Turkish Vowel Harmony and Disharmony:
An Optimality Theoretic Account

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0. Introduction

In this paper I analyze the pattern of [round] and [back] vowel harmony and disharmony in Turkish within the framework of Optimality Theoretic Phonology (Prince and Smolensky 1993).[1] In Optimality Theory, the phonological component of the grammar consists solely of a set of universal, violable constraints, ranked on a (partially) language-specific basis. My primary goal is to extend this framework to segmental phenomena, exploring the sorts of constraints which are required to account for a language with fairly rich segmental phonology.[2]

1. Data and Previous Analyses

1.1. Clements and Sezer. The well-known facts of Turkish vowel harmony (1) have standardly been taken as motivation for rules of [back] and [round] spreading, shown in primitive autosegmental notation in (2):

(1)	'rope'	'girl'	'face'	'stamp'	'hand'	'stalk'	'village'	'end'	
	ip–in	kız–ın	yüz–ün	pul–un	el̦–in	sap–ın	k̦öy–ün	son–un	(gen.sg.)
	ip–l̦er	kız–lar	yüz–l̦er	pul–lar	el̦–l̦er	sap–lar	k̦öy–l̦er	son–lar	(nom.pl.)

(2)
```
                                 +high
                                   |
      VC0V  (and mirror        VC0V    (and mirror
       \ |   image)             \ |     image)
      αback                    αround
```

In addition to the suffix alternations in (1), epenthetic vowels, which are high, receive rounding and backness specification from neighboring vowels according to the same rules, as shown in (3).

(3)	/hük̦m/	→	hük̦üm	'judgment'
	/koyn/	→	koyun	'bosom'
	/metn/	→	metin	'text'
	/sabr/	→	sabır	'patience'

However, Clements and Sezer (1982) observe that, while this harmony is almost entirely regular between roots and suffixes, disharmony within roots is quite extensive. The following examples are indicative of widely attested disharmonic vowel sequences:[3]

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[1] I do not discuss the consonant harmony facts, i.e. the interaction of particular palatalized and velarized consonants with the backness harmony system; nor do I discuss the palatal umlaut phenomenon, or raising and unrounding of vowels before [y], found in Istanbul Turkish.

[2] Most of the work on Optimality Theory has heretofore concerned itself with prosodic phenomena. Additional work in segmental phonology was presented at ROW-1 by Moira Yip; Diana Archangeli and Doug Pulleyblank; Junko Itô, Armin Mester, and Jaye Padgett; Paul Smolensky; and Charles Kisseberth.

[3] The /i...u/ sequence appear to be rare: aside from bil̦l̦ur, and ziggurat ('ziggurat'), Clements and Sezer were unable to adduce examples of words with this sequence.

(4)	hamsi	’anchovies’	fiat	’price’
	anne	’mother’	mezat	’auction’
	bobin	’spool’	sifon	’toilet flush’
	rozet	’collar pin’	peron	’railway platform’
	biļļur	’crystal’	muzip	’mischievous’
	kudret	’power’	nemrut	’unsociable’

On the other hand, this disharmony is not unrestricted: disharmonic vowels are only of the set [i,e,a,o,u], i.e. the typical five-vowel inventory of markedness theory (henceforth "the unmarked vowels"). The occurrence of the vowels [ü,ö,ı] ("the marked vowels") must be consistent with the backness harmony rule in (2). Borrowings which violate this generalization are frequently regularized:

(5)	komünizim ~ kominizim	’communism’
	mersörize ~ merserize	’mercerized’
	püro ~ puro	’cigar’
	ķüļot ~ ķiļot	’panties’
	nüzuļ ~ nüzüļ	’paralysis’
	nüfus ~ nufus	’population’
	kupür ~ küpür	’denomination, clipping’
	motör ~ motor	’engine, motorboat’
	šoför ~ šöför	’driver’
	bisķüvit ~ büsķüvüt	’biscuit’
	sövaļye ~ sovaļye	’knight’

Clements and Sezer observe that /i...ü/ and /ü...i/ sequences are licit (e.g. ümit (’hope’), tifüs (’typhus’)), suggesting that [round] harmony is not a condition on the distribution of marked vowels.[4] However, there are no roots containing [ı] which are disharmonic with respect to [round], such as *umıt or *tıfus. Note that regularization is not a uniform process: in püro ~ puro, [ü] becomes [u]; in ķülot ~ ķilot, [ü] becomes [i]. What unites these regularized loans is the generalization that they obey:

(6) Generalization: The vowels [ü,ö,ı] do not occur in roots which are disharmonic with respect to backness, and [ı] does not occur in roots which are disharmonic with respect to rounding.[5]

Furthermore, despite the general transparency of suffixes to vowel harmony (1), there are a handful of opaque suffixes, such as in (7):

[4] Consequently, the variation between bisķüvit and büsķüvüt, and between mersörize and merserize, in (5) cannot be explained as "regularization." I have no alternative explanation of this variation, however, unless perhaps (4) represents a conflation of distinct Turkish dialects/sociolects.

