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77. Long-distance Assimilation of Consonants

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Sections

1 Introduction

There are numerous patterns in languages in which consonants assimilate at a distance for some acoustic or articulatory property. When vowels and consonants intervening between the assimilating consonants show no observable effect of the assimilating property, such patterns are labeled "consonant harmony." Other terms such as "consonant agreement" have been used (Rose and Walker 2004) in order to distinguish them from cases of harmony involving both vowels and consonants, such as emphasis harmony (Shahin 2002; CHAPTER 25: PHARYNGEALS) or nasal harmony (Walker 2000a; CHAPTER 78: NASAL HARMONY). Consonant harmony has played a central role in debates concerning harmony patterns in general (Rose and Walker, forthcoming) with respect to several issues: locality of interaction, transparency or blocking in long-distance assimilation, and directionality. In this chapter, the main typological patterns of consonant harmony are outlined, highlighting the challenges that the typology presents, including a discussion of harmony domains and directionality. Two main theoretical approaches to consonant harmony are then explored: analyses involving *spreading* an assimilating feature or extending a gesture across all segments within a string, and analyses advocating distinct *correspondence* relationships between consonants independently of intervening segments. The role of contrast in determining harmony interaction is examined within both of these frameworks. Finally, experimental approaches to consonant harmony are discussed, showing how they shed light on the analysis of consonant harmony.

2 Typology of long-distance assimilation of consonants

Long-distance assimilation of consonants or "consonant harmony" can be defined as:

> (1) *Consonant harmony*
> Assimilation for an articulatory or acoustic property between two or more non-adjacent consonants, where intervening segments are not noticeably affected by the assimilating property.

An example is given in (2) from Tahltan, an Athabaskan language (Shaw 1991). The 1sg subject prefix /s-/ (2a) is realized as [θ] when a dental fricative or affricate follows (2b), or as [ʃ] when a lamino-post-alveolar fricative or affricate follows (2c). Intervening consonants and vowels, including other coronal consonants, are transparent to the harmony:

(2) *Tahltan coronal harmony*

a.	ɛsk'aː	'I'm gutting fish'
	nɛstɛɬ	'I'm sleepy'
b.	xaˀɛθt'aθ	'I'm cutting the hair off'
	ɛθduːθ	'I whipped him'
c.	ɛʃʤɪni	'I'm singing'
	jaʃtɬ'ɛʧ	'I splashed it'

Consonant harmony can involve morpheme alternations, as in (2), but may also occur as a morpheme structure constraint (CHAPTER 86: MORPHEME STRUCTURE CONSTRAINTS), requiring consonants within a root to share featural properties. In Ngizim (Chadic) roots, non-implosive obstruents must have the same voicing property (3a), unless the linear order of the obstruents is voiced … voiceless (3b) (Schuh 1997):

(3) *Ngizim laryngeal harmony*

a.	kùtə́r	'tail'	
	tàsə́u	'find'	
	zə̀dù	'six'	(Hausa /ʃídà/)
	gâazá	'chicken'	(Hausa /kàazáa/)
b.	bàkú	'roast'	
	gùmʧí	'chin'	

The asymmetrical nature of the restriction points to a harmonic process. Voiceless … voiced combinations are not sanctioned, and Hausa words with such sequences are realized as voiced … voiced in Ngizim. The Ngizim harmony is therefore a regressive harmony, in which voiceless consonants assimilate to voiced, but not vice versa.

The definition of consonant harmony provided in (1) excludes other types of long-distance harmony that also involve assimilation spanning several segments, including both vowels and consonants, such as nasal harmony (Piggott 1988, 1992, 2003; Piggott and van der Hulst 1997; Walker 2000a, 2000b, 2003; CHAPTER 78: NASAL HARMONY) or post-velar or emphasis harmony (Younes 1993; Watson 1999; Zawaydeh 1999; Shahin 2002; CHAPTER 25:

PHARYNGEALS). See also CHAPTER 75: CONSONANT–VOWEL PLACE FEATURE INTERACTIONS on consonant–vowel interactions in general. In these harmony systems, assimilation affects both vowels and consonants, and certain types of segments can block harmony. Transparency of consonants is observed only under very restricted conditions. Conversely, transparency is routine in consonant harmony, whereas blocking is rare.

There are several types of long-distance consonant assimilation identified in typological studies of consonant harmony, laid out in detail in Hansson (2001a) and summarized in Rose and Walker (2004). The main types are outlined in the following sections.

2.1 Laryngeal harmony

Laryngeal harmony requires consonants to agree in aspiration, glottalic airstream, or voicing. Laryngeal distinctions are characterized by the features [spread glottis], [constricted glottis], and [voice], respectively, although different feature specifications are possible. Laryngeal harmony is most frequently observed in morpheme structure constraints (MacEachern 1999).

Laryngeal harmony is found in Chaha, a Gurage Semitic language of Ethiopia (Rose and Walker 2004), in which oral coronal and velar stops in roots match for both [constricted glottis] and [voice]:

(4) *Chaha laryngeal harmony*

a.	ji-t'ək'ɨr	'he hides'		
	ji-t'əβk'	'it is tight'		
	ji-t'ək'ɨk'	'it is being crushed'	cf. Endegegn (Gurage)	ɨ-dəkk'
	ji-t'ərk'	'it is dry'	cf. Masqan (Gurage)	jɨ-dərk'
b.	ji-kətf	'he hashes (meat)'		
	ji-kəft	'he opens'		
	ji-təks	'he sets on fire'		
c.	ji-gədɨr	'he puts to sleep'		
	ji-dərg	'he hits, fights'		
	ji-gəda	'he draws liquid'	cf. Amharic	jɨ-k'əda-l

Cognates in related languages show laryngeal mismatches, giving insight into the direction and implementation of the harmony. Harmony was regressive, and either ejectives or voiced stops could trigger harmony. Exceptions to laryngeal harmony involve non-adjacent combinations of an ejective and a voiced stop, e.g. [jɨ-gəmt'] 'he chews off'.

Voicing and aspiration harmony is found in (non-click) stops in disyllabic roots of Zulu (Bantu), as in (5a) (Khumalo 1987; Hansson 2001a). Zulu contrasts plain stops (which may be realized as ejective), voiced stops (described as "depressors," as they can lower tone),[1] and aspirated stops. Loanwords (5b) are adapted to conform to laryngeal harmony.

(5) *Zulu laryngeal harmony*

a.	ukú-peta	'to dig up'	
	úku-p^{h}át^{h}a	'to hold'	
	uku-guba	'to dig'	
b.	í-k^{h}ôt^{h}o	'court'	
	um-bídi	'conductor'	< English *beat*

Ngizim voicing harmony was illustrated in (3). Kera (Chadic) appears to have voicing alternations in affixes conditioned by voiced stops or affricates in the stem (Ebert 1979; Rose and Walker 2004), e.g. [kə-sár-káŋ] 'black (coll.)' *vs.* [gə-ʤàr-gáŋ] 'colorful (coll.)'. However, Pearce (2005) argues that voicing is conditioned by a neighboring low tone rather than the voiced stop in the stem, so this does not constitute a case of voicing harmony. Hansson (2004) argues that in Yabem, a Huan Golf language of Papua New Guinea, voicing restrictions arose from tonal patterns, and only superficially resemble consonant harmony.

