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**FEATURE DOMAINS AND COVERT HARMONY IN TURKISH:
THE EXCEPTIONAL TRANSPARENCY OF /A/**

A thesis submitted in partial satisfaction
of the requirements for the degree of

MASTER OF ARTS

in

LINGUISTICS

by

Jennifer Bellik

September 2015

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Abstract:

Feature domains and covert harmony in Turkish:

the exceptional transparency of /a/

Jennifer Bellik

Turkish vowel harmony is very systematic, but in a little-studied class of words, appears to break down. I propose that this apparent harmony failure is actually covert harmony, or exceptional transparency.

Background: The backness of vowels in Turkish suffixes is determined by the backness of the nearest vowel in the word they attach to (1).

(1)	<i>Nom.</i>	<i>Dative</i>		<i>Gloss</i>
a.	kadran	→ kadran-a,	*kadran-e	'clockface'
b.	beden	→ beden-e,	*beden-a	'body'

Harmony within roots is often violated, but harmony between suffixes and the nearest root vowel is extremely robust (2). Nonetheless, in certain roots, /a/ exceptionally behaves as transparent and suffixes must surface with front vowels (3).

(2)	<i>Singular</i>	<i>Plural</i>		<i>Gloss</i>
a.	kitap	→ kitap-lar,	*kitap-ler	'book'
b.	kahve	→ kahve-ler,	*kahve-lar	'coffee'
(3)				
a.	harf	→ harf-ler,	*harf-lar	'letters'
b.	dikkat	→ dikkat-ler,	*dikkat-lar	'attentions'

To account for this exceptional transparency, I extend Smolensky's (2006) headed feature domains theory, and propose that the input to phonology contains HEADLESS FEATURE DOMAINS.

Proposal: Existing theories of vowel harmony require a segmental harmony trigger. But *harf* contains no [-back] segment to head a front feature domain and select front suffixes, so *harf-ler* remains unexplainable. Extending Smolensky (2006), I propose that ALL FEATURES ARE FEATURE DOMAINS, which replace traditional segmental feature specifications.

In Turkish, backness domains normally coincide with roots. Alternating suffixes lack their own backness domains and merge into the stem's domain. Exceptional transparency is driven by faithfulness considerations: the root as a whole is a front domain, but it contains /a/ in an embedded back domain. Suffixes are incorporated into the outermost backness domain as usual, resulting in transparency.

$$(4) (\text{dik}(\text{ka})_{\text{BT}})_{\text{F}} + \text{IEr} \rightarrow (\text{dik}(\text{ka})_{\text{BTler}})_{\text{F}}$$

Since vowels must realize the backness of their containing domains, high- and mid- vowels cannot occur in conflicting embedded domains. However, as a low vowel, /a/ is more central than the other back vowels, and unlike the other Turkish back vowels, it lacks an exactly height-matched front counterpart phoneme. Perceptual reasons, then, lead the Turkish constraint-ranking to allow only /a/ as an exceptionally transparent vowel. The feature-as-domain analysis of vowel harmony models the selection of front suffixes by *harf* and *dikkat* without the need to posit phonetically unrealized front features on consonants, or any other additional apparatus.

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Finally, thanks be to God: “He giveth more grace when the burden grows greater.”

1 Introduction

The majority of Turkish roots contain either only front vowels or only back vowels, and most Turkish suffixes agree in backness with the root vowels. Turkish suffix harmony is illustrated in (1), where *kadran* (1)a contains back vowels and takes back suffixes, whereas *beden* (1)b contains front vowels and takes front suffixes.

