5 The evolution of metathesis

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1 Introduction

Our object of study in this chapter is metathesis, which we define as any reordering of segments or features within the phonological string.[1] Representative cases, discussed in more detail below, are illustrated in (1).

(1) a. Rotuman: /mo**fa**/ → *mo**af*** 'rubbish'; cf. (20) below
Proto-Indo-European > Armenian: **kʲu**bʰr**os* > *su**rb*** 'holy' (initial **kʲ* > *s*); cf. (6) below
b. Nxilxcín (Colville): *sʕáy* 'they are noisy' vs *sy-m-əncʕàt* 'they make noise'; cf. (15) below
Classical > South Italian Greek: *gamb**r**ós* > *g**r**ambó* 'son-in-law'; cf. (10) below
c. Marathi: *õʈ**ʰ*** > ***h**õʈ* 'lip'; cf. (17) below

Adjacent segments seem to exchange positions in the common pattern seen in (1a), while (1b) shows examples of nonlocal movement. A case of feature metathesis is shown in (1c); such cases are relevant because feature and segment metatheses differ in their phonological effects but not their underlying causes.

Metathesis has long posed problems for phonological theory. These problems are of two main types: metathesis has resisted analysis in terms of phonetically natural or motivated sound change, and the reordering of sounds in metathesis has required extensions of otherwise highly restrictive phonological formalisms. We will argue here that metathesis can, despite these problems, be explained in a phonetically natural way based on precisely the same assumptions required to understand other phonological phenomena.

We also have a more programmatic goal. In recent years, phonologists have increasingly come to accept the view that phonological patterns, both within and across languages, can be explained by reference to the findings of experimental phonetics. As yet, however, there is no consensus as to the precise explanatory nexus between the two areas. In this chapter we will contrast two views of the relationship between phonetics and phonology, for which we will use the short-hand terms *phonetic optimisation* and *evolutionary phonology*. The first approach seeks to explain phonological patterns as the result of optimisation of some aspect of phonetics such as articulatory ease or perceptual salience. On this view, sound patterns are caused by (can be explained by) the phonetic optimisation they yield, and sound changes occur because their output is phonetically 'better' in some way – for example, easier to articulate or perceive. The phonetic optimisation approach has been advocated by numerous scholars, including many contributors to this volume (here and elsewhere).

We will suggest a very different approach here. Our view is that diachronic regularities play a major role in determining phonological typology. Since actual phonological systems have evolved diachronically, their properties reflect constraints on sound change as well as constraints on the nature of phonological systems. Explanations for phonological patterns may reside in synchronic analysis or diachronic evolution. Which explanation will emerge in any case is a matter to be resolved based on the evidence, but since historical accounts permit simpler grammatical models, they are preferable wherever possible.

Certain sound patterns are cross-linguistically frequent as a consequence of convergent evolution: the intrinsic properties of speech perception and production result in certain frequent sound changes; these in turn yield common sound patterns. We maintain that if sound patterns can be explained as the result of convergent evolution in this sense, the burden of proof falls on those who choose to duplicate such explanations in the synchronic domain. In short, one goal of the evolutionary phonology approach is to help simplify synchronic models by developing phonetically plausible diachronic explanations for phonological patterns.

Two problems that any model of phonological diachrony must confront are the mechanism of sound change and the cause of its typical regularity. In our view sound change is mainly caused by listener-based reinterpretation. This in turn may arise in several ways. For example, the actual phonetic string may present a listener with multiple potential phonological analyses; or a listener may simply misperceive the utterance due to biases in the perceptual system; or a listener may confront a choice of phonological analyses due to speaker variation on a continuum from hyperarticulated listener-oriented 'clear' speech to reduced, hypoarticulated 'casual' speech. In the last case, reanalysis reflects ambiguity presented by multiple phonetic forms in the input, not the ambiguous nature of a single phonetic form.

Sound change is regular for the same reason that language learners consistently categorise contextually determined phonetic categories with parallel phonological categories. English *pit*, *pat*, *pet*, *pot*, *put* are all 'learned' with initial /p/ and final /t/ because ranges of values for some set of cues (e.g. VOT, closure duration, burst properties, CV transition formant values) are interpreted as defining a single linguistic category. Because the sources of sound change all involve categorical perception, a shift in phonological representation for one lexeme will result in the same shift for another lexeme containing the same phonetic category. For example, in an English dialect where final /t/ is realised as [ʔt], the phonetic properties of this realisation may allow reinterpretation as /ʔ/. If this happens, since the cues now interpreted as defining /ʔ/ are found in *pit*, *pat*, *pet*, *pot*, *put*, a /t/ > /ʔ/ shift will occur in all these words. The regularity of sound change is thus a special case of the regularity of phonological category acquisition.

In comparing different approaches to sound change, it should be emphasised that the question of optimisation – are sound patterns functionally motivated? – is logically distinct from the question of whether phonetic explanations for sound patterns belong in the diachronic or synchronic arena. This suggests a four-way typology along the lines in (2).

(2) a. Synchronic + nonfunctionalist
b. Synchronic + functionalist (e.g. Flemming 1996; Hume 1997, 2001; Boersma 1998; Steriade 2001)
c. Diachronic + functionalist (e.g. Grammont 1950; Vennemann 1988)
d. Diachronic + nonfunctionalist (e.g. Ohala 1974, 1981, 1993; Blevins and Garrett 1998)

Various scholars' work is crudely classified in (2b–d); the nonfunctionalist synchronic approach in (2a) has been standard in phonological theory. The view we will defend here is diachronic and nonfunctionalist: phonetic explanations play an important diachronic role in explaining sound patterns, but (at least for the phenomena we investigate) optimisation is irrelevant.

Several forms of the phonetic optimisation approach can be envisioned. A relatively strong position is that optimisation is a property of *all* sound change (or all sound changes of a particular structural type). Arguing against the view that misperception causes metathesis sound changes, Steriade (2001: 234–5) writes as follows:

> [C]onfusability is, in principle, symmetric . . . [If] sound change is initiated as misperception, there would be no reason to expect metathesis in one direction and not in the other. In fact, however, the direction of metathesis is highly constrained. Only certain types of reversal, which can be identified as perception-optimising, are frequent and systematic . . .

The claim that all 'frequent and systematic' types of metathesis optimise perception represents a strong form of the phonetic optimisation approach.[2]

An alternative weaker position, as Donca Steriade reminds us, is simply that *some* optimising sound changes exist. Yet this weaker position is problematic. To refute the hypothesis that all sound change is optimising, it suffices to identify non-optimising sound changes, but it is harder to find evidence bearing on the weaker hypothesis that just some sound changes are motivated by optimisation.

On our account, some sound changes will have the effect of optimising aspects of phonetics simply by chance; indeed, in numerous cases, misperception leads directly to optimised phonetics. Therefore, the mere existence of optimising changes, even in great numbers, is not evidence for the phonetic optimisation model. To defend this model in its weaker form, one must argue either that there exist optimising sound changes that cannot involve perceptual reinterpretation (changes whose input and output cannot be related via misperception) or that the overall typology of sound changes follows from the optimisation model but not from our model. Our position is the reverse: the typology of sound changes follows from the evolutionary phonology model but not from the phonetic optimisation model.

For all these questions metathesis is of special interest. In traditional phonology, especially among the neogrammarians and structuralists, metathesis was treated as marginal precisely because it seemed to contradict standard doctrines separating phonetics and phonology. Essentially, all scholars who studied the matter came to conclusions like those of Grammont (1923), according to whom CC metathesis arises in order to avoid 'unpronounceable' clusters. It is also governed phonotactically, according to Grammont: less sonorous consonants (those with smaller 'aperture') are always positioned closer to a syllable boundary and more sonorous consonants closer to the syllable nucleus. In other words, unlike most other processes (e.g. assimilation), metathesis was seen as an output-driven phonological process.

In this chapter, extending earlier work on consonant-vowel metathesis (Blevins and Garrett 1998), we present a comprehensive and restrictive typology of regular metathesis in the world's languages. We identify four main types of metathesis, with specific phonetic characteristics. We list these metathesis types in (3), together with the phonetic features that allow us to explain and categorise them. We should emphasise that our names for these metathesis types are partly arbitrary labels, serving mainly to distinguish them from each other; coarticulation, perception, and audition play a role in all four types.

(3) Metathesis type	Phonetic feature
a. Perceptual metathesis (§3.1)	Elongated phonetic cues (§2.1)
b. Compensatory metathesis (§3.2)	Stress-induced temporal shifts (§2.2)
c. Coarticulatory metathesis (§3.3)	CC coarticulation (§2.3)
d. Auditory metathesis (§3.4)	Auditory-stream decoupling (§2.4)

The first type of metathesis involves features of intrinsically long duration (e.g. pharyngealisation); in multisegmental strings, such features are spread out over the entire sequence, allowing them to be reinterpreted in nonhistorical positions. The second type is prosodically conditioned: within a foot, features in a weak syllable undergo temporal shifts into the strong syllable. The third type of metathesis arises in clusters of consonants with the same manner of articulation but different places of articulation; the place cues do not necessarily have long duration, and we will suggest that metathesis results from coarticulation facilitated by shared articulatory gestures. The fourth type of metathesis results from the auditory segregation of sibilant noise from the rest of the speech stream.

Our typology is both restrictive and predictive. A segment or feature may undergo metathesis (be reinterpreted in a nonhistorical position) only if the phonetic signal is ambiguous or otherwise presents difficulties in feature or segment localisation. The phonetic properties underlying such ambiguities or difficulties are discussed in section 2. In section 3 we detail our metathesis typology. In section 4 we address some general issues, summarise our findings, and discuss the general role of phonetics in phonology: phonology is phonetically driven, but only in the diachronic dimension.