Laryngeal harmony is often restricted to apply between subclasses of obstruents. Harmony operates between pulmonic obstruents in Ngizim, whereas in Chaha and Zulu, it applies between stops with differing airstream mechanisms, but excludes fricatives. In Kalabari Ijo (Jenewari 1989; Hansson 2001a) and Bumo Izon (Efere 2001; Mackenzie 2005, 2009), Ijoid languages of Nigeria, plain voiced stops and implosives may not co-occur in roots. Other cases of laryngeal harmony require homorganicity or complete identity between consonants. In Bolivian Aymara, laryngeal harmony for aspiration and ejectivity occurs between homorganic stops, so they are identical, e.g. [k'ask'a] 'acid to the taste', whereas no harmony occurs between heterorganic stops: e.g. [t'aqa] 'flock, herd' (Hardman *et al.* 1974; Davidson 1977; de Lucca 1987; MacEachern 1996, 1999). Similar effects are found in Mayan languages, such as Chol (Gallagher and Coon 2009), Modern Yucatec (Straight 1976), and Tzutujil (Dayley 1985; Gallagher 2010).

In conclusion, laryngeal harmonies are attested in numerous languages, most typically those that exhibit a three-way contrast in laryngeal features. Laryngeal harmony is usually root-restricted, may be subject to homorganicity requirements, and appears to be regressive for those cases in which directionality can be identified.

2.2 Coronal harmony

Coronal harmonies involve articulations both for tongue tip/blade posture (apical *vs.* laminal) and tongue position (dental, alveolar, post-alveolar). Sibilant harmony is the most commonly attested type of consonant harmony and requires sibilant coronal fricatives and affricates to match for tongue tip/blade posture and location. It is widely attested in Native American languages, particularly in Athabaskan and Chumash languages, but it also occurs in Basque, Berber, Bantu, Cushitic, and Omotic languages. An example of sibilant harmony in Tahltan was illustrated in (2).[2] In Sidaama, a Cushitic language of Ethiopia (Kawachi 2007), the causative suffix /-is/ (6a) is realized as [iʃ] when palato-alveolar fricatives or affricates appear in the preceding stem (6b).

(6) *Sidaama sibilant harmony*

a.	dirr-is	'cause to descend'
	hank'-is	'cause to get angry'
	raʔ-is	'cause to become cooked'
b.	miʃ-iʃ	'cause to despise'
	ʃalak-iʃ	'cause to slip'
	ʧ'uf-iʃ	'cause to close'

Sibilant harmony operates across vowels and non-sibilant consonants, including other coronals. In (6b), the intervening segments do not block and do not participate in the harmony.

In some languages, such as Ineseño Chumash (Applegate 1972; Poser 1982; McCarthy 2007), both alveolar and post-alveolar sibilants may trigger harmony. The rightmost sibilant determines the tongue tip-blade realization of all sibilants in the stem. In (7a) and (7c), the 3rd singular subject prefix is /s-/, but it is realized as [ʃ] if there is a palatal sibilant to its right, (7b) and (7d). In contrast, the dual marker /iʃ-/ (7e) is realized as [is] if followed by an alveolar sibilant (7f).

(7) *Ineseño Chumash sibilant harmony*

a.	/s-ixut/	[sixut]	'it burns'
b.	/s-ilakʃ/	[ʃilakʃ]	'it is soft'
c.	/ha-s-xintila/	[hasxintila]	'his gentile'
d.	/ha-s-xintila-waʃ/	[haʃxintilawaʃ]	'his former gentile'
e.	/p-iʃ-al-nan'/	[piʃanan']	'don't you two go'
f.	/s-iʃ-tiʃi-jep-us/	[sistisijepus]	'they two show him'

Dental harmony is found in Nilotic languages such as DhoLuo (Stafford 1967; Yip 1989; Tucker 1994), Anywa (Reh 1996), Mayak (Andersen 1999), and Päri (Andersen 1988). It operates between dental and alveolar stops, including nasals if a contrast exists in the language, and may be triggered by either. In Päri (Andersen 1988; Hansson 2001a), dental harmony is respected in roots (8a). Root-final stops that are the product of final mutation combined with affixation match the dental or alveolar property of the initial stop (8b).

(8) *Päri dental harmony*

a.	n̪ɔt̪	'sucking'		
	àtwá:t̀	'adult male elephant'		
b.	dè:l	'skin'	dè:nd-á	'my skin'
	t̪ùol	'snake'	t̪ùon̪d̪-á	'my snake'

In Mayak (Andersen 1999), harmony is triggered by an alveolar and optionally affects suffixes of the shape /-Vt̪/, as in (9). Intervening stops that are non-contrastive for the dental-alveolar distinction are transparent to the harmony.

(9) *Mayak dental harmony*

a.	leɣ-it̪	'tooth'
	wʌð-it̪	'buttock'
	ʔin-ʌt̪	'intestine'
b.	tiɗ-ʌt̪ ~ tiɗ-ʌt	'doctor'
	kɛt-ɪn-ɛt̪ ~ kɛt-ɪn-ɛt	'star'

Retroflex harmony is reported for several languages. In Gimira (Benchnon), an Omotic language of Ethiopia (Breeze 1990), retroflex harmony restricts combinations of sibilants, requiring them to agree for retroflexion. In Malto (Dravidian) (Mahapatra 1979; Hansson 2001a), retroflex harmony operates between oral stops. In Australian languages such as Arrernte (Arandic) (Henderson 1998; Tabain and Rickard 2007), apical alveolar and retroflex stops match for retroflexion in a root. Retroflex harmony is also reported in Kalasha (Indo-Aryan) (Trail and Cooper 1999; Arsenault and Kochetov, forthcoming), where it operates between stops, between fricatives, or between affricates in a root, but combinations of different manners of articulation may disagree for retroflex. Kalasha contrasts dentals, retroflex, and palatals; dentals and palatals also tend not to co-occur, so this is a general coronal harmony.

(10) *Kalasha retroflex/palatal harmony*

a.	stops	dental	tʰedi	'now'
		retroflex	ʈoʈ	'apron'
b.	fricatives	dental	sastirek	'to roof a house'
		palatal	ʑoçi	'spring festival'
		retroflex	ʂuʂik	'to dry'
c.	affricates	dental	tsẽtsaw	'squirrel'
		palatal	tɕʰatɕi hik	'to take care of'
		retroflex	ɖʐaʈʂ	'spirit beings'

Other cases of coronal harmony involving alveolar stops and alveo-palatal affricates are reported in Hansson (2001a), and include Aymara (de Lucca 1987), Kera (Ebert 1979), and Pengo (Dravidian) (Burrow and Bhattacharya 1970). In each case, harmony rules out /t … ʧ/ sequences, but allows the reverse, /ʧ … t/.

