʃ)**$_x$ijep-uʃ$_x$				W		L	W
8	**s**-api-**tʃ**^{h}-o-it	ʃ$_x$-api-**(tʃ^h)**$_x$-o-it	**(s)**$_x$-api-**ts**$^h{}_x$-o-it				W		W	L
9	i**ʃ**-ti**ʃ**i-jep-u**s**	i**s**$_x$ti**s**$_x$ijep-u**(s)**$_x$	iʃ$_x$ti**ʃ**$_x$ijep-u**(ʃ)**$_x$					W	L	W
10	**s**-api-**tʃ**^{h}-o-it	ʃ$_x$-api-**(tʃ^h)**$_x$-o-it	s$_x$-api-**(ts^h)**$_x$-o-it					W	W	L

As shown by the support, in Chumash, the two constraints in the class **F.harm** behave identically. The skeletal basis is obtained by fusing pair of ERCs that differs in that the dominated constraint is either **Ident-IO(-ant)** or **Ident-IO(+ant)**. In the simplified support in (37), the two constraints in **F** are merged into a single faithfulness constraint. The basic ranking information is more neatly summarized, showing all constraints dominating **F.ant**, and the support for each ranking.

(37) Simplified support

ERC	Input	Winner	Loser	**Id-IO(+sib)**	**Corr-HD(+sib)**	**Id-HD(ant)**	**Align(c-head, R)**	**Id-IO(c-head)**	**F.harm**	Comments
1	ʃ…s	s$_x$…**(s)**$_x$	t…s	W					L	No dissimilation
2	ʃ…s	s$_x$…**(s)**$_x$	**(ʃ)**$_x$…s$_y$		W				L	Correspondence
3	ʃ…s	s$_x$…**(s)**$_x$	ʃ$_x$…**(s)**$_x$			W			L	Agreement
4	ʃ…s	s$_x$…**(s)**$_x$	**(ʃ)**$_x$…ʃ$_x$				W		L	Directionality
5	ʃ…s	s$_x$…**(s)**$_x$	ʃ$_x$…**(ʃ)**$_x$					W	L	No Dominancy

2.2 Blocking in Basque Dominant Harmony

Some dialects of Basque distinguish three series of sibilants: the laminal [s̻, ts̻], the apical [s̺, ts̺], and the palatal [ʃ, tʃ]. Harmony only occurs between dental and the apical sibilants, so [ʃ] and [tʃ] do not participate in harmony. In these dialects, harmony is manifested as a co-occurrence restriction in roots, and via assimilation in compounds and loanword adaptation (39a, b). Basque has dominant harmony, so the harmonizing feature is always the apical coronals [s̺, ts̺] and never the laminal [s̻, ts̻].

As shown in the examples (38a), assimilation is independent of directionality, since it goes both from left to right (LtoR) and from right to left (RtoL), and independent of root-control, since assimilation only occurs within roots (38d). I refer to these dialects simply as Basque.

Many western dialects (e.g., Vizcaya, much of Guipu’zcoa) have lost the distinction between laminal and apical sibilants, and so in these varieties there is no visible effect of harmony (Trask, 1996). In other dialects, harmony is directional, rather than dominant: Isaba has /s̪as̻oi/ > /s̻as̻oi/, Vidangoz /s̪as̻oi/ > /s̻as̻oin/. The dialects without the laminal/apical distinction, and the dialects with directional harmony are not be discussed in this section.

Sibilant harmony in Basque interacts with a process of neutralization in complex clusters. Laminal sibilants are neutralized before another consonant, so that /s̻C/ always maps to [s̪C]. Neutralized sibilants do not cause other sibilants to harmonize. For example, the input /s̻is̻ku/ (38c) maps to the disharmonic [s̻is̪ku], and not to [s̪is̪ku]. This neutralization process is no longer active in the grammar of Basque (Hualde, p.c.) as demonstrated, for example, by the words [gus̪ti] “all” and [bes̪te] “other”, and the harmony only applies within the root (38d).

(38) Basque coronal harmony (data from Michelena, 1961; Trask, 1996; Falk, 2014)

a. Compounds

/s̻in-ets̪i/ → [s̪in-ets̪i] ‘believe’ c.f. /s̻in/ ‘truth’
/es̻-ets̪i/ → [es̪-ets̪i] ‘persist’ c.f. /es/ ‘no’, /ets̪i/ ‘consider’

b. Sound change and loanwords

frants̻es̪ > frants̪es̪ ‘French’ from Spanish *francés*
s̪ats̻uri > s̪ats̪uri ‘mole’
s̪as̻oi > s̪as̪oi(n) ‘flavor’

c. Laminal neutralization in disharmonic roots

/s̻is̻ku/ → [s̻is̪ku], *[s̪is̪ku] ‘bag’
espacio (sp.) > es̪pas̻io, *es̪pas̪io Spanish ‘space’

d. Affixes do not harmonize.

hotses̻ ‘noise *instrumental*’ c.f. hots ‘noise’
itsasos̻ ‘sea *instrumental*’ c.f. itsas ‘sea’
sarts̻e ‘enter *gerund*’ c.f. sar- ‘enter *stem*’

The parameters for Harmony in Basque are summarized below.

