The phonologization of production constraints:
Evidence from consonant harmony

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1 Introduction
In the literature on harmony systems and their analysis, phonologists have generally taken for granted that whatever motivation or mechanism underlies consonant harmony (CH) is the same as that underlying vowel harmony (VH) and such vowel/consonant harmony (VCH) phenomena as nasal harmony, pharyngealization harmony, etc. The analytical tools whose application has been extended to CH from other types of harmony systems include metrical tree structures (Halle & Vergnaud 1981), autosegmental feature spreading (Steriade 1987; Shaw 1991) and, more recently, local spreading of articulatory gestures (Gafos 1996[1999]; Ní Chiosáin & Padgett 1997).

In a recent cross-linguistic study of a wide variety of CH phenomena (Hansson 2001), I have argued that the typological profile of CH systems is in fact strikingly different from that of VH and VCH systems in a number of important respects. In general, the evidence suggests that CH involves long-distance agreement, rather than spreading of phonological features and/or articulatory gestures. Several empirical findings indicate that consonant harmony has its sources in the domain of speech planning and phonological encoding. The strongest evidence pointing in this direction consists of a wide range of striking parallels between systematic phonological CH processes on the one hand and sporadic on-line speech errors on the other. This paper will focus on a few such parallels, most of which have not been noted in earlier works on harmony systems.

Many recent works in phonological theory take the fundamental view—henceforth referred to as the ‘strict locality’ approach—that spreading always respects segmental locality. Features or articulatory gestures thus spread only between segments that are adjacent on the root tier. Segments are never skipped, and gapped representations are not allowed as a matter of principle (see, e.g., Padgett 1995; Pulleyblank 1996; Gafos 1996[1999]; Ní Chiosáin & Padgett 1997; Walker 1998[2000]). This has an important corollary for CH processes, where the trigger and target consonants appear to interact at-a-distance, potentially across long stretches of intervening vowels and consonants. According to the strict locality approach, intervening segments are permeated by the spreading feature/gesture rather than being genuinely transparent (i.e. ‘skipped’). CH must therefore always involve gestures that happen not to interfere significantly with the articulation or acoustic quality of intervening vowels and consonants. Gafos (1996[1999]) argues quite forcefully that this is indeed the case, claiming that CH ‘is attested only for coronal consonants’ and that the features which assimilate ‘are
limited to those which describe the mid-sagittal or cross-sectional shape of the tongue tip-blade, the major articulator of coronal consonants’ (Gafos 1999:9).

However, this represents a somewhat idealized picture of the world of CH systems. If we define CH pre-theoretically as (apparent) long-distance assimilation between consonants, then non-coronal consonant harmony most certainly does exist. The list in (1) mentions some of the attested kinds of CH discussed in the typological survey in Hansson (2001), which builds on a database of roughly 120 distinct CH systems (including assimilatory cooccurrence restrictions).

(1) Examples of non-coronal CH phenomena discussed in Hansson (2001)

- Nasal consonant harmony (nasals vs. oral stops/sonorants)
- Voicing harmony (voiced vs. voiceless obstruents)
- Stricture harmony (stops vs. fricatives, fricatives vs. affricates, etc.)
- Dorsal consonant harmony (velars vs. uvulars)
- Liquid harmony (laterals vs. rhotics, liquids vs. glides)
- Secondary-articulation harmony (e.g., pharyngealized vs. plain sibilants)

In a series of recent papers, Walker (2000ab, to appear) develops an alternative approach for analyzing some of the ‘residue’ in (1), more specifically the nasal consonant harmony found in many Bantu languages (Walker 2000a) and the obstruent voicing harmony found in such languages as Kera and Ngbaka (Walker 2000a, to appear). The core of Walker’s proposal is that the observed assimilations result from a string-internal correspondence relation, which becomes established between cooccurring consonants that are sufficiently similar to one another. Agreement in the harmony feature \[F\] is then enforced by high-ranked IDENT[F] constraints that are specific to this particular dimension of correspondence.

The correspondence-based agreement analysis is motivated in the domain of speech planning and phonological encoding. Segments that are similar, i.e. share a large number of properties, are far more likely to interact with each other in slips of the tongue (see, e.g., Shattuck-Hufnagel & Klatt 1979; Frisch 1996; Dell et al. 1997). Walker’s analysis encapsulates this sensitivity to similarity in the constraints that give rise to correspondence.

Hansson (2001) modifies and expands Walker’s original proposal and makes the broader claim that all types of CH are to be analyzed synchronically as involving agreement at-a-distance, rather than spreading of features or articulatory gestures. This is true not merely of non-coronal harmony phenomena such as the ones listed in (1), but even of the most canonical type of CH, coronal harmony. Based on a detailed typological investigation of CH systems, it is concluded that CH in general, and coronal harmony in particular, shows a series of properties which support the theory that these phenomena are motivated in the domain of speech planning. I will now turn to discussing some of these properties, starting with effects related to directionality.