2 Phonetic background

In this section we outline the phonetics underlying the metathesis types to be surveyed in section 3.

2.1 Elongated phonetic cues

Segmentation is a long-standing problem in phonetic theory. For example, it is well known that consonant and vowel articulations, or their acoustic consequences, overlap in CV and VC contexts. Accurate perception of place of articulation for a prevocalic oral stop consonant is based primarily on information from the CV transition (Liberman 1970); the place features of the consonant are cued by information that co-occurs with the periodic waveform characteristic of a vowel, making it difficult to say where the consonant ends and the vowel begins.

Perceptual metathesis is closely linked to the segmentation problem as follows. As emphasised by Ohala (e.g. 1993) in his discussions of dissimilation, certain perceptual features are typically realised over relatively short time durations, whereas others are typically realised over relatively long durations. For example, irrespective of its phonological association with a consonant, vowel, or glide, pharyngealisation is typically phonetically realised over a minimal CV or VC domain. Listeners thus confront a problem if an entire CVC sequence is pharyngealised. If features are associated at some level with unique segments, there are at least seven logical possibilities for the phonological representation of the pharyngealised CVC sequence: any of the three segments could carry a secondary pharyngealisation feature ($C^{ʕ}VC$, $CV^{ʕ}C$, $CVC^{ʕ}$), or a pharyngeal could be the source of ambient pharyngealisation (ʕCVC, CʕVC, CVʕC, CVCʕ).[3] If the historical source of pharyngealisation is a pharyngeal glide and the listener posits a pharyngeal glide in a nonhistorical position, metathesis has occurred.

Phonetic studies show that many features have multisegmental domains spanning CV or VC strings, entire syllables, or strings of syllables. For example, West (1999, 2000) has established significant long-distance coarticulatory effects of English rhotics and laterals by replacing these segments with progressively longer sequences of noise; speakers can accurately identify the contrast between [ɹ] and [l] based on coarticulatory effects up to two syllables away from their phonological position in the string. This perceptual evidence is consistent with the articulatory findings of Kelly and Local (1986) and Kelly (1989). For at least one English dialect (Kelly and Local 1986), electropalatography data show that velar closure in *came* is significantly more front after *ballet* in (4a) than after *Barry* in (4b).

(4) a. Ballet came to my mind.
    b. Barry came to my mind.

The perceptual evidence is also consistent with acoustic studies. Kelly and Local (1986) show that the 'domain of resonance' of a liquid (i.e. its acoustic consequences) is measurable in all subsequent unaccented syllables. Tunley (1999) shows via measurements of vowel formants that English rhotics have significant long-distance effects on unstressed vowels, both perseveratively (on V_2 in rV_1CV_2 strings) and anticipatorily (on V_1 in V_1CV_2r strings). The effects documented by Tunley involve lowering of F2 and F3. She also shows that incorporating this sort of coarticulatory detail into synthetic speech can improve segmental intelligibility by 7–28 per cent, again providing evidence for long-distance coarticulation as a natural feature of speech which, when present, is perceptually accessible.[4]

In table 5.1 we list phonetic features with demonstrated drawn-out domains in one or more languages, along with their common phonological realisations and salient acoustic characteristics. Acoustic and articulatory data show that all these features have long domains spanning minimal VC/CV domains, entire syllables, or sequences of syllables. As mentioned above, long-domain effects of rhotics and laterals in English have been found to span domains up to three syllables long. Lip rounding and protrusion have been found to span multisyllabic domains in French and English (Lubker and Gay 1982; Benguerel and Cowan 1974). Palatalisation and velarisation with both vocalic and consonantal phonological sources have been shown to colour multisegmental domains in many different languages, including Catalan (Recasens 1984, 1987), English (Hawkins and Slater 1994), Japanese (Magen 1984), Marshallese (Choi 1992), Russian (Keating 1988), and several Bantu languages (Manuel 1987). In at least two Arabic dialects, pharyngealisation or tongue backing has been measured across multisyllabic domains while showing gradient properties typical

Table 5.1. *Features with typically long durations*

Feature	Segmental realisations	Acoustic property with long duration
rhoticity	rhotics, rhotic Vs	lowered F3 (LM: 244, 313)
laterality	laterals, lateral Vs	lateral formants (LM: 193–7)
rounding	rounded Cs, rounded Gs, round Vs	lowering of all formants (LM: 356–8)
palatalisation	palatalised Cs, palatal Gs, high front Vs	raised F2 (LM: 364)
velarisation	velarised Cs, velar Gs and high back Vs	lowered F2 (LM: 361–2)
pharyngealisation	pharyngealised Cs, Gs and Vs, ʕ, ħ	lowered F3, raised F1 (LM: 307)
laryngealisation	laryngealised Cs, Gs and Vs, ʔ	more energy in F1, F2 more jitter (LMJ)
aspiration	aspirated/breathy Cs, Gs and Vs, ɦ, h	more energy in F0; more noise (LMJ);
retroflexion	retroflex Cs and Vs	lowered F3, F4; clustering of F2, F3, F4 (L: 203, LM: 28)
nasalisation	nasals, nasalised vowels and glides	spectral zero/nasal anti-resonance (LM: 116)

(L = Ladefoged 1993; LM = Ladefoged and Maddieson 1996; LMJ = Ladefoged, Maddieson, and Jackson 1988.)

of phonetic coarticulation as opposed to phonological harmony (Ghazeli 1977; Card 1979); see Bessell 1992, 1997, 1998a, 1998b for phonetic analysis of multisegmental pharyngealisation domains in Interior Salish languages. Measurements of laryngealisation (creaky voice) and aspiration (voicelessness) in Cayuga by Dougherty (1993) show CV or VC domains that inform our analysis of metathesis in that language (Blevins and Garrett 1998: 509–12). The acoustic correlates of retroflexion typically have a minimal VC domain, as has been shown for Gooniyandi (McGregor 1990), Gujarati (Dave 1977), Hindi (Stevens and Blumstein 1975), Malayalam (Dart 1991), and Tiwi (Anderson and Maddieson 1994). Long-domain effects of nasalisation are also well documented; see Cohn 1990 and Walker 2000 for summaries of the vast phonetic literature on this subject. Finally, other features that have no standard phonological representation also show drawn-out domains, such as the jaw movement required for low front vowels (Amerman, Daniloff, and Moll 1970).

By ‘typically long duration’ in table 5.1 we mean that, in the majority of cases where the phonetic correlates of the features have been measured, they have been found to extend minimally across entire CV or VC strings. We do not claim that these features always take multisegmental domains, but simply that they can, and that they do so in the linguistic systems that give rise to metathesis sound changes. Missing in table 5.1 are major consonantal place of articulation (coronal, labial, dorsal), voicing, frication, continuancy, and the major class features. These features, unlike the features in table 5.1, typically show temporal alignment with single segments; on our approach they are not expected to take part in regular metathesis (though see sections 2.4 and 3.4 on the status of fricative noise).

For some phonetic features in table 5.1 a multisegmental coarticulatory domain has been phonologised, resulting in syllable-, foot-, and word-based harmonies. For example, though pharyngealisation is a feature of pharyngeal glides or coronal consonants in many Arabic dialects, it takes the syllable as its minimal domain in Cairene Arabic (Hoberman 1995 with further references) and has even broader domains in other dialects (Watson 1999); cf. Bessell 1992, 1998a, 1998b on Interior Salish pharyngealisation harmonies. Similarly, in at least two Australian languages, Mayali and Murrinhpatha, a retroflex coda consonant yields surface retroflex syllables (Evans 1995: 739–40). Word-level retroflex harmony is found in Yurok (Robins 1958: 12–13); this may be the long-distance effect of a formerly local coarticulatory effect found in Yurok's relative Wiyot, where a retroflexed affricate induced retroflexion on preceding low vowels (Reichard 1925: 8).[5] Labialisation and palatalisation/velarisation are well known from the word-domain harmony systems of Yokuts and Turkic languages respectively, and the typology of nasal harmony systems with syllable, foot, and word domains is detailed in Walker 2000.

At the same time, extended domains for certain features in table 5.1 are blocked in particular phonetic contexts where an incompatible phonetic feature abuts the one in question. This is important in understanding apparent exceptions to regular metathesis, or phonetic conditioning factors for particular metatheses. For example, though laryngeal metatheses of *h* and *ʔ* are common, and seem to result from the elongated phonetic cues of breathiness and laryngealisation often associated with these segments, laryngeal metathesis is typically blocked adjacent to a segment with conflicting laryngeal specifications. Thus, in Cayuga, the laryngeals (*h*, *ʔ*) metathesise with preceding vowels unless the output would be an *hʔ* or *ʔh* cluster (Foster 1982).[6] The anticipatory seepage of laryngealisation is blocked by a preceding segment that involves breathiness, and vice versa, since these two features involve antagonistic glottal gestures of constriction and spreading respectively; as a result, a vowel is not fully laryngealised, the signal is unambiguous, and metathesis does not occur. Contextual blocking effects of this type are widespread in perceptual metathesis; elsewhere (Blevins and Garrett 1998) we have discussed Cayuga in more detail together with similar cases of contextual blocking in Birom, Latin, and Le Havre French.

Now consider the nasalisation associated with a nasal stop. Spreading of this phonetic feature onto a preceding or following vowel is quite widespread and unremarkable. In phonetic terms, vowels and glides undergo coarticulatory nasalisation to a much greater extent than oral stops (Cohn 1990). We would therefore not be surprised to find nasal metathesis conditioned by an adjacent vowel, but perceptual metathesis of nasals and (oral) stops should not exist. (On putative counterexamples to this prediction see section 4.1 below.)

