

Consonantal Correspondence

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Abstract

This paper examines patterns of voicing agreement between consonants (Cs) at a distance. I argue that the agreement stems from a correspondence relation between similar Cs in the output, a relation with foundation in mechanisms of production processing. The occurrence of long distance voicing interactions is predicted under this approach. The account also brings explanation to an observed similarity effect whereby the agreement preferentially targets pairs of near-identical (or identical) Cs.

1. Introduction

This paper addresses the problem of long distance voicing agreement between consonants (Cs). Two related patterns are discussed:

- (1) i. Ngbaka: [voice] agreement is limited to homorganic stops.
- ii. Kera: [voice] agreement holds between homorganic and heterorganic stops.

In the voicing agreement of these languages, the interacting segments can occur at any distance in the morpheme or word. I propose to analyze these phenomena as arising through a correspondence relation (McCarthy & Prince 1995) that is established between similar Cs in the output. I argue that the relation has a basis in production processing, and agreement between similar Cs represents a kind of optimization of processing ease. The approach developed here brings explanation to two key aspects of the voicing agreement: (i) the possibility of long distance interaction between Cs, and (ii) the preference for voicing agreement to occur between similar stops.

The analysis is framed in Optimality Theory (OT; Prince & Smolensky 1993). The paper is organized as follows. In §2 I outline the voicing agreement data. In §3 I discuss theoretical background regarding locality in segmental interactions. Two main sources of interactions are identified: feature spreading and segmental correspondence. The latter is noted to correlate with the possibility of nonadjacency, as seen in the [voice] agreement. In §4 I develop a correspondence-based account of [voice] agreement. In §5 I present the conclusion and an issue for further research.

2. The Phenomenon of Long-Distance Voicing Agreement

Some languages exhibit an agreement for the feature [\pm voice] between segments at a distance. An example occurs in Ngbaka, a Niger-Congo language described by Thomas (1963) and discussed by Mester (1986). Ngbaka displays a distributional restriction whereby morphemes containing homorganic oral stops that differ in voicing are prohibited. However, identical stops are compatible, in other words, stops matching in place must also agree in voicing (2a). If a stop pair is heterorganic, a voicing mismatch is permitted (2b).¹

- (2) a. Homorganic stops must agree in voicing.

títa	‘grandparent’	*tída, *díta
pépu	‘vent’	*pébu, *bépu
babã	‘companion’	*bapã, *pabã
- b. Heterorganic stops may disagree in voicing.

bata	‘three’	
kébe	‘fast’	
duka	‘shoulder’	
gôtô	no gloss	

An interesting property of the above cases is that the Cs agreeing in [voice] specification can occur

at a distance, for instance, they can be separated by a vowel (V) which neither triggers voicing agreement nor is affected by voicing agreement across it.

A similar kind of pattern is seen in Kera, a Chadic language. Ebert (1979: 9) reports that Kera prohibits a mix of voiced and voiceless stops/affricates in a word (see also Odden 1994: 304). To avoid such combinations, a root containing a voiced oral stop/affricate induces voicing in voiceless affix stops, as illustrated in (3a). The data in (3b) show that these affix stops are voiceless elsewhere. Observe that the voicing agreement in (3a) can take place across a sonorant C. However, sonorant Cs do not themselves induce the voiced affix alternant (3b). As in Ngbaka, Vs can also intervene and are inert with respect to the voicing agreement. In these data the prefix V is epenthetic; alternations in its quality are the result of a vowel harmony. The data in (3c) show that the voicing agreement does not hold between fricatives and stops.

- (3) a. Voiced affix stop when root contains voiced noncontinuant obstruent
- | | | | |
|--------------|---|---------------|-------------------------|
| kV-dàarə | → | [gə̀dàarə] | ‘friend’ |
| kV-d̄ʒàr-káŋ | → | [gə̀d̄ʒàrgáŋ] | ‘colorful’ (collective) |
| d̄ʒàr-ká | → | [d̄ʒàrgá] | ‘colorful’ (fem.) |
| kV-dàjǵa-w | → | [gə̀dàjǵáw] | ‘jug’ (plural) |
- b. Voiceless stop in these affixes elsewhere
- | | | | |
|------------|---|-------------|------------------------|
| kV-kámná-w | → | [kəkámnáw] | ‘chief’ (plural) |
| kV-taata-w | → | [kə̀taataw] | ‘cooking pot’ (plural) |
| kV-màanə | → | [kə̀màanə] | ‘woman’ |
| kV-sár-káŋ | → | [kəsárkáŋ] | ‘black’ (collective) |
| sár-ká | → | [sárká] | ‘black’ (fem.) |
- c. Fricatives and stops may disagree in voicing
- | | |
|---------|----------|
| [fèrgé] | No gloss |
| [dèfé] | No gloss |

Additional examples of this general type involving a range of laryngeal features are found in Aymara dialects. MacEachern (1997) discusses cooccurrence restrictions in Aymara that prohibit similar but different laryngeal properties in segments matching in place. However, homorganic segments that are identical in laryngeal properties are permitted.

