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Markedness, Segment Realization, and Locality in Spreading*

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1 Introduction

An important goal of phonological theory has been the elucidation of "action at a distance." This term refers to processes, such as assimilations or dissimilations, in which the trigger segment and affected segment are not string-adjacent; there are segments that intervene, yet seem not to participate in the process. Transparency of this sort raises questions. How and why does it occur? What determines which segments, if any, will be transparent for a given process? The search for answers to such questions has been one of the important forces driving the elaboration of metrical and autosegmental representations.

Consider the case of long-distance feature spreading, or harmony. It is well known that segments within a spreading domain may appear to be non-participants, transparent to the harmony process. Various strategies have been proposed to account for such cases of transparency. Within non-linear phonological frameworks, a property many approaches have in common is the preservation of locality by relativizing it to what might very generally be called a *legitimate target*: some notion "anchor," "projection," or "feature-bearing unit." Locality is obeyed so long as spreading does not skip such a legitimate target. Notable examples of this line of thinking include Goldsmith (1976[79]) and Clements (1980) on the notion "feature-bearing unit," Halle and Vergnaud (1978) on "projections" of features, Kiparsky (1981) on the notion "harmonic vowel," and Archangeli and Pulleyblank (1987; 1994) and Anderson and Ewen (1987) on the relativization of adjacency to prosodically or geometrically defined anchors.[1] The basic idea is depicted in (1), where a feature F is linked to the elements $\mathbf{T_1}$ and $\mathbf{T_2}$, legitimate targets in some respect. Locality is not violated by the skipping of intervening α, since α lacks whatever property it is that grants legitimacy (e.g. it is not F-bearing, has the wrong prosodic status, or lacks a certain feature geometric node, see the references cited above). Equivalently, the elements $\mathbf{T_1}$ and $\mathbf{T_2}$ are adjacent for the purposes of F-spreading.

(1) Local linkage (relativized to legitimate targets **T**)

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T1  α  T2
 \    /
   F
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The above approaches are sometimes combined with assumptions about underspecification: the intervening segment α might be transparent because it is unspecified for either F, or whatever feature/node makes α a legitimate target. (See for example Paradis and Prunet 1989 and Shaw 1991 on [coronal] transparency.)

In a series of recent works an alternative view of locality in spreading is considered, in which spreading is seen as strictly, segmentally local (McCarthy 1994, Flemming 1995a, Padgett 1995, Gafos 1996, Gafos and Lombardi in press, Ní Chiosáin and Padgett 1997, Walker 1998). According to this view, all segments in a spreading domain are necessarily participants. The goal of this paper is to further motivate this view of locality in spreading. We assume that locality holds strictly, in two senses of "strict." First, spreading respects *segmental* adjacency, as proposed by the references above. An essential result of this view is that segments are either blockers or participants in spreading; there is no transparency or skipping. Second, segmentally strict locality is inviolable; in Optimality Theoretic terms, Gen does not produce structures in which segments are skipped in a spreading domain.

In an obvious sense, it is a simpler and more restrictive theory that countenances only blockers and participants in spreading, compared to one that includes a third class of transparent segments. This point can be compelling, however, only given a convincing alternative account of seemingly transparent segments. The main work of this paper is to motivate such an account for one class of cases, and thereby show that strict locality is indeed possible for such cases. The argument focuses on consonantal transparency in vowel harmony, examining the case of Turkish.

Strictly local spreading for such cases becomes possible once we reconsider some fundamental assumptions about markedness and segment realization in phonology, a move that is independently necessary. The general ideas we will pursue could be formalized and understood variously, but the framework we adopt for these purposes is Dispersion Theory (Flemming 1995b), an instantiation of the Theory of Adaptive Dispersion (Liljencrants and Lindblom 1972, Lindblom 1986; 1990), implemented within Optimality Theory (Prince and Smolensky in press). Dispersion Theory motivates an essentially bidimensional understanding of markedness and contrast: segment wellformedness depends on constraints phonetically grounded in articulatory complexity on the one hand, and others grounded in the needs of perceptual contrast on the other. Flemming (1995b) argues this point in considerable detail; here we extend the theory to show that the same ideas make sense of one kind of apparent transparency in a striking way.[2] The analyses and general thinking of this paper are in good part propelled by the central tenets of constraint ranking and violability of Optimality Theory (henceforth OT, Prince and Smolensky in press). A related property of this paper is the reduced role given to explanation in terms of the formal properties of a non-linear representation, counter to tradition in the area of locality. Rather, locality issues are understood by means of the interplay of substantive, typically phonetically grounded constraints in an Optimality Theoretic hierarchy of violability. For arguments and analyses underpinning this general view of explanation in phonology, we refer the reader to Prince and Smolensky (in press), Smolensky (1993), Cole and Kisseberth (1994; 1995), Padgett (1995), Gafos (1996), Zoll (1996) and Walker (1998).

The paper is organized as follows. Section 2 discusses the empirical evidence for strictly local spreading in Turkish vowel harmony, and considers the place of that evidence in phonological theory. In addition our representational assumptions are presented. Section 3 introduces Dispersion Theory. Section 4 applies this theory to the domain of consonantal backness contrasts, a prerequisite to the locality demonstration. Section 5 shows how the theory makes strictly local spreading possible for Turkish vowel harmony. Section 6 is the conclusion.

2 Background and assumptions

2.1 Segment skipping is theory-dependent

What facts are at stake when we weigh strict locality against relativized locality? We think that this question is more complicated than has been realized. On the one hand, the evidence for segment skipping in spreading seems compelling: in many cases of long-distance spreading, there are intervening segments that in one way or another do not seem to realize the spreading feature. On the other hand, it turns out a great deal can depend on what is meant by "realize the spreading feature." In fact, in some (and possibly most) cases of apparent transparency, the relevant segment *is* affected by spreading. How or even whether this fact is taken to bear on the transparency question depends on deeply held assumptions about markedness and segment realization, assumptions centering around contrast in particular. Here we demonstrate this point with respect to the case of spreading in Turkish vowel harmony, with some of the discussion covering vowel harmony more generally.

Turkish presents a well known instance of vowel harmony involving both backness (or palatality) and roundness. Spreading is rightward, so that the initial vowels in forms such as *son-un* 'end (gen.)' and *ip-in* 'rope (gen.)' determine the values for backness and roundness of the second vowel. (Two alternants of the genitive suffix *-In* are seen here.) In the work of generative phonologists, the spreading posited is from vowel to vowel, the intervening consonant being skipped. This is true of both earlier linear work (see for example Lightner 1972, who treats intervening C_0 as part of the structural condition of Turkish harmony, rather than a target), and of later non-linear work (Clements and Sezer 1982, and much subsequent work). This assumption is applied to other vowel harmonies as well. What is the empirical basis for this claim?

Many works outside of generative phonology have made quite the contrary claim, finding clear evidence of participation by the intervening consonant. A notable precedent to our general locality claim is found in works of Firthian Prosodic Phonology, with its notion "prosody." (See for example Allen 1951, Ogden and Local 1994, among others.) Working within the Firthian framework, Waterson (1956) posits uninterrupted vowel backness and roundness prosodies in Turkish, having the entire syllable or word as domain. (Also arguing for a kind of strict locality, Gafos 1996 notes the significance of the Waterson study, and of that by Boyce mentioned below.) Her notation for vowel prosodies is intended to highlight the equal participation of consonants and vowels. As evidence that consonants do indeed vary in the backness dimension, she provides palatograms of six Turkish word pairs (implied to be representative of an extensive study), e.g. *ün* 'voice' vs. *un* 'flour', etc. The consonants involved include the velars and the lateral, with [k,g,l] in back words and palatal [c,ɟ,lʲ] in front words respectively. These are well known alternations, but differences hold for the rest of the consonants shown (*r*, *n*, *z*, *tʃ*, and *ʃ*), and Waterson transcribes them as palatalized in front words. In such words most of these consonants are distinguished by wider tongue contact along the sides of the teeth, as well as more contact in the postalveolar area, consistent with a more palatal tongue body position. *tʃ* and *ʃ* do not differ in this way, possibly because these sounds make inherent demands on the tongue body, but they show slightly more contact further forward in the alveolar zone in front words, consistent with a fronted tongue body.