In terms of directionality, Hansson (2001a) points out two main directionality effects with respect to sibilant harmony. First, sibilant harmony shows a strong tendency to be regressive. In some cases, harmony is triggered by the rightmost sibilant, regardless of its location within a root or affix, as in Chumash (7) or Navajo (11) (McDonough 1991). The 1sg subject prefix /-iʃ/ is variably realized as [is] or [iʃ], depending on whether /s/

follows.[3]

(11) *Navajo sibilant harmony*

/j-iʃ-mas/	jismas	'I'm rolling along'
/dz-iʃ-ɬ-taːɬ/	ʤiʃtaːɬ	'I kick him (below the belt)'
/dz-iʃ-l-ts'in/	dzists'in	'I hit him (below the belt)'

Hansson (2001a, 2001b) relates the regressive bias of sibilant harmony to speech production. In speech production studies, anticipatory errors and assimilations are more common than are perseverative (Dell *et al.* 1997). This is modeled in a serial order theory of speech production, whereby one segment activates a consonant being planned and anticipates its production. There are cases of progressive sibilant harmony, as in the Sidaama case in (6), but in such cases, a suffix alternates in agreement with a root. The same pattern holds for dental harmony; no strong evidence for regressive patterns in dental harmony or retroflex harmony has been detected.

The second directionality effect concerns the nature of the trigger. While some cases of sibilant harmony are like Navajo in that either alveolar or post-alveolar consonants can trigger harmony, other languages only allow /s/ to become [ʃ] and not the reverse. Hansson (2001a: 472) cites sixteen cases of the /s/ → [ʃ] pattern, but only one case of /ʃ/ → [s]. Hansson connects this effect to speech planning and the *palatal bias* effect reported in speech error research (Shattuck-Hufnagel and Klatt 1979). The palatal bias effect refers to the higher frequency with which alveolar consonants act as targets of speech errors by palatals.

2.3 Nasal harmony

Nasal consonant harmony is attested primarily in Bantu languages. Nasal stops harmonize with voiced stops and oral approximants. If voiceless stops harmonize, they do so only if voiced stops harmonize. In Kikongo (Dereau 1955; Ao 1991; Odden 1994), a nasal stop in a verb root causes a [d] in the active perfect suffix (12a) or [l] in the applicative suffix to be realized as [n] (12b).

(12) *Kikongo nasal harmony*

a.	n-suk-idi	'I washed'	tu-nik-ini	'we ground'
	m-bud-idi	'I hit'	tu-sim-ini	'we prohibited'
b.	ku-sakid-il-a	'to congratulate for'	ku-nat-in-a	'to carry for'
	ku-toot-il-a	'to harvest for'	ku-dumuk-is-in-a	'to cause to jump for'

Intervening vowels and other consonants are transparent to the harmony. Yaka has a similar nasal harmony pattern (Hyman 1995). In other languages, the nasal harmony is restricted to apply only across an intervening vowel, as in Lamba (Odden 1994), Bemba (Hyman 1995), Ndonga (Viljoen 1973), and Herero (Booysen 1982), and may be restricted to roots only. The main distinctions between nasal consonant harmony and general nasal harmony are (i) vowels are not nasalized, (ii) the trigger is a nasal consonant that targets a similar consonant (voiced stop or approximant), and (iii) other consonants and vowels do not block harmony. See CHAPTER 78: NASAL HARMONY for more extensive discussion of the distinction between the two kinds of nasal harmony.

Nasal harmony operates progressively from root to suffix. However, it cannot be reduced in all cases to a stem-control effect. In Kikongo, roots such as /dumuk/ are possible, with a voiced stop preceding a nasal. The reverse order of nasal followed by voiced stop is not attested (Ao 1991; Piggott 1996), indicating that nasal harmony applied progressively within the root. The same pattern is attested in Yaka (Rose and Walker 2004).

2.4 Liquid harmony

Liquid harmony involves alternations between /r/ and /l/ (CHAPTER 31: LATERAL CONSONANTS). In Bukusu (Bantu), liquid harmony is attested in roots (Hansson 2001a). In addition, the benefactive suffix /-il-/ is realized as [-ir-] following a stem with [r] (Odden 1994). Vowel height harmony applies to the suffix.

(13) *Bukusu liquid harmony*

teex-el-a	'cook for'	reeb-er-a	'ask for'
lim-il-a	'cultivate for'	kar-ir-a	'twist'
iːl-il-a	'send thing'	resj-er-a	'retrieve for'

In Sundanese (Malayo-Polynesian), /l/ triggers harmony of /r/ to [l] (Cohn 1992), as illustrated with the plural infix /-ar-/ in the final form in (14).

(14) *Sundanese liquid harmony*

kusut	'messy'	k-ar-usut	'messy (PL)'
rahɨt	'wounded'	r-ar-ahɨt	'wounded (PL)'
ləga	'wide'	l-al-əga	'wide (PL)'

Liquid harmony is also attested in Pohnpeian (Rehg and Sohl 1981). There are cases in which liquids alternate with glides in Bantu languages, such as in Basaa (Lemb and de Gastines 1973) and Pare (Odden 1994), and in which /l/ alternates with a lateral tap in ChiMwiini (Kisseberth and Abasheikh 1975). All cases of liquid harmony are either root-restricted or involve suffix alternations, so no directionality bias can be detected.

2.5 Dorsal harmony

Dorsal harmony is found in Malto, Gitksan (Tsimshianic), Aymara, and the Totonacan languages, and involves alternations between velar and uvular consonants. In Tlachichilco Tepehua (Watters 1988; Hansson 2001a), a uvular /q/ causes a preceding velar to become uvular, which in turn conditions lowering of the preceding high vowel (15b).

(15) *Tlachichilco Tepehua dorsal harmony*

a.	ʔuks-k'atsaː	[ʔuksk'atsaː]	'feel, experience sensation'
b.	ʔuks-laqts'-in	[ʔoqslaqts'in]	'look at Y across surface'

Hansson (2001a) notes that intervening vowels are not affected by the harmony even though uvulars lower adjacent vowels. In the word /lak-puːtiq'i-ni-j/ → [laqpuːteˀenij] 'X recounted it to them' (the /q'/ is realized as [ˀ]) the vowel /uː/ fails to lower to [oː], despite appearing between two uvulars. Compare this with (15b). In Gitksan (Brown 2008), the harmony effect is a static co-occurrence restriction that can operate at a distance. Dorsal harmony causes velars to become uvular. While most dorsal harmony cases are regressive and target roots, this could be either a directionality effect or due to the trigger consonant, the uvular, being in an affix.

2.6 Stricture and secondary articulation harmony

In addition to the main types reported in §2.2–§2.5, Hansson (2001a) also lists stricture and secondary articulation harmonies. Stricture involves alternations between stops and fricatives, as in Yabem, e.g. /se-dàgùˀ/ → [tédàgùˀ] 'they follow (REALIS)'. Secondary articulation refers to labialization, palatalization, velarization, or pharyngealization. There are a few reported cases discussed in Hansson (2007a): pharyngealization in Tsilhqot'in (also known as Chilcotin, Athapaskan) (Cook 1983, 1993), which interacts with sibilant harmony, velarization in Pohnpeian (Micronesian) (Rehg and Sohl 1981; Mester 1988), and palatalization in Karaim (Turkic) (Kowalski 1929; Hamp 1976; Nevins and Vaux 2004), as shown below:

(16) *Karaim palatal harmony*

d^{j}ort^{hj}-un^{j}ʧ^{j}u 'fourth'
alt^{h}ɯ-nʧɯ 'sixth'

In sum, consonant harmony targets a range of segments: dorsals, liquids, and coronals, as well as segments differentiated by nasal and laryngeal features. Hansson (2001a) and Rose and Walker (2004) point out that a consistent characteristic of consonant harmony is the high degree of similarity between the interacting segments. Harmony is restricted to minor place or tongue features distinguishing among coronals and dorsals or to features that are also prone to local assimilation. Notably absent, however, is harmony for major place features such as [labial], [coronal], or [dorsal], as well as classificatory features that tend not to assimilate locally, such as [sonorant], [continuant], or [consonantal]. Rose and Walker (2004) relate the absence of place harmony to the inability of major place to change even in local assimilations, citing articulatory speech error research that shows that major place gesture errors tend to be additive rather than replacive (Goldstein *et al.* 2007; Pouplier 2007). Gafos (1999), on the other hand, argues that major place features cannot spread across vowels (*contra* Shaw 1991) without serious interruption of the vowel gestures. Only minor features such as tongue tip position can do this. See §3.1.1 for further discussion.