The above patterns present instances of long distance interactions between segments with respect to the feature [voice]. They share a similarity effect, that is, the agreement preferentially targets pairs of near-identical (or identical) Cs. The interactions are long distance in the sense that the agreeing segments are not root-adjacent. In addition, intervening segments that are voiced or voiceless can occur without triggering or blocking voicing agreement. These segments are phonetically voiced or voiceless and can also be phonologically specified for [voice] (though under certain underspecification approaches, [voice] might be posited to be absent in some of the segments).

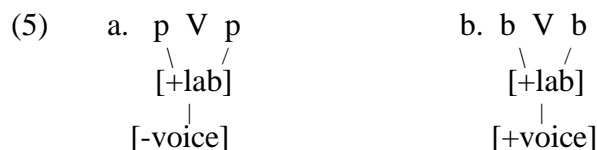
3. Theoretical Background: Locality, Spreading, and Segmental Correspondence

I turn now to some theoretical issues surrounding long distance agreement. The data in §2 call attention to two important and related questions confronting the theory of segmental phonology:

- (4) i. At what distance can segments interact with respect to their featural properties?
 ii. Is the locality of segmental interaction connected with the type of phenomenon involved (i.e. the constraints driving the interaction)?

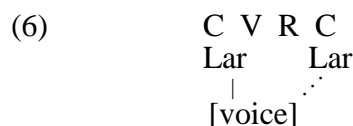
I deal with these questions in turn below. The first has received considerable attention, both in generative phonology and in the constraint-based framework of OT. Nonlinear representations formed the basis for a major approach which I will refer to as *tier-based locality*. Research in this line obtains different distances of interactions via elaborated feature-geometric structure and underspecification (see Clements & Hume 1995, Steriade 1995, and references contained therein).

A central assumption is that locality is relativized to adjacency on a tier so that linkage for the feature [voice] (and other features) may hold across intervening segments that are not specified for this feature or its dominating node. For example, Mester (1986: 42) proposes a dependent tier ordering for Ngbaka Cs as in (5). In this structure, [voice] is dependent on the primary articulator tier in order to capture the restriction of voice identity to homorganic Cs.²



The above represents what is commonly referred to as a “gapped” configuration: the links of a feature gap across an intervening segment of which it is not an associated property. In tier-based locality, features may be linked between segments at a distance provided that no other feature specification on that tier intervenes, as enforced by the No Crossing Constraint, which bans line crossing within a plane (Goldsmith 1976). In (5), there is gapping across the V because it is not specified for a consonantal place feature and it is underspecified (or unspecified) for [voice].

Tier-based locality is also assumed in the account that Odden (1994: 304) proposes for Kera: [voice] spreads between obstruent stops across a string of intervening and unaffected segments. Reconstructing from his discussion, the representation is close to that in (6):



While tier-based locality represented an important progression in the investigation of locality, this research direction did not eventually live up to its promise. Subsequent research has revealed that many feature spreading phenomena that were previously believed to be instances of action-at-a-distance in fact represent more local interactions. For example, recent investigations of coronal consonantal harmonies by Flemming (1995), Gafos (1996), and Ní Chiosáin & Padgett (1997) have argued against a gapping or skipping approach. Typological studies by these researchers reveal that the coronal tip/blade features which appear to spread at a distance are precisely those that do not affect the perceived acoustic quality of the intervening segments. Hence there is no need to posit that the transparent segments create discontinuities for the tip/blade gesture within the spreading domain of the feature. These studies make a cogent argument for eliminating the notion of gapping in feature spreading, at least in coronal harmonies, since the relevant gesture can be conceived of as being sustained throughout the spreading span.

Research on certain other cases of segmental transparency supports extending this viewpoint beyond coronal harmonies. Ní Chiosáin & Padgett (1997) make this argument for transparent Cs in vowel harmony. They argue that Cs actually undergo the vocalic feature spreading but may be perceived as transparent because the acoustic consequences of the spreading property are small in terms of contrast potential for these segments. Walker & Pullum (1999) assemble evidence that a lowered velum gesture carries through transparent glottal stops in nasal harmony. In addition, an extensive crosslinguistic study of nasal harmony by Walker (1998) that looks at obstruent transparency effects develops a typological argument that all segments within a nasality spreading span must be regarded as participants in [nasal] feature spreading. Further related work includes McCarthy (1994) on transparent coronals in vocalic pharyngeal harmony and Padgett (1995) on translaryngeal vowel harmony.