As Waterson points out (p.579, fn.4), these differences have not generally been taken into account in Western linguistics. On the other hand, there is a rich tradition among Soviet

phonologists and Turkologists, extending to the Prague School, of regarding consonants as participants in Turkic vowel harmonies. Indeed, a precursor to Waterson is Sharaf (1927), a palatographic study of (Volga) Tatar, another Turkic language. Sharaf finds systematic differences between Tatar consonants in front vs. back harmonic words, which he transcribes and refers to as "soft" vs. "hard" consonants respectively (palatalized and non-palatalized). The results broadly resemble Waterson's: consonants in front harmonic words generally show more contact along the sides of the teeth, and contact in the dental to postalveolar region that is both fronter, and greater in area. Sharaf states that similar results hold for other Turkic languages based on his observations (including Kirgiz and Bashkir), and he is led by these results to agree with the principle of *synharmonism*, which states that *all* segments in Turkic words agree in backness. The idea of synharmonism is reasserted in Jakobson (1962), Trubetzkoy (1939), and many other works relating to the phonology of particular Turkic languages.[3]

Turning then to roundness, Waterson's observations on this point are impressionistic. She states that all segments in a syllable with a round vowel are round, as in *kol* 'arm', in which "there is lip rounding throughout the articulation of *k*, *o*, *l*." More recently, Boyce (1990) undertakes a study of lip protrusion and EMG patterns in Turkish and English, and finds that lip rounding gestures in nonsense words like *kuktuk* are maintained in a more or less uniform "plateau" across the consonants in Turkish, while in English there are two gestures clearly distinguished with a period of diminished rounding, a "trough," during the consonants. Boyce suggests that Turkish speakers employ an articulation strategy different from that employed by English speakers, because the existence of rounding harmony in Turkish "provides ideal conditions for articulatory look-ahead." We do not know of any similar studies on other Turkic languages.[4]

The notion that vocalic gestures can overlap consonantal ones, significantly affecting them in both articulation and resultant auditory properties, is very well motivated. A large number of studies of articulatory dynamics (or their acoustic consequences) from diverse languages support the general view that for any language vocalic place gestures in a string VC_0V are articulatorily contiguous (at least to the extent that intervening consonants are not specified themselves for the relevant vocalic properties, whether contrastively or not, see note 4). Even when consonantal place gestures seem to intervene, they are in fact superimposed on these vocalic gestures, with the latter functioning as though on their own independent "channel." To put it more commonly, consonant and vowel places are coarticulated (Öhman 1966, Carney and Moll 1971, Fowler 1983, Browman and Goldstein 1990, Choi and Keating 1991, Farnetani 1997, and references therein). Gafos (1996) discusses the implications of this fact for phonology, coming to conclusions broadly consistent with those of this paper, and providing much further motivation. The coarticulation is best illustrated with a diagram, as in (2). This diagram renders a gestural score for the English utterance [pis 'plats] (treated as two words), and is based on figures 19.5 and 19.7 of Browman and Goldstein (1990), and the accompanying discussion. Browman and Goldstein's figures are themselves based on articulatory data. In this example and others like it (within or across words), the transition in tongue backness from [i] to [a] proceeds through the intervening consonants.

(2) Contiguous vocalic gestures inVC_0V ([pis # 'plats])

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                                i           a
Vowel "channel"          |------------|-------------|
                                s  p  l
Consonants                     |--------|
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More generally, the observation of Browman and Goldstein for English is that a vowel place gesture overlaps the place gestures of tautosyllabic consonants. Putting tautosyllabicity aside, however, consider just the environment VC_0V relevant to the transparency question. Languages might vary in the details of the relative timing of consonant and vowel place gestures (see the references above); however, where vowel harmony holds, the two vowels agree in the harmonizing feature, and so C_0 will be coarticulated with this feature under *any* scenario, given V-V contiguity. We assume that the results of Sharaf, Waterson, and others represent cases of such coarticulation.

Returning to the question posed at the outset, if the empirical claim implicit in the skipping of consonants by vowel harmony, for Turkish and similar languages, were that those consonants are not affected by the spreading feature, then this claim would certainly be incorrect. However, this claim most likely should not be attributed to generative analyses. In fact, the implicit claim is that consonants are not affected *enough to matter to phonology*, the issue being instead the responsibility of phonetics. Generative phonology is rooted in distinctive feature theory; a central tenet of that theory is that any posited feature must be motivated by contrast in some language(s). Distinctive features are also employed to account for predictable properties in language, but precisely because it is distinctive features that are employed in these accounts, these features therefore *must* be contrastive by definition in some language. For example, though *l*-velarization in English, or backness in Turkish suffixes, are predictable, it is equally true that velarization and backness can be contrastive sometimes. Given distinctive feature theory, in other words, the only phonetic properties "visible" to phonology are those with contrast potential, and the segmental realizations entertained by phonologists are *identified* with contrastive realizations, whether they act as contrastive in a particular scenario or not. The effects of vowel harmony on intervening consonants in Turkish do not generally meet the distinctive feature criterion of contrast potential: though consonants in front harmonic words are more palatal than those in back words, they are not palatal enough to elicit transcriptions such as [ip^jin^j] for *ipin*, where the off-glide realization is understood as having contrast potential for palatalization. Similar remarks hold for roundness: *sonun* is not [$s^won^wun^w$]. The genuine *coarticulatory* distinctions discussed above therefore fall outside of the purview of phonology.

Summing up, the claim of transparency for Turkish and similar cases does not follow from a trivial factual observation, but involves interpretation of the facts within distinctive feature theory. In other, non-generative, frameworks, the coarticulatory realizations of consonants within vowel harmony domains are very much part of the phonological analysis. In this paper we reconsider the distinctive feature position, and suggest that phonology should indeed embrace a range of segment types or realizations that may or may not form the basis of contrast (including the coarticulatory realizations discussed above). This conclusion is shared in other recent work,

including Steriade (1994), Flemming (1995c), Kirchner (1997, this volume), and references therein, for reasons independent of locality concerns. With this shift in perspective, there is no longer any reason to posit skipping in cases such as Turkish. In fact we are compelled not to, because this "transparency" can be understood in terms of an independently motivated theory of markedness and segment realization. Locality-specific stipulations are not required.

2.2 More on Turkish

With the preceding in mind, more discussion of the empirical claims here is in order. We take consonants within spans of rounding harmony to be round, those in front harmonic spans to be front, and so on. The consonants of Turkish participate in harmony if we understand this statement to mean that the consonants of *somun* are coarticulated with vocalic lip rounding, and those of *ipin* with tongue fronting, having the properties we would expect of them if some amount of these vocalic properties were maintained throughout the word, and nothing more. Since we identify these realizations with the well known finding of vowel-to-vowel coarticulation across consonants, and since the body of phonetic evidence suggests that such coarticulation occurs quite generally and regardless of the language (modulo interfering specifications on the consonants), we rely on these findings as support for the claim about Turkish in particular. However, as we saw above, there is also evidence that is specific to Turkish.

In the case of rounding, the mentioned Boyce study demonstrates that [k,t,l] are roughly as round articulatorily as the vowels that flank them in Turkish. This finding might suggest the strong claim that in order to consider consonants participants in a vowel harmony domain we must see the relevant gesture continuing from vowel to vowel through the consonant with unabated intensity, the "plateau" found by Boyce. Though this indeed occurs in many cases, judging from studies of coarticulation—even in languages that lack harmony—the worry for such a claim is that there is reason to believe that vowel harmony spans need not be phonetically completely uniform; for example, the degree of lip protrusion in round vowels depends on other properties of the vowel such as height and backness (Linker 1982), and so might vary even from vowel to vowel in vowel harmony spans. More generally, the phonetic correlates of phonological features are far from precisely uniform across segment types.

The more reasonable claim is simply that for consonants to be considered round (or front, etc.), they should be round (or front) to some degree, and in this way reliably distinct from consonants that are unround (or back) in similar contexts. In order to further test the claim for Turkish, we examined the spectra of the fricatives [ʃ,s] in round and unround harmony spans. The fricatives occurred finally in actual Turkish roots, with a suffix vowel occurring to the right, e.g., *iʃ-i*, *kɨʃ-ɨ*. A strategy we assumed for motivating hypothesized phonetic correlates of a phonological feature (see Stevens and Blumstein 1981 for a well known example) involves stating a quantitative procedure for classifying the spectral representations of tokens, subjecting a sample of tokens to the procedure, and reporting on the success rate at classification. Given the problem of variation across speakers and utterances and phonetic contexts, this is a persistently daunting task even for phonologically contrastive features. We chose fricatives because it is possible to examine their acoustic properties at their midpoint, unlike the case of plosives for instance, giving stronger evidence about the extent of coarticulation. We examined 48 tokens of [ʃ]; these tokens came from 12 words, each spoken twice, by two native speakers, one male, one female. The same

holds of [s]. For both sounds, the 12 words represented every possible vocalic environment allowed by Turkish that is harmonic (where the flanking vowels are both round or unround).[5]

In the case of [ʃ], a very simple procedure correctly classified 100 percent of the tokens into round versus unround categories. Specifically, if a spectrum had a peak in the 3200-4500 Hz range that was higher than any peak in the range 5000 Hz and above, then it was classified as unround; otherwise it was round. For [s], a different but equally simple procedure correctly classified 94 percent of the tokens (45/48). In both cases, the procedure gauged the gross shape of the spectrum in such a way as to identify frequency regions that for round tokens were relatively low in energy compared to another region. We assume that this difference is due to a shift in the shape of the resonant cavity between the constriction site for the fricative and the lips, giving a lower-frequency auditory impression in the case of the round tokens. (For relevant discussion of the spectral properties of fricatives, see Hughes and Halle 1956.) We conclude that there is justification for attributing (un)roundness to these consonants.