The lack of major place consonant harmony is intriguing in light of two related phenomena: child language and dissimilation. Consonant harmony for major place is attested in child language (Vihman 1978), and according to CHAPTER 72: CONSONANT HARMONY IN CHILD LANGUAGE, it is the most common type of consonant harmony in child language. Recent analyses and proposals are discussed in Goad (1997), Berg and Schade (2000), Rose (2000), Pater and Werle (2003), and Rose and dos Santos (2006). The same mechanisms that underlie child phonology and adult phonology may not be the same; some child productions may be due to developmental factors (Rose and dos Santos 2006; Inkelas and Rose 2008). See CHAPTER 72: CONSONANT HARMONY IN CHILD LANGUAGE for an overview.

Some authors have drawn a connection between long-distance consonant assimilation and long-distance consonant dissimilation (MacEachern 1999; Walker 2000c; Gallagher 2008), arguing that they are alternate responses to the same pressure. This does appear to be the case for laryngeal and liquid harmony. Yet there are key differences. A common dissimilation process occurs between labial consonants (Alderete and Frisch 2007), whereas labial consonant harmony is unattested. Nasal dissimilations involve prenasalized stops and nasals (Odden 1994), but these segments do not interact in nasal consonant harmony; prenasalized stops are transparent to nasal harmony and do not act as triggers (CHAPTER 78: NASAL HARMONY). A general theory of the relationship between long-distance consonant assimilation and consonant dissimilation currently appears elusive.

3 Analyses of long-distance assimilation

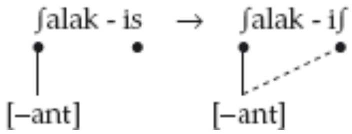
Two main theoretical analyses have been formulated for long-distance consonant harmony: *spreading* and *correspondence*. Spreading involves the extension of a gesture or feature across a string of segments, building upon early autosegmental analyses of vowel harmony and nasal harmony. Correspondence is proposed in Walker (2000b, 2000c), Hansson (2001a), and Rose and Walker (2004) and requires similar consonants to "correspond" and match each other for particular features, regardless of intervening consonants and vowels. The following sections outline these two approaches and identify the strengths of each proposal, as well as the challenges they encounter.

3.1 Spreading

Autosegmental phonology represented a major shift in the analysis of harmony systems. Although the distance effects of harmony systems had been explored within a Firthian prosodic analysis framework (Palmer 1970), Clements's (1980) groundbreaking analysis of vowel harmony and extension to nasal harmony launched the study of harmony systems using autosegmental spreading. Early autosegmental analyses of consonant harmony include Halle and Vergnaud (1981) on Navajo and Poser (1982) on Chumash.

In an autosegmental representation, the harmonizing feature (P-segment) is projected onto its own tier and linked to the segment (P-bearing segment) by means of an association line. Spreading involves extending the feature to other segments in the word via new association lines, as shown in (17) for the Sidaama word [ʃalakiʃ] 'cause to slip":

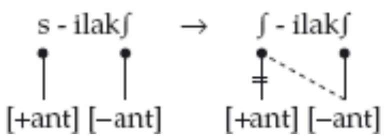
(17) *Long-distance spreading*



(17) illustrates a feature-filling rule, in which the feature [-anterior], characterizing the post-alveolar /ʃ/, spreads to the /s/, but the /s/ itself is unspecified for the feature [+anterior]. Within models of underspecification (Archangeli 1988; Paradis and Prunet 1989), the default feature [+anterior] is assumed to be filled in by a default rule at the end of the derivation if no specification is provided by a specific rule.

Consonant harmony may also be *feature-changing* where the target and trigger have opposite values for the spreading feature. Sibilant harmony in Inseño Chumash has been analyzed as feature-changing (Poser 1982, 1993; Lieber 1987; Steriade 1987b; Shaw 1991), because harmony can be triggered by either [+anterior] /s/ or [-anterior] /ʃ/, altering the specification of the other sibilant. The target consonant acquires the specification of the trigger through spreading, and loses its own feature specification by delinking its original association line. This is illustrated in (18) for [ʃ-ilakʃ] 'it is soft':

(18) *Feature-changing harmony*



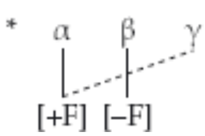
In (18), the feature [anterior] is shown linked to the rest of the segment. In more articulated models of feature geometry (Clements 1985, 1991; Sagey 1986; McCarthy 1988; Clements and Hume 1995), features link to organizing nodes, which in turn link to the root node, connected directly to prosodic structure.

3.1.1 Transparency and spreading

In both of the representations above, spreading takes place between two sibilants, despite the fact that other consonants and vowels intervene between the trigger and target. Intervening segments have the potential to block harmony, a phenomenon that is routinely observed in both vowel harmony and local vowel-consonant harmony. However, blocking is not generally observed with consonant harmony (Hansson 2001a; Rose and Walker 2004).[4]

Blocking segments, or "opaque" segments, can be characterized as those that are specified with the opposite value to the spreading feature. For example, in van der Hulst and Smith (1982a) [-nasal] segments block spreading of [+nasal] in nasal harmony. The [+nasal] feature cannot spread over the association line linking [-nasal] to a non-nasal segment, as this would violate the No-Crossing Constraint (Goldsmith 1979), a principle of autosegmental phonology (CHAPTER 14: AUTOSEGMENTS), which prevents association lines crossing. This is illustrated schematically in (19), where the symbols α, β, and c represent segments and [+F] the spreading feature, and where the [-F] value of a feature blocks the [+F] value from spreading.

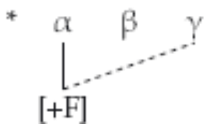
(19) *No-Crossing Constraint*



In more recent accounts, the blocking segment is assumed to be incompatible with the spreading feature due to an articulatorily grounded constraint (Archangeli and Pulleyblank 1994), preventing co-occurrence of the spreading feature and a specific feature or features of the blocking segment. For example, in nasal harmony, obstruents block nasal harmony in many languages (Walker 2000a), so [+nasal] may be restricted from associating to a [–sonorant] segment. Under this scenario, the No-Crossing Constraint does not apply; instead *locality* considerations prevent the spreading feature from skipping over the blocking segment and spreading to another segment. How locality should be defined has been a matter of debate.

If locality is defined at the level of the root node or segment, such that adjacent segments are local, no segment can be skipped in spreading, a theory referred to as *strict locality*. This is illustrated schematically in (20).

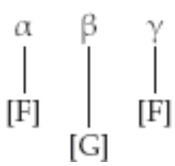
(20) *Strict locality*



Under this view, consonant harmony would be similar to local assimilation (CHAPTER 81: LOCAL ASSIMILATION), but extended over longer strings of segments.