In sum, the phonetic features listed in table 5.1 are often characterised by long durations spanning multisegmental domains. A result of this many-to-one association between phonetic features and segments is ambiguity in segmentation. If a listener attributes the spread-out feature to a nonhistorical position, (perceptual) metathesis occurs. On this approach, exceptions to metathesis are expected just in case an adjacent phonetic feature conflicts with the spread-out feature. Coarticulation is blocked in such cases, and there is no ambiguity in segmentation.

2.2 *Stress-induced temporal shifts of V-V coarticulation*

Coarticulation between sequential vowels across an intervening consonant appears to occur in all spoken languages, where, in a VCV sequence, transitions from vowel to consonant and from consonant to vowel are significantly influenced by the quality of the transconsonantal vowel. In the word-final cases of compensatory metathesis we cite, there is extreme anticipatory coarticulation. This is consistent with acoustic and articulatory evidence suggesting that articulatory movement for V_2 in a V_1CV_2 sequence may begin during V_1 (Bell-Berti and Harris 1976; Fowler 1981a, 1981b; Manuel and Krakow 1984).

We have argued elsewhere (Blevins and Garrett 1998) that prosodically conditioned cases of CV metathesis (compensatory metathesis) involve temporal shifts whereby the unstressed (word-peripheral) vowel comes to be coarticulated more and more into the stressed (word-internal) position, eventually leaving no trace. This model of prosodically conditioned CV metathesis implies a relationship between stress and coarticulation in which the duration and perceptual prominence of the stressed vowel can give rise to extreme anticipatory coarticulation. Other factors that may facilitate this extreme anticipatory coarticulation include size and distribution of vowel inventory, degree of vowel variation, absence of secondary consonant articulations, absence of long consonants and consonant clusters, increased duration of stressed syllables, and relatively steady-state vowels (Blevins and Garrett 1998: 548). Phonetic studies show that, independent of prosodic effects, size of vowel inventory affects V-to-V coarticulation. As suggested by Manuel and Krakow (1984) and Manuel (1987), the size and distribution of a phonemic inventory may determine the limits of phoneme variability: in a language with a relatively small vowel system, formant frequencies of a vowel are more likely to be influenced by a vowel in an adjacent syllable than in languages with larger vowel systems where acoustic variability is not as great. All cases of compensatory metathesis known to us are found in languages with small vowel systems (three to five vowels), steady-state vowels, and simple CV syllable structure.

2.3 CC coarticulation

Consonant clusters are typically subject to variation in casual or fast speech. This variation has been argued to follow, to a great extent, from coarticulatory effects (Kohler 1976; Barry 1984; Browman and Goldstein 1990). Coarticulation within consonant clusters can have dramatically different acoustic effects depending on the extent to which the articulatory gestures involved are independent of each other. As demonstrated by Browman and Goldstein (1990), deletion, insertion, and assimilation can all be attributed to gestural overlap, with acoustic consequences following from the nature of the independent gestures and the extent to which they overlap.

We suggest in section 3.3 that the most common types of stop metathesis (PK > KP, TP > PT) are the result of extreme gestural overlap. There are several logically possible patterns of gestural overlap in VC_1C_2V sequences. One possible pattern is medial overlap of gestures with VC_1 and C_2V transitions intact. Linear order remains constant, and an excrescent segment may emerge if the two consonants differ in laryngeal or manner features (Ohala 1974). A second possibility is 'swallow-up' overlap, with the closure and release of one of the two consonants containing the closure and release of the other. If the two consonants share laryngeal and manner features, then one completely hides the other, with the surface effect of total assimilation or deletion. Finally, if closure and/or release of two consonants with distinct articulatory gestures are nearly simultaneous, place of articulation cues become difficult to recover. If the righthand cluster edge contains unambiguous release cues, it is possible to reanalyse C_1C_2 as C_2C_1. This possibility appears to be entirely dependent on the perception of nearly simultaneous closure of C_1 and C_2 as an instance of C_2, and in cases known to us it is limited to certain combinations of place features. In one subtype the clusters in question are labial-velar stop sequences; another involves coronal-noncoronal stop sequences. In both cases, coarticulation can result in nearly simultaneous closure, with labial release following velar release in the first case and with coronal release following noncoronal release in the second case. These metatheses are both unidirectional, respectively yielding velar-labial and noncoronal-coronal stop sequences.

We suggest that the unidirectionality of velar-labial stop metathesis reflects the same factors that underlie the phonetics of labial-velar stops (Connell 1994), which represent the extreme case of gestural overlap. In all labial-velar stops, the acoustic and articulatory record shows that velar release occurs before labial release (usually by 30–60 ms). Velar closure always precedes labial closure or is synchronous with it, but as noted by Connell (1994: 451), even where velar and labial closures are synchronised, ‘the auditory impression is of an earlier velar closure’. In short, KP > PK metathesis is unattested because extreme coarticulation in such clusters leads naturally to a KP percept.

Gestural overlap may also explain unidirectionality in coronal-noncoronal stop metathesis, as well as illuminating an asymmetry in coronal-noncoronal stop assimilation patterns. As Bailey (1969, 1970) and Blust (1979) observe, there are striking parallels between possible place assimilation and attested metathesis in coronal-noncoronal clusters. In metathesis, coronal-noncoronal clusters invert position, giving rise to noncoronal-coronal clusters, but the reverse metathesis is unattested. A parallel asymmetry in the assimilation of heterorganic stop clusters in English is illustrated in (5) with examples from Blust (1979: 103).

(5)	Assimilation		No assimilation	
	tp	foo**tp**rint, hi**t p**arade	pt	ri**pt**ide
	tk	sui**tc**ase, ca**tc**all	kt	co**ckt**ail
	db	goo**db**ye	bd	ru**bd**own
	dg	hea**dg**ear	dg	do**gd**ays
	nm	fa**nm**ail, gu**nm**an	mn	roo**m n**umber
			ŋn	ha**ngn**ail

Regressive assimilation is possible and common in coronal-noncoronal clusters, but not perceptually salient for noncoronal-coronal clusters. These observations now have ample acoustic and articulatory support (e.g. Zsiga 1994; Byrd 1996), allowing us to conclude for English that gestural overlap in coronal-noncoronal stop clusters is greater than in noncoronal-coronal clusters, and that in coronal-noncoronal stop clusters the lips or tongue body often move toward closure in production of a noncoronal before closure for the coronal stop is achieved. We hypothesise that, as with labial-velars, the percept of simultaneous coronal and noncoronal closure can be one in which noncoronal closure features prevail.[7]

2.4 Auditory-stream decoupling

A number of regular metatheses involve sibilant-stop or stop-sibilant sequences. The primary acoustic cue for fricative manner of articulation, irrespective of place of articulation and voicing, is the presence of aperiodic noise in the spectrum (Delattre, Liberman, and Cooper 1962). Jongman (1989) demonstrates that the duration of this noise should be at least 20 ms. (In natural speech it is usually much longer, around 100 ms.) This noise is most intense for sibilant fricatives.

While there is still much work to be done on the acoustics and perception of sibilant noise, a number of studies suggest that, in consonant clusters containing sibilants, the sibilant noise somehow distracts the listener, leading to high confusion rates with respect to the linear order of segments (Bregman 1990). Specifically, there is a tendency to decouple sibilant noise from the rest of the speech stream, and this decoupling can result in dramatic misperceptions.[8]

An additional and possibly contributing factor is the misperception of fricatives as affricates or stops, and vice versa. Several studies demonstrate that the onset of noise must be fairly gradual for a segment to be perceived as a fricative. If it is too abrupt, the stimulus will be perceived as an affricate or a stop (Gerstman 1957; Cutting and Rosner 1974; Keating and Blumstein 1978; Cutting 1982). Even expert listeners have been found to perceive short intervals of sibilant noise as stops (Whalen 1991).

3 Typology of metathesis

In this section we will discuss the four different metathesis types identified in (3), showing how their properties receive natural explanations in the evolutionary phonology framework.

3.1 Perceptual metathesis

In cases of perceptual metathesis, a segment (or feature) with elongated phonetic cues as discussed in section 2.1 shifts its linear position in a phonological string. Our view is that this partly reflects the perceptual difficulty of localising the origin of a phonetic cue with long-distance effects. The result of perceptual metathesis is a 'mistake' from the point of view of the previous linguistic system: a segment (or feature) is reinterpreted as originating in a new position within the elongated span. This will involve the transposition of adjacent elements in some cases, and in other cases the metathesis will be nonlocal. Since we have already surveyed perceptual metathesis in adjacent CV sequences (Blevins and Garrett 1998), we focus here on other perceptual metathesis contexts: local CC metathesis and long-distance metathesis.[9]

The 'disproportionately high (and widespread) frequency of occurrence of liquids in metathesis' is called 'proverbial' by Ultan (1978: 375), and we begin with several cases involving rhotics. First, in the prehistory of Classical Armenian (Grammont 1908; Schmidt 1981; Ravnæs 1991), the linear order of stop (or affricate) + *r* clusters was regularly inverted, in initial as well as medial position. This is shown in (6).

(6)	Indo-European		Armenian			
a.	*k^{j}u**b**^{h}**r**os	>	*su**br**(V)	>	su**rb**	'holy'
	*b^{h}i**dr**os	>	*b^{h}i**tr**n(V)	>	bi**rt**	'rigid, rude'
	*me**g**^{jh}**r**i	>	*med͡z**r**(V)	>	me**rd͡z**	'near'
b.	*d^{h}a**b**^{h}**r**os	>	*da**br**in	>	da**rb**in	'smith'
	*swi**dr**os	>	*k^{h}i**tr**n	>	k^{h}i**rt**n	'sweat'
c.	***b**^{h}**r**ātēr	>	***br**ājr	>	eł**b**ajr	'brother'
	***b**^{h}**r**ēwr	>	***br**ewr	>	ał**b**ewr	'spring, well'
	***dr**ak^{j}u	>	***tr**asu-	>	a**rt**asu-	'tear(s)'
	***g**^{w}**r**āwōn	>	***kr**an	>	e**rk**an	'millstone'

Note that a prothetic vowel *e* (or *a*, if *u* or *w* follows) arose in Armenian words beginning with a rhotic. In the first two forms in (6c), *ł* < **r* as a dissimilatory effect of the following *r*.[10]

A comparable sound change has occurred in Rendille (a Cushitic language spoken in Kenya) and is still manifested in synchronic alternations involving underlying obstruent-*r* and nasal-*r* sequences (Heine 1976; Oomen 1981; Sim 1981). The metathesis is shown in (7a) and (8a); the forms in (7b) and (8b) are for comparison.