We do not expect to find acoustic evidence as easily in the case of backness. This is because the acoustic properties of frication depend virtually entirely on the properties of the oral cavity in front of the place constriction. Since lip rounding does not correlate with backness in Turkish, and given previous evidence that tongue body position has little effect on the place of constriction of coronal sounds (Carney and Moll 1971, Farnetani et al. 1985), we expect little systematic variation in the shape of this cavity due to shifts in tongue body backness. Indeed, it was much more difficult to distinguish among spectra of [ʃ,s] according to backness compared to roundness. However, upon examining more closely the spectra of [s] in unround words of one speaker, we were able to find a somewhat more complex quantitative procedure which, though it classified less well than was seen above, indicated a difference between unround back and front [s] that was statistically significant ($p < .01$ in a t-test), and we take this as some support.[6] It is important to bear in mind that there is no requirement that the distinctions we are considering be auditorily robust or even audible, since they need not have contrast potential. The criterion here is that there be a systematic articulatory difference. Waterson's palatographic data show for a range of consonants in Turkish that there is.

2.3 The statement of strict locality

Consider the formulation of locality given below (Kiparsky 1981, Levergood 1984, Archangeli and Pulleyblank 1994, Pulleyblank 1996; cf. Smolensky 1993). In contrast to the works cited, we take α,β,γ to be segments; that is, every segment is a legitimate target, so that locality is not achieved by relativizing adjacency to any notion of tier, projection, anchor, or the like.

(3) *α β γ
  \ / where F is any feature, and α,β,γ are segments
   F

Various works have attempted to elucidate the intuition underlying (3) and to explicate more fully the formal assumptions behind it, often in relation to the No Crossing Constraint. (See Sagey 1988, Hammond 1988, Bird and Klein 1990, Scobbie 1991, Archangeli and Pulleyblank 1994; see Coleman and Local 1991 for more general relevant discussion.) As some of these authors note, it

seems desirable to understand the restriction by reducing it to an issue of linear precedence relations. Assume, for instance, that the association lines in (3) mean that F overlaps α, while also overlapping γ (Sagey 1988). Since β is ordered between α and γ, F necessarily overlaps β as well. However, this conclusion follows only if F is taken to be a "continuous, uninterrupted, unitary" entity (Scobbie 1991:64) and some formal rigor is given to this notion. To this end, Bird and Klein (1990:41) provide a definition of a *convex* phonological event (the term is borrowed from van Benthem 1983:68), which we adapt in (4) (cf. Scobbie 1991).

(4) A featural event F is convex iff it satisfies the following condition: For all segments α, β, γ, if α precedes β, β precedes γ, α overlaps F and γ overlaps F, then β overlaps F.

This definition is not reduced in comparison to (3). It is a necessary axiom, however, a rigorous statement of what it means for a gesture to be continuous, uninterrupted and unitary. (These properties are plausible attributes of phonetic gestures, as Scobbie notes. They are entailed by the dynamical conception of a gesture in Articulatory Phonology, see Browman and Goldstein 1986 et seq.) We take convexity in the sense of (4) as our phonological locality statement, and assume it holds of phonological representations without exception: in Optimality Theoretic terms, it constrains the candidate set that Gen produces.

2.4 Coarticulation

We adopt from Smolensky (1993) and Cole and Kisseberth (1994; 1995) the convention of indicating feature association by means of labeled bracketing. Thus $[\text{ipin}]_{\text{Fr}}$ indicates a word with Front spread throughout. (We assume single-valued features, and focus only on the those relevant to Turkish vowel harmony, Back, Front, and Round.) $[[\text{p}]_{\text{Bk}}]_{\text{Rd}}$ is *p* with associated backing and rounding, as in *upun*, and so on. We transcribe the effects of coarticulation with a superscripted segment, so that p^i indicates *p* coarticulated with the vowel *i*, and so on.

Consider the difference between a palatalized *p* as in p^ju and a plain *p* as in *pu*. From a phonetic point of view we can actually distinguish even among "plain" consonants, given the discussion of coarticulation in section 2.1: a "plain" consonant generally shares the vowel place properties of a neighboring vowel. For instance, *p* bears the backness and rounding properties of *u* in *pu*. The *p* in *pa* likewise shares the backness of *a*. Speaking generally, there are as many kinds of *p* as there are vowels with which *p* can be coarticulated. Focusing only on the common five vowels, this gives the five kinds of *p* illustrated in (5), with the feature specifications of interest shown on the right. Similar variants exist for other consonants. We propose to expand the number of segments that phonology can entertain along these lines.

(5) p^i, p^e $\quad [\text{p}]_{\text{Fr}}$
p^a $\quad [\text{p}]_{\text{Bk}}$
p^u, p^o $\quad [[\text{p}]_{\text{Bk}}]_{\text{Rd}}$

In this context, consider the representation of palatalization, velarization and rounding on consonants. Since the "plain" consonants shown above are specified for vocalic place features due to coarticulation, how are we to distinguish them from consonants with secondary articulations? If

we take our cue from the transcriptions p^j, $p^ˇ$, and p^w, we can reduce this to the question, how do we distinguish high vowels from glides? According to Ladefoged and Maddieson (1996:323), glides across languages are produced with a narrower constriction of the vocal cavity compared to their vocalic counterparts. (They are classified as approximants by Ladefoged 1993 and Catford 1988.) Similarly, a difference conventionally transcribed as [pi] versus [p^ji] (in our terms $p^i i$ versus $p^j i$) must imply a greater degree of constriction for the high front tongue body during the consonantal release of the latter. We assume that this difference between vowels and glides is encoded featurally.

To be concrete, suppose we assume a feature [vocalic], such that vowels are [+vocalic, -consonantal], while glides are [-vocalic, -consonantal]. Though vowels and glides were similarly distinguished in Chomsky and Halle (1968) (by means of the feature [syllabic], a term that would be inappropriate in the current context), it was subsequently widely accepted that high vowels and glides are identical in featural make-up (Kaye and Lowenstamm 1984, Selkirk 1984, Levin 1985). The basis of the latter view, however, is that vowels and glides cannot *contrast*. In Dispersion Theory, such facts fall out from output constraints regulating the goodness of contrast directly, as shown next section. As we have already noted, having such constraints removes the most compelling reason to limit the representational distinctions of phonology.

In fact, there are well known instances in which glides contrast with vowels, Berber for example (Guerssel 1986). For the great majority of languages in which they do not contrast, we can simply assume that vocoids are redundantly [+vocalic] in a syllable nucleus, and [-vocalic] otherwise. Such a featural distinction can be motivated on independent grounds. For example, there are languages in which nasal harmony is blocked by glides but not vowels, such as Sundanese (Cohn 1989).

The discussion here presupposes that the strictural specifications of both the primary and secondary articulations of consonants like p^i and p^j, which are a species of complex segment, can be independently given. There are a number of ways to accomplish this, including adopting the articulator group of Padgett (1991[95]), or separate closure and release representations for consonants, following Steriade (1994). Assuming the latter, representations for hypothetical $ip^i i$ and $ip^j i$, assuming one harmony span of Front for each, are given below. *X* stands for whatever representational entity denotes segmenthood, e.g., the Root node of feature geometry, or 'aperture' node of Steriade; *C*, *G*, and *V* are abbreviations for the stricture specifications of consonants, glides, and vowels respectively.

(6) a. $\begin{array}{cccc} i & p^{\,i} & & i \\ [X_V & X_C & X_V & X_V]_{Fr} \end{array}$ b. $\begin{array}{cccc} i & p^{\,j} & & i \\ [X_V & X_C & X_G & X_V]_{Fr} \end{array}$

3 Dispersion Theory in OT

Underlying the problem of segment realization are very general issues of markedness and contrast. Within one line of work in generative phonology, markedness and contrast are intrinsically linked via constraints on feature cooccurrence: a segment is marked to some degree if it violates a constraint of the form *[F, G, ..., Z], and the activity of such a constraint in the phonology can suppress a potential contrast (Kiparsky 1981; 1985, Archangeli and Pulleyblank 1986; 1994). In Optimality Theoretic terms, Prince and Smolensky (in press) recast this idea in

the following way: if a constraint *[F, G, ..., Z], which for convenience can be abbreviated *S, where S is the relevant (class of) segment(s), dominates the relevant faithfulness constraints, then a contrast will be suppressed; otherwise, it will emerge.