(39) Harmony in Basque

Harmony type	pure dominant
Domain	Root-only
Correspondence feature	[+sibilant]
Harmonizing feature	[distributed]
Comments	blocked by neutralization, only in roots

GEN and CON

The set of constraints used in the analysis is obtained from the template in (17). Because of the neutralization process, this set also includes the constraints ***s̻C**. It is possible that no such constraint exists in CON and that its effect is due to the interaction of other markedness constraints, or constraints that favor local assimilation.

An interesting possibility is that local assimilation is also governed by surface correspondence and identity (Shi and Inkelas, 2014). The analysis would be more complex, since the interaction of the two assimilation processes would involve two co-occurring harmonies. Since it is unclear at the moment whether local and long distance assimilation are governed by the same mechanism, and multiple harmonies are beyond the scope of this paper, I leave this issue aside, and assume that ***s̺C** thus stands for a set of markedness constraints that favors the mapping /s̺C/ → [s̻C] over /s̺C/ → [s̺C]. The actual definition of the constraint is the following:

(40) Definition of ***s̺C**:
Penalize s̺C clusters in the output
Assign a violation for each s̺C cluster in the output.

The other constraint used for Basque is **Edge-HD(root**), which is used to account for the fact that harmony only occurs within the root. The constraints appear in the ABC literature as **CC-Edge(*dom*)**, and prohibit correspondence between two segments that do not belong to the same morphological or prosodic domain (Bennett, 2014:73–80). In the analysis I use the constraint **Edge-HD(root)**, defined as follows:

(41) Definition of **Edge-HD(root**):
Penalize HD-correspondence across root boundaries
For each consonant X in the root, assign a violation if:
a. X is in correspondence with Y, &
b. Y is not in the root, &
c. X and Y are in the same morphological word

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 **Edge-HD(root**) is only violated by segments that correspond. Segments not in correspondence are ignored, no matter what their morphological position or their featural specification. The set of all constraints used in the analysis is summarized below.

(42) Constraint set CON$_{Basque}$
CON$_{HD\text{-}Corr}$
Corr-HD(+sib): "*Penalize [+sib] segments not in the same correspondence domain*"
Ident-HD(ant): "*Penalize correspondents with a different feature value [anterior]*"
Edge-HD(root): "*Penalize correspondence across morpheme boundaries*"
CON$_{c\text{-}head}$
Align(c-head, R): "*Penalize c-heads that are not aligned to the right edge of the prosodic word*"
Ident-IO(c-head): "*Penalize any unfaithful mapping of c-heads*"
CON$_{m/f}$
***s̺C**: "*Penalize s̺C clusters in the output"*
Ident-IO(+dist): "*Penalize any unfaithful mapping of the feature value [+distributed]*"
Ident-IO(-dist): "*Penalize any unfaithful mapping of the feature value [-distributed]*"
Ident-IO(+sib): "*Penalize any unfaithful mapping of the feature value [+sibilant]*"
Ident-IO(root): "*Penalize any unfaithful mapping of a segment in the root*"

Regarding GEN, the set of inputs consists of the forms further above in (38). The correspondence table contains three critical segments: the apical [s̺], the laminal [**s̻**], and the non-sibilant [t] for the dissimilation candidate.

In Basque, a sibilant preceding a consonant is neutralized for the apical/laminal distinction. Since this is a crucial aspect of the analysis, it is also important to consider non-sibilant consonants that follow sibilants, which indicate a neutralization context.

(43) GEN for Basque

a. Mapping rules

s̻	→	s̺, s̻, t
s̺	→	s̺, s̻, t
*	→	faithful

b. Others
All combinations of surface correspondence among sibilants
one-to-one I/O mapping only

Analysis

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 (DEE) /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 (44). In candidate (a), the output is harmonic, has all the sibilants in correspondence, and agrees on 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 their position. In candidate (a), the [-distributed] sibilant is aligned to the left of the word. Since, the head is not right-aligned, the candidate violates **Align(c-head, R)**.

Candidate (b) is not harmonic. A disharmonic candidate violates either **Corr-HD**, or **Ident-HD** constraint. If the segments with the correspondence feature do not correspond, they violate **Corr-HD**. Alternatively, the segments may correspond, but not agree. In this case, the candidate violates **Ident-HD**. In Chumash, disharmonic winners always violate **Corr-HD(+sib)**. Since the two sibilants do not correspond, no c-head or HD-Correspondence constraint is violated.

Finally, because it is adjacent to another consonant, the [+distributed] sibilant is mapped unfaithfully in this candidate as well, resulting in a violation **Id-IO(+dist)**.