This body of work converges on a finding that feature spreading propagates only between segments adjacent at the level of the root node—it does not gap across segments. A common thread that carries through many of these studies is that tier-based locality predicts a host of long distance feature spreading between Cs, such as major C-place assimilation, which are simply not borne out. To achieve a more restrictive view of locality, the outcome of spreading, where a single

structural node or feature becomes linked across segments is viewed as the result of the extension of a unitary and continuous feature or gesture or a group of such elements. As discussed by the researchers named above, understanding spreading in this way has foundation in the modelling of Articulatory Phonology (Browman & Goldstein 1986). Spreading of a continuous feature cannot produce an outcome in which the span of the spreading property contains discontinuities (i.e. interruptions); hence it must obey locality at the level of root node adjacency, termed *strict segmental locality* by Ní Chiosáin & Padgett.

At this juncture, we seem to be faced with a dilemma in regard to the voicing agreement data. On the one hand, extensive crosslinguistic research supports strict segmental locality for feature spreading; on the other hand, Ngbaka and Kera show that agreement for voicing features can take place across segments that appear to be true nonparticipants in the phenomenon. If this were feature spreading and all intervening segments were participants, we would expect devoicing of intervening sonorant Cs and Vs in the case of [-voice] agreement at a distance. Sonorants might also be expected to trigger [+voice] agreement—the ubiquitousness of postnasal and intervocalic voicing suggests that [+voice] is not universally underspecified on these segments (Itô, Mester, & Padgett 1995). One alternative would be to reject strict segmental locality; however, such a step would mean losing a major set of generalizations across languages. A second alternative is to consider the possibility that the voicing agreement is not an instance of feature spreading but rather arises from some other kind of interaction. This brings us to the second question raised in (4) above: whether locality is connected with the phenomenon involved in driving the interaction.

The answer to this question put forward by Gafos (1996, 1998) and Walker (1998, 1999) is in the affirmative. They distinguish two kinds of agreement phenomena and their resulting locality effects. The first one is spreading, which is subject to strict segmental locality, as outlined above.³ The second one is reduplication, where segments are copied from a base in order to form a reduplicative morpheme. For example, Gafos argues that patterns of C identity at a distance in Temiar (Mon-Khmer) are best analyzed as morphological reduplication rather than spreading. He shows that a reduplication analysis offers an elegant account where seemingly complex patterns arise out of general conditions on prosodic structure and morphological alignment. An alternative analyzing the agreement as long distance spreading of Cs across Vs fails to capture these insights. In addition it must assume admit representations that are overly powerful in the range of patterns that they predict. Walker diagnoses a pattern of long-distance nasal agreement in Mbe (Niger Congo) as reduplication based on similar considerations: limits on the size and shape of the reduplicant are shown to follow from the interaction of general phonological and morphological constraints. An alternative assuming spreading must not only introduce ad hoc stipulations but also undermines a typological finding that nasalization spreading does not skip Vs.

In the reduplication studies by Gafos and Walker, the copied segments are not adjacent to their corresponding elements in the base. Although reduplication most commonly copies segments starting at the edge at which affixation takes place, they argue that this edge-anchoring effect is violable. Walker (1999) surveys a number of languages in which edge-anchoring in reduplication is violated in order to satisfy a higher-ranked constraint, in other words, the distance between the copied segment and its corresponding segment in the base arises as a familiar case of optimality-theoretic optimization. For instance, in the example from Mbe in (7), a reduplicative diminutive prefix that copies only a single C copies the second C of the base [bam] rather than the first one. Although reduplicative prefixes are anchored at the left edge of the base, copy of the leftmost base C would result in an oral geminate, which is disallowed in the syllable structure of this language. In order to copy some material from the base, left-anchoring is violated and the nasal C is copied, which is a well-formed coda in the language.

(7) /ka-RED-bam/ → [kambam] ‘little bag’
 CLASS 4-DIM.-bag *[kabbam]

Importantly, what is viewed as violable here is edge-anchoring, which predicts the possibility of a distance between a copied segment and its corresponding segment in the base, but not between the trigger and target of feature spreading. In the case of reduplication, a correspondence relation is

posited between the phonological content of one morpheme and another—it is this correspondence relation that is viewed as potentially taking place at a distance. The relation checks identity between corresponding segment pairs but does not posit linkage of a feature or node across segments at a distance. In this respect, reduplication and its locality is crucially different from that of spreading.

In the analysis developed below I build on this result, namely, that segmental interactions at a distance do not arise in feature spreading but may occur via a correspondence relation between segments. In particular, I propose that long distance agreement for [voice] is not an instance of [voice] spreading but results from a type of correspondence between Cs.

4. A Correspondence-based Analysis

4.1 Consonant Agreement as a Correspondence Effect

I formalize the analysis in the constraint-based framework of OT and assume a basic familiarity with the underpinnings and formalisms of this theory. I adopt the Correspondence model of faithfulness, as elaborated in McCarthy & Prince (1995). Correspondence constraints demand identity of structure and content between related structures, such as an input and output. Following the definition proposed by McCarthy & Prince (1995: 262), two structures are said to be in *correspondence* if a relation is established between their component elements, and elements that are in a correspondence relation are referred to as *correspondents* of one another. Correspondence relations are not limited to related input-output structures. Familiar examples of related output structures include a base and reduplicant (McCarthy & Prince 1995), and a base-output and morphologically-related output (Benua 1997, among others). Correspondence between these related structures can produce similarity or identity between correspondent segments.