[5] Since presenting this paper at ROW-1, I have come across a number of apparent counterexamples to this generalization, e.g. müsaade ‘permission’, jüzdan ‘wallet’. Orhan Orgun (p.c.),a native speaker of Turkish, confirms that these forms do not undergo regularization. I have nothing to say about these forms at present. Obviously, if they represent genuine counterexamples to Clements and Sezer’s generalization, much of the analysis in this paper will have to be substantially revised.

(7)

/Iyor/		/Edur/	
gel̦–iyor–um	’I am coming’	gid–edur–sun	’let him keep going’
k̓oš–uyor–um	’I am running’	k̓oš–adur–sun	’let him keep running’
gül̦–üyor–um	’I am laughing’	gül̦–edur–sun	’let him keep laughing’
b̓ak̓–ıyor–um	’I am looking’	b̓ak̓–adur–sun	’let him keep looking’
/istan/		/va:ri/	
mo:l–istan–ı	’Mongolia’	ask̦er–va:ri	’soldier–like’
arab–istan–ı	’Arabia’		
ermen–istan–ı	’Armenia’		

(/I/ is Turkological shorthand for a high vowel; /E/ for a non-high vowel.) Note that the first syllable of /Iyor/ and /Edur/ undergoes vowel harmony, but the second syllable is invariant, as is the entirety of the /istan/ and /va:ri/ suffixes. The suffixes which follow an opaque suffix agree in backness (and if high, in rounding), with the rightmost vowel of the opaque suffix. These opaque suffixes obey generalization (8), which is quite similar to (6).

(8) <u>Generalization</u>: The marked vowels [ü,ö,ı] do not occur in opaque suffix syllables.

These distributional facts present a curious state of affairs from the perspective of rule-based theories. The existence of root-internal disharmony suggests an analysis of harmony as a derived environment rule.[6] Yet the restrictions on the marked vowels in roots and opaque suffixes, which are psychologically real enough to induce regularization of loanwords, require that the backness harmony rule play some further role as a morpheme structure constraint. The redundancy in having these two devices, spreading rules and constraints on underlying representation, to enforce the same condition on the distribution of [round] and [back], indicates that a generalization has been missed. Moreover, the fact that [back] and [round] harmony can function statically, as constraints on underlying representation, undermines the view of vowel harmony as a rule in the conventional sense, i.e. a structural change.

1.2. <u>Goldsmith</u>. Goldsmith (1990) presents an alternative analysis of the root-internal disharmony facts which relies on underspecification of [back] for the unmarked vowels.

(9)

	i	e	a	o	u
low		+	+	+	
round	–	–		+	+

Rather, [back] is filled in by the following default rules:

(10) [–round] $\rightarrow$ [–back]
otherwise [0back] $\rightarrow$ [+back]

The marked vowels, however, are underlyingly specified for [back].

(11)

	ü	ö	ı
low		+	
round	+	+	–
back	–	–	+

Now, if spreading of [back] is ordered before default [back] insertion, we derive the result that the marked vowels only occur in words which obey [back]

[6]Clements and Sezer state this slightly differently: they stipulate that all root vowels count as "opaque" for purposes of the spreading rules.

harmony.

As a threshold matter, Goldsmith's use of underspecification seems rather ad hoc. For example, use of [−round] to distinguish [a] from [e] (which are both phonetically unrounded) is precisely the kind of ternary power that constrained theories of underspecification (radical and contrastive) have attempted to avoid. Indeed, the very use of underlying [−round] is problematic, since [−round] generally appears to be phonologically inert, if it exists at all. See Steriade (1987, forthcoming), arguing for privative [round], and Archangeli and Pulleyblank 1986, arguing for underspecification of [−round]. One would not wish to abandon these claims regarding the inertness of [−round] except in the face of strong evidence.

In this instant case, however, the motivation for active [−round] is not particularly compelling, since Goldsmith's account cannot be extended to the opaque suffixes (7). Recall that opaque suffixes do not undergo harmony, instead transmitting their own values of [round] and [back] onto following suffixes. On the other hand, these suffixes contain no marked vowels: there are no opaque suffixes such as /istön/ or /Edır/. This state of affairs is precisely the opposite of what Goldsmith's account predicts: by the standard reasoning of underspecification theory, if any suffixal vowels ought to be opaque to harmony, it is the marked vowels, since in this analysis they are the ones which are underlyingly specified for [back]. Thus, under Goldsmith's analysis, the opacity these suffixes must be stipulated, the absence of marked vowels in opaque suffixes must be separately stipulated, and no connection can be drawn between generalizations (6) and (8), despite their striking similarity.

2. Features and Representations

In the following sections, I propose an Optimality Theoretic analysis of the Turkish facts which allows for a more unified account of the relation between vowel harmony and unmarkedness, in both roots and suffixes.

2.1. The Turkish vowel inventory. I posit the following feature specifications for the Turkish vowel inventory.

(12)

	i	e	a	o	u	ü	ö	ı
high	+	−	−	−	+	+	−	+
low	−	−	+	−	−	−	−	−
front	■	■				■	■	
round				■	■	■	■	

(■ = presence of privative feature)

The privativity of [round] has been argued for by Steriade (1987, forthcoming), among others. I do not believe [front] in my analysis is crucially privative; but since [+back] is inert in Turkish, I have found it simpler to assume for purposes of this paper that it does not exist. As for height, any system of vowel height features which can yield a three-way height distinction appears to be compatible with my analysis: the standard bivalent height features are used here merely for the sake of concreteness. I assume that the theory of representations bans candidates containing vowels which lack height specification, and that cooccurrence of [high] and [low] is also universally ruled out.