(7)		2 sg. = 3 sg. fem.	1 sg. = 3 sg. masc.
a.	'see'	á**gar**-te	á**rg**-e
	'shiver'	ħá**mar**-te	ħá**rm**-e
	'sleep'	ú**dur**-te	ú**rd**-e
b.	'be full'	ɖá**r**a**g**-te	ɖá**rg**-e

(8)		Singular	Plural
a.	'bag'	u**gár**	u**rg**-ó
	'clothing'	da**fár**	da**rf**-ó
	'mother'	a**bár**	a**rb**-ó
b.	'gate'	a**rít**	a**rt**-ó

In the Armenian and Rendille metatheses, an original *Cr* sequence inverts its order: *Cr* > *rC*. While common, this is not the only pattern for rhotic metathesis. A regular *rð* > *ðr* sound change has occurred in several eastern dialects of Judeo-Spanish (Ladino). This is shown in (9) with data from the Istanbul dialect (Subak 1906: 171–2) as well as standard Spanish for comparison.

(9) Standard Spanish	Istanbul Judeo-Spanish	
ta**rd**e	la ta**ðr**e	'evening'
basta**rd**o	bastá**ðr**o	'bastard'
ve**rd**ura	ve**ðr**úra	'verdure'
cue**rd**a	kwé**ðr**a	'cord'
co**rd**ero	ko**ðr**éro	'lamb'
so**rd**o	só**ðr**o	'deaf'

Note that standard *rd* is [ɾð] and Judeo-Spanish *r* is [ɾ].[11]

Two interesting points about the directionality of metathesis emerge from the patterns in (6–9). First, directionality is independent of pre-existing phonotactics, since Armenian, Rendille, and Spanish all had both *Cr* and *rC* clusters prior to metathesis. Second, the directionality of the Armenian and Rendille metatheses, affecting various *Cr* cluster types, differs from that of the Judeo-Spanish metathesis, affecting only [ɾð] clusters. We suggest that the perseverative nature of the Judeo-Spanish rhotic shift may be a consequence of coarticulatory effects.

The three rhotic metatheses discussed above operate locally, transposing adjacent segments only. Long-distance liquid metathesis has occurred as a sound change in South Italian dialects of Greek (Rohlfs 1950, 1964).[12] In these dialects, prevocalic *r* or *l* in a noninitial syllable has been transposed into the initial syllable in certain circumstances. This occurred whenever (i) the liquid was positioned after an obstruent and either (iia) the initial syllable had a prevocalic noncoronal obstruent or (iib) the liquid was *r* and the initial syllable had a prevocalic *t*. If these conditions were satisfied, the liquid moved into prevocalic position in the initial syllable. As shown in (10), this resulted in word-initial *(s)Cr* clusters.[13]

		Classical Greek	South Italian Greek	
(10)				
	a.	*bótʰ**r**akos	v**r**úθako	‘frog’ (Rohlfs 1924: 15–16; 1933: 19)
		februā́rius (L)	f**r**evári (O)	‘February’
		gamb**r**ós	g**r**ambó	‘son-in-law’
		kóp**r**os	k**r**ópo (O)	‘dung’
		kʰond**r**ós	x**r**ondó	‘thick’
		pas**tr**ikós	p**r**ástiko	‘clean’
		pik**r**ós	p**r**ikó	‘bitter’
		tágist**r**on	t**r**ástina	‘food bag’
	b.	fáku**l**a (L) > *fák**l**a	f**l**áka	‘torch’
		*fúsk**l**a	*f**l**úska	‘chaff’ (Rohlfs 1933: 74–5)
		spékula (L) > *spék**l**a	sp**l**éka	‘elevated place’

Contexts where the metathesis fails to occur are illustrated in (11).

		Classical Greek	South Italian Greek	
(11)				
	a.	ka**l**ós	ka**l**ó	‘attractive’
		ka**r**día	ka**r**día	‘heart’
		pa**r**atʰý**r**a	pa**r**aθí**r**a	‘side door’
	b.	ántʰ**r**ōpos	áθ**r**opo	‘man’
		lūt**r**ón	lut**r**ó	‘bath’ (place name)
		mét**r**on	mét**r**o (O)	‘measure’

	nep^{h}**r**ós	nef**r**ó	'kidney'
	*pléktra	pléθt**r**a	'plait'
c.	dák**r**yon	ðák**r**i	'tear'
	déndron	ðend**r**ó	'(oak) tree'
	dip**l**ûs	ðip**l**ó	'doubled'
	kyk**l**íon	t͡ʃik**l**í	'small circle'
	*sék**l**ion	sék**l**i	'beet greens'
	tábula (L) > táb**l**a	táv**l**a	'table'

The data in (11a) show that intervocalic and preconsonantal liquids are unaffected, and (11b) shows that liquids are transposed only into initial syllables with prevocalic obstruents. The data in (11c) show that metathesis never yields clusters consisting of a coronal obstruent plus *l* (e.g. *tl*, *sl*, *ðl*, *t͡ʃl*) or consisting of a coronal fricative or affricate plus *r* (e.g. *ðr*, *t͡ʃr*). This is interesting because some inherited clusters of these types do exist. Compare, for example, the first two forms in (11c) with the forms in (12).

(12)	Classical Greek	South Italian Greek	
	drákōn	ð**r**áko	'dragon'
	dráks	ð**r**áka	'handful'
	drómos	ð**r**ómo	'way'

The failure of metathesis in *ðákri* 'tear' (not **ðráki*) cannot be attributed to structure preservation and has no obvious interpretation in the phonetic optimisation approach.

Perceptual metathesis involving labialisation and palatalisation is also well attested (Blevins and Garrett 1998). Here the difference between CV and CC metathesis is minimal, being essentially the positionally determined difference between *VCu* > *VwC* and *VCwV* > *VwCV* metathesis. Comparable long-distance cases are found among the Ethiopian Semitic labialisation and palatalisation processes described by Hetzron (1971; 1977: 45–9), Rose (1997), and other authors.

Perceptual metathesis also involves pharyngeals. For example, a synchronic adjacent-element pharyngeal metathesis has been reconstructed for Proto-Indo-European, and regular pharyngeal interpolation into adjacent vowels has occurred in the history of Cypriot Greek; both cases are cited in Blevins and Garrett 1998. A local pharyngeal metathesis is said to exist in Rendille, where 'the pharyngeal fricative switches with an adjacent consonant when preceded by the low vowel /a/' (Hume 1997: 294). This is illustrated in (13) by three plural nouns and verbs (Heine 1976: 214; 1978: 73; Oomen 1981: 50, 63).

(13)

Non-prevocalic	Prevocalic	
aħa**m** (sg.)	a**m**ħ -a (pl.)	'eat!'
baħá**b** (sg.)	ba**b**ħ -ó (pl.)	'armpits'
saħa**b** (sg.)	sa**b**ħ -o (pl.)	'clap of hand'

Other forms, however, apparently fail to undergo this metathesis. Thus the word *sáħta* 'tomorrow' (Heine 1976: 222) has a surface [aħC] sequence in an apparently underived context, and the prevocalic forms cited in (14) from Heine (1976: 213, 220) lack metathesis despite being generally comparable to those in (13).

(14)

Non-prevocalic	Prevocalic	
bí**ħ**i-	bá**ħc**-	'remove'
na**ħas** (sg.)	na**ħs**-ó (pl.)	'breast'

A possible explanation suggests itself if, as these data suggest, the real generalisation is that *aħC* → *aCħ* metathesis occurs only when C is voiced. Since only voiced segments are compatible with the spread of the voiced pharyngeal articulatory gesture, this extended feature is blocked by a following voiceless consonant. Restriction of the vocalic context to *a* is natural too, since an extended feature is especially likely to be mislinearised (to undergo metathesis) if it is hard to perceive in its original location.[14]

A long-distance pharyngeal metathesis occurs in the Interior Salish language Nxilxcín (Colville). In Nxilxcín, roots whose citation forms begin with a *Cʕ* cluster surface as such in forms with root stress, but in forms with suffix stress the pharyngeal instead surfaces immediately before the stressed vowel. In (15) this process, called 'pharyngeal movement' by Mattina (1979), is illustrated with contrasting forms derived from four different roots. In each case, the first form cited has stress on the root while the second form has stress on a suffix; the pharyngeal regularly precedes the stressed vowel.[15] For clarity we underline the root in all forms.