I propose that the voicing agreement effects outlined above are also the result of a correspondence relation, specifically one that holds between Cs in the output. The basis for this correspondence is not morphological relatedness or reduplication, rather it has a foundation in production processing of phonological structure. Psycholinguistic studies of the phonological encoding and production of words reveal that the production of a given C “activates” other Cs that share a large number of features. For instance, a robust finding of speech error research is that Cs which are identical in all but one phonological feature are more likely to induce slips of the tongue (MacKay 1970, Fromkin 1971, Shattuck-Hufnagel & Klatt 1979, Kupin 1982, Stemberger 1982, Frisch 1996). Hence the tongue twister that begins *she sells sea shells* is often produced as *she shells she shells*, shifting similar but different sounds to identical ones. Similarly, *really rural* is often mispronounced as *reary rural* (Kupin 1982: 8). These phenomena are addressed by spreading activation models of speech production (e.g. Dell & Reich 1980, Stemberger 1985, Dell 1984, 1986, among others). For our purposes a key element of the modelling is that each of the articulatory properties of a C causes the associated neurons to become activated in production processing. The activation begins in the word prior to production of the C and persists after it is uttered. In words containing two Cs that have only a small degree of difference there is a high amount of overlap in the neurons that are activated. A production difficulty for Cs that match in all but one property thus arises in coordinating them and keeping the similar segments distinct. As seen in the tongue twisters, the tendency is to move towards processing ease by overriding the small difference between the Cs and making them identical.

This psycholinguistic research provides support for the proposal that speakers construct a relation between similar segments in the output. I propose to formalize the requirement that such relations be actualized as a set of violable constraints requiring that similar segments in the output be correspondents of one another. The schema for this type of constraint is given in (8) (generalized here over all Cs). Though the order of the Cs is not always crucial in the voicing agreement data, an ordering is assumed in the definition below. This assumption is for ease of exposition in cases of agreement within a morpheme where no alternation is seen.⁴

- (8) Consonantal Correspondence: $\text{CORR-}C_1 \leftrightarrow C_2$
 Given an output string of segments S , and consonants $C_1 \in S$ and $C_2 \in S$, where C_2 follows C_1 in the sequence of segments in S , then C_1 is in a relation with C_2 , that is, C_1 and C_2 are correspondents of one another.

Further support for linguistic requirements that phonological elements be repeated or copied outside of morphological reduplication phenomena comes from work by MacEachern (1997), Zuraw (1999), and Kitto & de Lacy (to appear).

The speech error studies and voice agreement data indicates that the degree of similarity between Cs is an important factor in triggering a relation between them. Accordingly, I suggest that CORR-C \leftrightarrow C constraints are arrayed in a hierarchy such that the more similar the Cs, the higher-ranked the constraint requiring that a relation be established between them. The relevant portion of the hierarchy for the voicing agreement phenomena is given in (9).

- (9) Similarity-based Correspondence Hierarchy:
 CORR-t₁ \leftrightarrow t₂ >> CORR-t₁ \leftrightarrow d₂ >> CORR-k₁ \leftrightarrow d₂

These constraints are interpreted as follows. CORR-t₁ \leftrightarrow t₂ enforces correspondence between any oral stops matching in place and voice (e.g. [t...t], [b...b], etc.), CORR-t₁ \leftrightarrow d₂ holds over the superset of stops that match in place, i.e. ones that are at least as similar as [t] and [d] (e.g. [t...d], [b...p], [k...k]). CORR-k₁ \leftrightarrow d₂ expands to any pair of oral stops. The ranking of these constraints need not be stipulated, but rather the hierarchical effects fall out from the superset relations between constraints incorporating increasingly less similar segments.

An obvious generalization underlying the hierarchy in (9) is that if a given C pair shares a set of features, then another C pair that shares a superset of those features will be more similar. A more complex situation arises when two C pairs each differ in a separate feature, for instance, the pair t \leftrightarrow d differs in [voice] and t \leftrightarrow s differs in [continuant]. How is their relative similarity scaled? In a study of similarity as a basis for correspondence across a range of segment types, Rose & Walker (in prep.) find that certain features hold more weight in establishing differences between segments. Some broad parallels to the scaling of the sonority hierarchy are observed. Rose & Walker note that the feature [sonorant] represents a major separation between segments—similar segments are generally identified within the categories sonorant and obstruent. Amongst the obstruents they find that the next major cut is with respect to continuancy, that is, the separation between stops and fricatives, and finally, within the set of stops, similar segments are next segregated by place. The similarity scaling that is derived from the observations of Rose & Walker puts t \leftrightarrow s as less similar than t \leftrightarrow d, in fact, t \leftrightarrow s is expected to be less similar than any oral stop pair. The scaling in (9) is consistent with these findings.