(13) Vowel Height Requirement
In all candidates, a vowel must be specified for height (inviolably).

(14) <u>Non-cooccurrence of [+high] and [+low]</u>
*[+high,+low] (inviolably)

I further assume, following Itô, Mester and Padgett (1993), that Gen (the function that generates output candidates from a given input) has the power to insert features, but that insertion of features incurs a cost, namely violation of the following constraint:

(15) *INS(F): Do not insert features.

(I will not address the formal issue of how inserted features are detected as such, i.e. by comparison with the input or by some sort of distinct representation for inserted features.)

Note that the value of the feature [low] in this inventory is in accordance with the following constraint, (subject, of course, to the universal, absolute cooccurrence restriction on [+high] and [+low]):

(16) COLOR: A vowel is [front] or [round] iff it is [−low].

This constraint, which reflects the acoustic enhancement relation between vowel backness and rounding (see, e.g., Stevens, Keyser and Kawasaki 1986), will do a fair amount of additional work for us in the following analysis.

The COLOR constraint rules out front or rounded low vowels as well as non-low vowels without color features. However, since the vowel [ı] can surface in Turkish, COLOR must be ranked below *INS(F):

(17)

input: /ı/	*INS(F)	COLOR	
☞ V | \\ +hi −lo		*	(= [ı])
V /	\\ fr +hi −lo	*!		(= [i])
V /	\\ ro +hi −lo	*!		(= [u])
___ V / / ╪ ⍀ +lo −hi +hi −lo	**!		(= [a])

On the other hand, colorless mid−vowels do not occur in Turkish. They can be ruled out by positing a more restricted version of the COLOR constraint which is ranked <u>above</u> *INS(F).

(18) MID−COLOR: If a vowel is [−low,−high], it is [front] or [round].
(by the Pāṇinian Theorem, if MID-COLOR is active, MID-COLOR ≫ COLOR).

(19)

input: /ʌ/	MID-COLOR	*INS(F)	
a. V ☞ / | \ fr −hi −lo		*	(= [e])
b. V ☞ / | \ ro −hi −lo		*	(= [o])
c. V ☞ / | ⍀ +lo −hi −lo		*	(= [a])
d. V | \ −hi −lo	*!		(= [ʌ])

(Since the point here is to rule out [ʌ], it need not concern us that candidates (a-c) are equally optimal, so long as (d) is sub-optimal.)

In sum, the Turkish vowel inventory has been derived from the constraint ranking in (20).

(20) MID-COLOR ≫ *INS(F) ≫ COLOR

3. Spreading.

3.1. Feature alignment. Recall that in Turkish, [front] can spread onto a round vowel, although (speaking somewhat pre-theoretically) round vowels do not require specification for [front]. There must therefore be some independent factor compelling features to spread towards the left or right edge of the relevant domain. McCarthy and Prince (1993ab) posit a family of constraints which refer to the alignment of morphological constituent edges with prosodic domain edges. This idea can be extended to edge alignment of features as in (21):[7]

(21) ALIGN(F,L/R,MCat): For any parsed feature F in morphological category MCat (= Root, Word), F is associated to the leftmost/rightmost syllable in MCat (violations assessed scalarly).

The failure of particular features to associate edge-wards in particular grammars may be accounted for in terms of higher-ranked constraints as well as (inviolable) principles of the theory of representations. For example, I assume, following Archangeli and Pulleyblank (1992), that candidates containing gapped configurations (e.g. skipping a syllable nucleus) are ruled out, absolutely, by the theory of representations.[8]

[7] I find that this move has been anticipated by a number of the other participants at ROW-I.

[8] The treatment of "neutral" vowels in languages such as Finnish may require some relaxation of this prohibition.

(22) <u>Prohibition on Gapped Configurations</u>

```
* V  V  V
   \   /    (inviolably)
     F
```

If a feature is prelinked to some medial syllable, and ALIGN(F,L) is ranked sufficiently high, the optimal output will be one in which the feature is also associated to the leftmost syllable in the domain, plus any intervening syllables, i.e. right-to-left spreading (vice-versa for ALIGN(F,R); bidirectional spread if both are ranked high):

(23) <u>Spreading under ALIGN(F,L)</u>: <u>Spreading under ALIGN(F,R)</u>:

```
 [V V V V V]     [V V V V V]     [V V V V V]     [V V V V V]
      |      →     \_\|               |      →         |/_/
      F               F               F                F
```

<u>Spreading under ALIGN(F,L) and ALIGN(F,R):</u>

```
 [V V V V V]     [V V V V V]
      |      →     \_\|/_/
      F               F
```

Note that in monosyllabic words, ALIGN(F) is satisfied trivially.