(44) Violation tableau for the three winners in the support of Basque

Input	Output	**Id-HD(dist)**	***s̻C**	**Id-IO(-dist)**	**Id-IO(c-head)**	**Corr-HD(+sib)**	**Id-IO(+dist)**	**Align(c-head, R)**
a. s̺olas̻	(**s̺**)$_x$olas̺$_x$						*	*
b. s̻is̻ku	s̻$_x$is̺$_y$ku					*	*	
c. its̺$_x$a(**s̺**)$_x$os̻$_y$	its̺$_x$a(**s̺**)$_x$os̻$_y$					*		

The support in (45) shows the three strata of the grammar. In the bottom stratum are the constraints Id-IO(+dist) and Align(c-head, R). The former constraint is violated by the winners that exhibit harmony, since [-distributed] segments will be unfaithfully mapped to [+distributed] to achieve harmony. The ranking of Align(c-head, R) determines that directionality/alignment does not affect the selection of the harmonizing feature in Basque.

Corr-HD is ranked on the second stratum. Winning candidates with a disharmonic sibilant in an affix, and candidates with s̻C neutralization violates this constraint, since the disharmonic segments do not correspond in the output.

(45) Support for Basque SKIB

ERC	Input	Winner	Loser	CC-Edge(R)	*s̻C	Id-HD(dist)	Id-IO(+sib)	Id-IO(c-head)	Id-IO(-dist)	Corr-HD(sib)	Id-IO(+dist)	Al(C-Head, R)
2	its̺as̺o+s̻	its̺$_x$a**(**s̺**)**$_x$os̻$_y$	its̺$_x$as̺$_x$o**(**s̻**)**$_x$	**W**						**L**	**W**	
3	s̻is̺ku	s̻$_x$is̺$_y$ku	s̻$_x$i**(s̻)**$_x$ku		**W**					**L**	**L**	
4	s̻is̺ku	s̻$_x$is̺$_y$ku	s̻$_x$i**(s̺)**$_x$ku			**W**				**L**		**W**
5	s̻is̺ku	s̻$_x$is̺$_y$ku	s̻$_x$it$_y$ku				**W**			**L**	**L**	
6	s̻is̺ku	s̻$_x$is̺$_y$ku	s̺$_x$i**(s̺)**$_x$ku					**W**		**L**	**W**	
7	s̺olas̻	**(s̺)**$_x$olas̺$_x$	s̻$_x$ola**(**s̻**)**$_x$						**W**		**L**	**L**
8	s̺olas̻	**(s̺)**$_x$olas̺$_x$	s̺$_x$olas̻$_y$							**W**	**L**	**L**

In the analysis, I will start with the harmonic candidate, and then proceed to illustrate the cases of blocking.

ERC 7 shows that the dominant feature in Basque harmony is [-distributed], since Id-IO(-dist) ≫ Id-IO(+dist), and that harmony is dominant. Both the loser and the winner candidates are harmonic. However, in the winner the head is on the segment with the dominant feature, while in the loser the head is right-aligned.

ERC 7 shows the contrast between right-alignment and dominancy. Languages like Chumash always prefer the candidate with the right-aligned head, while in Basque the winner has the head assigned to a dominant segment. In the case of Basque, the crucial condition illustrated by ERC 7 is that Id-IO(-dist) dominates Align(c-head, R).

To have some harmony in a grammar, a correspondence constraint must dominate at least one Ident-IO constraint that refers to a harmonizing feature. In Basque, this ranking is Corr-HD(sib) ≫ Ident-IO(+dist).

In Basque grammar unfaithfully mapping the recessive feature is better than having the two sibilants not in correspondence. For the reason explained in the previous paragraph, having harmony means that Align(c-head, R) is also violated in the winning candidate.

Id-HD(dist), Id-IO(c-head), and Id-IO(-sib) also dominates Ident-IO(-dist), as shown in (46). This ranking information is not directly visible in the support, but it can be derived from transitivity. ERCs (4–6) show that Id-HD(dist), Id-IO(c-head), and Id-IO(-sib) ≫ Corr-HD(+dist). In ERC (8), Corr-HD(+sib) ≫ Id-IO(+dist). Because of transitivity (see ERC entailment in Brasoveanu and Prince, 2005), Corr-HD(+dist). In ERC 8, Corr-HD(+sib) also dominates Id-IO(+dist).

(46) Extracted CT from the support

ERC	Input	Winner	Loser	CC-Edge(R)	*s̺C	Id-HD(dist)	Id-IO(+sib)	Id-IO(c-head)	Id-IO(-dist)	Corr-HD(sib)	Id-IO(+dist)	Al(C-Head, R)
4	s̺is̺ku	s̺$_x$is̺$_y$ku	s̺$_x$**i(s̺)**$_x$ku			**W**				**L**		W
5	s̺is̺ku	s̺$_x$is̺$_y$ku	s̺$_x$it$_y$ku				**W**			**L**	L	
6	s̺is̺ku	s̺$_x$is̺$_y$ku	s̺$_x$**i(s̺)**$_x$ku					**W**		**L**	W	
8	s̺olas̺	**(s̺)**$_x$olas̺$_x$	s̺$_x$olas̺$_y$							**W**	**L**	**L**

The interaction between neutralization and harmony can be observed in the mapping /s̺is̺ku/ → [s̺$_x$is̺$_y$ku]. The winning candidate does not harmonize, and the loser of ERC 3 faithfully maps the input. Since the two sibilants are identical, they correspond and harmonize. However, faithfully mapping the cluster [s̺k] fatally violates ***s̺C**, so the candidate with the unfaithful mapping of /s̺/ and no correspondence wins.