Take as an example three kinds of consonant: plain, palatalized, and velarized. On typological grounds we might posit the following universal ranking of constraints: $*C^j$, $*C^ɣ$ >> *C. (We do not argue for a ranking between the first two constraints; nothing here depends on it.) The hypothesized ranking, immutable, is intended to express a typological generalization: plain consonants occur more often in inventories. Further, a language that has C^j or $C^ɣ$ must have *C* according to this hierarchy. To see this, we must consider what happens when faithfulness is included in the hierarchy. To simplify the discussion we assume one general constraint IDENT requiring identity of feature content between input and output (McCarthy and Prince 1995); this constraint ensures that a posited contrast will surface if the relevant markedness constraints are lower ranked. As Prince and Smolensky (in press) argue, markedness hierarchies coupled with faithfulness provide an appealingly direct and elegant account of markedness implications and contrast. An important result of the Optimality Theoretic account, in addition, is that contrast is an emergent output property, following entirely from the ranking of constraints in the grammar:

(7) Typological predictions of markedness and faithfulness

	Ranking	*Result*
a.	IDENT >> $*C^j$, $*C^ɣ$ >> *C	C^j, $C^ɣ$, C surface
b.	$*C^ɣ$ >> IDENT >> $*C^j$, C	C^j, C surface (*alternatively*, $C^ɣ$, C)
c.	$*C^j$, $*C^ɣ$ >> IDENT, *C	C surfaces

This Optimality Theoretic account for the consonantal typology shares an important drawback with all phonological approaches to markedness known to us. On the one hand cases such as (7)a are attested. For example, there are languages with a contrast among plain, palatalized and velarized laterals, including Bernera Scots Gaelic (Ladefoged and Ladefoged 1997) and Marshallese (Bender 1969, Choi 1992). (7)c is also uncontroversially attested. On the other hand, the prediction entailed by (7)b is too strong: in languages with a palatalization contrast, the opposing "plain" consonants are frequently *velarized*. This is true of Irish (see below), of Russian (Trubetzkoy 1939, Reformatskii 1958, Fant 1960, Padgett in press) and of Marshallese (outside of laterals). The hierarchy in (7) specifying plain C as the inevitable best is fatally incapable of capturing this fact. The facts present a markedness paradox for the theory, and this problem is general to any theory that uniformly favors C over C^j and $C^ɣ$.

Flemming (1995b) raises other markedness paradoxes with similar properties. For example, while languages with two vowels overwhelmingly prefer *i* and *u* (compare palatalized versus velarized consonants), those with only one high vowel select *ɨ* (compare plain consonants). The "linear" vowel systems of the Caucasus such as Abkhaz and Kabardian provide well-known examples of the latter, Trubetzkoy 1939; see Ladefoged and Maddieson 1996:286-7 and Flemming 1995b for other examples.)

Flemming shows how such facts argue for Dispersion Theory (henceforth DT). In a more general form this argument is due to the work of Lindblom and precursors, and DT adapts the

well-known phonetic explanation for such markedness dichotomies from the Theory of Adaptive Dispersion (Lindblom 1986; 1990). According to that theory, inventories strike a balance between two often contradictory needs. There is a tendency to maximize the perceptual distinctiveness (dispersion) of contrasts; however, there is also a need for articulations to be minimally complex. Given two high vowels in a language, perceptual considerations demand that they be *i* and *u*, since these are highly distinct; achieving this distinction comes at the cost of articulating these particular vowels. On the other hand, a language with no high vowel contrast by definition makes no demands of distinctiveness or dispersion in the front-back dimension. In such a language, articulatory concerns carry the day, and the result is *ɨ*: This vowel is articulatorily simpler, involving the least displacement of the vocal tract configuration from the neutral position of *ə*. These points extend in a straightforward way to the case of plain, palatalized and velarized consonants, where the perceptual and articulatory considerations are roughly the same.[7]

In the context of OT, the drawback of the approach to markedness exemplified in (7) is its unidimensionality: segments are ranked along one universal scale of markedness, such that C^j and $C^ˠ$ are invariably more marked than *C*. DT is instead bidimensional, in the sense that there are separate families of constraints regulating articulatory simplicity on the one hand and the perceptual distinctiveness of contrast on the other, and these constraints often conflict. Thus *C* can be *disfavored* in comparison to C^j and $C^ˠ$ precisely when there is contrast involving palatalization/velarization, because a contrast between C^j and $C^ˠ$ is more perceptually distinct.

To capture the articulatory markedness facts, we simply carry over the constraints and rankings seen already: $*C^j$, $*C^ˠ$ >> *C.[8] Consider then the perceptual markedness relations. These are illustrated by the hypothetical segment spacings shown in (8)a, each distinguished by how much of the available perceptual space is given to every segment. (We make the idealizing assumption that the perceptual space is divided into equal intervals, with a segment located in the center of each.) Obviously the more contrasting segments, the less the perceptual space for each. We posit a family of Space constraints, (8)b, assumed to be indexed by type of contrast, here consonantal backness. The relevant acoustic correlate is roughly the second formant value at the release of the consonant (see Ladefoged and Maddieson 1996). We also assume a universal ranking among them, (8)c, from which it follows that more spacing between contrasting segments is preferred, all else equal.[9]

(8) Space constraints for consonantal backness (C-F2)

a. Spacing: |....C^j....|....C....|.....$C^ˠ$....| Each segment gets 1/3 of the perceptual space
|.....C^j.....|.....$C^ˠ$.....| Each segment gets 1/2 of the perceptual space
|.....C.....| Each segment gets 1/1 of the perceptual space

b. $\text{SPACE}_{\text{C-F2}} \geq 1/\text{N}$: For every pair of words differing only in the F2 value of one consonant, the contrasting consonants differ by at least *1/n*th of the full F2 range[10]

c. $\text{Space}_{\text{C-F2}} \geq 1/3$ >> $\text{Space}_{\text{C-F2}} \geq 1/2$ >> $\text{Space}_{\text{C-F2}} \geq 1$

The number of space constraints required in the theory depends on the type of contrast. In the case of consonantal backness, we find at most a three-way contrast in languages (as in the examples mentioned above). We account for this by assuming that $\text{SPACE}_{\text{C-F2}} \geq 1/3$ is in Gen. (This does the work of distinctive feature theory's stipulation that there is only one [back] feature, or privative Front versus Back.) Hence only the two remaining constraints can be ranked in a constraint hierarchy.

To understand space constraints, we must posit a third family of constraints, following Flemming (1995b), that favor maximizing the number of contrasts. This third constraint family is necessary, since constraints punishing both articulatory effort and spacing needs could always be vacuously satisfied by having no contrasts at all. However, we depart from Flemming in our formulation of these constraints. Flemming (1995b) largely considers only inventories of segments. In order to fully integrate the ideas of DT into phonology, we must be able to evaluate entire words—otherwise there is no way to consider most phonological processes, such as stress, assimilation, final devoicing, etc., simultaneously with matters of contrast. Indeed, contrast can be context sensitive or positional, as is well-known. The constraint family in (9)a therefore considers not the number of contrasting segments, but of contrasting words. We assume that two words contrast if they differ by any feature specification. It should be borne in mind that it is the job of the SPACE constraints, and not of these constraints, to ensure that a contrast is perceptually well formed.

(9) *n*Word constraints

a. *N*WORDS: A language must have at least *n* contrasting words
b. 1WORD >> 2WORDS >> ... >> N-1WORDS >> NWORDS

Tied up with these proposals is the question of what candidates are in DT, and how they are to be evaluated by these constraints. Following Flemming (in press), we take candidates to be *languages*. In generative phonology a language can be understood as the set of forms generated by a grammar (Halle 1962). (Of these forms, only some need be actually occuring forms. For instance, [tɪg] is a grammatical, but not actual, word of English. It will be useful to keep this idea in mind later, when we include both actual and merely possible words in our tableaux.) Though the idea of candidates as languages seems daunting, we propose to manage the task by means of severe idealization. In approaching the problem in this way we differ from Flemming (in press). Consider, for example, the following idealization: assume that a language can have words of the form $C^{(j/\text{ˠ})}a$ only, that is, the only possible words are *Ca*, $C^{j}a$ and $C^{\text{ˠ}}a$, and the nature of *C* is irrelevant. Given this idealization, a language can have at most three words. Therefore, we need only rely on the *N*WORD constraints 2WORDS and 3WORDS. Violations of 1WORD will not be of interest to us, and we assume this constraint is in Gen.