(15)

	Root (and suffix)		Forms with root vs suffix stress		
a.	ɬʕac	'soak(ed), drip'	c-k-ɬʕàc-p	'(it) still had a drop'	(S #308)
	(-əp)		c-ɬə-ɬc-ʕ**á**p	'(it) had water on'	(S #346)
b.	q'^{w}ʕáy	'black, soiled'	q'^{w}ʕáy-lqs	'preacher' (<'black robe')	(S #655)
	(-**í**c'aʔ)		i-s-t-q'^{w}əy-ʕ**á**c'aʔ	'I am dirty'	(S #753)
c.	sʕáy	'make noise'	sʕáy	'they are noisy'	(S #890)
	(-ənc**ú**t)		sy-m-əncʕ**à**t	'they make noise'	(S #563)
d.	χʕál	'day(light)'	s-χəl-χʕàl-t	'day'	(S #8)
	(**-ú**l'ax^{w})		χəl-p-ʕ**á**l'ax^{w}	'it's daylight'	(Mattina 1979)

This case too is readily analysed in our framework. Unstressed vowels in Interior Salish languages are typically either reduced or deleted – an effect which could only enhance the intrinsic difficulty of hearing pharyngeals.[16] For the prehistory of Nxilxcín, we assume that pharyngealisation had an extended phonetic domain, that it was hard to perceive, and therefore sometimes not perceived in its original (root-internal) position when the root was unstressed, and that the linear position of this feature was then reinterpreted as being in the position where it was perceived, namely in the stressed syllable. This change *results* in perceptual optimisation, for the natural reason that what is harder to hear is sometimes not heard, but our account does not invoke perceptual optimisation as a mechanism or cause of the change.

Local and long-distance glottalisation metathesis is widespread. An interesting long-distance case is found in the Interior Salish language Secwepemctsín (Shuswap). According to Kuipers (1974), Secwepemctsín nonsyllabic glottalised sonorants do not surface as such in postconsonantal position. The sample data in (16) show various surface forms associated with a single suffix containing a glottalised sonorant. If an underlyingly glottalised sonorant is postconsonantal and to the right of the main accent, then its glottalisation shifts either leftward onto an immediately post-tonic sonorant (as in ‘priest’, ‘break off boughs’, ‘I heat stones’), if there is one, or rightward onto an immediately following syllabic sonorant (as in ‘to heat stones’).[17]

(16)	Roots and suffixes		Derived forms	
a.	-é**l’**qs	‘clothing’	t-k^{w}ltk-é**l’**qs	‘underwear’
	q’^{w}e**y-**	‘black’	q’^{w}é**y’-l**qs	‘priest’
b.	-í**l’**əp	‘foundation’	c’lx^{w}-í**l’**əp	‘chair’
	q’i**w**-	‘break’	c-q’í**w’-l**əp	‘break off boughs for bedding’
c.	-ésx**n’**	‘rock’	t-χy-ésx**n-m’**	‘to heat stones’
	χe**y**-	‘heat’	t-χyé**y’**sx**n**-m-kn	‘I heat stones’

This case is of special interest not just because it involves a long-distance metathesis, but because the metathesis is strictly featural: glottalisation is detached from its segmental source.

A comparable long-distance featural metathesis has occurred in the history of Marathi, where aspiration (or breathy voice) has regularly shifted to word-initial position from the onset of a second syllable. This can be seen in (17), comparing Marathi forms with their Sanskrit ancestors and in some cases with more proximately related Prakrit forms (Bloch 1915; Turner 1962–66).

(17)	Sanskrit	Prakrit	Marathi	
a.	du**h**itr̩-	du**h**ia-	d$^{\mathbf{h}}$uːv	'daughter'
	gr̩hɳāti	gaɳ**h**aːti	g$^{\mathbf{h}}$eɳẽ	'takes, seizes'
	jab$^{\mathbf{h}}$ati		d͡ʒ$^{\mathbf{h}}$aɳẽ	'copulates'
	kakʂ̥a-	kakk$^{\mathbf{h}}$a-	kãːk$^{\mathbf{h}}$, k$^{\mathbf{h}}$ãːk	'armpit'
	kaʈ$^{\mathbf{h}}$ina-	kaɖ$^{\mathbf{h}}$iɳa-	kaɖ$^{\mathbf{h}}$iːɳ, k$^{\mathbf{h}}$aɖiːɳ	'hard' > 'difficult'
	ma**h**attara-		m$^{\mathbf{h}}$aːtaːraː	'greater' > 'old'
	ma**h**iʂ̥a-	ma**h**isa-	m$^{\mathbf{h}}$ais	'buffalo'
b.	ast$^{\mathbf{h}}$i	att$^{\mathbf{h}}$i-	**h**aːd	'bone'
	oʂ̥ʈ$^{\mathbf{h}}$a-	oʈʈ$^{\mathbf{h}}$a-	õʈ$^{\mathbf{h}}$, **h**õʈ	'lip'

Aspiration in (17a) has shifted to a word-initial consonant or consonant cluster; in the originally vowel-initial words in (17b), aspiration has shifted to initial position. Note that by-forms with and without metathesis are said to exist in several cases.

Two general issues arise in the analysis of long-distance perceptual metathesis. The first concerns directionality effects. As we note elsewhere (Blevins and Garrett 1998), in cases known to us a segment or feature moves either into an initial syllable or into a position defined by proximity to stress. Examples of the stress type include the Nxilxcín and Secwepemctsín metatheses in (15–16) above; examples of the initial-syllable type include the South Italian Greek and Marathi metatheses in (10) and (17) above, Romani aspiration metathesis (Matras 2002: 35–6), and *r* metathesis in Luchonnais Gascon (n. 12) and Sardinian (Geisler 1994; Molinu 1999). Both patterns involve movement into what is plausibly regarded as a relatively prominent position. In phonetic optimisation approaches, this could be related to ease of perception: a liquid, pharyngeal, or laryngeal surfaces in a position where perception is optimised. The same patterns can also easily be explained on our approach: if a segment (or feature) has extended cues of the sort responsible for perceptual metathesis, then if its linear origin is misperceived it is likelier to be misperceived as originating in a more perceptually salient (prominent) position.

A second general issue concerns blocking in long domains. A referee notes that our analysis predicts that 'when there is a blocker (a gesturally incompatible segment that blocks coarticulation or the long cue extension) there should be no metathesis'. This prediction distinguishes our account from the phonetic optimisation approach, and it seems to be the correct prediction. For example, as seen in (18a), the South Italian Greek liquid metathesis in (10) above was not restricted to adjacent-syllable transpositions.

(18)	Classical Greek	South Italian Greek	
a.	kapíst**r**ion	k**r**apísti	'halter'
	konū́ku**l**a (L) > *konū́k**l**a	k**l**onúka	'distaff'
	pédik**l**on	p**l**étiko (O)	'fetter'

b.	skólumbros	sku**l**ímb**r**i	'wild artichoke sp.'
	*spé**l**end**r**on	spé**l**end**r**o	'watercress sp.'
	k^{h}a**r**ád**r**a	xa**r**áð**r**a	'fissure'

As shown in (18b), this transposition did not occur if there was an intervening liquid.[18] Local metatheses too, as noted in section 2.1, show blocking effects in the form of contextual constraints.[19]

3.2 Compensatory metathesis

We use the term 'compensatory metathesis' for the sound changes schematised in (19), where a vowel at the edge of the phonological domain undergoes phonetic weakening in quality and duration, with compensation for this weakening in terms of anticipatory or perseverative coarticulation of the original peripheral vowel quality in nonperipheral stressed position.

(19) Right edge: $\cdots \acute{V}_1CV_2] > \cdots \acute{V}_1V_2C\breve{V}_2] > \cdots \acute{V}_1V_2C]$
Left edge: $[V_1C\acute{V}_2 \cdots > [\breve{V}_1CV_1\acute{V}_2 \cdots > [CV_1\acute{V}_2 \cdots$

Our diachronic analysis of compensatory metathesis is simple. VCV sequences undergo extreme V-to-V coarticulation, with one vowel persevering or anticipating itself in full as the unstressed vowel gradually shifts its temporal alignment to the stressed syllable. Relevant phonetic literature was summarised in section 2.2.

Rotuman, an Oceanic language, instantiates the right-edge sequence in (19), which occurs within a final trochee; Ngkot̪, a Northern Paman language of Australia, exemplifies these sound changes occurring within word-initial iambs.[20] Representative examples are cited in (20–21).

(20) Rotuman

ses**é**v**a**	→ ses**éa**v	'erroneous'
tík**o**	→ **tío**k	'flesh'
f**ú**t**i**	→ f**ý**t	'to pull'
m**ó**s**e**	→ m**ǿ**s	'to sleep'

(21) Ngkot̪

***a**l**í**-	> l**áj**-	'to go'
***a**m**í**-	> m**áj**-	'up'
***i**·n**á**-	> n**já**-	'to sit'
***u**l**á**n	> l**wá**n	'possum'

All cases of compensatory metathesis known to us are identified and described in Blevins and Garrett 1998: 527–39. Compensatory metathesis has occurred independently in several Austronesian languages and in five branches of Pama-Nyungan. This attested limitation to the Austronesian and Pama-Nyungan families is unsurprising in the context of our analysis: within both language families, the requisite prosodic contours are found, vowel systems are small, diphthongs are for the most part absent, and secondary consonantal articulations are relatively uncommon.

3.3 Coarticulatory metathesis

Coarticulatory metathesis is a type of metathesis with articulatory origins. As outlined in section 2.3, extreme coarticulation is possible in a sequence of stops, each of which involves closure of a distinct articulator. When C_1C_2 gestural overlap results in nearly simultaneous closure, with C_1 released after C_2, a C_2C_1 cluster may be perceived. There are two identifiable subtypes, labial-velar stop sequences and coronal-noncoronal stop sequences, which we discuss in turn.

We begin with labial-velar stop sequences. We are aware of at least four independent cases of a PK > KP sound change, but no cases of a KP > PK sound change.[21] As suggested in section 2.3, the unidirectional nature of this metathesis may be related to the phonetic properties of coarticulated labial and velar stops. In at least one language, the coarticulation of labial-velar sequences appears to be optional, resulting in optional metathesis. In the Micronesian language Mokilese, as seen in (22), all /pk/ sequences are optionally realised as [kp] (Harrison 1976: 45). No such reordering occurs with any other consonant clusters, nor are Mokilese /kp/ sequences (as in /likpia/ 'flying fish with eggs') ever realised as [pk].