2 Directionality effects

In a recent study of VH systems and their typology, Baković (2000) recognizes two basic directionality patterns which are robustly attested cross-linguistically. One is stem control, whereby an affix vowel harmonizes with a vowel in the stem it attaches to; in other words, the directionality of assimilation is determined by morphological structure. The other pattern is dominance, whereby a vowel with the ‘recessive’ feature value \[\alpha F\] harmonizes with a nearby vowel with the ‘dominant’ value \[ -\alpha F\];
in this case directionality of assimilation is determined by the feature specifications of the interacting vowels.

In a comprehensive cross-linguistic study of CH systems, Hansson (2001) finds that such systems follow one of two fundamental directionality patterns. One of the attested patterns is stem control, as explained above and outlined schematically in (2a). The other attested pattern is anticipatory harmony (absolute right-to-left directionality); in a $C_1...C_2$ sequence, $C_1$ thus consistently harmonizes with $C_2$. This is shown schematically in (2b).

(2) Attested directionality patterns in CH systems (Hansson 2001)

a. Stem-controlled harmony
   - Left-to-right harmony in [[stem]+suffix] contexts
   - Right-to-left harmony in [prefix+[stem]] contexts

b. Anticipatory harmony
   - Right-to-left harmony in all contexts, regardless of morphology

One implication of the dichotomy in (2) is that left-to-right directionality in CH systems can only arise as a by-product of stem control, whereby suffixes harmonize with the preceding stem to which they attach. An example of stem-controlled CH resulting in left-to-right directionality is the sibilant harmony found in many Omotic languages, as illustrated by the Koyra examples in (3). The root is indicated in boldface.

(3) Stem-controlled sibilant harmony in Koyra (Omotic; Hayward 1982)

/ʃaj-(u)s-/ \(\rightarrow\) [ʃaj]- ‘cause to urinate’
/ʃɔtʃ-(u)s-/ \(\rightarrow\) [ʃɔtʃ]- ‘cause to pull’
/ʔɔrdʒ-(u)s/- \(\rightarrow\) [ʔɔrdʒ]- ‘make big, increase (tr.)’
/ʔɔrdʒ-ɔsɔ/ \(\rightarrow\) [ʔɔrdʒɔ]- ‘he/they got big’
/ʤaʃ-(u)s-æʃɛ/ \(\rightarrow\) [ʤaʃ]- ‘let him/them frighten (s.o.)!’

In the first three examples in (3), the /s/ of the causative suffix /-(u)s/ assimilates in [±ant] to a sibilant in the preceding verb root. The same is true of the geminate /s/ of the 3SgMasc perfective ending /-osɔ/ in the fourth example. Finally, the last example shows that this ‘inside-out’ harmony is recursive. Causative /-(u)s/ harmonizes with the preceding stem /ʤaʃ/-, giving rise to /ʤaʃ-ʃɛ/-; this in turn triggers harmony in the 3SgMasc jussive ending /-æʃɛ/, yielding [ʤaʃ-ʃɛ] as the resulting surface form.

Progressive harmony always results from stem control, and hence one never finds prefixes triggering harmony in the following stem. Under anticipatory harmony, on the other hand, where the directionality is absolute and independent of morphological structure, affixes (i.e. suffixes) do trigger assimilation in the preceding stem. One famous example is the sibilant harmony found in various Chumashan languages, such as Ineseño, illustrated in (4). The stem is again indicated in boldface (these forms have a compound stem, consisting of /-api/- ‘quick’ and /-ʧʰo/- ‘good’).

(4) Anticipatory sibilant harmony in Ineseño (Chumashan; Applegate 1972)

/s-apidʧʰɒo-it/ \(\rightarrow\) [apidʧʰolit] ‘I have a stroke of good luck’
/s-apidʧʰɒo-us/ \(\rightarrow\) [sapitʃʰolus] ‘he has a stroke of good luck’
/s-apidʧʰ-o-us-waf/ \(\rightarrow\) [apidʧʰolufwaʃ] ‘he had a stroke of good luck’
In the first form in (4), the 3Subj prefix /s-/ harmonizes with the /tʰ/ of the following stem, whereas in the second form, the /s/ of the 3Obj suffix /-us/ in turn triggers harmony in the preceding stem. When the past tense suffix /-wa/ is added, the /j/ of this suffix now triggers harmony in all preceding morphemes, whether they belong to other suffixes, the root, or prefixes.