Tableau (10) illustrates how all of this works. Each candidate should be regarded as a possible language, within the idealization. For example, (10)a is a language having a three-way backness contrast in consonants, and (10)e is one having only palatalized consonants. The ranking here selects (10)f as optimal, a language with a two-way backness contrast that is maximally dispersed. The *N*WORD constraints simply count the number of words in a candidate language,

and disfavor languages with fewer than *n* words. The SPACE constraints evaluate a candidate language in the following way: each (unordered) pairing of words is checked once, and a violation is recorded for each such pair violating the required spacing. For example, there are three words in candidate (10)a; for three words there are three possible pairings, i.e., *C^ja–Ca, Ca–$C^ɣ$a*, and *C^ja–$C^ɣ$a*. Since these all differ only in consonantal backness, $\text{SPACE}_{\text{C-F2}} \geq 1/2$ requires that each such pair differs by one-half the total perceptual space (refer to (8)a above). The candidate receives two violation marks since only one of these pairs–the third– respects this requirement. (We group together the constraints *C^j and *$C^ɣ$ only for expository convenience. Also, candidates are arranged so as to suggest the relative positioning of words in the perceptual space.)

(10) Contrast can force articulatorily marked realizations

	2Words	Space≥1/2	3Words	Space≥1	*$C^{ɣ/j}$
a. C^ja Ca $C^ɣ$a		*!*		***	**
b. C^ja Ca		*!	*	*	*
c. Ca $C^ɣ$a		*!	*	*	*
d.☞C^ja $C^ɣ$a			*	*	**
e. C^ja	*!		*		*
f. Ca	*!		*		
g. $C^ɣ$a	*!		*		*

(10) shows how NWORD and SPACE constraints work together to force a maximally dispersed contrast. (The high vowels *i* and *u* would be selected in the same way.) This perceptually motivated contrast comes at the cost of extra articulatory markedness (and violates the lowest ranking but demanding SPACE constraint also). On the other hand, when contrast is suppressed for any reason, articulatory constraints make the selection, since SPACE constraints are vacuously satisfied. This is shown in (11). Here the SPACE constraints are undominated; this ranking entails that no amount of perceptual spacing is good enough for a contrast, hence the neutralization. (*ɨ* would be chosen in this way.) This same result would be obtained if one or both of the articulatory markedness constraints themselves were undominated, regardless of the ranking of SPACE constraints.

(11) Articulatory simplicity wins under neutralization

	Space≥1/2	Space≥1	2Words	3Words	*C$^{ˠ/j}$
a. C^{j}a Ca Cˠa	*!*	***			**
b. C^{j}a Ca	*!	*		*	*
c. Ca Cˠa	*!	*		*	*
d. C^{j}a Cˠa		*!		*	**
e. C^{j}a			*	*	*!
f. ☞ Ca			*	*	
g. Cˠa			*	*	*!

We note that all of these candidates, except for (11)e and (11)g, can be chosen as optimal under some ranking of these constraints. This correct prediction differs from that of the unidimensional markedness approach of (7) in only one way: the latter has no way of favoring the maximally dispersed two-way contrast, since plain *C* is regarded as universally the best. As Lyovin (1997) points out, Russian's contrast between palatalized *l*^{j} and velarized *ɫ* (and that of Irish, Ní Chasaide 1979), therefore presents standard markedness with a problem. The case outlined above exemplifies one class of argument for DT: the markedness of a segment depends both on its inherent properties and on the system of contrasts in which it participates. Flemming (1995b) provides more examples, to which we refer the reader. This markedness pattern is central to an understanding of locality in phonology, we argue below.

Before moving on, we briefly touch on several fundamental points concerning DT. The first concerns the status of faithfulness, and of underlying representations, in DT. As noted above, one of the fundamental roles of faithfulness constraints in OT is to ensure (or dispel) contrast. Yet DT posits constraints that demand contrast directly in the output, entirely taking over this job. Flemming (1995b) in fact argues that faithfulness, and underlying representations, should be eliminated from the theory. To address the other major role of underlying forms, the encoding of morphological relatedness, he suggests that similarity among morpheme alternants be dealt with exclusively by constraints governing the similarity of *surface* forms. Similar ideas to this latter one resonate in an increasing number of works arguing for constraints on the identity of output forms, or other means of maintaining surface similarities, e.g. Benua (1995), Buckley (1995), Burzio (1994; 1996), Itô and Mester (1997), Kager (1996), Kenstowicz (1996), McCarthy (1995), cf. Orgun (1994; 1996), Kenstowicz (1995). For the sake of discussion in this paper, we follow Flemming, as well as Burzio (1996), in requiring no underlying representations for the forms we consider, at least as crucial determinants of output wellformedness. For the same reason we employ no faithfulness constraints, instead letting the NWORD constraints do the relevant work. A consequence of this is that lexical entries correspond to surface representations, that is, forms licensed by output-based grammars such as OT.

A second point concerns the apparent "phonetic" nature of DT. The theory might seem especially phonetic compared to other theories of phonology for two reasons. First is the fundamental reliance on constraints based on articulatory simplicity and perceptual distinctiveness. Second is the increased number of segmental representations we entertain, a move that is possible once contrast is regulated separately by output constraints (see below). However, these properties of DT do not make it qualitatively different from other theories of phonology, virtually all of which have relied on constraints with some phonetic grounding, and all of which entail some rather large number of possible segments. In DT phonetic grounding is made especially explicit, and the number of possible representations is larger. Yet as understood here, the theoretical language remains one of constraints that consider a finite number of categorical entities and choose only some as optimal. To be clear, we are claiming neither that phonology and phonetics are "the same," nor that phonology is determined solely by phonetically grounded principles (as opposed to principles grounded in other domains, cognitive or otherwise), nor even that phonology cannot have abstract inclinations of the sort suggested by derivational opacity effects. The idea is simply that a good deal of phonology is determined by phonetic principles.

Finally, an important research goal for DT is to further refine our understanding of constraints on contrast and spacing, the nature of candidates, and the manner in which candidates are evaluated. Though the direct evaluation of contrast requires a kind of globality that might seem daunting at first—since candidates are not simply forms, but (idealized) languages—we take the view eloquently expressed by Prince and Smolensky (in press) that explanatory developments should not be constrained by a priori computational assumptions. This point is all the more forceful when there is clear and wide-ranging empirical support for the relevant ideas. This is the case with DT.

4 More on consonantal backness contrasts: Irish

The argument we make about locality depends on the claim that phonology can distinguish segment types such as C^i verus C^j without overgenerating contrasts.[11] This claim in turn depends on the basic phonological model we assume, DT. It is therefore important to examine the DT account of consonantal backness contrasts against real data involving such contrasts. In addition, it is necessary to consider distinctions such as C^i verus C^j in more detail in order to follow the discussion of Turkish next section. Here we examine facts of the western dialect of Irish, which reveal ways in which the account above for consonantal backness contrasts should be elaborated. As it turns out, the Irish facts provide further support for DT over unidimensional markedness.

The facts of interest involve the realization of a consonantal backness contrast before long vowels. (Short vowels in Irish acquire their backness specification from neighboring consonants.) The contrast is realized as shown in (12): a secondary articulation is pronounced when the consonant is followed by a long vowel that carries the opposite specification for backness, otherwise the consonant is plain. Thus a contrastively Front labial consonant is realized with a palatal off-glide preceding a long back vowel, while the corresponding Back labial consonant is realized as plain in the same context, as in (12)a-c. On the other hand, a Back consonant is strongly velarized before front vowels, and plain otherwise, as in (12)d-e.

(12)	a.	fʲu:	'worth'	fu:ə	'hate'
	b.	bʲo:	'alive'	bo:	'cow'
	c.	fʲɔ:n	'skin, flay'	fɔ:n	'straying, wandering'
	d.	bi:	'be (imp.)'	bˠi:	'yellow'
	e.	be:l	'mouth'	bˠe:l/bˠi:l	'danger'

The distribution of plain, palatalized and velarized consonants in Irish therefore depends very much on the vocalic context. An understanding of the pattern begins to emerge when we consider the effect of context on the perceptual spacing of consonantal backness contrasts. (13) shows sequences of a consonant followed by a vowel, arranged in a manner to suggest their relative similarity. The palatalized *C* before *i* is perceptually very close in this context to its "plain" counterpart. (The latter is actually coarticulated with the vowel *i*, as discussed in section 2.1) Both consonants are quite distant from a velarized *C* in this context. The facts are different when the vowel is *u*; now it is the coarticulated and velarized consonants that are very similar (indeed, given the rounding of *u* added in, virtually indistinguishable). The facts are similar in the case of mid and low vowels, though the problem of perceptual similarity is less severe in this case.[12]

(13) Spacing is context-dependent

$C^{j}i..C^{i}i$.....$C^{ˠ}i$ $C^{j}u$.....$C^{u}u..C^{ˠ}u$
$C^{j}e$.....$C^{e}e$.....$C^{ˠ}e$ $C^{j}o$.....$C^{o}o$.....$C^{ˠ}o$
$C^{j}ɔ$.....$C^{ɔ}ɔ$.....$C^{ˠ}ɔ$
$C^{j}a$.....$C^{a}a$.....$C^{ˠ}a$

This diagram is only schematic, but what matters is that we can infer the following: if the contrast $C^{j}a$ versus $C^{a}a$ violates $\text{SPACE}_{\text{C-F2}} \geq 1/2$, as assumed in the last section, then so do the contrasts $C^{j}i$ versus $C^{i}i$, $C^{j}e$ versus $C^{e}e$, $C^{u}u$ versus $C^{ˠ}u$, $C^{o}o$ versus $C^{ˠ}o$, and $C^{o}ɔ$ versus $C^{ˠ}ɔ$. That is, the latter contrasts are as bad as, or worse than, the former. (This inference is easily confirmed by spectrographic estimations.) We take the remaining spacings shown to pass this constraint (also based on rough acoustic comparisons). Given this state of affairs, the array of realizations found in Irish turns out to be optimal for a consonantal backness contrast, from the bidimensional viewpoint of DT.