(1) Normal suffix harmony

<i>Nom.</i>		<i>Dative</i>	<i>Gloss</i>
a. <i>kadran</i>	→	<i>kadran-a</i> , * <i>kadran-e</i>	'clockface'
b. <i>beden</i>	→	<i>beden-e</i> , * <i>beden-a</i>	'body'

Turkish thus exemplifies vowel harmony:

(2) “In vowel harmony, the vowels in a domain, such as the word, systematically agree, or ‘harmonize’, in some phonological property [backness, for Turkish]”
(Walker 2012)

This description of vowel harmony suggests the intuition that there is a single specification of that property which all the matching pieces share. That is, a word like *kadran-a* would be marked once as [+back], rather than each of its vowels having its own [+back] marker. Psycholinguistic and articulatory evidence supports the idea of word-level harmony specifications in languages that use harmony. For example, Turkish speakers use backness harmony to recognize word boundaries. But French speakers, whose language does not observe backness harmony, do not use it for word

segmentation (Kabak et al 2010). In addition to backness harmony, Turkish also has a rounding harmony process. All the high vowels in a word are required to agree in rounding, suggesting a single rounding specification for an entire word. Articulatory studies show that, unlike French speakers (no rounding harmony), Turkish speakers use a single rounding gesture when pronouncing a word containing multiple round vowels (Boyce 1990, Ni Chiosain and Padgett 2001). These articulatory realities mirror language-particular phonological facts. French does not exhibit harmony for rounding or backness, so French speakers do not conceive of backness or rounding as potentially word-level markers. Turkish does exhibit both types of harmony, and Turkish speakers seem to employ word-level representations of a word's backness and rounding. These facts give credence to the intuition that harmony involves domain-level representation of a feature.

A theory of vowel harmony can formalize this intuition in at least two ways: harmony as feature spreading, or harmony as feature domains. The feature-spreading approach is employed in autosegmentalism, as well as several prominent analyses situated in Optimality Theory (Prince and Smolensky 1993). In their well-known account of disharmony in Turkish, Clements and Sezer (1982) take the autosegmental approach and model backness harmony as the spreading of a single backness feature from one segment onto other segments in the word. Thus, in a Turkish word like *ip-ler-in* 'rope.pl.gen', there is one [-back] feature to which all three vowels are connected.

Autosegmental-style spreading analyses situated in Optimality Theory (Prince and Smolensky 1993) use the same representation, although the spreading of the feature from one vowel onto the others is driven by constraints such as ALIGN (Kirchner 1993, among others). Similarly, Kimper (2011) employs a positive constraint SPREAD to motivate harmony in the framework of Harmonic Serialism, again with the result that all the matching vowels in a word are associated with a single feature.

All feature-spreading analyses represent the shared feature in a way that directly reflects the number of segments that share it – i.e., using one association line for each harmonizing segment. Each line reflects either a step in the derivation for serial theories (e.g., Clements and Sezer 1982), or in parallel OT, a violation of the constraint penalizing spreading, such as IDENT. Thus, this representation focuses attention on the number of harmonizing segments.

Domain-based theories of vowel harmony, on the other hand, represent harmony in a way that draws attention to the number of *features* in the word, rather than the number of harmonizing *segments*. In these theories, Gen constructs feature domains which can incorporate multiple segments, even the whole word. A feature domain takes its value from the properties of a segment in it which is designated as its head, and all the segments in a domain are supposed to realize the domain's feature value. Thus, a perfectly harmonic word like Turkish *ip-ler-in* 'rope.pl.gen' contains just one backness domain, and this domain contains all the segments in the word, as

shown in (3). Underlining marks the head of the domain, and suffix vowels which always depend on a harmony trigger for their backness are represented with capital letters.

(3) /ip-lEr-In/ → (ip-ler-in)

The domain-based approach is used in Optimal Domains Theory (Cole and Kisseberth 1994), Span Theory (McCarthy 2004, O'Keefe to appear), and Smolensky's (2006) headed feature domains.

Both feature-spreading and domain-based theories share the insight that harmony involves a featural structure that transcends the single segment. However, these larger featural structures typically¹ remain dependent on an individual segment (the head of the domain or the anchor for the spreading feature). This segment-dependence predicts that the value of harmony will always be traceable to the value of a particular segment or segments within the domain of harmony.

This paper examines a class of Turkish words which violate this prediction. The words of interest require front suffixes, and yet they contain no segment that can be a plausible trigger for front harmony. Some examples appear below in (4).