Other examples of anticipatory sibilant harmony include Rwanda (Kimenyi 1979), as can be seen from examples like /ku-saz-i]-a/ → [ku'azii]a] ‘to cause to get old’ or /ku-uzuz-i]-a/ → [ku'izii]a] ‘to cause to fill’, where the causative suffix /-i]/ triggers harmony in the preceding root. Occasionally related languages with the same CH type will differ along the stem control vs. anticipatory harmony parameter, as the examples in (5) illustrate.

(5) Directionality differences in Bantu nasal consonant harmony

a. Stem control

Yaka (Hyman 1995):

/ -tsúm-idí/ → [ -tsúm-iní] ‘sewed (perf.)’

Tiene (Hyman & Inkelas 1997):

/ -són-Vk/- → [ -són-oñ] ‘be written’

b. Anticipatory harmony

Pangwa (Stirnimann 1983):

/ -pulix-an/- → [ -pulín-an-] ‘listen to each other’

In morpheme-internal contexts, where stem control is obviously irrelevant, anticipation is also the norm—although here the directionality of harmony can often only be determined on the basis of comparative-historical evidence (see Hansson 2001 for discussion).

In sum, anticipation (right-to-left assimilation) appears to be the default directionality for CH phenomena. Perseveratory (left-to-right) harmony does occur, but is merely the surface manifestation of stem control. In Hansson (2001), following Baković (2000), stem control effects emerge from constraint interaction, whereby faithfulness to the stem of affixation—essentially a paradigm levelling effect—has the potential of forcing left-to-right harmony from stem to suffix.

Interestingly, the same bias in favor of anticipation has been observed to be characteristic of the CH processes frequently found in child language. In her survey of CH in child language, Vihman (1978) notes that the reported data predominantly shows anticipatory assimilation. Of all the documented examples of consonant harmony in the corpus surveyed by Vihman, 67% involved anticipation. The same bias remained when the data was broken down further. For example, in Amahl’s speech (see Smith 1973), anticipations constituted 79%, whereas in Virve’s speech the relevant figure was 69%; these two children accounted for nearly half of the harmony forms in Vihman’s corpus. For the remaining group of children, 61% of the harmony assimilations were anticipatory.

What is even more important in this context is the fact that a general bias towards anticipation has been robustly documented in the psycholinguistic literature on speech errors and phonological encoding. Let us first reconsider what the predominance of anticipatory CH means, seen from the perspective of speech planning and phonological encoding: in short, the realization of a given consonant (Cₙ) tends to be influenced by a consonant which is being planned (Cₙ₊₁), rather than by one which has already been realized (Cₙ₋₁). This tendency is not too surprising, given the fundamental properties necessary in any efficient serial-order production system, summarized by Dell et al. (1997) as in (6).
(6) Functional requirements of a serial-order production mechanism
   a. Turn-on function: The system must activate the *present*.
   b. Turn-off function: The system must deactivate the *past*.
   c. Prime function: The system must prepare to activate the *future*.

In most language-production models, (6c) is implemented by activating a plan representation. The activation of the plan causes anticipatory activation of upcoming elements—which may thus interfere with the production of the present element. The crucial thing to note is that even when the system is working well, upcoming segments are *always* activated to some degree (i.e. primed) at the time the current segment is being executed, whereas this is ideally *not* the case with past segments, i.e. those preceding the current one. As Dell et al. (1997:123) put it, ‘when the language-production system is working well, it looks to the future and does not dwell on the past’.

This has direct and observable consequences for the relative frequency of anticipatory vs. perseveratory interference effects in speech errors. Several psycholinguistic studies of slips of the tongue have found that, other things being equal, anticipatory errors are far more common than perseveratory errors (see esp. Schwartz et al. 1994; Dell et al. 1997). Under normal circumstances, anticipatory speech errors tend to outweigh perseveratory errors by a ratio of 2:1 or even 3:1, a fact which Dell et al. (1997) refer to as the *general anticipatory effect*. This appears to be the normal state of affairs in a relatively error-free production system.

Unlike anticipatory errors, perseveratory errors appear to be more characteristic of relatively more ‘dysfunctional’ states of the production system, as reflected in a higher overall error rate. The various factors that may contribute to higher incidence of perseveratory errors are summarized in (7).

(7) Correlation of perseveratory errors with ‘dysfunctional’ (error-prone) states
   a. Practice effect
      When producing unfamiliar and difficult phrases, practice reduces the overall error rate and also greatly lowers the proportion of perseveratory errors as compared to anticipatory ones (Schwartz et al. 1994; Dell et al. 1997).
   b. Speech rate effect
      The proportion of perseveratory errors relative to anticipatory ones increases with increasing speech rate—i.e. as available time for speaking decreases (Dell 1990; Dell et al. 1997).
   c. Aphasic speech
      The speech of many aphasic patients is characterized by a much higher proportion of perseveratory errors than nonaphasic speech (Schwartz et al. 1994).
   d. Children’s speech
      The proportion of perseveratory errors over anticipatory ones is considerably higher in the speech of children—especially younger children—than it is in adult speech (Stemberger 1989).