Let us now consider how the consonantal correspondence constraints in (9) will apply to a hypothetical input /tede/:

- (10) Consonantal Correspondence model:
 Input /tede/
 ↓ Faith-IO
 Output [tede]
 ↔ Faith-CC

As represented in (10), the standard Faith-IO correspondence relation will hold between the input and output forms of the word. Within the output, a consonantal correspondence relation establishes a connection between the two Cs. Faith-CC constraints will enforce identity of structure and content between these segments. For illustrative purposes, the tableau in (12) shows how different candidates fare with respect to the CORR-C \leftrightarrow C hierarchy and IDENT-CC(voice), which requires that correspondent Cs be identical in [voice] specification, as defined in (11). Tableau (12) is intended simply to tabulate the constraint violations for a variety of candidates; the ranking of the constraints will be determined presently.

- (11) IDENT-CC(voice)
 Let C₁ be a consonant in the output and C₂ be any correspondent of C₁ in the output. If C₁ is [αvoi], then C₂ is [αvoi].

(12) Consonantal correspondence in output candidates

/t ₁ ed ₂ e/	IDENT-CC(voi)	IDENT-IO(voi)	CORR-t ₁ ↔t ₂	CORR-t ₁ ↔d ₂	CORR-k ₁ ↔d ₂
a. t _{1,i} ed _{2,j} e				*	*
b. t _{1,i} et _{2,j} e		*	*	*	*
c. t _{1,i} et _{2,i} e		*			
d. t _{1,i} ed _{2,i} e	*				

In (12), subscripted numbers mark IO correspondence and subscripted letters mark CC correspondence. Candidates (a) and (b) fail to set up a correspondence relation between the two output stops; hence they violate C correspondence constraints. Recall that violation of a C correspondence constraint entails violation of the lower-ranked ones. For example, (a) violates CORR-t₁↔d₂ because it has a pair of Cs that are at least as similar as [t] and [d], and it incurs a mark with respect to CORR-k₁↔d₂, since [t...d] are also at least as similar as [k...d]. Candidates (c) and (d) each set up a correspondence relation between the two output Cs. These Cs are also in a relation with their corresponding input segments. In (c), the pair agrees for voicing, satisfying IDENT-CC(voi) and violating IDENT-IO(voi). In candidate (d) the pair disagrees for voicing, incurring a Faith-CC violation but obeying Faith-IO. Depending on the ranking of these constraints, each of candidates (a), (c), or (d) is expected to be optimal. Candidate (b) will not be selected under any ranking, since there is no motivation for the second C to change its [voice] specification—in this form, the output Cs are not in correspondence. Candidates (a) and (d) represent outcomes in which the Cs remain faithful to their input voicing specification, and thus no agreement effect is apparent, as occurs in many languages. Candidate (c) is an example where a correspondence relation is established between similar Cs and the high-ranked demand on voicing identity between correspondent Cs produces long distance voicing agreement, as seen in Ngbaka and Kera.

Importantly, the account proposed here posits that long distance voicing agreement arises as result of correspondence between similar Cs in the word, as in (13a), rather than the result of spreading of [voice] across intervening segments that are not affected, as shown in (13b). The generalization that feature spreading phenomena are strictly segmentally local is thus maintained.

- (13) a. [voice] agreement by correspondence b. Not long-distance feature spreading
- | | |
|-----------------------------------|------------------------------------|
| C _i V C _i | *C _i V C _j |
| | \ / |
| [-voi] [-voi] | [-voi] |

Because consonantal correspondence is enforced between any two Cs within a psycholinguistically significant processing unit, such as the morpheme or word, [voice] agreement is expected to take place between similar Cs at a distance within this domain without affecting intervening segments (but see discussion below in 4.3 on gradient proximity effects).

To review, the correspondence approach makes two key predictions. First, the more similar the pair of Cs, the more likely they are to participate in voicing agreement. Second, the voicing agreement can occur between stops at a distance in the word; sonorant Cs and Vs that appear between the interacting segments are not expected to trigger or undergo the [voice] agreement. Both of these predictions correlate well with the data, and they present difficulties for the representationally-driven spreading alternatives. Let us take Ngbaka as an example. The similarity effect is clear in this language, since only homorganic Cs interact. However, the restriction to homorganic Cs does not fall out of the universal feature geometry—it requires a move to language-specific dependent tier ordering like that proposed by Mester (see (5) above). In contrast, the limitation of [voice] agreement to segments that match in all other properties is a pattern expected under the correspondence account. The interaction of Cs for voicing across Vs in Ngbaka is also expected under C correspondence. The alternative must assume tier-based locality and underspecification of [voice] in all sonorants, neither of which is well-supported.