(4) Turkish front harmony without a front trigger segment

<i>Nom.</i>		<i>Dative</i>		<i>Gloss</i>
a. dikkat	→	dikkat-e,	*dikkat-a	'attention'
b. harf	→	harf-e,	*harf-a	'letter'
c. rab	→	rabb-e,	*rabb-a	'God'

1 Autosegmental analyses in which the harmonic feature is underlyingly floating are an exception.

Unlike the rest of the Turkish harmony system, which has long been a favorite target for analysis due to its apparently clean behavior, the class of words exemplified in (4) have received little attention. Diverse theoretical mechanisms have been brought to bear on the regular part of the Turkish harmony system: “root markers” in early approaches (e.g. Lightner 1965); autosegmental spreading (Clements and Sezer 1982); the constraints ALIGN (Kirchner 1993), AGREE (Bakovic 2000), and Optimal featural domains (Cole & Kisseberth 1994) within Optimality Theory; rewards for feature spreading in Harmonic Serialism (Kimper 2011); and the Search and Copy algorithm (Nevins 2010). All of these theories deal with the regular pattern of Turkish vowel harmony. That is, they discuss the first row of the table in (5). This paper is concerned with the second row of the table: the group of roots mentioned above which are predicted to take back suffixes, but instead are required to take front suffixes.

(5)

	A. Harmonic root	B. Disharmonic root
1. Suffixes harmonizing	kabak-lar (... - ...) _B	dükkan-lar (...) _F (... - ...) _B
2. Suffixes failing to harmonize	kabahat-ler (...) _B -(...) _F	dikkat-ler (...) _F (...) _B -(...) _F

This phenomenon has received only one previous analysis (Clements and Sezer

1982), which treated it as consonant conditioned vowel harmony, attributing the frontness of these suffixes to a floating [-back] on the final consonant in the word.

Previously unnoticed is the fact that the vowel failing to trigger harmony is always /a/. There is no word like **hurf-ler* to correspond to *harf-ler*. The specialness of /a/ for this group of words is surprising given that /a/ is a normal participant in harmony for the vast majority of the Turkish lexicon. The normal behavior of /a/ is shown in (6) for contrast: /a/ requires back suffixes and does not normally allow front suffixes to follow it.

(6) Normal harmony with /a/

<i>Nom.</i>		<i>Dative</i>		<i>Gloss</i>
a. zarf	→	zarf-a	*zarf-e	'envelope'
b. kadran	→	kadran-a	*kadran-e	'clockface'
c. cihan	→	cihan-a	*cihan-e	'universe'
d. kitap	→	kitap-a	*kitap-e	'book'

That is, /a/ is not systematically transparent to harmony in Turkish; it only behaves as transparent in a small group of roots. I refer to this behavior as exceptional transparency.

The exceptions (4) are not distinguished from regularly harmonizing roots (6) by any systematic synchronic characteristics apart from their puzzling failure to trigger back harmony. Thus, an explanation based on co-phonologies is unavailable.

Existing theories of vowel harmony rely on the harmonizing feature originating from a segment, but there is no relevant segment-level difference between the exceptional words and the regularly harmonizing words. Moreover, while numerous theories of harmony address the phenomenon of systematic transparency (when a vowel is transparent throughout a language), to my knowledge no theory accommodates exceptional transparency, which is what we see with Turkish /a/. Consequently, current theories of vowel harmony cannot account for the divergent behavior of roots like *harf-ler* and *dikkat-ler* that require front suffixes after a back vowel. To successfully account for this pattern in Turkish, a theory of vowel harmony should allow for a non-segmental harmony trigger (e.g., a feature domain that is not segment-dependent but word-dependent), thus avoiding stipulative notation of associating a feature to a segment which does not phonetically realize that feature. The representation of harmony should also accommodate the possibility of lexically-conditioned transparency. Moreover, it should explain why /a/ is the only vowel that is eligible for transparency. In a satisfying analysis of the Turkish data, the apparent exceptions to harmony will be accounted for by the same mechanisms that cause regular harmony.