To sum up, the predominant directionality found in the cross-linguistic typology of consonant harmony systems (in adult and child language alike) closely mirrors that found in psycholinguistic studies of speech errors. In both cases, *anticipation* is the norm. The bias towards anticipation ultimately falls out from the nature of the serial-
order mechanism responsible for speech production: a segment which is currently being realized may be influenced by an upcoming segment that is already being planned (and thus activated). This parallelism strongly supports the view that consonant harmony is motivated in the domain of speech planning and phonological encoding.

3 Palatal Bias effects
3.1 Speech errors and the Palatal Bias
In a landmark study of phonological speech errors and their sensitivity (or lack thereof) to segmental markedness, Shattuck-Hufnagel & Klatt (1979) noted a curious asymmetry in how frequently certain segment types occurred as targets vs. intrusions in single-segment errors. (In an error utterance like ‘change the first part’, the /f/ of the intended word ‘first’ is referred to as the target segment and the /p/ which substitutes for it is the intrusion segment.) What Shattuck-Hufnagel & Klatt discovered was the surprising fact that certain high-frequency alveolar consonants, in particular /s/ and /t/, are significantly more often targets than they are intrusions, whereas their lower-frequency ‘palatal’ counterparts /ʃ, tʃ/ are more often intrusions than they are targets. They found this asymmetry to hold in both the MIT and UCLA speech error corpora. Moreover, both corpora clearly show that the asymmetric target/intrusion distributions of /s, t/ and /ʃ, tʃ/ are connected. The true generalization is that alveolars tend to be replaced by palatals significantly more often than vice versa, e.g., errors like /s/ → /ʃ/ are much more commonly found than /ʃ/ → /s/. This generalization is summarized in (8), illustrated with examples from Stemberger (1991).

(8) Asymmetries in phonological speech errors involving coronal obstruents
a. Palatal intruding on alveolar (frequent)
   /s/ → /ʃ/ And sho (= so) she just cashed it.
   /t/ → /tʃ/ Then we could just choss (= toss) out these checks.

b. Alveolar intruding on palatal (less frequent)
   /ʃ/ → /s/ ...seventy percent to sow—to show that it’s not random.
   /tʃ/ → /t/ Rapa Tortilla tips—chips.

Since Shattuck-Hufnagel & Klatt (1979) made their discovery, this Palatal Bias has been reported in other speech error corpora as well, e.g., in that collected by Stemberger (see Stemberger 1991). Furthermore, it has been documented in other languages as well, e.g. in the German speech error corpus of Berg (1988). Bolozky (1978) also describes the same asymmetry as being typical of slips of the tongue in Hebrew. Aside from corpora of naturally occurring speech errors, Stemberger (1991) also found the Palatal Bias to be reliably present in experimentally induced errors. In his experiment, Stemberger found 65 errors where an alveolar was replaced by a palatal, vs. only 38 errors where a palatal was replaced by an alveolar. The difference was most striking for the pairs sʃ (22 ‘palatalizations’ vs. 8 ‘depalatalizations’) and tʃ (14 vs. 1). In short, the existence of a Palatal Bias has been robustly confirmed by experimental methods, whatever its ultimate explanation may be.

3.2 Palatal Bias effects in sibilant harmony systems
Coronal harmony is by far the most widely attested type of CH in the world’s languages. More specifically, the predominant variety is coronal sibilant harmony, which is found in a great number of language families across different continents. In
most cases, sibilant harmony involves the fricative contrast /s/ vs. /ʃ/ (though the precise phonetic parameter may vary from language to language, and is not always clear from descriptive sources) and often corresponding affricate contrasts like /ts/ vs. /ʃʃ/ are involved in the harmony as well. If the source of CH is indeed to be found in the domain of speech planning and phonological encoding, then any generalizations found to characterize consonantal speech errors might be expected to manifest themselves to some degree in the typology of CH systems. Given the fact that segment distinctions like /s/ vs. /ʃ/ are so frequently involved in CH, we would expect to find some analogue of the Palatal Bias in sibilant harmony processes.

As argued at length in Hansson (2001), this is indeed the case. Note first that sibilant harmony systems of the relevant type can be characterized as either symmetric or asymmetric. In the former case, the assimilating feature value may equally well be [+ant] (yielding ē → s, etc.) or [-ant] (yielding s → ē, etc.), depending on the context. An example of this is Ineseño sibilant harmony, as illustrated in (4) above. Of the sibilant harmony systems surveyed by Hansson (2001), the fully symmetric ones are those listed in (9).