(22)	/a**pk**as/	[a**pk**as], [a**kp**as]	'now'
	/ka**pk**iːla/	[ka**pk**iːla], [ka**kp**iːla]	'to drop'
	/di**pk**elkel/	[di**pk**elkel], [di**kp**elkel]	'to stumble'

A PK > KP metathesis is also found in some Bisayan languages. For example, according to Zorc (1977: 54), Aklanon has no surface *bg* clusters; historical **bg* and underlying /bg/ clusters surface with metathesis as *gb*. The two examples in (23) are given with Cebuano comparanda to show surface *bg* in another Bisayan language.

(23)	Cebuano	Aklanon	
	lí**bg**us	lí**gb**us	'mushroom'
	palí**bg**a	palí**gb**a (/pa-libug-a/)	'confuse him'

Finally, in two more poorly documented cases, a similar Klamath metathesis is cited by Barker (1964: 97) and a **pk > kp* change is suggested by the comparison of Wiyot *kbad* /kpat/ 'pitchwood' and Yurok *pkenc* 'pitch' from

Proto-Ritwan **pkanc* (Berman 1990: 432–3; Algonquian cognates show that the original sequence was **pk*).

Further support for our coarticulatory account comes from the common type of sound change in which a coarticulated labiovelar becomes a velar-labial sequence: $w > ɣ^w$, $w > g^w$; $p^ɣ >$ k͡p, $b^ɣ >$ g͡b, $m^ɣ >$ ŋ͡m; $p^ɣ > k^w$, $b^ɣ > g^w$, $m^ɣ > ŋ^w$. Changes like the first two (e.g. $w > g^w$) are found in several early Indo-European languages, while the last six changes are found in some Oceanic languages. For instance, Proto-Oceanic $*p^ɣ$, $*b^ɣ$, and $*m^ɣ$ respectively are reflected as k͡p, g͡b, and ŋ͡m in Mwotlap and as k^w, g^w, and $ŋ^w$ in Western Fijian (Ross 1998: 16–17). If the labiovelars are segments whose independent gestures are phonologically unordered, then their phonologisation as velar-labial sequences likely reflects the same phonetic factors referred to above: the velar closure prior to labial closure as the jaw closes, and simultaneous or nearly simultaneous closure having the percept of velic closure.

The unidirectionality of the Mokilese, Klamath, Bisayan, and Wiyot changes, as well as the variation characteristic of the first two cases, both support our view of these alternations as coarticulatory metathesis. As a coarticulatory effect KP > PK would not be expected, since coarticulated velar-labial stop clusters would be expected to maintain their linear sequencing properties or to show (perceptual) reanalysis to KK, PP, K, or P. The variation described for these phonological sequences parallels the variation inherent in other effects of gestural overlap, like the assimilatory effects noted for English in section 2.3.[22]

We turn now to coronal-noncoronal stop sequences. We know four examples of metathesis affecting such sequences, two of which are in closely related Austronesian languages. As suggested in section 2.3, the unidirectional nature of TP > PT and TK > KT changes seems to be related to the degree of gestural overlap in coronal-noncoronal clusters as opposed to noncoronal-coronal clusters. We hypothesise that, as with nearly simultaneous velar and labial closures, nearly simultaneous coronal and noncoronal closures provide a percept that is noncoronal. Such a case is found in the prehistory of ancient Greek, where **tk* > *kt* and **tp* > *pt* regularly, though the relevant clusters only occurred in the two words $*k^w$*íd-pe* > $*k^w$*ítpe* > *típte* (a particle) and **títkō* > *tíktō* 'I bear' (Lejeune 1972: 70; Rix 1992: 96). As with PK > KP changes, stops agree in all manner and laryngeal features and differ only with respect to place of articulation, with distinct articulators involved, allowing for gestural overlap.

Similar metatheses have occurred in the history of some Central Philippines languages. Blust (1979) discusses data from Tagalog and Cebuano Bisayan, languages in which T{P,K} > {P,K}T can also be viewed as a regular sound change. Representative Cebuano Bisayan data are cited in (24) from Blust (1979: 110).

(24)

Metathesis		No metathesis	
nm	i**num** : i**mn**-a ‘drink’	mn	da**mán** : da**mn**-un ‘talk, walk in one’s sleep’
nŋ	tu**nú**ŋ : tu**ŋn**-a ‘directly at a point’	ŋn	i**ŋún** : i**ŋn**-un ‘say, tell’
tp	a**túp** : a**tp**-an, a**pt**-an ‘roof’	pt	sá**put** : s-al-a**pt**-un ‘bad temper’
tk	li**tik** : li**tk**-an, li**kt**-an ‘snap the fingers’	kt	la**kát** : la**kt**-un ‘walk’
		kp	da**kúp** : da**kp**-an ‘arrest’

The Cebuano Bisayan facts are especially interesting because, as in Mokilese and Klamath, there are both metathesised and unmetathesised variants for obstruent clusters, suggesting that metathesis is directly related to degree of gestural overlap in the phonetic component. Metathesis with nasal clusters appears to be obligatory. It is also interesting to note that Bisayan languages show both PK > KP and T{P,K} > {P,K}T, since we are suggesting the same articulatory phonetic explanation for both phenomena.

A final case described by Blust (1979) is found in the historical phonology of Leti and Moa, two Austronesian languages of the Lesser Sunda group. Leti is well known for its synchronic CV metathesis alternations (van der Hulst and van Engelenhoven 1995; Hume 1998), which arose historically from the telescoping of final vowel copying and medial vowel syncope (Mills and Grima 1980; Blevins and Garrett 1998: 541–7). Blust shows that regular CC metathesis has also occurred just in case syncope results in a coronal-noncoronal cluster with shared manner and laryngeal features; cf., e.g., _*sa**Rm**an_ > Leti _se**mn**a_ ‘outrigger float’ vs _*i**num**_ > Leti _e**mn**u_ ‘drink’ and _*ta**nem**_ > Leti _to**mn**a_, Moa _ta**mn**a_ ‘to plant’.

Table 5.2. *Some attested regular sibilant metatheses*

Language	Metathesis	Source
Old English	sk > ks	(25) below
Faroese	sk > ks /___ t	Lockwood 1955: 23–4
Lithuanian	coronal fricative + velar stop > k + fricative / ___t	Seo and Hume 2001
Colloquial French	ks > sk /___ #	(26) below
Savoyard	*ts > st /#___	Ultan 1978
Classical Aramaic languages	*t + sibilant > sibilant + t / V___ V	Malone 1971, 1985, 1999
Ancient Greek	*dz > zd	Lejeune 1972: 113–16
Calabrian Greek	ps > sp	Rohlfs 1950: 74–6
Dutch	ps > sp	Stroop 1981– 2

3.4 Auditory metathesis

As discussed in section 2.4, auditory-stream decoupling leads to metathesis involving sibilants. Regular sibilant-stop and stop-sibilant metatheses are listed in table 5.2; we will discuss two examples here. The first is a well-documented case in the late West Saxon dialect of Old English (Weyhe 1908; Campbell 1959: 177–8; Luick 1921–40: 913–14; Jordan 1974: 168–70). In this dialect *sk* clusters regularly inverted their linear order and became *ks* clusters. The examples in (25a) show word-final metathesis; intervocalic metathesis is shown in (25b); and (25c) shows metathesis between a vowel and a sonorant.

(25)		Old English	Late West Saxon	
	a.	fro**sk**	fro**ks**	'frog'
		hu**sk**	hu**ks**	'insult'
		ma**sk**	ma**ks**	'meshes' (neut. pl.)
		tu**sk**	tu**ks**	'tooth' (cf. *tusk*)
	b.	a**sk**e	a**ks**e	'ash'
		aː**sk**ian	aː**ks**ian	'to ask'
		fi**sk**as	fi**ks**as	'fishes'
		hne**sk**ian	hne**ks**ian	'to soften'
		to**sk**a	to**ks**a	'frog'
		wa**sk**an	wa**ks**an	'to wash'
	c.	hor**sk** ('quick')	hor**ks**lic	'dirty'
		mu**sk**le	mu**ks**le	'mussel'
		θer**sk**an	θer**ks**an	'to thresh'
		θer**sk**old	θer**ks**old	'threshold'

In all the examples in (25), stress fell on the vowel immediately preceding the metathesising cluster (i.e. the root syllable). It would therefore be possible in principle to say that the change was restricted to immediately post-tonic position (though the more general statement also remains possible in principle).

By contrast, according to Grammont (1923: 73), a *ks* > *sk* change has occurred word-finally in colloquial French. The status of this example is somewhat unclear, since Grammont gives no phonetic or dialectological details, but in (26) we cite examples he mentions.

(26)	Standard	Colloquial	
	fi**ks**	fi**sk**	'fixed' (*fixe*)
	ly**ks**	ly**sk**	'luxury' (*luxe*)
	sɛ**ks**	sɛ**sk**	'sex' (*sexe*)
	a**ks**	a**sk**	'axis' (*axe*)
	feli**ks**	feli**sk**	'Félix' (*Félix*)

The Old English and French changes are apparently mirror images, *sk* > *ks* and *ks* > *sk*, with both occurring in final position. Citing several of the cases in table 5.2, Steriade (2001: 234–5) argues that all systematic ST > TS reorderings result in postvocalic stops, while all TS > ST metatheses result in prevocalic stops. In each case, she argues, stop cues are improved by providing a previously lacking VC or CV transition respectively; as she points out, French final stops are released. Yet the Old English change yields intervocalic *ks* clusters, and thus seems to contradict Steriade's claim.