(47) Blocking

ERC	Input	Winner	Loser	CC-Edge(R)	*s̺C	Id-HD(dist)	Id-IO(+sib)	Id-IO(c-head)	Id-IO(-dist)	Corr-HD(sib)	Id-IO(+dist)	Al(C-Head, R)
3	s̺is̺ku	s̺$_x$is̺$_y$ku	s̺$_x$**i(s̺)**$_x$ku		**W**					**L**	L	
4	s̺is̺ku	s̺$_x$is̺$_y$ku	s̺$_x$**i(s̺)**$_x$ku			**W**				**L**		W
5	s̺is̺ku	s̺$_x$is̺$_y$ku	s̺$_x$it$_y$ku				**W**			**L**	L	
6	s̺is̺ku	s̺$_x$is̺$_y$ku	s̺$_x$**i(s̺)**$_x$ku					**W**		**L**	W	
8	s̺olas̺	**(s̺)**$_x$olas̺$_x$	s̺$_x$olas̺$_y$							**W**	**L**	**L**

ERCs 4 and 5 contain the candidates with dissimilation and disharmony with correspondence. The crucial ERC is 6. ABC constraints alone cannot capture the interaction between harmony and neutralization, as shown in Falk (2014). This impossibility is due to the contradictory interaction between Ident-IO and Ident-HD constraints illustrated in (48). **Ident-CC** has to be ranked above **Ident-IO[-dental]** in order to have assimilation (48e), while at the same time it must be ranked lower than the same **Ident-IO(-dental)** to avoid overapplication in neutralized forms (48b).

The loser of ERC 6 wins in ABC, since there is no constraint to rule it out. An input such as /s̺is̺ku/ can either harmonize for [-distributed] or for [+distributed]. In Basque, such an input cannot harmonize for [+distributed], because the second sibilants always neutralize to [-distributed], and would thus violate ***s̺C** (ERC 3).

In HABC (i.e. Headed ABC), the second option—which would be the winner in the ABC system—is also ruled out. All segments in correspondence must be headed, so harmonizing for [+distributed] violates **Id-IO(c-head)**, since the head is mapped unfaithfully.

(48) Basque with no heads (adapted from Falk, 2014)

Winner	Losers	***s̪C**	**Corr(sib)**	**Id-IO(-dist)**	**Id-CC**	**Id-IO(+dist)**
s̪is̪ku → s̪$_x$is$_x$ku	a. **s̪**$_x$i**s**$_y$ku		W		L	
	b. **s̪**$_x$i**s̪**$_x$ku	W		W	L	
	c. **s**$_x$i**s**$_x$ku				L	W
s̪olas̪	d. s̪$_x$olas̪$_y$		W			L
	e. s̪$_x$olas̪$_x$				W	L
	f. s̪$_x$olas̪$_x$			W		L

This analysis predicts that an input with a non-neutralized [-distributed] sibilant causes other sibilants to harmonize. For example, the input /s̪…s̪…s̪k/ maps to [**(s̪)**$_x$…s̪$_x$…s̪$_x$k]. Since there is a [-distributed] sibilant in the input, it can be the head and thus causes the second sibilant to harmonize. The third sibilant neutralizes, and since all other sibilants are [-distributed], it corresponds and harmonizes with them. Unfortunately, I could not find any such word in the Basque lexicon "Lexikoa Atzo eta Gaur"[8].

The last issue that is still left unaddressed is the fact that suffixes do not harmonize with the root. The instrumental suffix /-s̪/ 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+s̪/ maps faihtfully to [its̪a s̪os̪], and not to *[its̪as̪os̪] or *[its̪as̪os̪]. This phenomenon has little to do with headedness, and is explained by the presence of an undominated **Edge-HD(root)** constraint that penalizes correspondence across a root boundary.

Candidates (49a–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 **Edge-HD(root)**. The only way to avoid the final dental from being a head is to not have the segment in correspondence, as shown in (49c).

(49) Domain restriction in Basque

ERC	Input	Winner	Loser	**CC-Edge(R)**	***s̪C**	**Id-HD(dist)**	**Id-IO(+sib)**	**Id-IO(c-head)**	**Id-IO(-dist)**	**Corr-HD(sib)**	**Id-IO(+dist)**	**Al(C-Head, R)**
2	its̪as̪o+s̪	its̪$_x$a**(s̪)**$_x$os̪$_y$	its̪$_x$as̪$_x$o**(s̪)**$_x$	**W**						**L**	**W**	
8	s̪olas̪	**(s̪)**$_x$olas̪$_x$	s̪$_x$olas̪$_y$							**W**	**L**	**L**

[8] The digitalized version of the lexicon was kindly provided by J. Falk.