(9) Symmetric sibilant harmony systems (both /s/ → /ʃ/ and /ʃ/ → /s/)
    Navajo (Athapaskan)
    Chiricahua Apache (Athapaskan)
    Kiowa-Apache (Athapaskan)
    Tanana (Athapaskan)
    Barbareño (Chumashan)
    Ineseño (Chumashan)
    Ventureño (Chumashan)
    Southern Paiute (Uto-Aztecans)
    Nebaj Ixil (Mayan)
    ?Misantla Totonac (Totonacan)

A considerably more common state of affairs is for sibilant harmony systems to be asymmetric. In an asymmetric system, harmony only manifests itself in the change [+ant] → [-ant], or only in [-ant] → [+ant]. On the hypothesis that the Palatal Bias does shape the typology of sibilant harmony systems, the former (giving rise to /s/ → /ʃ/, etc.) would be expected to have privileged status, whereas the latter should be less common (i.e. /ʃ/ → /s/ and so on).

The list in (10) shows that this prediction is indeed borne out by the facts. Of the sibilant harmony systems of the relevant type surveyed in Hansson (2001), these are the ones that show some sign of asymmetry. With the sole exception of Tlachichilco Tepehua, the asymmetry is consistently in favor of [+ant] → [-ant], in conformity with the Palatal Bias described above. Note that in the headings in (10), ‘s’ and ‘ʃ’ stand for entire series of alveolar vs. ‘palatal’ sibilants, since often voiced fricatives like /z/, /ʒ/ and/or affricates like /ts/, /ʃʃ/ participate in the harmony as well. For more detailed discussion of the precise manifestation of the asymmetry in some of the individual cases listed in (10), see Hansson (2001).
Asymmetric sibilant harmony systems

$s \rightarrow f$ only

Sarcee (Athapaskan)
Slave (Athapaskan)
Wiyot (Algonkian)
Tzeltal (Mayan)
Koyra (Omotic)
Benchon Gimira (Omotic)
Zayse (Omotic)
Moroccan Arabic (Semitic)
Berber (various dialects; Afroasiatic)
Coptic (various dialects; Afroasiatic)
Nkore-Kiga (Bantu)
Rwanda (Bantu)
Rundi (Bantu)
Izere (Bantu)

The overview in (10) speaks for itself: in all but one case, the asymmetry is in the direction predicted by the Palatal Bias. The generalization is that if only one type of assimilation is attested—or if one is somehow privileged over the other—the favored one will be $s \rightarrow /s/ \rightarrow /\text{f}/$ rather than $/\text{f}/ \rightarrow /s/$. A ‘palatal’ sibilant thus has a greater tendency to induce harmony in a nearby alveolar sibilant than vice versa.

Interestingly, the same asymmetry appears to be typical of sporadic sound changes involving sibilant assimilations at a distance. In the first work to mention consonant harmony (Konsonanten-Harmonisierung) as a general linguistic phenomenon, Jespersen (1904) discusses sound changes such as French chercher $\rightarrow$ chercher (cf. English search), where the historical development is $/s/.../\text{f}/ \rightarrow /\text{f}/.../\text{s}/$, and also the ‘vulgar’ pronunciations $/[\text{ser}^\prime\text{chant}] \rightarrow [\text{ser}^\prime\text{chant}]$ in Danish and German, instead of correct $/[\text{ser}^\prime\text{chant}] \rightarrow [\text{ser}^\prime\text{chant}]$; here too we see $/s/.../\text{f}/ \rightarrow /\text{f}/.../\text{s}/$ or $/s/.../\text{s}/ \rightarrow /\text{f}/.../\text{f}/$. Note that both examples are consistent not only with the Palatal Bias but also with the bias towards anticipatory assimilation discussed earlier. Although these examples constitute sporadic rather than systematic sound changes, they are directly parallel to the regular phonological assimilations found in the languages listed in (10).

3.3 Palatal Bias effects in non-sibilant CH systems

Although most CH systems involving the alveolar vs. ‘palatal’ distinction are sibilant harmony systems, there exists a handful of cases where alveolar stops like $/t/, /d/$ interact with affricates like $/\text{t}\text{ʃ}/, /\text{d}\text{ʒ}/$. Recall that in the domain of speech errors, the Palatal Bias also applies to slips of the tongue involving such contrasts as $/t/ \rightarrow /\text{t}\text{ʃ}/$. This raises the question whether the few attested cases of coronal stop-affricate harmony show any sign of Palatal Bias effects.