We suggest that the crucial difference between the Old English and French examples may be prosodic. French has (weak) final stress, and this final stress could result in final sibilants being longer than medial ones; in (25), by contrast, the affected *sk* clusters were preceded by the strong initial stress of (Old) English.[23] The general pattern, we speculate, is that longer sibilants may induce a greater confusion effect on segmental order and are thus more likely to undergo metathesis with an adjacent stop. The apparent mirror-image effect that arises in comparing these two examples may thus be a by-product of independent differences in the languages' prosodic systems.

4 Phonetic explanations in phonology

At least two general issues emerge from the typological survey of metathesis in section 3. Before summarising our findings in section 4.3, we discuss gaps in the metathesis typology in section 4.1 and the general issue of directionality in section 4.2.

4.1 Typological gaps in metathesis patterns

Our approach to sound change predicts that certain logically possible metathesis types should not exist. One such type is the inversion of sequences consisting of a nasal and an oral stop. Given the articulatory requirements of nasal and oral stops, there is no way for nasality or orality to migrate across a neighbouring segment without directly affecting it; in such clusters assimilation is natural, but not metathesis. We thus predict that local nasal-obstruent metathesis should not occur as a sound change.[24] By contrast, the phonetic optimality approach predicts that at least intervocalic TN > NT metatheses are well motivated: TN clusters are rare while NT clusters are common (the only nongeminate clusters in some languages); and stop contrasts are relatively easy to perceive in prevocalic position.

For these reasons, the question of whether nasal-obstruent metathesis exists as a sound change offers a way of testing the two approaches. The literature does contain several cases where nasal-obstruent metatheses have been proposed, but in all such cases, we contend, other explanations not involving metathesis are available. The examples fall into two classes. The first class consists of three cases where there is no phonological process (neither a sound change nor a synchronic process) involving nasal-obstruent metathesis, and where metathesis has simply been erroneously proposed.[25] The second class consists of cases where there are synchronic metathesis patterns which, however, did not arise via any metathesis sound change. For these cases, restricted to a set of East Cushitic and South Omotic languages, we have shown elsewhere that the relevant patterns originated via a morphological process we call 'analogical morphophonology'.[26] In short, contrary to the assumptions of earlier work, careful analysis reveals that there are no cases in which local nasal-obstruent metathesis can be shown to have occurred as a sound change. This is predicted by our view of metathesis, while the phonetic optimisation view not only fails to predict it but predicts the opposite pattern for certain phonetic contexts.[27]

Other unattested metathesis sound changes include the inversion of velar-labial and noncoronal-coronal stop sequences, despite well-attested PK > KP and T{P,K} > {P,K}T changes (section 3.3). The phonetic optimisation model of sound change also apparently predicts the existence of *pg* > *gp* changes (n. 22) or a hypothetical $V_1 np V_2 > V_1 n V_2 p$ metathesis (in which the place cues of a nonhomorganic nasal are optimised by intervocalic positioning).

In addition to metathesis types that should not occur as sound changes, our approach predicts the possible existence of some metathesis patterns that we have not yet encountered. Such predicted but unattested metatheses include *ɾV* > *Vɾ* (or the reverse). The articulation of taps typically involves transitory vowels preceding and following the brief constriction; if a phonetically predictable transition is reinterpreted as a full vowel, and a historical vowel is reinterpreted as a transition, metathesis will have occurred. (This potential metathesis type is not easily situated in our current typology.) The auditory-stream decoupling we have suggested as an explanation for sibilant metatheses (sections 2.4, 3.4) also predicts the possibility of similar metatheses for other noisy segment types such as [ɬ] and clicks, though, again, no such examples are yet known to us.

Apparent counterexamples to observed typological patterns highlight important provisos on the general role of phonetics in phonology. Such examples demonstrate that regular synchronic phonological metatheses are a superset of those that can arise through purely phonetic sound change, and thereby contribute to the literature on phonological alternations that do *not* reflect phonetic naturalness or phonological markedness.[28] Three known pathways other than sound change by which metathesis alternations may arise are listed in (27).

(27) Sources of metathesis alternations other than sound change
- a. Loan adaptation, e.g. Spanish (n. 25)
- b. Telescoping (epenthesis + deletion), e.g. Leti, Najdi Arabic (Blevins and Garrett 1998), Classical Mandaic (Malone 1995)
- c. Analogical morphophonology (Garrett and Blevins in press)

This list excludes erroneous analyses as well as cases whose diachrony remains unclear.

4.2 Directionality patterns

Many specific types of metathesis show directionality effects; a (schematic) metathesis XY > YX may be well attested while the reverse metathesis YX > XY is undocumented in the world's languages. Our model of sound change would fail to predict such asymmetries if all misperception patterns were symmetric, but in fact the various articulatory, acoustic, and perceptual factors underlying misperception and sound change are often intrinsically asymmetric (Guion 1996, 1998; Plauché 2001). Our metathesis survey in section 3 shows several directionality patterns that follow from our general model. We have already mentioned the unidirectionality of PK > KP and T{P,K} > {P,K}T metatheses, which follows from the intrinsic articulatory properties of stops of various places of articulation (sections 2.3, 3.3). Another pattern apparent from our research is that long-distance metathesis shifts liquids, pharyngeals, and laryngeal segments into relatively prominent (i.e. initial or stressed) positions but not into less prominent positions, a pattern that follows from the greater likelihood of not perceiving phonetic cues in positions where they are relatively hard to perceive (section 3.1). Similarly, a common metathesis pattern is AXY > AYX (or YXA > XYA), where A and X share features (and A and Y need not); examples include Rendille pharyngeal metathesis (13), Old English *r* metathesis (n. 14), and Le Havre French *r* metathesis (Blevins and Garrett 1998). The reverse pattern (e.g. AYX > AXY) is undocumented. This asymmetry ('like elements repel each other') is easily explained: an extended phonetic feature is less likely to be perceived in a position adjacent to a segment that possesses the same feature; it is more likely to be perceived (and then reinterpreted as originating) in a position farther away from such a segment.[29]

4.3 Summary and conclusion

We have had three main goals in this chapter. First, we have offered an empirically motivated typology of metathesis sound changes in the languages of the world. Diachronic metathesis sound changes are summarised in section 3.3, table 5.2, and Blevins and Garrett 1998; synchronic metathesis patterns for which we posit other origins are cited in notes 25–26, (27), and Garrett and Blevins in press. Our second goal, especially in section 2, has been to relate the typology of metathesis to the findings of experimental phonetics; this should be useful both to those who accept and to those who may doubt our overall argument. This overall argument has been our third goal: based on our analysis of metathesis and its phonetic roots, we contend that reinterpretations of the ambiguities in real speech are the main force driving sound change. In particular, the majority of attested regular historical metatheses in the world's languages can be explained as the result of phonetically natural sound changes in which coarticulation leads to a segment or feature being perceived in some nonhistorical position. Perceptual metathesis, compensatory metathesis, and coarticulatory metathesis are all of this type. We have also argued that sibilant-stop metatheses result from inherent perceptual difficulties in recovering sequential order from sibilant-stop and stop-sibilant clusters.

Just as phonetic studies can inform phonology, our phonological typology of metathesis suggests directions for further phonetic research. Attested compensatory metatheses suggest that directionality of V-to-V coarticulation in languages with unreduced vowels can be determined by the position of stress, with the unstressed vowel anticipated or persevering into the stressed vowel. Attested perceptual metatheses should encourage further research into possible long-domain effects of underdocumented phonetic features like aspiration, breathiness, and glottalisation. Examples of coarticulatory metathesis raise many interesting questions concerning complementarity between a percept of assimilation or deletion in CC clusters and a percept of metathesis. Finally, our account of attested sibilant/stop metatheses invokes a disruptive effect of sibilant noise on perception of linear order, and the percept of a short or abrupt sibilant (transition) as a stop: both hypotheses need to be rigorously tested by a range of perceptual experiments.

We conclude that metathesis can indeed be explained in a phonetically natural way based on the same assumptions required to understand other phonological phenomena. Future studies of perception and acquisition can test our hypotheses by investigating more precisely the conditions under which phonetic strings are phonologically ambiguous or subject to reanalysis. Insofar as our explanations are well founded, they suggest that phonetics determines emergent sound patterns. The typology of metathesis largely follows from convergent evolution, demonstrating the extent to which phonology is phonetically determined in the diachronic dimension.

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Notes

For valuable comments, criticism, and discussion we are grateful to Tom Field, Bruce Hayes, Larry Hyman, Sharon Inkelas, Joe Malone, Ian Maddieson, Donca Steriade, and participants in the second author's Fall 1999 seminar at Berkeley. We use the following abbreviations for segment classes: C = consonant, G = glide, K = velar stop, N = nasal, P = labial stop, S = sibilant, T = stop or coronal stop (depending on context), and V = vowel.