Locality may also be defined at the level of vowel nuclei of adjacent syllables (Archangeli and Pulleyblank 1987, 1994), in which case intervening consonants would be considered transparent. This is referred to as *maximal scansion* in Archangeli and Pulleyblank (1987). A third possibility is to define locality with respect to autosegmental feature tiers, or feature node tiers in a feature-geometry model, referred to as *minimal scansion* (Archangeli and Pulleyblank 1987; Steriade 1987a). Segments that lack specification on such tiers would not be computed for locality. In the following schematized representation, the features [F] of the segments α and γ would be adjacent on the F tier, despite not belonging to adjacent segments:

(21) *Tier-based locality*



Tier-based locality lies at the heart of autosegmental spreading analyses of transparency in harmony.

Steriade (1987b) argued that intervening transparent consonants and vowels in Ineseño Chumash sibilant harmony lack specification for the feature [anterior] at the point when the harmonic spreading rule applies. Dorsal and labial consonants are excluded from participation in the harmony, as they have place feature specifications on other tiers – Dorsal and Labial. The feature [anterior] is assumed to be relevant only for coronal consonants. The same holds true for vowels in a system in which vowels are considered dorsal (Sagey 1986; Steriade 1987a).[5] Yet the coronal consonants /t l n/ are also transparent in Chumash. Steriade adopts a form of contrastive specification, wherein only segments that contrast for a given feature need to be specified for that feature. The feature [anterior] is needed to distinguish sibilants in Chumash, but /t l n/ do not have [-anterior] counterparts, and so are predictably [+anterior]. Predictable features are left unspecified and filled in as default later in the derivation. Harmonic spreading of the [anterior] feature operates unhindered between sibilants before a redundancy rule ([+coronal, -continuant] → [+anterior]) fills in predictable values on the other coronals. Locality is defined on the tier [anterior] as the spreading rule targets only consonants specified for [anterior], not those specified as Coronal, the organizing node on which [anterior] is dependent (Shaw 1991). Chumash is a feature-changing rule, but if spreading rules are feature-filling, targets would need to be defined with respect to other features or the node to which the feature attaches.

Harmony does not always operate at the level of individual features, however. Shaw (1991) argues that a more complex harmony system in Tahltan involves spreading the Coronal node (CHAPTER 12: CORONALS). Tahltan has a rich inventory of coronal consonants, contrasting dental stops, lateral continuants, interdental/ pre-dorsal sibilants, alveolar sibilants, and palatal sibilants. The latter three sibilant classes participate in coronal harmony, but the stops and laterals do not (examples in (2)). Shaw argues that in order to distinguish among a series of three sibilants, at least two features dependent on Coronal are needed. Under the assumption that a single unified spreading rule should capture the harmony, Shaw proposes that harmony involves spreading of the Coronal node. The other two transparent classes must be underspecified for Coronal at the time the rule applies. Similar harmonic effects (e.g. /s/ → [ʃ]), therefore, involve different spreading rules, depending on the particular inventory of the language.

Gafos (1998, 1999) rejects tier-based locality, and presents a model of "Articulatory Locality," in which locality is defined in terms of articulatory gestures (Browman and Goldstein 1986, 1989, 1990). Vowel gestures are contiguous across a consonant, whereas consonant gestures are not contiguous across a vowel. Vowel harmony may appear to skip over consonants, but consonants are in fact unaffected audibly by the spreading gesture. This strict locality view is also adopted by Ní Chiosáin and Padgett (1997, 2001), Walker and Pullum (1999), and Walker (2000a). Under strict locality, only coronal harmony, which involves assimilation for a tongue tip-blade feature, is predicted to be possible, due to non-interference with vowels. The tongue tip-blade is independent of the tongue dorsum used in the production of vowels, and its exact posture has no significant acoustic effect on vowel quality. By the same reasoning, dorsal and labial consonants would be predicted to intervene as "transparent," since changes in the tongue tip-blade would not affect their production. Moreover, if the feature that distinguishes /s/ and /ʃ/ is apicality (tongue tip) *vs.* laminality (tongue blade), languages with no apical-laminal coronal stop contrast may allow stops to fluctuate between apical and laminal in different harmonic contexts, a suggestion made by Peter Ladefoged, as reported in Steriade (1995). Gafos (1999) formalizes this idea and proposes two new tongue tip-blade parameters: Tongue Tip Constriction Orientation (TTCO) and Tongue Tip Constriction Area (TTCA), gestures that do not skip over other segments, but are maintained through their production with little perceptible effect. Coronal segments /t n l/ in Chumash harmony are predicted to alter their production in accordance with the harmonic domain in which they occur, either apical [n̺] in words like /k-sunon-us/ → [ksun̺o n̺us] 'I obey him' or laminal [n̻] in words like /k-sunon-ʃ / → /[kʃun̻on̻ʃ] 'I am obedient'. TTCO is identified as tip-up (↑) for apical and tip-down (↓) for laminal. As non-sibilant coronals do not contrast on this dimension in Chumash, they are not perceived as distinct.

(22) *Gestural extension under strict locality*

	apical	*laminal*
	k - s u n̺ o n̺ - u s	k - ʃ u n̻ o n̻ - ʃ
TONGUE TIP	TTCO ↑	TTCO ↓

Gafos argues that the strict locality view of consonant harmony explains the absence of other types of place harmonies. Major place gestures that define dorsal and labial consonants cannot spread across vowels (*contra* Shaw 1991) without serious interruption of the vowel gestures. Minor features such as tongue tip position can. Tier-based locality is unable to adequately explain why only Coronal, and not Labial and Dorsal, nodes can spread in feature geometry. In addition, the restriction of harmony to subclasses of coronals, such as sibilant fricatives and affricates, is explained, as these segments involve contrast along the tongue orientation dimension.

In conclusion, spreading approaches to harmony involve the spreading of a feature or the extension of a gestural parameter over other vowels and consonants. The non-participation of these consonants receives two explanations. In the autosegmental framework, it is due to a version of feature underspecification (CHAPTER 7: FEATURE SPECIFICATION AND UNDERSPECIFICATION) and tier-based locality, allowing for certain kinds of harmony interactions between specific features. In a gestural framework (Gafos 1999), transparency is illusory – articulators perform the harmonic gestures, but have little impact on consonants and vowels that do not involve those articulators, or for which changes in the articulation are non-contrastive and hence perceptually non-distinct.

3.1.2 Challenges to the spreading approach

While the analysis of consonant harmony as feature spreading or gestural extension seems appropriate for characterizing retroflex harmony and some sibilant harmony cases, it encounters several challenges when applied to a fuller typology of consonant harmony systems as outlined in §2. Gafos (1999) assumes that coronal harmony is the only type of consonant harmony. Shaw's (1991) typology of consonant harmony identifies only laryngeal harmony as another possibility.[6] Laryngeal features primarily distinguish among obstruents. As vowels and sonorants are inherently voiced and unspecified for laryngeal features (Itô and Mester 1986), laryngeal harmonies can operate between laryngeal tiers specified only on obstruents, thereby respecting tier locality. Gafos (1999) does not explicitly discuss laryngeal harmony within the Articulatory Locality model.