The answer is that they do. Of the handful of harmony systems involved, all appear to show (anticipatory) assimilations of the type $/t.../\text{t}\text{ʃ}/ \rightarrow /\text{t}\text{ʃ}.../\text{t}\text{ʃ}/$, with an alveolar stop harmonizing with a following ‘palatal’ affricate. None has corresponding assimilations of the type $/\text{t}\text{ʃ}.../t/ \rightarrow /t.../t/$. Only two examples will be mentioned here. One is the Chadic language Kera (Ebert 1979), where the stop $/t/$ assimilates (to some extent optionally) to an
affricate /tʃ/ later in the same word, as shown in (11a). The forms in (11b) show that this harmony even results in [tʃ][tʃ] alternations in the feminine prefix /t-/ . Finally, forms such as the one in (11c) indicate that the harmony is asymmetric, resulting in the ‘palatalization’ of /t/ , never the ‘depalatalization’ of /tʃ/ .

(11) Asymmetric coronal harmony in Kera (Chadic; Ebert 1979)

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<tr>
<td>a.</td>
<td>tutʃi ~ tʃutʃi</td>
<td>‘tamarind’</td>
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<tr>
<td></td>
<td>tʃɔtʃerẽ</td>
<td>‘backbone’ (cf. Tupuri /tʃerẽ/)</td>
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<tr>
<td>b.</td>
<td>t-ʔoʃã</td>
<td>‘dog (fem.)’ (cf. masc. /k-ʔoʃã/)</td>
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<td></td>
<td>tʃ-ʔoʃã</td>
<td>‘dry (fem.)’ (cf. masc. /k-ʔoʃã/)</td>
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<tr>
<td>c.</td>
<td>tʃɛrtẽ</td>
<td>‘small (fem.)’ (cf. masc. /k-ɛrtẽ/)</td>
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Another example is the morpheme-internal coronal harmony exhibited by Aymara, at least in the dialects spoken in Bolivia (see MacEachern 1997[1999]). In Bolivian Aymara roots, the cooccurrence of alveolar stops /t, t̪, t'/ and ‘palatal’ affricates /tʃ, tʃ̪, tʃ'/ is severely restricted. When two cooccurring plosives are both laryngeally specified—i.e. each is either aspirated or ejective—then they cannot be alveolar vs. palatal. However, when one or both of the plosives is plain unaspirated, the restriction is asymmetric (Hansson 2001, based on a search of De Lucca 1987). Palatal…alveolar sequences are allowed, whereas alveolar…palatal sequences are not; this is shown in (12).

(12) Asymmetric coronal harmony in Bolivian Aymara (isolate)

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<tr>
<td>a.</td>
<td>Disallowed roots mixing alveolars and palatals</td>
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<tr>
<td></td>
<td>*t…tʃ</td>
<td></td>
</tr>
<tr>
<td></td>
<td>*t̪…tʃ</td>
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<td></td>
<td>*t’…tʃ</td>
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<tr>
<td>b.</td>
<td>Permitted root shapes</td>
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<tr>
<td></td>
<td>tʃatu ‘jug, small vessel of clay’</td>
<td></td>
</tr>
<tr>
<td></td>
<td>tʃ̪uʃa</td>
<td>‘string, row of objects put on a thread’</td>
</tr>
<tr>
<td></td>
<td>tʃ’uta</td>
<td>‘collision of two round objects’</td>
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Although the Bolivian Aymara pattern is a static cooccurrence restriction, it has the same effect as in Kera (as well as in other similar cases discussed by Hansson 2001): if a palatal affricate occurs in the word/root, any preceding coronal plosive must also be palatal, not alveolar. The distributional patterns of Bolivian Aymara thus display a Palatal Bias effect. Anticipatory coronal harmony involving /t/ → /tʃ/ is enforced, but the reverse change /tʃ/ → /t/ is not.

To sum up, Palatal Bias effects are found in the cross-linguistic typology of CH systems. This is true not only of sibilant harmony systems of the sʃ type, but also of the much rarer kind of coronal harmony whereby stops and affricates interact (i.e. t/tʃ). Note that these are precisely the segment pairs for which Palatal Bias effect were originally documented in the literature on speech errors. In both cases alveolars have a far stronger tendency to assimilate to a nearby ‘palatal’ than vice versa. Insofar as this asymmetry mirrors the Palatal Bias that has been robustly demonstrated in speech error studies, it can be taken as strong circumstantial evidence that coronal harmony—and, by extension, consonant harmony in general—has its roots in the domain of speech planning and phonological encoding.
4 Other evidence

Several more aspects of CH phenomena could be cited which are mirrored by speech errors. Two will be mentioned here: sensitivity to the relative similarity of the interacting consonants, and ‘transparency’ of the segmental material intervening between them.