In the event that spreading onto a particular anchor is blocked, e.g. due to a higher-ranked feature cooccurrence constraint, violations are assessed scalarly, in terms of the number of unassociated syllables:

(24)

/V_G V V V_F/	*[F,G]	ALIGN(F,L)
[V V V V] | | G F		***!
[V V V V] | \\\| G F		**!
☞ [V V V V] | _\\\| G F		*
[V V V V] |__\\\| G F	*!	

This approach thus captures the general autosegmental property that features spread towards some domain edge until blocked. Also note that, with an additional assumption, ALIGN(F) can account for the widespread phenomenon of particular features which are "licensed" only at the left or right edge of a word or root (sometimes viewed as a species of extrametricality); see Steriade (forthcoming).[9]

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[9]The "additional assumption" is something like "*MULT: No multiply linked features." Note that, since ALIGN(F) refers only to <u>parsed</u> features, it can be satisfied trivially by failing to parse a non-spreading feature (this line of reasoning is developed more fully in following sections). Under the ranking {ALIGN(F,L), *MULT} ≫ PARSE(F), the only instances of feature F which will surface are those in which F is linked to the leftmost syllable in the domain, and to that syllable only.

For Turkish, we can assume, for the moment, bidirectional spread within the word. The feature [front] spreads from nucleus to nucleus without restriction (ignoring the disharmonic roots for the moment). Spreading of [round], however, is limited to high vowels, as we saw in (2). This result can be obtained by positing a cooccurrence restriction on round and [−high], which is ranked above ALIGN(F):

(25) *RO,−HI: *[round,−high]

(26) *RO,−HI ≫ ALIGN(F)

*RO,−HI reflects the frequently observed markedness of [o] relative to [u] or [a], cf. Schane (1984).

However, round mid vowels must not thereby be excluded from the Turkish inventory, since [o] and [ö] exist in Turkish. The result that *RO,−HI is a condition on spreading but not on parsing can be obtained by positing a featural parsing constraint, and ranking it above *RO,−HI, as shown in (27) and (28):

(27) PARSE(F) (initial formulation): No stray (unsyllabified) features.

(28) PARSE(F) ≫ *RO,−HI

(Incidentally, PARSE(F) appears to subsume Prince and Smolensky’s segmental notion "PARSE", since segments are nothing more than structured sets of features). Now, since PARSE(F) is ranked above *RO,−HI, it is preferable to parse a mid round vowel, notwithstanding *RO,−HI:

(29)

Input: o	PARSE(F)	*RO,−HI	
☞ V / | ro −hi		*	(= o)
V ≠ | ro −hi	*		(= a)

Nevertheless, it is preferable to satisfy *RO,−HI rather than ALIGN(F) where these conflict, as shown in (30).

(30)

/u...a/	*RO,−HI	ALIGN(F,R)	ALIGN(F,L)	
☞ [I E] | ro		ro: *		(= [u...a])
[I E] | / ro	*!			(= [u...o])

Finally, I assume that the failure of the height features to spread is due to the following constraint:

(31) *MULT-HEIGHT: No multiply linked height features.

Some such constraint seems justified by the relative rarity of height harmony systems.[10] If *MULT-HEIGHT is ranked above ALIGN(F), [high] and [low] spreading will be ruled out.

(32)

$[V\ V_{lo}]$	*MULT-HEIGHT	ALIGN(F,L)	
☞ [V V] 	| (+hi) lo		*	(= ı...a)

[V   V]
  \ |
     lo
	*!		(= a...a)

Since [low] cannot spread, the initial anchor receives its height specification by default insertion of [+high]. (For this reason, *MULT-HEIGHT must be ranked above *INS(F) as well.)

In sum, we have considered some theoretical devices for handling feature spreading phenomena in an OT framework, and derived the Turkish roundness and backness harmony "rules" from the following ranking of constraints:

(33) PARSE(F) ≫ *RO,–HI ≫ {ALIGN(F,L,Wd), ALIGN(F,R,Wd)}

*MULT-HEIGHT ≫ {*INS(F), ALIGN(F,L,Wd), ALIGN(F,R,Wd)}

The analysis of the basic vowel harmony facts in (1) may be summarized as follows:

(34)

ip–in, yüz–ün, eļ–in, ķöy–ün, ip–ļer, yüz–ļer, eļ–ļer, ķöy–ļer	[front] spreads to satisfy ALIGN(F)
kız–ın, pul–un, sap–ın, son–un kız–lar, pul–lar, sap–lar, son–lar	there is no [front] specification to spread
yüz–ün, ķöy–ün, pul–un, son–un	[round] spreads to satisfy ALIGN(F)
ip–in, eļ–in, eļ–ļer, ip–ļer, kız–ın, sap–ın, kız–lar, sap–lar	there is no [round] specification to spread
yüz–ļer, ķöy–ļer, pul–lar, son–lar	[round] spreading blocked by *RO,–HI

[10] *MULT-HEIGHT is unnecessary if full underlying specification of vowel features is assumed, since the height features are bivalent. However, such a constraint on underlying representation smells of brute force. Alternatively, Lisa Selkirk (p.c.) suggests that the failure of height features to spread in "color" harmony languages follows from a representation in which vowel color features are dependent on height features (see Selkirk 1990). Since vowel height features are then on the same tier as consonant place features, the failure of height features to spread can be explained in terms of general locality constraints. In height harmony languages, on the other hand, we must assume that color features dominate height features.