However, the larger typology outlined in §2 prompts Hansson (2001a) and Rose and Walker (2004) to conclude that autosegmental spreading is inadequate as a general model of consonant harmony. Their arguments rest on several key properties of consonant harmony not shared with vowel harmony and vowel- consonant harmony, as well as predictions that some spreading models make about the participation of intervening segments. I focus on two main properties here: (i) no blocking and transparency, and (ii) similarity of target and trigger. Hansson (2001a) also notes the lack of sensitivity to prosody and regressive directionality as defining properties of consonant harmony, but the prosody insensitivity may be due to other factors. Regressive directionality is a strong tendency, but progressive directionality is also observed for consonant harmony. Furthermore, regressive directionality is not an exclusive domain of consonant harmony; it has also been observed for vowel harmony (Hyman 2002) and some forms of vowel-consonant harmony – i.e. emphasis harmony exhibits more restrictions and blocking when progressive than when regressive (Watson 1999).

3.1.3 Blocking and transparency

Consonant harmony differs from other types of harmony with respect to blocking effects and transparency. If nasal consonant harmony is compared with nasal vowel-consonant harmony, there are two key differences with respect to the participation of segments. In nasal consonant harmony, nasal consonants harmonize with voiced stops or approximant consonants across other consonants and vowels, even obstruents. In contrast, nasal vowel-consonant harmony shows blocking effects, usually by the same segments that are skipped in nasal consonant harmony. Second, intervening vowels do not show nasalization in nasal consonant harmony, whereas they make the best targets in nasal vowel-consonant harmony and are generally not skipped. If nasal vowel-consonant harmony involves autosegmental spreading or gesture extension, how does one explain the differences with nasal consonant harmony? It does not appear to behave as if spreading of [nasal] is involved.

A similar argument can be applied to two other types of consonant harmony. Laryngeal harmony shows no extension of voicing/devoicing or glottalization over intervening segments. Dorsalization shows no effects on intervening vowels, despite the fact that uvulars routinely lower adjacent vowels. If harmony operates as advocated by Gafos (1999), with gestures extended across other segments, these facts are unexpected. If tier-based locality is the explanation, it is hard to give a reason for the neutrality of contrastive voiced and voiceless fricatives in a laryngeal harmony involving voice harmony between stops, as is the case in Chaha.[7]

3.1.4 Similarity

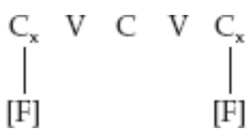
The concept of similarity is implicitly recognized in autosegmental spreading analyses of sibilant harmony, as spreading occurs only between segments specified for the spreading feature. However, it is not a formalized aspect of spreading theory. Hansson (2001a, 2001b) and Rose and Walker (2004) propose that similarity is the driving factor in consonant harmony, and has its functional roots in speech production. For example, sibilants are highly similar to one another and it is hypothesized that production is eased if they match for the position of the tongue tip-blade. Similar, but different, consonants present production difficulties that are manipulated in tongue-twisters and emerge as speech errors in both natural and experimentally induced situations (Fromkin 1971; Shattuck-Hufnagel and Klatt 1979; Frisch 1996; Rose and King 2007; Walker 2007; Kochetov and Radišić 2009). Nasal stops harmonize with oral sonorants or voiced stops, which differ minimally from nasals. Voicing harmony occurs between obstruents, but is usually restricted to stops, excluding fricatives. Homorganicity further contributes to similarity; some laryngeal and nasal harmonies operate only between homorganic segments.[8] All cases of harmony involve strong similarity between the harmonizing segments, even in ways that local assimilations do not. For example, while local voicing assimilation operates between all obstruents, voicing harmony may be restricted to a sub-type of obstruents based on manner.

Rose and Walker (2004) determine similarity using the metric developed in Frisch *et al.* (2004), wherein similarity is assessed on the basis of shared natural classes of distinctive features in a given language. The numbers of shared and unshared natural classes of two consonants are compared. Both the size and contrastiveness of the segment inventory contribute to the similarity ratings. Natural classes, which incorporate the notion of contrastiveness, are better able to predict gradient phonotactics and capture major class subregularities than are models based simply on distinctive feature specification. However, see Mackenzie (2005, 2009) for some criticisms of this metric.

3.2 Correspondence

Given these observations about the typology of consonant harmony, Hansson (2001a) and Rose and Walker (2004), based on Walker (2000a, 2000c), developed an account of consonant harmony within Optimality Theory (OT), termed "agreement-by-correspondence." A correspondence relationship is created between similar segments, expressed as Corr-C↔C constraints (indicated in the diagram in (23) by co-indexation). This is reminiscent of Zuraw's (2002) aggressive reduplication model, although this model does not encode similarity directly. Crucially, there is no autosegmental feature spreading between the segments, so their feature specifications are distinct.

(23)



The Corr-C↔C constraints are arranged in a fixed implicational hierarchy from most similar to least similar, for example Corr-T^h↔T^h >> Corr-T^h↔T >> Corr-K^h↔T (Rose and Walker 2004: 500). Separate Ident-CC constraints require the corresponding consonants to agree for a given feature. Input-output faithfulness constraints are placed between the Corr-C↔C constraints to achieve harmony of different similarities, or below them to produce full harmony.

The following tableau illustrates an example of sibilant harmony in Sidaama for the word /ʃalak-is/ → [ʃalak-iʃ]. Corr-s↔ʃ refers to anterior and non-anterior fricative pairs, while Corr-t↔ʃ refers to anterior stop and non-anterior fricative combinations. Candidate (24a) has a CC-correspondence relationship (indicated by the subscript $_x$ on the output sibilant consonants) and sibilant agreement, thereby satisfying the two high-ranked constraints. This candidate violates Ident-OI[ant], due to the change /s/ → [ʃ]. Ident-OI[ant] is violated by segments that alter an input [anterior] specification in the output. Candidate (24b) has no correspondence relationship between /s/ and /ʃ/, indicated by the different subscripts $_x$ and $_y$. Due to the lack of CC-correspondence, this candidate does not violate Ident-CC[ant]. Candidate (24c), on the other hand, does have sibilants in a CC-correspondence relationship. The sibilants do not agree for anteriority, thereby violating Ident-CC[ant]. The [anterior] feature is used here although other features such as [distributed] or [Tongue Tip Constriction Orientation] are also possible.

(24)

/ʃalak-is/	Ident-CC[ant]	Corr-s↔ʃ	Ident-OI[ant]	Corr-t↔ʃ
☞ a. $ʃ_x$alak-i$ʃ_x$			*	
b. $ʃ_x$alak-is_y		*!		
c. $ʃ_x$alak-is_x	*!			

No correspondence relationship is established between the fricative and the voiceless stop /k/, or with the vowels, as these two sounds are not sufficiently similar. Other work analyzing coronal harmony systems as involving corresponding segments or feature copy includes Clements (2001) and McCarthy (2007).

The correspondence-based approach to consonant harmony allows similar consonants to agree at a distance; transparent segments are those that are not similar enough to participate in the harmony. No blocking is predicted, as lack of harmony is due to either the lack of or the low ranking of correspondence between intervening segments. This approach sets consonant harmony apart from vowel harmony and vowel-consonant harmony in using a different analytical mechanism.[9]

A more accurate typology of consonant harmony has led to alternate analytical devices, using correspondence-based relations rather than autosegmental spreading. The assumption that all harmony systems are alike and therefore subject to the same type of analysis has also been called into question, representing a significant departure in the analysis of consonant harmony *vs.* other harmony systems.