3 Typology

3.1 Formal Typology

Assumptions

In this section, I will show the basic predictions the theory make by using a simplified, abstract model of a consonant harmony system. The parameters of the harmony used for the typology are listed below. The typology can indeed be extended to other harmonies by changing the parameters. For example, the typology of retroflex harmonies in coronal is simply obtained by replacing the relevant parameters in the model.

(50) Parameters for the typology

Correspondence feature	[+sibilant]
Harmonizing feature	[anterior]
Domain	unbounded

The simplifications and the assumptions are listed in (51). The first simplification concerns the length of the mappings and the number of harmonies (correspondence domains) possible in an output. I only use candidates composed by a two segments, with a single correspondence domain. Systems with more than one harmony are beyond the scope this paper, as they would depend on a careful examination of the empirical data, which in the domain of consonant harmony is scarce with respect to interacting harmonies.

(51) Domain and simplifications for the typology

Module	**Domain**	**Alternatives**
GEN	2 segments	2 > segments
GEN – Harmony	One harmony	Multiple harmonies
GEN – Morph	Root	Prefix(es), Suffixes, suffix(es) + prefix(es)
CON	Ident-IO(-ant) ⋙ Ident-IO (+ant)	Only Ident-IO(-ant), free ranking, stringency
CON	Align(c-head, R)	Align(c-head, R) and Align(c-head, L)

In the candidate sets, I also do not include any morphological or prosodic position effect. The selection of harmonizing feature is in some cases determined by a specific morphological or prosodic position. In particular, directionality in many cases of harmony is root to affixes. The simplification, however, is not unjustified, and the results are still significant for the following reasons.

First, root-control effects are obtained in HABC on the basis of the interaction of **Ident-IO(root)** with the constraint set discussed in this paper, the theory remains exactly the same.

Second, even in root-control harmonies there is a sub-system where the conflict between directional and dominant harmony has to be resolved. If a root is disharmonic in the input, a choice has to be made within the root itself to determine which feature value is the harmonizing one. This choice is determined by either dominancy, alignment to an edge, or both.

Third, the resulting typology includes all the harmony types already generated in the simplified typology. In other words, the typology that includes root-control effects is just an extension of the one discussed in the paper.

For these reasons, in the empirical survey I still indicate whether a harmony has root-control effect, although such effects are not captured by the formal typology.

The last two items in (51) are assumptions. The first assumption reflects the generalization that in consonant harmony the harmonizing feature is always marked in dominant harmony, and always on the rightmost segment in directional harmonies. The fixed ranking relation between the **Ident-IO(-ant)** and

Ident-IO(+ant) accounts for the former generalization, while the absence of a constraint **Align(c-head, L)** accounts for the latter. The discussion concerning why stringency or a model with only **Ident-IO(-ant)** do not make the right typological predictions, and concerning the empirical evidence for these generalization would require an extensive discussion and an analysis of the empirical typology which cannot be included in this paper.

As for the other simplifications, though, these assumptions do not significantly change the structure of the typology. The language types discussed still belong to the typologies that include the two Ident-IO constraints freely ranked, and both **Align(c-head, R)** and **Align(c-head, L)**.

To conclude, while important simplifications have been made for expository reasons, none of them significantly affects the typology of basic harmony types generated by the theory.

GEN and CON

A complete characterization of the candidates is provided in (52).

(52) GEN

a. inputs
   [s, ʃ, t…s, ʃ, t]

b. Mappings
   ʃ → s, ʃ, t
   s → s, ʃ, t
   * → faithful

c. Other
   All combinations of surface correspondence among sibilants
   one-to-one I/O mapping only

The input and the output consist of two segments with the correspondence feature [s, ʃ], and a non-correspondence segment [t]. Vowels are irrelevant, and they are thus always indicated as [a]. The structure of the input is /CVCV/.

The output follows the same format used in §3. It may contain one and only one head, the indices indicate correspondence, and it contains the same set of segment [s, ʃ, t] included in the input. For example, the algorithm generates the following candidate: /ʃasa/ → [$\mathbf{s}_x$a$\mathbf{(s)}_x$a].

There is no deletion or epenthesis in the candidates, and so the input and the output always contains six segments (2 consonants and 2 vowels).

Unlike the previous characterizations, the input in this set has also been generated. The input contains the same set of segments of the output, but no correspondence indices or heads. The number of candidates generated is 5839.

The constraint set used is $\text{CON}_{\text{sib-ant}}$, which includes the same constraints used in the analysis of Chumash. The list of constraints is reproduced below.