4.2 Ngbaka Voice Agreement

At this point, I turn to the details of the constraint rankings under the correspondence approach for [voice] agreement in Ngbaka, and then I go on to Kera. In Ngbaka, stops that match in place must agree in their voicing specification. Hence the [voice] identity constraint for Cs in correspondence in the output must outrank the IO identity constraint for [voice]. This is illustrated in (14) with a hypothetical input /t₁id₂a/ for the Ngbaka word [tita] ‘grandparent’. I assume that MAX-IO outranks IDENT-IO(voi) to prevent deletion of the second C.

(14) IDENT-CC(voi) >> IDENT-IO(voi)

/t ₁ id ₂ a/	IDENT-CC(voi)	IDENT-IO(voi)
a. \Rightarrow t _{1,i} it _{2,i} a		*
b. t _{1,i} id _{2,i} a	*!	

Since stops that match in place are the ones subject to voicing agreement, correspondence constraints for Cs agreeing in place must also dominate IDENT-IO(voi) in order to compel a correspondence relation between the homorganic stops in the output. The ranking of IDENT-IO(voi) below CORR-t₁↔d₂ in the C correspondence hierarchy is illustrated in (15).

(15) Homorganic Cs are in correspondence: CORR-t₁↔d₂ >> IDENT-IO(voi)

/t ₁ id ₂ a/	IDENT-CC(voi)	CORR-t ₁ ↔t ₂	CORR-t ₁ ↔d ₂	IDENT-IO(voi)	CORR-k ₁ ↔d ₂
a. t _{1,i} id _{2,i} a			*!		*
b. t _{1,i} it _{2,i} a		*!	*	*	*
c. \Rightarrow t _{1,i} it _{2,i} a				*	
d. t _{1,i} id _{2,i} a	*!				

Candidate (c) wins in the above tableau, because it is the only one satisfying IDENT-CC(voi) and the constraints requiring that Cs with the same place of articulation be correspondents of one another in the output. These constraints are obeyed at the cost of IO voicing identity.

Since voicing agreement does not hold between Cs that differ in place, IDENT-IO(voi) must itself outrank CORR-k₁↔d₂, preventing a correspondence relation from arising between heterorganic stops that differ in voicing. This is shown in (16) with the example [duka] ‘shoulder’. The crucial candidates to compare here are (a) and (b). The winner in (a) obeys IDENT-IO(voi) but fails to establish [d] and [k] as correspondents. In candidate (b), the stops are correspondents of one another, but the resulting violation of IDENT-IO(voi) (compelled by IDENT-CC(voi)) proves fatal.

(16) Heterorganic Cs are not in correspondence: IDENT-IO(voi) >> CORR-k₁↔d₂

/d ₁ uk ₂ a/	IDENT-CC(voi)	CORR-t ₁ ↔t ₂	CORR-t ₁ ↔d ₂	IDENT-IO(voi)	CORR-k ₁ ↔d ₂
a. \Rightarrow d _{1,i} uk _{2,i} a					*
b. d _{1,i} ug _{2,i} a				*!	
c. d _{1,i} uk _{2,i} a	*!				

Ngbaka is thus a language where a correspondence relation is established only between Cs that match in place, producing a [voice] agreement effect just among homorganic stops. This is achieved via top-ranked IDENT-CC(voi) and ranking IDENT-IO(voi) at the break in the consonantal correspondence hierarchy between homorganic and heterorganic C pairs.

It should be noted that although IDENT-IO(voi) is violated in the optimal output in cases like (15), other alternative candidates that change the sonority or place of one of the Cs are assumed to be nonoptimal, e.g. [tira], [tiga]. In the Ngbaka data, there are no actual alternations found, since C correspondence is limited to segments with a morpheme. However, the nonoptimality of these other forms is supported by Kera, which exhibits alternations but also does not present violations

of IDENT-IO(son) or IDENT-IO(place). I assume that these languages have in common a ranking that places IDENT-IO(son) and IDENT-IO(place) at the top of the hierarchy shown here (and also over IDENT-CC(place)). More generally, Rose & Walker (in prep.) find that input specifications for major place are unaltered in C correspondence agreement phenomena, a point that I return to in §5. Rose & Walker also observe that typically sonority is unaffected (but see Walker forthcoming a). This matter too is returned to below with some suggestions for further research.