The ranking in (14) is identical to that of (10) above. In (14), however, we replace the vowel *a* with *u* in our idealized languages. Both (14)a and (14)c include the problematic contrast $C^{u}u$ versus $C^{ˠ}u$, which falls short of the spacing requirement of $\text{SPACE}_{\text{C-F2}} \geq 1/2$. The two remaining candidates pass this constraint, and the choice between them is made on the basis of articulatory difficulty alone. Of these, (14)b maintains a contrast while involving the least articulatory effort. Thus preceding a back vowel, the optimal contrast is a palatalized-plain one. (We omit single-word candidates here, which are trivially eliminated by 2WORDS, as shown last section.)

(14) Before back vowels: "plain" vs. palatalized

	2Words	Space≥1/2	3Words	Space≥1	*C$^{ɣ/j}$
a. C^{j}u Cu C^{ɣ}u		*!		***	**
b.☞C^{j}u Cu			*	*	*
c. Cu C^{ɣ}u		*!	*	*	*
d. C^{j}u C^{ɣ}u			*	*	**!

Preceding a front vowel, on the other hand, the optimal contrast is a velarized-plain one, as seen in (15).

(15) Before front vowels: "plain" vs. velarized

	2Words	Space≥1/2	3Words	Space≥1	*C$^{ɣ/j}$
a. C^{j}i Ci C^{ɣ}i		*!		***	**
b. C^{j}i Ci		*!	*	*	*
c. ☞ Ci C^{ɣ}i			*	*	*
d. C^{j}i C^{ɣ}i			*	*	**!

We do not have "idealized Irish," strictly speaking, until we combine these two analyses. Suppose we allow words of the form $C^{(j/ɣ)}V$ in a new idealization now, where *V* is either *i* or *u*. There are then six possible words rather than three, and four words to be chosen as optimal, rather than two. An expansion of the idealization of this kind requires that we consider higher NWORD constraints in order to achieve the desired result. That is, where 2WORDS is undominated in the above tableaux, 4WORDS must be in this new idealization. This is shown in (16) below. Again, the SPACE constraints consider every logically possible pair of words in a candidate language, and record a violation for every pair that fails for the relevant amount of spacing. The statement of these constraints (see (8)b) requires that the words compared be identical except for a difference in backness for one consonant. This is in order not to penalize pairs such as $C^{j}i$ versus $C^{j}u$, as in (16)a, for failing to differ in consonantal backness, since this contrast is borne by their respective vowels. Hence there are only two pairs violating $\text{SPACE}_{\text{C-F2}}\geq 1/2$ in (16)a, and so on for the other candidates. (Some logically possible candidates are omitted.)

(16) Idealized Irish

	4Words	Space≥1/2	5Words	Space≥1	*C$^{ɤ/j}$
a. C^{j}i Ci C^{ɤ}i C^{j}u Cu C^{ɤ}u		*!*		******	****
b. C^{j}i Ci Cu C^{ɤ}u		*!*	*	**	**
c. ☞ Ci C^{ɤ}i C^{j}u Cu			*	**	**
d. C^{j}i C^{ɤ}i C^{j}u C^{ɤ}u			*	**	**!**
e. Ci Cu	*!		*		

As these tableaux show, DT's bidimensional approach to markedness predicts exactly the kind of variability in realization seen in the Irish case above: articulatory complexity is forced where necessary to fulfill the spacing requirement on contrast, giving one of C^{j} or C^{ɤ}, depending on the vocalic context. Articulatory simplicity determines the remaining realization.[13] The Irish case is not unique: the distribution of consonantal backness before vowels in Russian is remarkably similar (see Padgett in press). The explanatory intuition here is not available to traditional distinctive feature theory, which makes no reference to the output wellformedness of contrast. In that theory, though one can posit that some consonants are palatalized and others are not (or are velarized), the shift seen above in the actual realization of this contrast will remain entirely unrelated to this fact, having nothing to do with contrast preservation.[14]

5 Markedness, segment realization, and permeability in spreading: Turkish

The previous discussion paves the way for a return to Turkish vowel harmony and the issue of locality. An important result above is that "plain" consonants like *C^{i}* and *C^{u}* can be posited without overgenerating contrasts. In fact, such consonants actually *participate* in backness contrasts in certain contexts, as we saw. The emergence of the coarticulated realization of consonants in these contexts, it turns out, is mirrored by what is found in vowel harmony domains: once the needs of contrast are met or rendered irrelevant, segment realization is determined by articulatory constraints alone. The goal of this section is to demonstrate that, given Turkish vowel harmony, consonantal participation follows automatically from assumptions already laid out.

Vowels in Turkish agree in backness with the preceding vowel. A high vowel in addition agrees in roundness. For an understanding of the Turkish facts we rely on Lewis (1967), Underhill

(1976), Clements and Sezer (1982), van der Hulst and van de Weijer (1991), Kirchner (1993), Orgun (1996), and references therein. (Root-suffix morpheme boundaries are indicated.)

(17)	[Round]			
[Back]	son-un	'end gen.'	kɨz-ɨn	'girl gen.'
	kol-u	'arm acc.'	sabɨr-ɨ	'patience acc.'
	pul-un	'stamp gen.'	sap-ɨn	'stalk gen.'
	kurd-u	'worm poss.'	at-ɨ	'horse poss.'
[Front]	köy-ün	'village gen.'	el-in	'hand gen.'
	göz-ü	'eye acc.'	dere-si	'river poss.'[15]
	yüz-ün	'face gen.'	ip-in	'rope gen.'
	ütü-sü	'iron poss.'	it-i	'dog acc.'

There is some controversy over the issue of whether vowel harmony holds within roots, given the existence of many disharmonic roots largely due to borrowings from other languages, e.g. *politika* 'politics'. (Compare Clements and Sezer 1982 and van der Hulst and van de Weijer 1991, who differ greatly in approaching this issue.) Since our claims here concern only consonants in a vowel harmony domain, we focus on cases of unambiguous spreading, such as those above (and many others) in which suffixes are involved. In addition, for the sake of brevity we analyse only backness harmony among high vowels. As should be clear, the ideas extend in a straightforward way to predict consonant participation in vowel harmony generally.

In most work within Optimality Theory, feature spreading is compelled by constraints requiring that a feature align with either a left or a right word edge; in conjunction with locality constraints, satisfaction of alignment often results in long-distance feature spreading. (See for example Kirchner 1993, Smolensky 1993, Pulleyblank 1993, Cole and Kisseberth 1994, and Akinlabi 1997 on alignment for this purpose, and McCarthy and Prince 1993 on the general notion of alignment.) To effect harmony in Turkish, we assume the alignment constraint shown in (18). This formulation follows Zoll (1996) and Walker (1998) in making certain aspects of featural alignment more precise. The rightward direction mimics the rightward spreading posited in many analyses of Turkish. (See Anderson 1980 for arguments in favor of rightward spreading in Turkish).

(18) ALIGN-R(BACKNESS, PWD), where *Backness* = {Front, Back}

> Let f be a variable ranging over occurrences of any feature specification $F \in$ *Backness*, S be the string of segments $s_1 \ldots s_n$ in the prosodic word domain, and $s_i \delta f$ mean that f is dominated by s_i. Then $\forall s_i, f\ [s_i \delta f \rightarrow \forall s_j\ [s_j \delta f]]$, where $j > i$.

Less formally stated, for every instance of Front or Back in a prosodic word, if that feature is dominated by any segment, it is dominated by all segments to the right of that segment. Alignment is generally taken to be gradiently violable (see the references cited above). Though we assume this is correct, the analysis below does not require that we consider gradience of violation, since

ALIGN-R is undominated, and so we will simply distinguish candidates that fully satisfy alignment from those that do not.