(53) Constraint set $\text{CON}_{\text{sib-ant}}$

$\text{CON}_{\text{HD-Corr}}$

Corr-HD(+sib)/Corr: "*Penalize [+sib] segments not in the same correspondence domain*"
Ident-HD(ant)/m.HD: "*Penalize correspondents with a different feature value [anterior]*"

$\text{CON}_{\text{c-head}}$

Align(c-head, R)/Align: "*Penalize c-heads not aligned to the right edge of the prosodic word*"
Ident-IO(c-head)/f.HD: "*Penalize any unfaithful mapping of c-heads*"

CON$_{m/f}$

Ident-IO(+sib)/f.+sib: “*Penalize any unfaithful mapping of the feature value [+sibilant]*”
Ident-IO(+anterior)/f.+ant: “*Penalize any unfaithful mapping of the feature value [+anterior]*”
Ident-IO(-anterior)/f.-ant: “*Penalize any unfaithful mapping of the feature value [–anterior]*”

The Typology

The list of six language types generated by the typology is given in (54). Since in this section I survey the empirical attestation of grammars, phonetically identical languages are considered to be of the same type. For example, the same of mappings in the Faith.noCor and Faith.Cor grammars are phonetically identical: they always map input faithfully. The only difference between the two languages is whether the segments in the outputs are in correspondence or not.

Unlike in ABC, this difference is relevant in HABC because segments in correspondence are also headed, so they can interact with other constraints. Nevertheless, since there is no acoustic phonetic realization of headedness or of correspondence, languages with the same segmental mapping are merged together in this section, and considered as a single grammar.

(54) Language types in the OT typology

Inputs →	*ʃasa*	*saʃa*	*Language description*	*Possibly attested in...*
Dom.Hright	**(ʃ)**$_x$aʃ$_x$a	ʃ$_x$a**(ʃ)**$_x$a	**Dominant harmony.**	Malto, Basque (Moroccan Arabic)
Dom.Hfaith	ʃ$_x$a(ʃ)$_x$a	ʃ$_x$a**(ʃ)**$_x$a	Harmonize to the marked segment	
Pure Dir	s$_x$a**(s)**$_x$a	ʃ$_x$a**(ʃ)**$_x$a	**Direction harmony.** Harmonize to the rightmost segment	Tsilhqot’in, Chumash, Saisiyat, Thao
Dom-Dir.noCor	ʃ$_x$as$_y$a	ʃ$_x$a**(ʃ)**$_x$a	**Dominant-Directional harmony.**	Ngizim, Pengo, Kera
Dom-Dir.Cor	ʃ$_x$a**(s)**$_x$a	ʃ$_x$a**(ʃ)**$_x$a	Harm. only if rightmost segment is dominant	
Diss-Dir	ʃ$_x$at$_y$a - t$_x$as$_y$a	ʃ$_x$a**(ʃ)**$_x$a	**Dominant-Directional dissimilation.** If rightmost marked harmony, diss. otherwise	(Javanese)/unattested?
Diss.	ʃ$_x$at$_y$a - t$_x$as$_y$a	ʃ$_x$at$_y$ - t$_x$as$_y$a	**Dissimilation** Dissimilation for disharmonic inputs	Chol
Faith.noCor	ʃ$_x$as$_y$a	s$_X$aʃ$_y$a	**Faithful** No harmony or dissimilation	All languages
Faith.Cor	ʃ$_x$a**(s)**$_x$a	s$_x$a**(ʃ)**$_x$a		

The list of all rankings, and the analysis of the structure of the typology, and the code used to generate the typology can be found in the supplement to this work.

3.2 Empirical Survey

In this section I review the empirical attestation of the types generated by the typology. The focus will be 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 for reasons of space.

Dominant harmony

While in many variety of Arabic, sibilant assimilation is directional, in Moroccan harmony, it is argued to be pure-dominant (55). Heat (1987) provides the following data:

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

Classical Arabic	**Moroccan**	
a. zadʒ-[9]	ʒaʒ	'glass'
b. zulajdʒ-	ʒlliʒ	'tiles'
c. sardʒ-	ʃrʒ	'saddle'
d. ʃams-	ʃomʃ	'sun'

Another example of a **pure dominant harmony** is Basque, discussed in §3.2. In Basque, coronal harmony manifests itself as 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/.

The examples in (56) show that the assimilation target is independent of directionality, since it goes from LtoR. It is also independent of root-control, since the assimilation also occurs within roots, as also seen in (56).

(56) Basque coronal harmony

a. /sin-ets̺i/ →	[s̺in-ets̺i]	'believe'	c.f. /sin/ 'truth'
b. /es-ets̺i/ →	[es̺-ets̺i]	'persist'	c.f. /es/ 'no', /ets̺i/ 'consider'
c. /frantses̺/ >	/frants̺es̺/	'French'	from Spanish *francés*
d. /s̺atsuri/ >	/s̺ats̺uri/	'mole'	
e. /s̺asoi/ >	/s̺as̺oi(n)/	'flavor'	

In some Mayan languages, harmony interacts with other processes of vowel lowering and debuccalization (Hansson 2010:88-94). For example, in Tlachichilco Tepehua, dorsalized /p, t/ harmonizes with uvular /q, q'/ (e.g., /q'ut-ɬi/ → [ʔoq-ɬi]).