Psycholinguistic studies of speech errors have shown that segments are far more likely to interact in slips of the tongue if they share a large number of phonological properties (see, e.g., Nooteboom 1969; MacKay 1970; Fromkin 1971; Shattuck-Hufnagel & Klatt 1979; Frisch 1996). In neural network models of speech production (e.g., Stemberger 1985; Dell 1986), this falls out from spreading activation. When two cooccurring consonants share a large number of features, there is extensive overlap in the neurons activated for $C_1$ and $C_2$. The greater the overlap, the greater the potential for interference effects between the two consonants.

In the cross-linguistic typology of phonological CH systems, similarity effects abound. The trigger and target consonants are frequently required to agree in a particular feature, or set of features, in order for harmony to apply. In several cases, harmony between less similar consonants is restricted in ways that do not apply to harmony between more similar consonants. A few examples discussed by Hansson (2001) can be mentioned. Sibilant harmony may be limited to fricatives, excluding affricates (e.g., in Rwanda), or it may apply only to fricative-fricative and affricate-affricate combinations, but not mixed affricate-fricative ones (e.g., in Tzutujil). Alternatively, sibilant harmony may be sensitive to differences in laryngeal features; for example, in Nkore-Kiga, harmony is more limited in mixed-voicing combinations such as /ʃ…z/ than it is in same-voicing ones such as /ʃ…s/ or /ʒ…z/. Laryngeal harmony, such as voicing harmony, is always restricted to obstruent-obstruent combinations (e.g., in Ngizim or Yabem). However, it may be further limited to stop-stop or fricative-fricative combinations (e.g., in Kera and various Berber dialects, respectively), excluding stop-fricative ones. Finally, many types of CH systems are sensitive to differences in place of articulation. Stricture harmony may thus be limited to homorganic obstruents (e.g., Yabem), and laryngeal harmony is frequently limited in the same way to homorganic consonants (e.g., in Ngbaka). Alternatively, laryngeal harmony may override certain phonotactic constraints in the case of homorganic combinations but not in heterorganic ones (e.g., in Ndebele).

A second notable parallel has to do with the inertness of the vowels and consonants intervening between the trigger and target. When two nearby consonants interact in speech errors, the intervening segments are clearly and genuinely transparent. In no way are they ‘permeated’ by the intruding feature or articulatory gesture. This can be seen, for example, from data reported by instrumental studies on gradient speech errors, such as the EMG study by Mowrey & MacKay (1990) and the kinematic study by Pouplier et al. (1999). In both cases, an /ʃ/-related gesture or motor activity that intrudes upon a preceding /s/ does so at a distance; in other words, the anticipatory ‘assimilation’ observed involves a separate articulatory gesture, not the extension of one and the same gesture across intervening vowels and consonants.

In the case of phonological CH systems, the evidence is less conclusive. Are segments intervening between the trigger and target consonants genuinely transparent, or are they instead permeated by the harmonic feature/gesture? It should be emphasized that the hypothesis that coronal harmony involves local spreading of articulatory gestures (e.g., Gafo 1996[1999]; Ní Chiosáin & Padgett 1997) has so far been supported exclusively by conjectural evidence. It has never been confirmed
with the experimental study of any actual coronal harmony language, such as Navajo or Rwanda.

In non-coronal CH systems, what direct evidence there exists is in favor of genuine transparency. This is trivially true of such phenomena as nasal consonant harmony, whereby an oral consonant assimilates to a nearby nasal without intervening vowels or sonorants becoming phonetically nasalized. But even in other types of CH, where permeation would be perfectly possible in principle, the same is also true. A case in point is the dorsal consonant harmony found, e.g., in some of the Totonacan languages (Watters 1988; MacKay 1999). In this type of harmony, velars and uvulars interact, resulting in /k...q'/ → /q...q/. This phenomenon is illustrated in (13), with forms from Tlachichilco Tepehua (Watters 1988). Note that ejective /q'/ is realized phonetically as [ʔ], but nevertheless has the same harmony effect as a proper uvular.

(13) Dorsal consonant harmony in Tlachichilco Tepehua (Watters 1988)

/ʔuks-laqt's'in/ → [ʔoqslaqt's'in] ‘look at Y across surface’
/mak-t'jaq'a-j/ → [maqtjaʔaj] ‘X washes hands (imperf.)’
/lak-t'jiq'i-l/ → [laqt'jeʔel] ‘X broke them (perf.)’

The first and third forms in (13) illustrate another relevant effect that uvulars have on nearby segments in these languages. The high vowels /i, u/ become lowered to [e, o] when immediately adjacent to an (underlying) uvular; cf. also /qiʔ-ʔuq/ → [qent'uj] ‘two (people)’, /ʔaq-ʔuq/ → [ʔaqt'oq] ‘pot’, etc. If dorsal consonant harmony were a matter of the local, uninterrupted spreading of some relevant articulatory gesture, we would expect the vowel lowering effect to obtain throughout the span of segments intervening between the triggering uvular and the target velar. However, forms such as the ones in (14) show that this is not the case. An intervening /i/ or /u/ which is not immediately adjacent either to the triggering uvular or to the target velar (which becomes uvular through harmony) is not lowered. (Note, again, that the triggering /q'/ is realized phonetically as [ʔ]; this has no direct bearing on the argument.)