Consider as our idealization languages having words of the form $Ip^{(j/\text{ˠ})}In$, where *I* is either *i* or *ɨ*. *ipin* 'rope, gen.' is an occurring Turkish word of this form. As promised above, this idealization limits us to an examination of backness harmony among high vowels. Suppose in addition we do not consider words that violate ALIGN-R, except by virtue of having a conflicting secondary articulation on *p*. The reason for this is that we are interested only in the fate of consonants in harmony domains, and the role that secondary articulations on such consonants can have assuming harmony. Given these assumptions, all of the possible words occurring in any of these idealized languages are given below.

(19) Possible words under current idealization

a.	$[\text{ipin}]_{\text{Fr}}$	d.	$[\text{ɨpɨn}]_{\text{Bk}}$
b.	$[\text{ip}^{\text{j}}\text{in}]_{\text{Fr}}$	e.	$[\text{ɨp}^{\text{ˠ}}\text{ɨn}]_{\text{Bk}}$
c.	$[\text{i}]_{\text{Fr}}[\text{p}^{\text{ˠ}}\text{ɨn}]_{\text{Bk}}$	f.	$[\text{ɨ}]_{\text{Bk}}[\text{p}^{\text{j}}\text{in}]_{\text{Fr}}$

As should be clear, strict locality directly entails segments such as $[\text{p}]_{\text{Fr}}$ and $[\text{p}]_{\text{Bk}}$ (more fully, p^i and $p^{ɨ}$) occurring in forms such as (19)a and (19)d. These are the coarticulated segments seen earlier. Yet phonologists have generally assumed that consonants are *not* participants in vowel harmony. Taking up our discussion from section 2.1, this is because to conclude the opposite—that consonants *are* participants—leads to a paradox within distinctive feature theory, where representational distinctions are generally identified with contrastive distinctions. Given distinctive feature theory, the expectation derived from observations of realizations in contrast (as in Irish or Russian) is that Front harmony in a form like *ipin* 'rope (gen.)', together with strict locality, should entail $[\text{ip}^{\text{j}}\text{in}^{\text{j}}]$, since there is no other notion of "frontness" in a consonant available to the theory. Similarly, Round harmony in *somun* 'rope' should give something like $[\text{s}^{\text{w}}\text{om}^{\text{w}}\text{un}^{\text{w}}]$. Since the Turkish forms do not actually elicit transcriptions of this sort, the conclusion is that consonants do not acquire these spreading features, and thus cannot be considered participants.

The issue can be approached from another angle by granting first that locality is segmentally strict. Then consonants participate in vowel harmony, and segments like p^i must be rather unmarked, since this kind of participation is almost ubiquitous, and indeed p^i occurs throughout languages by coarticulation. But if p^i is unmarked (or even exists), why does it not occur contrastively, e.g., p^i versus p^j? From the perspective of OT with unidimensional markedness, for example, contrastiveness should arise straightforwardly from a constraint ranking such as that in (20).[16]

(20) Unmarked → contrastive for unidimensional markedness

IDENT >> $*p^j$ >> $*p^i$ *p^j versus p^i is contrastive*

Approached from either direction, the source of the problem above lies in the assumption that potentially contrastive distinctions are the only distinctions known to phonology. Our

approach instead is to give up identifying the two, and to acknowledge the extra realizational possibilities this move provides. Within DT it is possible to embrace strict locality while avoiding the problems caused for distinctive feature theory. It does not follow from the occurrence of p^{i} and so on in harmony spans that this segment should also freely contrast with other segments. This is because contrast is directly limited by output constraints in DT. As we saw in the case of Irish, DT actually makes predictions in this area that are correct and somewhat intricate. Further, with contrast aside, given the choice of either p^{i} or p^{j} in a harmony domain, all else equal, the former will always be favored in DT, since it is less marked articulatorily. Parallel reasoning holds for p^{u} versus p^{w} and many similar cases. To see this, consider the tableau shown in (21).

(21) Consonant permeability in vowel harmony

	2Words	Space≥1/2	Align-R	3Words	*C$^{ˠ/j}$
a. [ipin]$_{Fr}$	*!			*	
b.☞[ipin]$_{Fr}$ [ɨpɨn]$_{Bk}$				*	
c. [ip^{j}in]$_{Fr}$ [ɨp^{ˠ}ɨn]$_{Bk}$				*	*!*
d. [i]$_{Fr}$[p^{ˠ}ɨn]$_{Bk}$ [ɨ]$_{Bk}$[p^{j}in]$_{Fr}$			*!	*	**
e. [ipin]$_{Fr}$ [ɨpɨn]$_{Bk}$ [ip^{j}in]$_{Fr}$ [ɨp^{ˠ}ɨn]$_{Bk}$		*!*			**
f. [ipin]$_{Fr}$ [ɨpɨn]$_{Bk}$ [ip^{j}in]$_{Fr}$ [ɨp^{ˠ}ɨn]$_{Bk}$ [i]$_{Fr}$[p^{ˠ}ɨn]$_{Bk}$ [ɨ]$_{Bk}$[p^{j}in]$_{Fr}$		*!*	*!		****

(21)a is a language that fully obeys backness harmony; however, it is possible to be such a language and still respect 2WORDS (i.e., have more contrasts), as (21)b does. This second candidate is our idealized Turkish. (21)c also respects harmony and 2WORDS. In this language, the secondary articulations on *p* are consistent with the Front or Back harmony spans of words; yet they also represent gratuitous violations of articulatory markedness, since the secondary articulations achieve nothing in the way of contrast or harmony. In fact, the violations incurred by such a candidate are a superset of those incurred by (21)b, and so such a candidate can never win. (21)d is even worse, since the secondary articulations on *p* are *not* consistent with vowel harmony (velarization is Back, palatalization Front), and so ALIGN-R is violated. (Since our goal is to consider consonants in harmony spans, Align-R is undominated by assumption.) The backness specification on $p^{j/ˠ}$ blocks the spreading of Front/Back from the root vowel, and itself spreads due to ALIGN-R. (21)e is an interesting attempt to respect harmony while increasing contrast, maintaining a contrast in consonantal backness as well as initial vowel backness. As we saw in the discussion of Irish, however, a contrast such as *ipin* versus *ip^{j}in* fails badly in the area of perceptual salience, as does *ɨpɨn* versus *ɨp^{ˠ}ɨn*, and so this candidate incurs two violations of

$\text{SPACE}_{\text{C-F2}} \geq 1/2$. (Recall that this constraint records a violation only for a pair of words that are identical except for the backness specification of one consonant. Therefore the other pairings seen in this candidate do not violate it.) Finally, (21)f (which includes all possible words under our idealization) has the same fatal faults as (21)d-e, and so loses as well.

To summarize the implications of this tableau, the existence of vowel harmony implies that consonants in the harmony domain bear the harmonizing feature, given the assumption of strict locality. This does not entail secondary articulations as in p^j or $p^{\text{ɤ}}$, for two reasons. On the one hand, a contrast based on such articulations, in a language having vowel harmony, violates an independently motivated constraint on the perceptual well formedness of contrast, as in (21)e. On the other hand, secondary articulations not motivated by contrast, as in (21)c, violate articulatory markedness with no redeeming gain. For the purposes of this demonstration we assumed that the constraints on articulatory markedness, $*C^{\text{ɤ}/j}$, are low ranked. The same result would be achieved under any ranking of these constraints, as the reader can verify.[17]

While (21)c is not optimal in the analysis given above, it does not follow that it could never be. Indeed, we would not want this to follow, since the Turkish consonants *k*, *g*, and *l* are in fact allophonically palatalized in Front-harmonic words (see the references on Turkish cited earlier). Allophonic palatalization of these segments is not uncommon across languages; this implies that there are constraints (other than those governing a consonantal backness contrast) favoring palatalization and therefore articulatorily marked C^j. For example, if we were to include in the tableau above undominated constraints requiring that velars and laterals be palatalized in a front vowel context, this would force realizations such as [ik^{j}in] for just these segments.

The conclusion we are led to here is rather that harmony in itself does not imply secondary articulations on consonants, even under strict locality, and that indeed secondary articulations under harmony are disfavored by basic constraints on both articulatory and perceptual wellformedness. As should be clear, similar reasoning holds for consonants in harmonic words having non-high vowels, and for those bearing other harmonic features, e.g., consonants like p^w in words with rounding harmony.

We see here another example of the markedness pattern predicted by DT: a segment p^i that is marked for the purposes of contrast due to spacing requirements is unmarked when contrast is irrelevant; what determines the consonantal realization here is articulatory complexity alone, and so coarticulation holds. The situation here fully parallels that concerning the facts of C^j, C, $C^{\text{ɤ}}$ discussed earlier: a unidimensional markedness paradox resolves itself once the two genuine dimensions of markedness are recognized. Stepping back, we have the larger conclusion: segment skipping in cases such as this can be viewed as an artifact of a particular approach to markedness, distinctive feature theory. Given another markedness theory, the issue of locality disappears.