3.2.1 Challenges to the correspondence approach

Despite the advances of the correspondence approach in unifying the typology of consonant harmony and setting it apart from other types of harmonies, challenges to this model have arisen.

In the arena of coronal harmony, there is still debate over whether correspondence is the appropriate mechanism. McCarthy (2007) argues that Chumash harmony should be analyzed via correspondence, as it shows clear differences from local assimilations and dissimilations. Arsenault and Kochetov (forthcoming) also support the correspondence approach in their analysis of sibilant and retroflex harmony in Kalasha. They argue that since coronal harmony in Kalasha is restricted to apply only between consonants with the same manner of articulation, this lends support to the correspondence approach, which formally encodes similarity. Spreading approaches would need to explain why harmony operates only between consonants of like manner.

Gallagher and Coon (2009) nevertheless argue that correspondence is appropriate for harmonies that require complete identity between consonants, but not for those that induce limited featural agreement, such as most sibilant harmonies. Gallagher and Coon focus on harmony data from Chol, a Mayan language of Mexico. The Chol pattern is an interaction between laryngeal harmony and coronal strident harmony. Total identity (25a) between consonants is required in two cases: (i) two ejectives in a root or (ii) two plain stridents. If the two consonants differ in terms of laryngeal features (ejective and plain), then only strident harmony is enforced (25b).

(25)	a.	*Total identity*					
		Plain stridents			Ejectives		
		*ts-s	sus	'scrape'	*k'-p'	k'ok'	'healthy'
		*s-ʧ	ʧiʧ	'older sister'	*tʲ'-ts'	tʲ'otʲ'	'snail'
						ʧ'iʧ'	'blood'
	b.	*Strident harmony*					
		*ts'-ʃ	ts'is	'sew'			
		*s-ʧ'	ʃuʰʧ'	'thief'			

Strident harmony is always enforced, regardless of laryngeal specification, but laryngeal harmony requires complete identity. Gallagher and Coon's analysis requires that similar consonants (those that share certain features) are “linked” (i.e. correspond), and an identity constraint requires them to be completely identical. Ejectivity renders consonants more similar than stridency. Although the proposal accounts for the particular case of total identity seen in Mayan languages,[10] it does not extend to other cases of consonant harmony outlined in §2, which show partial identity effects, but cannot receive a spreading analysis due to the transparency of the intervening segments. Moreover, it is not clear why ejectivity in particular requires a total identity between segments. Laryngeal harmonies are often restricted to a subset of obstruents (stops) and homorganicity is also frequently involved. This signals that more research on how to define similarity is required.

In the arena of blocking, Hansson (2007b) argues that while lack of blocking is a descriptive characteristic of consonant harmony systems, it does not necessarily follow from the agreement-by-correspondence approach. Blocking could arise in scenarios in which three segments are in correspondence, but in different correspondence relationships, either different local relationships for the same feature or different featural relationships. More research is necessary to determine whether such scenarios are actually attested, or whether the correspondence analysis requires modification. If attested, this would undermine one of the strong arguments for why consonant harmony should not receive the same analysis as vowel harmony or vowel-consonant harmony.

Despite various criticisms, the correspondence approach to harmony has stimulated new areas of research in the analysis of long-distance assimilations and has pushed researchers to examine languages in more detail, to conduct corpus studies of morpheme structure constraints, and to investigate harmony from an experimental angle.

3.3 The role of contrast in consonant harmony

The concept of *contrast* (CHAPTER 2: CONTRAST) has long played a role in auto-segmental spreading analyses of consonant harmony, specifically in determining feature specification. Steriade (1987b) and Shaw (1991) rely on the fact that only sibilants contrast for [anterior] to explain the transparency of stops and sonorants to sibilant harmony. In the correspondence model of harmony, the role of contrast is not emphasized. Although Hansson (2001a) and Rose and Walker (2004) mention contrast, its role in determining harmony systems does not figure prominently in their model, except indirectly via the natural classes model of computing similarity (Frisch 1996; Frisch *et al.* 2004), which Rose and Walker (2004) adopt. Yet recent research has returned to the issue of contrast, both as a means of constraining harmony, and in promoting contrast as the driving force behind consonant harmony.

Mackenzie (2005, 2009) argues that similarity in consonant harmony should be formalized on the basis of contrastive featural specifications determined by a language's inventory. Segments that are similar to one another in their contrastive specifications, not necessarily segments that are most similar phonetically, interact in harmony. In the harmony system of Bumo Izon, an Ijoid language, voiced implosives and voiced stops may not co-occur, with two exceptions: /g/ and /ɠɓ/ (Efere 2001); these sounds freely co-occur with stops of the opposite pulmonic value: [ɗúgó] 'to pursue' or [ɠɓódaɠɓóda] 'rain (hard)'. Mackenzie points out that these sounds lack a contrastive counterpart: there is no /ɠ/ or /gb/. The natural classes model (Frisch *et al.* 2004) of calculating similarity does take phonemic inventory into account when computing natural classes and similarity, but it fares poorly with asymmetric inventories in which contrastive counterparts are missing. Hansson (2004) notes this problem with respect to laryngeal harmony in Ngizim, where implosives do not participate. Mackenzie's solution is to determine similarity via pairwise contrasts that are partially language-specific. If two sounds are not specified for a feature due to lack of contrast, they do not participate in the harmony, which references presence of features.

Hansson (2008) examines the role of contrast in the typology of vowel harmony and consonant harmony and notes that only consonant harmony has cases of "symmetric neutralization," in which a lexical [±feature] contrast emerges in affixes only with neutral roots. The regressive sibilant harmony systems of Chumash and Navajo involve neutralization of contrasts on both roots and affixes, as either /s/ or /ʃ/ can trigger harmony as long as it is the rightmost sibilant in the word. Hansson argues that systems of this type are attested in consonant harmony, but not vowel harmony, because they are *recoverable*. The loss of contrast between /s/ and /ʃ/ is minimal in the consonant inventory, and affects only a small subclass of consonants. The learner has a large number of contexts provided by neutral roots to compensate for neutralization. Hansson (2001a) notes that the specific combination of symmetric neutralization with absolute directionality of assimilation creates problems for some models of phonology, such as Declarative Phonology and standard Optimality Theory.

Finally, Gallagher (2008, 2010) argues for a notion of laryngeal contrast rooted in dispersion theory with a more global view of contrast within a language's lexicon. A constraint, Laryngeal Distance, penalizes contrasts between roots that have only one laryngeally marked stop *vs.* those with two. Plain stops are unmarked for laryngeal features. Gallagher argues that the distinction between a root with one laryngeal feature and a root with two laryngeal features is perceptually weak. Avoidance can play out as harmony (only two ejectives [k'ap'a] or two plain stops [kapa] are allowed) or as dissimilation (only one plain and one ejective are allowed [k'apa] or two plain [kapa]).

In conclusion, contrast remains a powerful and debated concept in the study of consonant harmony, one that is sure to resonate in future research.

4 Experimental approaches to consonant harmony

As debate about the most appropriate analysis of consonant harmony has come to center on hypotheses about its grounding in articulation or perception, experimental studies of consonant harmony have been conducted (CHAPTER 96: EXPERIMENTAL APPROACHES IN THEORETICAL PHONOLOGY). The correspondence approach to consonant harmony proposes that harmony is grounded in production difficulties caused by phonological planning and the similarity of interacting consonants. Several experiments have been undertaken to test this hypothesis in the area of speech errors.