The harmony is purely dominant, since it is root-internal and from LtoR. In Misantla Totonac harmony is predominantly RtoL, and from root to prefix. However, Watters (1998) notes two exceptions: /ʔaq-lukut/ → [ʔaq-qloquti] 'horn', c.f. /ʔaq-/ 'head' and /lukut/ 'bone'; and [ʔaqlaqawaːnan] from /lakaw/ 'dream'. The exceptions are sporadic, but they cannot be derived from directionality, since the target is the leftmost sibilant, nor can it be derived from root-orientedness, since the uvular is in a prefix.

In Kera, the prefix /ka/ is realized as [ga] if there is a voiced segment in the root. This harmony is more precisely of type **dom-root** (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 and suffixes. Similarly, several Coptic dialects (Sahidic, Akhminic, Assiutic) underwent a sound change where /s/ > /ʃ/, via assimilation to tautomorphemic /ʃ, tʃ/.

(57) 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 (plur.)'
kə-kamma-w	'chief (plur.)'
gə-daːrə	'friend'
gə-dajka-w	'jug (plur.)'

[9] Leston Buell (p.c.) pointed out to me that the Classical Arabic for is zuʒaaʒ, so Moroccan Arabic probably comes through an intermediary stage: zuʒ.

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 ***dom-root*** type. A sonorant in a suffix becomes a nasal if there is a nasal at a certain distance in the root. As in Yaka, harmony is always obtained via nasalization, the only exception being Tiene. Some languages, however, such as Kukuya and Baasa, show alternations and agreement independently of morphological constituency (pure dominant harmony). 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.

Directional

An example of pure directional harmony is Chumash, discussed in §3.1.

(58) RtoL Sibilant harmony in Chumash (data from Applegate 1972)

/s-api-tʃʰ-o-it/	→	[ʃ-api-**tʃʰ**-o-it]	‘I have a stroke of good luck’
/s-api-tʃʰ-o-us/	→	[s-api-sʰ-o-**us**]	‘He has a stroke of good luck’

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 show 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; Hansson, 2010). The two alveolar sibilant series harmonize for [RTR], and the harmonizing feature is determined by the rightmost segment in the word, as in (59).

(59) Tsilhqot’in [RTR] harmony

/łæ jɛ-tɛ-sˤɛ-ʁæ-id-jɛz/	→	[łæ jɛtɛʰ**z**{ʌʁɑ}d͡ʒɛ**z**]
/łæ næ#tɛ-sˤɛ-ʁæ-id-l-k'ɛs/	→	[łæ næ#tɛʰ**z**{ʌʁɑ}lk'ɛ**s**]

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 (60). In (60a) 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 **dom-dir** (see below).

(60) Directional harmony in Rwanda

a. Root harmony

/ba-ra-saː**z-j**e/	→	[bara**ʂ**aː**ʐ**e]	‘they are old’
/a-sa**s-j**e/	→	[a**ʂ**a**ʂ**e]	‘he just made the bed’
/a-soko**z-j**e/	→	[a**ʂ**oko**ʐ**e]	‘he just combed’

b. Suffix to root harmony

/ku-sas-iːʂ-a/	→	[ku-**ʂ**a**ʂ**iː**ʂ**a]	'to cause to make the bed'
/ku-saːz-iː**ʂ**-a/	→	[ku-**ʂ**aː**ʐ**iː**ʂ**a]	'to cause to get old'
/ku-uzaz-iː**ʂ**-a/	→	[ku-u**ʐ**a**ʐ**iː**ʂ**a]	'to cause to fill'

Both Sarece (61) and Navajo (62) have directional harmony, with the harmonizing feature determined by the rightmost sibilant in the root. Wiyot (Algic; Teeter, 1959, 1964) and Rumsen (Costanoan; Garrett, 1999) are also argued to have directional harmony, although from left to right.

(61) Sibilant harmony in Sarcee

/si-tʃiz-aʔ/	→	[**ʃ**it**ʃ**idza]	'my duck'
/si-tʃogo/	→	[**ʃ**it**ʃ**ogo]	'my flank'
/na-s-ɣatʃ/	→	[na**ʃ**ɣa**tʃ**]	'I killed them again'

(62) Sibilant harmony in Navajo (data from McDonough, 1991)

/j-iʃ-mas/	→	[j-i**s**-ma**s**]	'I am rolling along'
/ʃ-is-na/	→	[**s**-i**s**-na]	'he carried me'
/si-d͡ʒeːʔ/	→	[**ʃ**i-**d͡ʒ**eːʔ]	'they lie (slender stiff objects)'
/dʒ-i-zda/	→	[**dz**i**z**da]	'he sat down'
/dz-isʃ-l-haːl/	→	[**dʒ**i**ʃ**haːl]	'I tumble into water'

Dominant-directional

In **dom-dir** 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.