4.3 Kera Voice Agreement

In the Kera pattern of [voice] agreement all noncontinuant obstruents in a word must agree in voicing. As in Ngbaka, Kera must thereby rank IDENT-CC(voi) and MAX-IO over IDENT-IO(voi) (see (14)). Where the languages differ is in the ranking of IDENT-IO(voi) in relation to the CORR-C \leftrightarrow C hierarchy. In Kera, IDENT-IO(voi) moves down one step below CORR- $k_1 \leftrightarrow d_2$ to include heterorganic stops in the set for which a correspondence relation is established. This ranking is illustrated in (17) with / $\overline{d}_3 ar-k_2 a$ / ‘colorful’ (fem.).⁵ I assume that [\overline{d}_3] is subject to the CORR-C \leftrightarrow C constraints for stops by virtue of its noncontinuant element. Indeed, phonologically this phoneme might be treated as a stop rather than an affricate, with affrication arising as a predictable phonetic property of palatal stops (see also Odden 1994: 304, who groups [\overline{d}_3] with stops). Note that Kera provides additional support for multiple correspondence in the output Cs: when Cs agree for [voice] through IDENT-CC, they still remain faithful to their input place specification.

(17) All stops are in correspondence: CORR- $k_1 \leftrightarrow d_2 \gg$ IDENT-IO(voi)

/ $\overline{d}_3 ar-k_2 a$ /	IDENT-CC(voi)	CORR- $t_1 \leftrightarrow t_2$	CORR- $t_1 \leftrightarrow d_2$	CORR- $k_1 \leftrightarrow d_2$	IDENT-IO(voi)
a. $\overline{d}_3 ar-k_2 a$				*!	
b. $\overline{d}_3 ar-g_2 a$					*
c. $\overline{d}_3 ar-k_2 a$	*!				

In (17), the ranking of CORR- $k_1 \leftrightarrow d_2$ and IDENT-IO(voi) is apparent in comparison of candidates (a) and (b). Candidate (b) is the winner: it establishes correspondence between the stops, resulting in a violation of IO voicing identity. Candidate (a) is faithful to input voicing specifications, but loses on a violation of the C correspondence constraint CORR- $k_1 \leftrightarrow d_2$. Observe that in the optimal output, the correspondence relation takes place across a sonorant [r]. Since this segment is not in correspondence with the stops, it is not a participant in the voicing agreement.

The tableau in (18) shows the application of this hierarchy to a word containing only one noncontinuant obstruent: / $s_1 ar-k_2 a$ / ‘black’ (fem.). This form contains other Cs, a fricative and a liquid, but these are not set up as correspondents of the stop, since they are not sufficiently similar to be subject to CORR-C \leftrightarrow C constraints. As a consequence, no voicing agreement takes place, and the suffix stop is faithful to its input [-voice] specification in the output.

(18) Sonorant Cs do not trigger agreement

/ $s_1 ar-k_2 a$ /	IDENT-CC(voi)	CORR- $t_1 \leftrightarrow t_2$	CORR- $t_1 \leftrightarrow d_2$	CORR- $k_1 \leftrightarrow d_2$	IDENT-IO(voi)
a. $s_1 ar-k_2 a$					
b. $s_1 ar-g_2 a$					*!

An alternative candidate in which the sonorant C and stop are correspondents of each other, i.e. [$s_1 ar-g_2 a$] will lose on the basis of a faithfulness constraint that prohibits multiple source (S_1) correspondents for a segment in the output. In this failed alternative, [g] has S_1 correspondents [k] in the input and [r] in the output. This will incur a violation of UNIFORMITY, which prohibits coalescence (McCarthy & Prince 1995: 371). Familiar examples of coalescence merge segments belonging to the same S_1 domain (e.g. the input), but here a merger has occurred between an input segment and an output segment. I will refer to the constraint against this kind of merging as UNIFORMITY-IO/CC. Since this constraint is violated in [voice] agreement

configurations, it must be ranked below IDENT-IO(voi) in Ngbaka and Kera. However, even with this low ranking, the force of this constraint will be apparent in blocking correspondence between C-pairs that are not subject to CORR-C \leftrightarrow C constraints, such as stops and sonorants.

Interestingly, the UNIFORMITY-IO/CC constraint brings explanation to another widespread phonological phenomenon. When top-ranked in a grammar, this constraint can compel dissimilation effects between similar or identical Cs. UNIFORMITY-IO/CC will prevent correspondence relations between output Cs from being established. If correspondence between output Cs is blocked, then a pair of identical stops will dissimilate in order to be more harmonic with respect to the CORR-C \leftrightarrow C hierarchy. The extent to which the stops dissimilate will depend on the ranking of IDENT-IO constraints. Dissimilation effects for voicing are attested in Japanese (Mester & Ito 1989) and Kikuria (Odden 1994). The details of this approach are discussed by Walker (forthcoming b). It unites long distance agreement and dissimilation: both are the product of ranking of faithfulness constraints in relation to the C correspondence constraint hierarchy.