6 Conclusion

As we have shown, once markedness is factored into independent components which have articulatory and perceptual underpinnings respectively, with the well formedness of contrast regulated by output constraints, a seemingly obvious example of transparency in spreading can be eliminated, reduced to a more basic issue of markedness and segment realization. We have argued this for Turkish only, but current work by us and others suggests that the same principles apply to a significant range of phenomena, including consonants in other vowel harmonies, and

consonantal harmonies. The hope is that this approach can help bring increased explanatory unity to these phenomena, and more significantly, unify these locality facts with the fundamental facts of markedness. Apart from the prohibition on segment skipping itself, the account we have presented makes no mention at all of locality or locality-specific notions.

There are of course other kinds of apparent transparency in spreading that present different challenges to the notion of strict locality, for example transparent vowels in vowel harmony, or transparent obstruents in nasal harmony. Walker (1998) argues that even such cases are best handled by independently required theoretical notions requiring no segment skipping or locality-specific statements. Similarly, recent work by Gafos (1996) makes a persuasive case that templatic effects of Semitic, and other similar facts, require neither planar C-V segregation nor the concomitant cross-vowel spreading of consonants in words (as in McCarthy 1979). Instead these facts are subsumed under the independently necessary realm of reduplicative effects. Walker (in press a,b) similarly analyzes certain spectacular examples of alleged long distance spreading as involving consonantal correspondence instead, and provides forceful arguments for this point of view. Though much investigation remains to be done in this area, we consider the question of transparency in spreading to be very much an open one.

What of phenomena other than spreading that seem to require "action at a distance"? Obligatory Contour (dissimilatory) effects can involve apparent action at a distance, as when consonants in a CVC form must not be of identical place. (See McCarthy 1986, Mester 1986, Yip 1989, Padgett 1991[95], and for new perspectives Pierrehumbert 1993, Frisch 1996, Alderete 1997, and Itô and Mester in press.) Since the reasons for the existence of OCP effects have not been made clear, it is not at all obvious that they can be considered action at a distance in the sense that alleged transparency in spreading is action at a distance. It *is* clear that the locality-related facts in the two areas are not the same. For instance, while the place features [labial], [coronal], and [dorsal] famously dissimilate long-distance, they do not spread long-distance. (See Gafos 1996, Flemming 1995a, and Ní Chiosáin and Padgett 1997 for arguments that this is true even of [coronal].) These considerations suggest that, rather than seek a unified "theory of locality," it would be more promising to derive seeming transparency effects from a better understanding of the specific phenomena involved. This has been our goal here.

Notes

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1. See Odden (1994) for a recent example of this strategy and a review of the area. For long-distance spreading in the Sound Pattern of English framework, see especially Chomsky and Halle (1968), Johnson (1972), Howard (1973), Anderson (1974), Jensen and Strong-Jensen (1976), Ringen (1976), Vago (1976), and Kenstowicz and Kisseberth (1977).

2. Some other recent works arguably advocating a kind of strict (non-relativized) locality are Smolensky (1993) and Cole and Kisseberth (1994; 1995), though these works pursue the locality and segment realization issues in a very different way.

3. Jakobson states (our translation), "...vowel harmony is indissolubly connected to consonantal harmony: some words consist of soft consonants and soft vowels, others of hard consonants and hard vowels." Trubetzkoy says similarly (p.285), "Synharmonism can be compared to tonality in music. In a 'synharmonic' language each word is like a string of sounds moving within a particular key." As an intriguing aside, Sharaf (p.98) mentions that the alphabet employed in the Yenisey-Orkhon runic inscriptions attesting Old Turkic (approximately 700 AD, Comrie 1981), is "built on the foundation of pairings of consonants" (in frontness vs. backness), a point made to us also by Vügar Sultanov (p.c.).

4. The trough seen in English uC_0u has been observed in Swedish, French, and Spanish as well, and it is not fully understood. One class of coarticulation theories ("look-ahead") predicts that the consonants should be fully rounded even in these languages, and another ("coproduction") at least allows for some overlap of the consonants by rounding, assuming there are no contrary forces at work. There is some evidence that certain consonants have some phonetic specification for lip protrusion/retraction even though this property is not phonemic, a fact that might be responsible for certain troughs. See the references and discussion in Boyce (1990) and Perkell (1986). Given the complexity of the issue, and the general possibility of coarticulation (see below), it seems unsafe to conclude that languages without vowel harmony should always exhibit troughs.

5. We thank Sibel Bargu, and Orhan Orgun, for volunteering as speakers. We especially thank Orhan Orgun for devising the extremely helpful list of Turkish forms. The forms were recorded by a Walkman Professional, and analyzed on a Kay Elemetrics CSL 4300. They were digitized at 20,000 Hz (and automatically low-pass filtered). For each fricative, we examined LPC-derived spectra, using a 20 ms window around the fricative’s midpoint, a filter order of 20, and full pre-

emphasis. The authors can provide more details on the materials and methodology upon request.

6. The procedure was the following: find the ratio P1/P2, where P1 is the highest peak (in decibels) in the 3-6 KHz range, and P2 is the highest peak above 6 KHz. The values were generally higher for [s] in front contexts.

7. Throughout the paper we make the simplifying assumption that articulatory simplicity is computed for a segment in isolation. In truth it is context-dependent. For example, *ə* is not the favored reduced vowel in some contexts, as in English *dish[ɪ]s*, where the surrounding consonants have some effect. Similarly, Kabardian /ɨ/ has realizations ranging from [i] to [u] when following a consonant with tongue body or round specifications, but is [ɨ] otherwise (Choi 1991). In the same way, though we speak of "plain" consonants, the realization of a consonant can vary according to language and context.

8. Though interpreting these particular constraints as articulatory gives us the rankings that would be assumed on typological grounds, the same is not true of the similar example involving vowels, where articulatory considerations give us *i, *u >> *ɨ

9. These constraints and rankings are modeled after Flemming (1995b)'s "Minimal Distance" constraints, but avoid some artifacts of the latter. (See Padgett 1997, note 4.)

10. Several issues for future research are raised by this formulation. To mention just one, it is important that differences are gauged along the perceptual dimension (couched crudely here as consonantal F2), and not in terms of articulatory specifications. This ensures that, e.g., $p^{i}i$ and $p^{j}i$ differ in just the same way that $p^{j}i$ and $p^{ˠ}i$ do (though to a lesser degree), and only in that way. Hence these two word pairs fall under the same spacing requirement. On the articulatory side these contrasts cannot be characterized in a uniform way, the first pair differing in a strictural specification at the consonantal release (as discussed in section 2.4), the second in Front/Back specifications.

11. Recall that contrasts are not overgenerated because Gen is assumed to put a lower limit on the spacing of contrasts. For example, we assumed earlier that the constraint $\textsc{Space}_{C\text{-}F2} \geq 1/3$ is in Gen.

12. It is important to note that the discussion here is based only on the secondary off-glides transcribed (with roughly F2 location as the acoustic correlate), perhaps along with the slight frication that can typically accompany them, especially for C^{j}. It is well known that palatalization can lead to full-fledged affrication, especially for coronals, e.g., *tʃʲ dʒ*. In such cases the distance between $C^{j}i$ and *Ci* can be much greater than suggested here. This degree of affrication does not occur in the dialect of Irish described here.

13. It is conceivable that C^{i} occurs with even greater frequency under palatalization contrasts then our account suggests. Though we assume the optimal contrast $C^{j}u$ vs. *Cu*, the contrast $C^{i}u$ vs. *Cu* might satisfy spacing requirements too, and would then be prefered on the grounds of articulatory simplicity. That is, what is called "palatalization" might involve a lesser degree of off-glide constriction than C^{j} implies.

14. Probably the best account for these facts within distinctive feature theory appeals to the Obligatory Contour Principle. See Padgett (in press) for arguments against such an alternative.

15. The non-possessed form is *dere*. The *s* in *deresi* is inserted by a regular morphophonemic alternation. The same is true of *ütü* 'iron'.

16. Assuming that there are no constraints of the form $*p^V$, where *V* stands for any coarticulated vocalic features, would also predict that such segments are unmarked, but would still predict contrastiveness. All languages would have segments like p^i, and those with the ranking Ident >> $*p^j$ would contrast them with p^j.

17. On the other hand, given the ranking 3WORDS >> $\text{SPACE}_{\text{C-F2}} \geq 1/2$ we would derive (21)e as optimal. In the discussion of Irish we left open the question whether contrasts such as $p^j i$ versus *pi* should be universally ruled out, that is, whether they violate $\text{SPACE} \geq 1/3$, assumed to be in Gen. We are not aware of a clear case of contrast involving "plain" versus palatalized consonants before phonetic [i] (assuming C is not affricated of spirantized). It does not occur in either Irish or Russian. Nyangumarda contrasts "Ci" versus "Cyi." However "i" is described by Hoard and O'Grady (1976) as lax [ɪ], so we actually have [Cɪ] versus [C^jɪ].

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