(63) Kera coronal harmony

a. tutʃi ~ tʃutʃi	'tamarind'	
b. tʃe tʃerke	'backbone'	c.f. Tupuri /titʃere/

In Baasa, the velar stop /k/ nasalizes if the previous consonant is a nasal. There is no mention of the segments being in a different morphological domain. Rather, segment adjacency is the only factor involved.

Another **dom-dir** language is Pengo. In Pengo, coronals harmonize for [distr_release], for example /t…tʃ/ → [tʃ…tʃ] (64). However, as in the case of Kera and Aymara, harmony is blocked if [+distr_release] coronal is not the rightmost segment in the correspondence domain. 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 (64).

(64) Dominant coronal harmony in Pengo (data from Burrow and Bhattacharya, 1970)

a. titʃ ~ tʃitʃ	'to eat (past stem)'	
b. toːtʃ ~ tʃoːtʃ	'to show'	
c. taːnd͡ʒ~ tʃaːnd͡ʒ	'to appear'	
e. tʃeta man	'to be awake'	*tʃetʃa man
f. d͡ʒaːti	'castle'	*dʒaːtʃi

Non-harmonic types

In addition to three types of harmony, there are several grammars with non-harmonic candidates. As in ABC, the typology of HABC 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. Notice that what (H)ABC predicts in these grammar is not the common type of dissimilation where segments that share a particular set of features dissimilate. Dissimilation only occurs if a pair of segments shares a certain set of features *and* these segments are not identical. If the two segments are identical in the input, they are mapped faithfully. Since c-heads only appear in outputs with at least some correspondence, dissimilation is not discussed in this paper.

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 domain 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 due to the fact that the conditions for such a grammar to come about are very unlikely to occur in a language.

Domain restrictions

Harmony can be thought of as composed of two interacting mechanisms. One determines which segments are in correspondence, while the other determines the harmonizing feature of harmony. The first component is mainly governed by HD-Correspondence, while the latter is the predominantly the locus of c-head constraints.

The generalizations and the properties discussed in this section apply to the harmonizing feature component and should not be confounded with other correspondence effect, 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).

(65) Rwanda domain restriction (Mpiranya and Walker, 2005, cited in Bennett, 2014:78)

/ku-**s**a**s**-ii**ş**-a/	→	[gu<ş**a**şii**ş**a>]	'to cause to make the bed'
/zi-**s**aa**ş**-e/	→	[zi<**ş**aa**ş**a>]	'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 and 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.

4 Conclusions

When a set of segments participate in a harmonic process, there is one segment in the set that determines the harmonizing feature of the domain. My proposal uses the concept of headedness as an explanation of such effect and argues that directionality is the result of the interaction of well-studied concepts in phonological theory (headedness, generalized alignment, and positional faithfulness constraints), rather than an effect of targeted constraints or of special mechanisms specifically dedicated to it.

The theory generates the basic types of directional and dominant harmony, exemplified in the analysis of Chumash §2 and Basque §3. The theory also generates a grammar that is a combination of dominant and directional harmony, which is attested but was previously unanalyzed, and an unattested grammar that has both dissimilation and dominant-directional harmony.

The analysis of Basque in §3 also shows that headedness has an effect not directly related to directionality. Faithfulness to a head can create DEE that blocks harmony in neutralization context.

There are three additional issues that are closely related to HD-Correspondence and directionality, but that could not be investigated here because they are not essential to the illustration of the theory.

A property of HD-Correspondence is the reduction of the complexity and the number of constraints necessary to account for directionality types. As a consequence, only certain aspects of directionality are captured by c-head constraints. The most notable case concerns root-control harmonies. There is no c-head constraint in the theory that refers to any privileged morphological position. Instead, root-control effects are due to the effect of **Ident-IO(root)**. Including root-control effects on the typology introduces several empirical complications that could not be discussed in this paper. Nonetheless, the effects of **Ident-IO(root)** on the typology of HD-Correspondence are of great relevance for the theory.

Similarly, in §3.2, it was mentioned that in dominant harmony, the harmonizing feature is always the marked feature value, a property which is reflected in the factorial typology in §3.1. However, no c-head constraint is responsible for such typological asymmetry. The markedness effect is captured by ranking restrictions on standard Ident-IO constraints. Whether such asymmetry is an actual property of the grammar and what the markedness theories are that can account for it are questions that are relevant for both consonant harmony and markedness theory.

The last issue concerns the definition of the formal properties of Surface Correspondence and of HD-Correspondence constraints. It can be shown that HD-Correspondence has the same formal properties of the other classic correspondence relations (IO, BR, IR) and that it shares the same constraint schemata. The new definition of Surface Correspondence thus opens the possibility that there might be just one kind of correspondence relation in the grammar, with a single set of formal properties and constraints; a fascinating hypothesis, indeed, which has yet to be fully investigated.

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