Walker (2007) conducted an experimental study inducing speech errors. Consonants that were more similar and known to participate in nasal harmony, such as nasals and voiced stops, were predicted to be more prone to speech errors than other combinations. Nonce words with combinations of nasals and voiced stops and nasals and voiceless stops were tested with English speakers, as English is not reported to have nasal consonant harmony. Indeed, more errors arose with nasal-voiced stop combinations than nasal-voiceless. Walker concluded that nasal harmony could indeed be grounded in difficulties with the production of similar sounds.

Kochetov and Radiŝić (2009) performed a similar experiment on combinations of four sibilant fricatives /s s^j ʃ $ʃ^j$/ in Russian in a repetition task performed at a fast rate of speech. Errors (assessed by examining acoustic effects of production) were observed for both primary place of articulation and secondary articulation. The primary-place assimilation errors were generally regressive and involved /s/ changing to [ʃ], reflective of the “palatal bias” effect reported in other speech-error studies on English. Although Russian is not reported to have sibilant consonant harmony, the speech-error effect is similar to that found in harmony languages, supporting Hansson's (2001a, 2001b) observation of the correlation. However, Kochetov and Radiŝić (2009) also note that consonants differing only in secondary articulation did not participate in as many errors and that those errors were progressive. This seems to lend support to Hansson's (2007a) contention that speech production difficulties may not underlie secondary articulation harmonies. Kochetov and Radiŝić (2009) speculate that feature spreading or gestural extension may be a better analysis for these cases, paralleling vowel harmony.

Rose and King (2007) examined the impact of harmony constraints on speech errors in languages observed to have laryngeal harmony, namely Chaha and Amharic. They found higher speech-error rates for certain sequences that violated laryngeal harmony than for those that did not. In particular, the researchers compared the laryngeal pairs with consonant pairs that were also highly similar and infrequent in verb roots, but did not violate any constraints. These pairs did not show high error rates in comparison. Rose and King conclude that laryngeal harmony is not only based on production difficulties, but also, once encoded grammatically, triggers more errors when speakers encounter sequences that violate it.

Walker *et al.* (2008) investigated coronal harmony in Kinyarwanda by means of electromagnetic articulography. Kinyarwanda exhibits retroflex harmony, previously reported in the literature as an alveolar-post-alveolar sibilant harmony (Walker and Mpiranya 2006). Harmony is blocked by alveolar stops and affricates, retroflex stops, and palatal consonants. Intervening vowels and non-coronal consonants do not block the harmony and are not perceptibly affected. The blocking effect is suggestive of spreading, while the transparent vowels and non-coronals point to a correspondence analysis. This is important since retroflex harmony is recognized as both a type of consonant harmony (Arsenault and Kochetov, forthcoming) and a possible vowel-consonant harmony for which spreading may be a more appropriate analysis than correspondence (Gafos 1999; Hansson 2001a; Rose and Walker 2004). Walker *et al.* (2008) found evidence that the harmonizing retroflex posture persists during apparent transparent non-coronal consonants when they occur between harmonizing fricatives. Such a result is more supportive of a spreading or gestural analysis, in line with Gafos's (1999) Articulatory Locality model. Results were not conclusive for the intervening coronals. Research of this nature should be conducted on languages that have robust non-retroflex sibilant harmony to help address the question of whether spreading or correspondence is a more appropriate analysis. At the same time, this raises the issue of whether gradient phonetic articulatory results should be used to determine phonological representations.

Finally, Gallagher (2010) utilizes perceptual experiments to test the validity of her contrastive perceptual distance model of laryngeal harmony. American English subjects who listened to pairs of Bolivian Quechua words with combinations of ejectives and plain stops had the greatest difficulty perceiving contrasts between two words where an ejective and a plain stop contrasted with two ejectives ([k'apa] *vs.* [k'ap'a]). The two harmonic forms wherein two ejectives contrast with two plain stops ([k'ap'a] *vs.* [kapa]) were the easiest to perceive, with [k'apa] *vs.* [kapa] occupying an intermediary position. It is argued that these results provide support for a perceptual motivation for consonant harmony, with harmony viewed as a response to avoid difficult perceptual contrasts.

Experimental research in consonant harmony using a variety of techniques may help illuminate the causes of harmony (perceptual, articulatory, or both) and the best phonological analysis of this phenomenon. It may help sort out whether consonant harmony should be viewed as a unified phenomenon or as several disparate phenomena that share the common characteristic of assimilation at a distance.

5 Conclusion

Consonant harmony has intrigued researchers for many years, due to its tantalizing similarities to other types of harmony. Recognizing what distinguishes it from other harmony systems has nevertheless pushed analysis in new directions. Two competing approaches have been advanced: *spreading* of features or gestural extension and *correspondence* between segments requiring matching for features. Both analyses have positive attributes, but both are not without challenges. It is also possible that spreading is appropriate for some harmony systems but correspondence for others, as has been suggested by different researchers (Hansson 2001a; Gallagher and Coon 2009; Kochetov and Radišić 2009). Research in experimental directions may help shed light on which analysis is ultimately correct and whether altogether new analyses will eventually emerge.

ACKNOWLEDGMENTS

Thanks to Beth Hume, Marc van Oostendorp, and two anonymous reviewers for their instructive comments on various aspects of this chapter. All errors are my own.

Notes

1 Zulu voiced stops may be phonetically voiceless (Traill *et al.* 1987), so this is not a clear case of "voicing" harmony.

2 Tahltan harmony may be only partially sibilant, since it is not clear the fricatives [θ] and [ð] are sibilant. They are described as predorsal alveolar in Nater (1989).

3 Navajo actually has examples of progressive sibilant harmony in the prefix string. See McDonough (1990, 1991) and Hansson (2001a: 193–198) for discussion.

4 One identified case is a voicing alternation in Imdlawn Tashlhiyt Berber, which is parasitic on sibilant harmony. Voiceless obstruents block voicing from transferring from stem to prefix.

5 This analysis might be problematic for feature systems in which coronals and front vowels share specification (Clements and Hume 1995), depending on how locality is defined (see Odden 1994 for discussion of vowel-consonant locality issues in this model).

6 Shaw does identify other harmonies, such as labial, but these are *dissimilatory* morpheme structure constraints or morphological affixation, rather than true consonant harmony as defined in this chapter.

7 One solution might be to use the feature [spread glottis] to characterize fricatives and the feature [voice] for stops (Vaux 1998). However, voiceless stops become voiced preceding voiced stops and voiced fricatives alike in Chaha (Rose and Walker 2004).

8 Hansson (2007a) has argued that secondary articulation consonant harmonies may have a diachronic explanation related to (re)interpretation of C-V co-articulation, but similarity at the level of the secondary articulation is still observed.

9 Krämer (2001, 2003) develops a surface correspondence approach for vowel harmony, with adjacency defined

at a moraic or syllabic level. Pulleyblank (2002) offers a different perspective that accounts for both vowel and consonant harmony using a "no-disagreement" harmony-driver (see also Archangeli and Pulleyblank 2007).

10 Indeed, the analysis predicts that combinations such as /ts ts'/ are acceptable as they disagree for ejectivity, when in fact they are not attested.

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