4. Disharmonic Roots.

4.1. Blocking of spreading. PARSE(F) and *INS(F) are both aspects of "faithfulness," or minimal divergence of the phonological output from the underlying representation (see PS). But if features may be linked to phonological structure in UR, surely the reassociation of features to anchors must be constrained as well. Following Itô, Mester, and Padgett (1993), and Kirchner (1993), I formalize this aspect of faithfulness in terms of the following constraint:

(35) *SPREAD: Do not insert association lines.

Therefore, prelinking (or rather the absence thereof) will be respected, ceteris paribus, but may be overridden in particular cases by higher-ranked constraints. In general, the higher *SPREAD is ranked in a particular grammar, the fewer synchronic assimilation phenomena the language will display; i.e. the more featurally "inert" the phonology will be.

Assume that *SPREAD is ranked above ALIGN(F,L/R) in Turkish: the result is that, in general, there is no synchronic [front] or [round] spreading in Turkish roots; there is only underlying multiple association. Front-disharmonic roots are merely those roots in which [front] is not multiply linked underlyingly:

(36)

/hamsi/	*SPREAD	ALIGN(F,L)	

☞ [E I]
       |
      fr
		fr: *	(= hamsi)

[E I]
  \ |
   fr
	*!		(= hemsi)

This result may be contrasted with a harmonic root, such as güzel ('beautiful'), which we may assume has [front] linked to both vowels underlyingly.[11]

(37)
```
 ro
 |
g I z E l   →   (unchanged)     = güzel ('nice')
̥  \ /                           Multiple linking of [front] satisfies
   fr                           ALIGN(F) without violating *SPREAD
```

This analysis extends to roots which are disharmonic with respect to [round], e.g. muzip ('mischievous'): the failure of [round] to spread onto the second vowel is likewise due to *SPREAD. Back harmonic roots, such as adam ('man'), have no [front] feature to spread, and therefore satisfy ALIGN(F) with respect to [front] trivially.

This approach captures Clements and Sezer's observation that root vowels are opaque to active spreading. Let us contrast this approach to the (per-

[11]Alternatively these harmonic roots might be represented as having separate specification of [front] for each vowel, under the assumption that a feature cannot spread onto an anchor already specified for that feature, and that the OCP (however formulated) is inactive w.r.t. the [front] tier. However, it is demonstrated in the following section that, at least in the case of roots containing front round vowels, the correct representation involves multiple association, not multiple specification, of [front].

haps) more standard assumption that root vowels are opaque because they may be specified [+back], and that [front] (or [−back]) may not spread onto an anchor that is already specified [+back]. While this explanation may be adequate for backness disharmony, the extension of this explanation to [round] opacity, for forms such as <u>muzip</u>, commits us to an equipollent treatment of [round] -- an undesirable consequence, in light of Steriade's (1987, forthcoming) arguments as to its privativity.[12]

4.2. <u>Disharmony and vowel unmarkedness</u>. Having developed a mechanism to account for feature spreading in Turkish, we have now concluded that there is no active spreading within roots. But the generalization to be captured is not that [round] and [front] must spread, but that their failure to spread has consequences for the distribution of marked vowels.

4.2.1. Absence of disharmonic [ı]. Recall that the COLOR constraint prohibits, <u>inter alia</u>, non-low vowels without color features, namely [ı]. Assume that COLOR is ranked above *SPREAD.

(38)

<table>
<tr><td>/i...ı/</td><td>COLOR</td><td>*SPREAD</td><td></td></tr>
<tr><td>☞ I   I
  | /
  fr</td><td></td><td>*</td><td>(= [i...i])</td></tr>
<tr><td>I   I
|
fr</td><td>*!</td><td></td><td>(= [i...ı])</td></tr>
</table>

The result is that the [front] specification must spread, notwithstanding the violation of *SPREAD, to satisfy COLOR. This spreading likewise obtains if one of the vowels is specified [round] rather than [front], by the same reasoning. It follows that [ı] cannot appear in a root which is disharmonic with respect to [front] or [round]. Further observe that an epenthetic vowel is featurally identical to [ı]: it is a [+high] vowel unspecified for color features. So by the same reasoning, spreading of [front] or [round] onto an epenthetic vowel is not blocked by *SPREAD.

But what if the source vowel is specified both [front] and [round]? COLOR can be satisfied by spreading one or the other; but the data in (3) indicate that both features must spread. Assume, however, that violations of *SPREAD are assessed, not in terms of the raw number of association lines inserted, but in terms of the number of segments affected by the spreading:

(39) <u>Addendum to *SPREAD</u>: Violations of *SPREAD are assessed in terms of the number of segments whose specification has been altered by intersegmental feature association.

This interpretation of *SPREAD parallels Steriade's (1982) notion of parasitic harmony. In effect, once an association line has been inserted connecting a feature of one segment to another segment position, other features may spread parasitically onto the target segment without incurring additional *SPREAD violations:

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[12]A further shortcoming of the standard approach is its inability to capture the generalization that there are no disharmonic suffixes which are opaque as to a particular feature but harmonic with respect to other features. See section 5.1.