(14) No lowering effect within ‘uvularization’ harmony span

/lak-pituq'i-ni-j/ → [laqt'uteʔenij] ‘X recounted it to them’
/ʔak-pituq'i-j/ → [ʔaqt'uteʔej] ‘X folds it over’

As for coronal harmony, although no direct evidence exists which bears on the transparency vs. permeation issue, one might still ask why it is never the case that intervening segments are never opaque. In the domain of VH systems, as well as in such VCH systems as nasal harmony or pharyngealization harmony, blocking effects are extremely common. In such cases, particular segment types are treated by the phonology as incompatible with the spreading feature—either because this would obliterate an underlying contrast or because the resulting segment would be highly marked. As a result the propagation of harmony is blocked by such segments.

Note that a given segment type may be compatible with the spreading feature in one language but incompatible with it—and thus opaque to harmony—in another language (see Walker 1998[2000] for a typology of opacity effects in nasal harmony systems). Given that coronal harmony is a fairly common phenomenon, one might therefore expect such blocking effects to be found in at least a handful of cases. However, one of the findings of the typological investigation of CH systems
in Hansson (2001) is that segmental opacity is entirely unattested, in coronal as well as non-coronal CH systems. This would be a rather unexpected state of affairs if local spreading of features/gestures were indeed involved.

5 Conclusions
Evidence from a number of empirical generalizations indicates that CH is based in the domain of speech planning. In a sense, CH effects can be viewed as ‘phonologized speech errors’ (though this phrase should not be taken too literally). The wide-ranging parallels that hold between slips of the tongue and phonological CH processes provide strong support for the hypothesis that the latter have their roots (diachronic and/or synchronic) in the domain of speech planning and phonological encoding.

This hypothesis in turn underlies the synchronic analysis of CH as phonological agreement, rather than local feature/gesture spreading, as developed in Hansson (2001; see also Walker 2000ab, to appear; Rose & Walker 2001). To the extent that the hypothesis is validated by facts such as the ones that have been discussed here, the agreement-based analysis of CH is justified. Most importantly, the affinities with speech-error effects are found even in the most canonical type of CH—coronal harmony, and sibilant harmony in particular—which has often been regarded as the strongest piece of evidence for the strict-locality approach to phonological spreading.

Notes
1 It is an interesting question whether some (or all) VH and VCH phenomena may also involve agreement, potentially holding at-a-distance (for an analysis of VH as local agreement, see Baković 2000). Although I do by no means wish to exclude this possibility, my main point here is simply to emphasize that CH processes appear to be different in fundamental respects. Whether this is a mere matter of distinct diachronic origins of the synchronic phenomena in question remains to be seen.
2 See also Rose & Walker (2001), who similarly advocate extending the agreement-based analysis to (at least some) coronal harmony phenomena.
3 For an optimality-theoretic implementation of the anticipation bias, and of fixed directionality in general, see Hansson (2001).
4 It so happens that the examples cited in (8b) both involve perseveratory errors, as compared to the anticipatory errors in (8a); this is purely accidental.
5 In an earlier experimental study, Levitt & Healy (1985) had failed to find this asymmetry. However, as pointed out by Stemberger (1991), this was likely due to the design of the target stimuli used in their experiment.
6 The sole exception in (10), Tlachichilco Tepehua sibilant harmony (Watters 1988), shows only the assimilation /ʃ...ʃ/ → /ʃ...ʃ/, and in fact the same may also be true of its relative Misantla Totonac (MacKay 1999), which was listed with a question mark in (9) above. In Hansson (2001) I offer a possible explanation for the anomalous behaviour of sibilant harmony in these Totonacan languages, conjecturing that this phenomenon may have its origins in the analogical reanalysis of global sound-symbolic sibilant alternations. This hypothesis was briefly mentioned in the oral presentation of this paper, but has been omitted here due to space limitations.
7 A well-known case which is usually treated under the heading ‘coronal harmony’, and which does display segmental opacity effects, is Vedic Sanskrit n-retroflexion (see, e.g., Schein & Steriade 1986; Gafos 1996[1999]; Ni Chiosáin & Padgett 1997). This particular phenomenon does indeed appear to involve spreading, but there are strong reasons not to equate it with CH at all. As argued at length in Hansson (2001), Sanskrit n-retroflexion displays a number of characteristics that are otherwise entirely unheard of in the typology of CH systems.
References