1. This corresponds to both 'interversion' and 'metathesis' (i.e. respectively local and nonlocal metathesis) as defined in some earlier work (e.g. Grammont 1950).
2. Steriade is discussing stop-sibilant metathesis in particular (cf. section 3.4 below), and her general claim may be restricted to that subtype. Note that it is not true in principle that confusability is symmetric. For instance, Guion (1996, 1998) has shown that English /ki/ is misperceived as /t͡ʃi/ (in certain experimental contexts) significantly more often than /t͡ʃi/ is misperceived as /ki/; she argues that this asymmetry is related to the well-known asymmetry in sound change whereby *ki* > *t͡ʃi* is common but *t͡ʃi* > *ki* is not; see also Plauché 2001. It is not the case, as we will show in detail for metathesis, that an asymmetry in sound patterns or sound changes necessarily disproves a misperception account of their origins.
3. The possibilities increase if pharyngealisation can be associated with multisegmental phonological domains, or if multiple pharyngeal glides are posited at the phonological level.
4. See also Newton 1996 for references to other phonetic studies of English liquids and their contrast.
5. Retroflex harmonies (dental > retroflex C assimilation across intervening V) are also documented in several Dravidian languages (Subrahmanyam 1983: 361–3). For general discussion of retroflex and other consonant harmonies, see Hansson 2001.
6. The Cayuga alternations clearly involve spreading of laryngeal features, though metathesis as a phonological process may not yet be complete. It is irrelevant that Cayuga lacks /hʔ/ or /ʔh/ clusters, since sound change need not be structure-preserving; Cayuga laryngeal metathesis is demonstrably not structure-preserving (Blevins and Garrett 1998: 519–20).
7. Bailey's (1969, 1970) original argument was that the assimilation and metathesis facts are evidence for the marked status of coronal-noncoronal clusters. Blust provides further evidence, and considers the possibility that this arises from perceptual factors – in particular, a backward masking effect of noncoronal on coronal consonants (1979: 116). After considering weaknesses of the perceptual account, Blust (1979: 117) anticipates the kind of analysis we present when he concludes that 'on the basis of present evidence, it seems best to assume that the facts in question result from an innate limitation on the production of speech'.
8. We are grateful to Bruce Hayes for helping us formulate these statements. The common misperception of the positioning of [s] is demonstrated in a perception experiment by Ladefoged (2001: 175), with accompanying CD. Consistent with Ladefoged's experimental results, there is at least one example of long-distance sibilant metathesis in Ilokano, a Northern Philippine language (Anttila 1972: 75; Tryon 1995); a representative example is Ilokano ***saaŋit*** 'weep' vs Aklanon ***taaŋis***.

9. All published reports of perceptual metathesis known to us are cited here or in other general studies of metathesis (Grammont 1950; Ultan 1978; Hock 1985; Hume 1997, 2001; Blevins and Garrett 1998), or are included in this list of examples: liquid metatheses in Bisayan (Zorc 1977: 54), Chawchila Yokuts (Newman 1944: 32), Old English dialects (Alexander 1985), Somerset English (Elworthy 1875: 74–5), West Midland Middle English (Jordan 1974: 158), Koṇekor Gadaba (Bhaskararao 1980: 12–13), Oromo dialects (Heine 1980, 1981), Old Spanish (Malkiel 1950), and South-Central Dravidian 'apical displacement' (Krishnamurti 1955, 1961, 1978; Subrahmanyam 1983: 225–44); glide or high-vowel metatheses in Calabrian Greek (Rohlfs 1950: 82) and Old Spanish (Menéndez Pidal 1958; Penny 1991); laryngeal metatheses in Acehnese (Sawyer 1959: 143–4, 148; Durie 1985: 95–6, 146–7), Arbore (Hayward 1984: 72), Arnhem Land languages (Evans 1995: 738–9), Bisayan (Zorc 1977: 53), La Huerta Diegueño (Hinton and Langdon 1976), Ener and Endegeñ (Hetzron 1977: 39), Western Munster Irish (Malone 1971: 413 n. 69), Kiliwa (Langdon 1976: 874), Lycian (Garrett 1991–93), Classical Mandaic (Malone 1971, 1985), and Yokuts languages (Newman 1944: 15); and pharyngeal metathesis in Kurmanji Kurdish (Kahn 1976).
10. Intermediate forms in (6) are meant to clarify the historical developments; they may not be accurate, since the relative chronology of some sound changes is unknown.
11. We believe it is uncontroversial that the metathesis postdates Spanish *d* > *ð* lenition (i.e. that lenition occurred before 1492). For examples from other dialects, see Crews 1935 and Sala 1970: 171–2; 1971: 154.
12. On similar Romance patterns, see Lipski 1990/1991, Tuttle 1997, and, for the well-known example of Luchonnais Gascon, Grammont 1905–1906, Dumenil 1987, and Blevins and Garrett 1998; we mistakenly called this a French dialect. Such long-distance liquid metathesis is dubbed 'slope displacement' by Vennemann (1988, 1996), who calls its cause 'straightforward: like all language change, slope displacement is language improvement' (1996: 318).
13. Forms are cited from the dialect of Bova (unmarked) or Otranto ('O'); words originally borrowed from Latin are so noted ('L'; many South Italian Greek words with obstruent-*l* clusters are loanwords).
14. Compare the Northumbrian Old English metathesis whereby *Vr* > *rV*/__ *h*, e.g. *berht* > *breht* 'bright' (Luick 1921–40: 917–18); it is well established that Old English *r* shared a velar or other back constriction with *h* ([x]). In (13) and (14) note that the symbol ħ follows Heine, who notes that it varies for some speakers with ʕ, which he classifies as a stop. The phonetics of these symbols is unclear from his discussion.
15. 'S' citations in (15) refer to sentence numbers in Seymour 1985. Bessell 1998a, 1998b and Mattina 1999 are the most recent discussions of pharyngeal movement in Nxilxcín and related processes in other Interior Salish languages.
16. Nxilxcín pharyngeals are called 'difficult to hear' in one phonetic study (Bessell 1992: 159).
17. If no glottalisation shift is possible, the glottalised sonorant surfaces as a *Ceʔ* sequence (e.g. *ʔíχ*^{w}*-**le**ʔp* 'broom' < *ʔíχ*^{w}- 'sweep' + -í ***l'****əp*).
18. The Sardinian long-distance metathesis shows comparable blocking effects; cf., e.g., *f**r**enúku* < **fēnuk**l**um* < Latin *fēnuku**l**um* 'fennel', *p**r**eðúku* < **pēduk**l**um* <

*pēduku**l**um* ‘louse’ vs *fa**rr**í**k**ru* < **fa**rr**i**k**l**um* < *fa**rr**iku**l**um* ‘spelt cake’, *ke**rr**í**k**ru* < **ke**rn**ik**l**um* < *ke**rn**iku**l**um* ‘sieve’ (Geisler 1994: 112, 123).

19. A referee suggests that we might not expect Nxilxcín pharyngealisation to shift across a segment requiring tongue body fronting, e.g. perhaps the glide *y* in (15b), and that Secwepemctsín glottalisation might be expected not to shift across the fricative cluster *sx* in the second example in (16c). With respect to Nxilxcín, note that precisely comparable pharyngealisation harmonies are well documented cross-linguistically, even among cognate harmonies elsewhere in Interior Salish (Bessell 1998a, 1998b). In Secwepemctsín, where the long-distance movement shows no blocking effects, we must assume phonologisation of an originally phonetically motivated sound change.
20. In Rotuman, the original V-to-V coarticulation has been obscured by further changes (e.g. **ui* > *y*, **oe* > *ø*). Note that it is possible in compensatory metathesis that the timing shifts between adjacent unstressed and stressed syllables need not be analysed as foot-internal, though we are aware of no evidence against such an analysis. On Rotuman metathesis, see now also McCarthy 2000.
21. We thus disagree with the tentative conclusion of Hume (2001) that the expected pattern is KP > PK metathesis (which, she contends, is perception-optimising). Her conclusion is based on metathesis patterns in South-Central Dravidian languages, which we analyse as the result of analogical change, not phonetically based sound change (Garrett and Blevins in press). Apart from these Dravidian patterns, which did not arise via genuine metathesis, the typical pattern is PK > KP metathesis.
22. A phonetic optimisation account might explain the unidirectional nature of this change as enhancement of the weak burst of the labial through prevocalic positioning. One difference between the two accounts is that the optimisation account predicts metathesis with segments whose laryngeal and/or manner features are not shared. Our articulatory account does not involve a ‘shift’ of voicing or manner features, but simple overlap of gestures by the major articulators, ruling out a sound change like *pg* > *gp*.
23. Fougeron and Jun (1998) have shown that French accentual-phrase-final syllables are significantly longer than non-accentual-phrase-final syllables; cf. Fougeron and Keating 1997. For French we cannot exclude an alternative analysis, invited by Grammont’s brief description, on which metathesis is a loan adaptation in semi-learned vocabulary (and therefore not the result of any metathesis sound change).
24. In languages where nasality is associated with sequential vowels and affects intervening consonants’ onset closure or release, the appearance of metathesis may arise due to variation in timing of velic closure. This is our interpretation of the reconstructed TN > NT changes in several Kwa languages discussed by Hyman (1972) and Williamson (1973), an interpretation supported by the fact that free variation of this sort actually occurs in the Kolokuma dialect of Ịjọ.
25. Unfortunately we lack space here to discuss these three examples in detail: Latin (apparent **dn* > *nd* via nasal infixation not sound change), Mutsun (erroneous analysis by Hume 1997), and Spanish (apparent *tn* > *nd* via loan adaptation not sound change).
26. See Garrett and Blevins in press, where we explicitly discuss only the East Cushitic examples; our analysis is equally applicable to the Hamer (South Omotic) example described by Lydall (1976, 1988) and recently discussed by Zoll (n.d.).

27. Our analysis thus resolves a paradox noted by Herbert (1986: 195): 'Although no other cases of similar metatheses [i.e. CN > NC metatheses other than the Kwa cases cited in our n. 24 above] are reported in the literature, we might expect that they should occur. The basis for this expectation is the statistical fact that nasal-oral sequences occur much more frequently in the world's languages than oral-nasal sequences.' As Herbert writes, 'reference to "ease of articulation" gives the wrong prediction in this case'.
28. See Wang 1968, Bach and Harms 1972, Vennemann 1972, Anderson 1981, and more recently, e.g., McCarthy 1991, Blevins and Garrett 1993, Blevins 1997, 2002, Hyman 2001, and Garrett and Blevins in press.
29. Such directionality patterns do not contradict the phonetic optimisation approach, of course, since the result of metathesis is that segments appear in relatively more perceptible positions. The point is that perceptual optimisation is a natural by-product on our analysis, and need not be posited as a mechanism or cause of change.