(40)

/hüķm/	COLOR	*SPREAD	ALIGN(F,R)	

☞ ro
   |\\
[hüķIm]
   |/
   fr
		*		(= [hüķüm])

ro
   |
[hüķIm]
   |/
   fr
		*	ro: *!	(= [hüķim])

Since the number of *SPREAD violations is the same for the two candidates, the winner is the candidate which satisfies ALIGN(F).

4.2.2. Absence of disharmonic [ü,ö]. To develop the analysis further, we must reexamine the notion PARSE(F). Consider a constraint ℂ on the cooccurrence of features F,G,H, which states: "if F or G, then not H."

(41)

	ℂ	PARSE(F)
☞ A / | F G H		*
A \\ F G H		**!
A /	\\ F G H	*!	

The result predicted in (41), that the outcome depends on the raw number of PARSE(F) violations, irrespective of the identity of the features involved, does not appear to be attested in natural language.[13] The problem lies in the assumption that the parsing of all features must be equally ranked in the constraint hierarchy. I propose that PARSE(F) be exploded into a set of independently rankable PARSE constraints that refer to particular features:

(42) PARSE(hi): No stray (unsyllabified) [high].
PARSE(lo): No stray (unsyllabified) [low].
PARSE(ro): No stray (unsyllabified) [round].
PARSE(fr): No stray (unsyllabified) [front].

Cf. Prince and Smolensky (1991), Kirchner (1993), and Black (1993), motivating independent ranking of PARSE(consonant) and PARSE(vowel).

In (29), it was observed that PARSE(F) must be ranked above *RO,−HI, otherwise the mid round vowels [o,ö] could not surface in Turkish. This may now be taken as motivation for ranking PARSE(ro) and PARSE(hi) above *RO,−HI.

[13]Imagine, for example a syllabification algorithm such that, given the choice between failing to parse one of two consonants, the consonant with the most features was always parsed -- surely no natural language works this way.

(43) {PARSE(ro), PARSE(hi)} ≫ *RO,−HI

Further assume that PARSE(fr) is ranked below ALIGN(F).[14] Since ALIGN(F) refers solely to parsed features, ALIGN(F) can be satisfied trivially by leaving a feature unparsed. Thus, in the winning candidate in (44), [front] is left unparsed; and since PARSE(fr) is the lowest-ranked of the relevant constraints, this is the optimal output.

(44)

/ü...a/	*SPREAD	PARSE(ro)	ALIGN(F,R)	PARSE(fr)	
fr ╪ ☞ [I E] | ro			ro: *	*	(= [u...a])
fr | [I E] | ro			ro: * fr: *		(= [ü...a])
fr | [I E] ╪ ro		*!	fr: *		(= [i...a])
fr / \\ [I E] | ro	*!		ro: *		(= [ü...e])

The result is [u...a] rather than [ü...a]. In contrast, if [front] in this root were <u>underlyingly</u> multiply linked, as in (37), the [front] specification could be parsed without violating *SPREAD. Generalizing this result, we see that a front round vowel can never surface in a root which violates backness harmony.

But how can a back disharmonic root ever surface, given the option of failing to parse [front]? Consider the same input as in (44), but without the [round] specification, shown in (45).

(45)

/i...a/	COLOR	ALIGN(F,R)	PARSE(fr)	
a. [I E] ☞ | fr		*		(= [i...a])
b. [I E] ╪ fr	*!		*	(= [ı...a])

Without the [round] specification, the [front] specification is crucial for

[14]The ranking of PARSE(lo) appears to be non-crucial.

the vowel to avoid violation of COLOR. In contrast, in (44), all of the candidates satisfy COLOR. The difference between (44) and (45) thus lies in the superfluousness of [front] in a round vowel. We have therefore accounted for the generalization in (6) in terms of the ranking in (46).[15]

(46) COLOR ≫ *SPREAD ≫ {ALIGN(F,L,Wd), ALIGN(F,R,Wd)} ≫ PARSE(fr)

This set of crucial rankings can be incorporated into the previously established rankings in the form of a Hasse diagram:

```
(47)  MID-COLOR  *MULT-HEIGHT  PARSE(ro)  PARSE(hi)
          └─────┬─────┘            └────┬────┘
            *INS(F)                  *RO,-HI
                │                       │
              COLOR                     │
                │                       │
            *SPREAD                     │
                ├───────────────────────┤
          ALIGN(F,L,Wd)         ALIGN(F,R,Wd)
                └───────────┬───────────┘
                        PARSE(fr)
```

A final question involves the "unregularized" forms of the loanwords in (5). The analysis thus far seems to suggest that no Turkish speaker, no matter how educated, could ever have these forms as the output of her/his phonology. In Kirchner (1993), however, it is proposed that exceptional forms can be handled within OT in terms of lexical ranking statements. In Turkish, the unregularized loans would have the exceptional ranking "PARSE(fr) ≫ {ALIGN(F,L), ALIGN(F,R)}" as part of their lexical entries. Regularization, then, involves the loss of such lexical ranking statements.