A final point concerns limits on the distance at which correspondent Cs can occur. In Kera I have been unable to find any words in which the alternating affix segment is separated from its agreeing root C by an intervening syllable. Hence, it cannot be determined whether the agreement holds across nonadjacent syllables (a point noted also by Odden 1994). Odden's study of long distance agreement and dissimilation effects finds unambiguous examples where the interacting segments must be in adjacent syllables (e.g. Lamba for the feature [nasal]). In terms of the present analysis, the generalization is that the strength of the demand for a correspondence relation increases with the proximity of the Cs, an observation consistent with the psycholinguistic foundation for CORR-C \leftrightarrow C constraints. In spreading activation models, activation of the features of a segment decreases across structural boundaries, that is, it is stronger within syllables than across syllables, within morphemes than across morphemes, and so on. The contribution of proximity could be built into the present approach by incorporating a proximity hierarchy into the CORR-C \leftrightarrow C constraints, parallel to the proposal made by Suzuki (1998) for the OCP (see also Flemming 1995, Kitto & de Lacy to appear). The resulting hierarchy will be such that enforcement of a correspondence relation between segments at a distance entails that nearer segments of the same similarity must also be in correspondence. Interleaving of the relevant faithfulness constraints with the proximity hierarchy will achieve agreement effects that are limited to Cs in adjacent syllables. Fuller elaboration of the proximity analysis is left for future research.

5. Conclusion and Further Research

In (4), two related questions were raised in regard to the locality of segmental interactions. One question asked whether the locality of segment interaction is connected to the type of phenomenon involved. The analysis defended here supports an answer in the affirmative (corroborating the position of Gafos 1996, Walker 1998). This approach distinguishes segmental correspondence and feature spreading as sources of feature agreement. The present study argues that a correspondence relation between similar Cs in the output underlies voicing agreement at a distance. This approach predicts that the interacting Cs may potentially occur at any distance within a morpheme, word, etc., though stricter limits on the distance can be levied via a proximity hierarchy. A substantial body of previous work has argued that feature spreading displays a more restricted locality, in particular, spreading holds only between root-adjacent segments. These findings constitute the answer to the other question in (4) about the distance at which segments can interact.

I have argued that the correspondence approach has foundation in mechanisms of production processing, and the featural agreement of similar Cs represents a move towards processing ease. This proposal predicts the similarity effect in correspondence-based agreement, namely, that the agreement will preferentially target more similar Cs. Along with locality, the presence or absence of a similarity effect could be used as part of a diagnostic of the source of featural agreement. For example, Walker (1998) finds that nasal harmony always includes Vs first among its set of targets. Since the trigger nasal stop is quite different from Vs, this pattern is not consistent with a segmental correspondence approach—stops or liquids are expected to be the preferred targets of a correspondence-based agreement. In the case of nasal harmony, Walker argues that the basis for preferred targets is compatibility with superimposed nasalization. In

addition, Walker finds that nasal harmony propagates only among root-adjacent segments. Both of these properties are consistent with feature spreading. In contrast, the long distance interaction and similarity effect seen in the [voice] agreement studied here is diagnostic of correspondence.

This correspondence-based analysis opens the door to a number of further issues in the study of segmental interactions. It provokes the question whether any segmental properties can agree (or dissimilate) at a distance. The answer suggested by Rose & Walker (in prep.) is that many but not all C properties can agree at a distance. They note that long distance agreement is not found for the traditional root features, [son] and [cons]. A possible explanation is that these properties should not be characterized by features, but rather are emergent from other aspects of segment structure. A more perplexing case is the absence of long distance C-place agreement. Understanding why C correspondence relations do not induce place agreement is an issue that demands further study and may benefit from examining the psycholinguistic factors involved.

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1. The distributional restrictions on Cs in Ngbaka discussed here are a subset of those found in the language. The restriction on voicing holds across the obstruents. Hence, the occurrence of a fricative within a morpheme excludes its counterpart differing in voicing (*[sozi]), but homorganic fricatives that agree in voicing are allowed ([zozi] 'judge'). There are also restrictions among the voiced noncontinuants that limit the cooccurrence of prenasal stops with homorganic voiced oral stops or nasals. In the present work I focus on the cooccurrence effects for [voice] among stops, but the additional restrictions could also be handled by the general approach developed here.

2. Mester assumes that [-voice] is underspecified and filled in by a later redundancy rule, but that is not crucial to the present discussion.

3. Gafos formalizes locality for spreading in terms of his principle of Articulatory Locality. This has some subtle differences from the requirement of root-adjacency, but they will not be relevant to the present discussion.

4. The ordering of the Cs may be relevant in some long distance agreement effects, such as the nasal agreement found in many Bantu languages (Walker forthcoming a). In cases like Kera, where prefix and suffix stops agree with the [voice] property of root stops, the dependency of affixes on root material could be handled by a nondirectional version of CORR- $C_1 \leftrightarrow C_2$ where C_1 belongs to the root and C_2 is affiliated with an affix.

5 For ease of exposition, in exemplification for Kera I restrict attention to alternations in suffix forms, where the dependent agreeing C is the rightmost one in the C-pair. On prefix alternations, where the dependency is in the opposite direction, see n. 4.

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