5. Root-Suffix Harmony

5.1. Attested harmonic and opaque suffixes. The root-suffix harmony/opacity facts largely follow from the foregoing assumptions. First, consider a suffix vowel which is specified [+high], and is unspecified for color features.[16] This vowel, like the epenthetic vowel within roots, is featurally identical to [ı]. Therefore, the analysis is identical to that of section 4.2.1: the COLOR constraint will force color features (if any) of the preceding stem vowel to spread onto the suffix vowel, notwithstanding *SPREAD. Such suffix vowel behavior is attested, e.g. the genitive singular suffix (−In) in (1). And since a high colorless suffix vowel necessarily triggers spreading of available color features from the stem, it follows that [ı] cannot occur as an opaque suffix vowel.

Next, consider a suffix vowel which is specified [−high,−low], and is unspecified for color features:

[15]Note that this analysis predicts that a front round vowel may occur in a disharmonic root just in case it is adjacent (syllable-wise) to a front unrounded vowel: since the COLOR constraint requires the presence of the [front] feature for unrounded vowels, it cannot be left unparsed, and therefore may also be prelinked to the rounded vowel. This is contrary to Clements and Sezer’s generalization; nevertheless, the prediction is correct, e.g. Süleyman (’masc. name’), küheylan (’wild horse’).

[16]By (14) (the non-cooccurrence of [+high] and [+low]), and the Vowel Height Requirement (13), this vowel must surface as [-low], regardless its underlying specification for [low], or lack thereof.

(48)

<table>
<tr><th>yüz−lE$_{-lo}$r</th><th>*RO,−HI</th><th>MID-COLOR</th><th>*INS(F)</th><th>COLOR</th><th>*SPREAD</th><th>PARSE(lo)</th><th></th></tr>
<tr><td>a. yIz lEr
/ \ / \
☞ ro fr −lo</td><td></td><td></td><td></td><td></td><td>*</td><td></td><td>(= [yüzler])</td></tr>
<tr><td>b. yIz lEr
/ \ \
ro fr +lo <−lo></td><td></td><td></td><td>+lo: *!</td><td></td><td></td><td>*</td><td>(= [yüzlar])</td></tr>
<tr><td>c. yIz lEr
/ \ \
ro fr −lo</td><td></td><td>*!</td><td></td><td>*</td><td></td><td></td><td>(= [yüzl∧r])</td></tr>
<tr><td>d. ro
/ \
yIz lEr
\ / \
fr −lo</td><td>*!</td><td></td><td></td><td></td><td>*</td><td></td><td>(= [yüzlör])</td></tr>
</table>

The MID-COLOR constraint forces the [front] specification of the preceding stem vowel to spread onto the suffix vowel, notwithstanding *SPREAD. However, since the vowel is [−high], *RO,−HI blocks spreading of [round] onto the suffix vowel (cf. candidate c). If the preceding stem vowel has no [front] specification to spread, the underlying [−low] specification is replaced by [+low] to avoid a MID-COLOR violation:

(49)

<table>
<tr><th>son−lE$_{-lo}$r</th><th>*RO,−HI</th><th>MID−COLOR</th><th>*INS(F)</th><th>COLOR</th><th>*SPREAD</th><th>PARSE(lo)</th><th></th></tr>
<tr><td>a. sEn lEr
| |
☞ ro +lo <−lo></td><td></td><td></td><td>+lo: *!</td><td></td><td></td><td>*</td><td>(= [sonlar])</td></tr>
<tr><td>b. sEn lEr
| |
ro −lo</td><td></td><td>*!</td><td></td><td>*</td><td></td><td></td><td>(= [sonl∧r])</td></tr>
<tr><td>c. sEn lEr
\ / \
ro −lo</td><td>*!</td><td></td><td></td><td></td><td>*</td><td></td><td>(= [sonlor])</td></tr>
</table>

Such suffix vowel behavior is attested, e.g. the nominative plural suffix (−lEr) in (1).

But what if a suffix vowel were underlyingly specified [+low]? Since the low vowel satisfies the COLOR constraint, COLOR does not force any stem features to spread -- indeed, COLOR prohibits association of color features to a [+low] vowel. Consequently, the suffix vowel is an opaque [a], as in suffixes such as −va:ri (7).

(50)

asķer–va:ri	COLOR	*SPREAD	ALIGN(F,R)	

☞ asķEr–vE:ri
  | |
  fr +lo
			*	(= [asķerva:ri])

asķEr–vE:ri
  | _/|
  fr +lo
	*!	*		(= [asķervæ:ri])

Similarly, if a suffix vowel is underlyingly specified [round], it will be opaque to spreading of <u>any</u> color feature from the stem:

(51)

ģeļ–Iyor	COLOR	*SPREAD	
ģEļ–IyEr | / | ☞ fr ro		*	(= [ģeļiyor])

ģEļ–IyEr
  \ |/|
  fr ro
		**!	(= [ģeļiyör])

ģEļ–IyEr | | fr ro	*!		(= [ģeļıyor])

Since the [o] of this suffix already has a color feature, COLOR does not require the spreading of other color features onto it; therefore *SPREAD governs. By the same analysis, a suffix vowel which is underlyingly specified [front] will be opaque to [round] harmony from the stem. Such opacity of suffix vowels is attested, e.g. the –<u>Iyor</u> and –<u>istan</u> suffixes (7). The failure of [round] to spread is dealt with in the following section.

In sum, depending on the features for which a given suffix vowel is prespecified, this analysis generates an attested type of harmonic or opaque suffix.

(52)

Specification	Harmonic or Opaque?	Analysis	Example
[+high, −low]	harmonic	Color specifications spread onto suffix to avoid COLOR violation, or by parasitic harmony.	−In (1)
[−high, −low]	harmonic	[front] spreads, [round] spreading blocked by *RO,−HI. If no stem color features are available for spreading, it becomes [+low].	−lEr (1)
[+low]	opaque	Since [+low] vowel satisfies COLOR, no need to spread color features.	−va:ri (7)
[round or] [front]	opaque	Since target vowel already has color feature (satisfying COLOR) no need to spread.	−Iyor (7) −istan (7)

Further note that this analysis captures the generalization that there are no suffix vowels which are opaque as to a particular feature but transparent as to other features (such a possibility seems to be predicted by standard autosegmental treatments of disharmonic suffixes, as discussed in Kiparsky 1990), without Kiparsky's stipulation of "harmonic spans."

5.2. Absence of marked vowels in opaque suffixes. We have already observed that this analysis rules out [ı] as an opaque suffix vowel. It remains to rule out opaque [ü,ö].

As a preliminary matter, note that the color feature specification of an opaque suffix never spreads onto the stem, even to avoid a COLOR violation, thus /čalıš-Iyor/ → čalıšıyor, not *čalušuyor ('he/she/it is working'). Indeed, the [round] feature of the opaque suffix vowel in this case does not even spread onto the preceding (colorless) suffix vowel: *čalıšuyor. This phenomenon appears to be related to the more general observation that vowel harmony systems are often "root-controlled" (see Clements 1977), or more precisely "stem-controlled," since an opaque suffix can spread its features onto a following suffix. I stipulate this generalization as the following constraint:

(53) STEM-CONTROL: Feature spreading is from stem to affix (modulo root-internal spreading).

This constraint is obviously inadequately formalized, as well as inelegant; it should be regarded merely as a promissory note, rather than a serious attempt at explanation of the phenomenon of stem control. In any case, the correct result is obtained by ranking STEM-CONTROL above COLOR:

(54)

čalIš–Iyor	STEM-CONTROL	COLOR	
☞ čalIš-IyEr │ ro		**	(= [čalıšıyor])
čalIš-IyEr \│ ro	*!	*	(= [čalıšuyor])
čalIš-IyEr \ │/ ro	**!		(= [čalušuyor])

Now, assume that there is an opaque suffix –ün. Due to the high ranking of STEM-CONTROL, neither the [front] nor the [round] specifications of the suffix vowel will be able to satisfy ALIGN(F,L) by spreading to the left edge of the word. At this point, the analysis is identical to that of front round vowels in disharmonic roots (see section 4.2.2). Since ALIGN(F,L) can be satisfied trivially with respect to [front] simply by failing to parse the [front] specification, the [front] specification will not surface.

(55)

[[V V] ün]	STEM-CONTROL	ALIGN(F,L)	PARSE(fr)
☞ [[V V] In] ≠ \ fr ro		ro: **	*
[[V V] In] / \ fr ro		ro: ** fr: **!	
ro /│ \ [[V V] In] \│ / fr	****!		

Since the [front] specification can never surface, the language learner has no reason to posit suffixes containing underlying front round vowels. Therefore the generalization in (8) is fully accounted for.

5.3. Opaque suffixes and stem features. Note, however, that the inability to spread [front] from a stem onto an opaque affix does not result in the non-parsing of [front], as it does within roots containing a front round vowel. That is, /gül̦–Iyor/ ('he is laughing') surfaces as gül̦üyor, not *gul̦-uyor. This fact can be accommodated by distinguishing between the morphological categories which are relevant to ALIGN(F), namely root and word. Now, assume the ranking:

(56) {ALIGN(F,R,Root), ALIGN(F,L,Word)} ≫ PARSE(fr) ≫ ALIGN(F,R,Word)

By the Pāṇinian Theorem, since ALIGN(F,L,Root) is not crucially ranked above the more general ALIGN(F,L,Word), it is inactive in Turkish. Since the root [gül] satisfies ALIGN(F,Root), the front feature will be parsed, notwithstanding the violation of ALIGN(F,R,Word):

(57)

gü̦l̦-Iyor	ALIGN(F,R,Rt)	ALIGN(F,L,Wd)	PARSE(fr)	ALIGN(F,R,Wd)	
☞ ro ro | \ | [[g̦Il̦]IyEr] | / fr		ro: **		ro: * fr: *	= [gü̦l̦üyor]
ro ro | \ | [[g̦Il̦]IyEr] ╪ fr		ro: **	*!	ro: *	= [guluyor]

6. Conclusion

By distinguishing the operation of feature spreading (the insertion of association lines) from the resulting configuration (a representation which satisfies ALIGN(F)), this analysis captures in a unified manner the two distinct effects of vowel harmony in Turkish: namely, spreading of [front] and [round] features onto affixes and epenthetic vowels, and absence of marked vowels within disharmonic roots and opaque affixes.

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