Theoretical desiderata: account for exceptional transparency...
without stipulative notation
explains why only /a/ can fail to trigger harmony (be transparent)
uses the same mechanisms to account for regular harmony

This paper proposes that such an analysis can be provided by FEATURE DOMAIN THEORY (FDT). FDT is a new theory of features which extends Smolensky's (2006) model of harmony as involving headed feature domains. FDT diverges from Smolensky (2006) by positing feature domains that are specified on the underlying forms, and which are independent of individual segments. This extension connects FDT to gesturally-grounded models of phonology like Articulatory Phonology (Browman and Goldstein 1993), and enables FDT to provide a unified account of harmonic, disharmonic, and exceptional roots in Turkish. The FDT analysis of Turkish also extends naturally to lexically-conditioned transparency in other languages, such as Hungarian.

The outline of the remainder of the paper is as follows: Section 2 provides the background of the regular pattern of Turkish backness harmony, then presents the problem and the previous autosegmental analysis. Feature Domain Theory is presented in §3. The relationship of /a/'s transparency to cross-linguistic patterns of transparency and existing theories of transparency are discussed in §4. Section 5 considers alternative explanations for /a/'s exceptional transparency, and draws connections between FDT and other theories of harmony. Finally, §6 concludes by discussing FDT's implications for harmony systems in general and languages that do not display harmony, as well as directions for future research.

2 Harmony and disharmony in Turkish

The first part of this section introduces the regular system of harmony in Turkish (§2.1). Section 2.2 presents data illustrating the apparent failure of harmony, and explains why a segment-driven account is unsatisfactory.

2.1 Regular backness harmony in Turkish

The Turkish vowel inventory consists of 8 vowels in a 2 by 2 by 2 vowel space. Each vowel is contrastive for backness, height, and rounding. This paper uses Turkish orthography² to more clearly represent the front-back phoneme pairings—all dotted symbols are [-back].

(7) Vowel inventory of Turkish

	[-back]		[+back]		Unspecified (archephonemes)
[+high]	i	ü	ı	u	I
[-high]	e	ö		o	E
[+low]			a		

I also adopt the Turkicist convention of using capital *I* and *E* to refer to vowels specified for height only, and underspecified for backness. That is, *I* picks out [+high] {i, ı, ü, u}, while *E* picks out [-high] {e, a, o, ö}.

All eight vowels participate in backness harmony³, alternating with the vowel

2 Turkish orthographic symbols mostly coincide with IPA symbols, but there are a few differences: ö = /ø/, ü = /y/, ı = /ɯ/, c = /dʒ/, ç = /tʃ/, ş = /ʃ/

3 High vowels additionally participate in rounding harmony, which this paper will not address.

that they match in for [high] and [round]. Suffixes harmonize in backness with the nearest root vowel.

(8) Normal backness harmony (plural suffix /lEr/ is realized as [ler] or [lar]):

a. Front root:

- | | | | | |
|------------|-------|---|------------|------------|
| i. gün | + lEr | → | gün-ler | 'days' |
| ii. gündüz | + lEr | → | gündüz-ler | 'daytimes' |

b. Back root:

- | | | | | |
|---------|-------|---|---------|----------|
| i. ay | + lEr | → | ay-lar | 'months' |
| ii. ayı | + lEr | → | ayı-lar | 'bears' |

c. Disharmonic root:

- | | | | | |
|-----------|-------|---|------------|-------------|
| i. ka:til | + lEr | → | ka:til-ler | 'murderers' |
| ii. kitap | + lEr | → | kitap-lar | 'books' |

According to Kabak and Weber (2013), 60-70% of Turkish roots are harmonic, containing either only front vowels as in (8)a, or only back vowels as in (8)b.

However, 30% of the Turkish lexicon is comprised of disharmonic roots borrowed from Arabic, Farsi, French, etc. As seen in (8)c, when suffixes follow a root that contains vowels that disagree in backness, they regularly harmonize with the nearest vowel in the root. This is further exemplified in (9), where the dative suffix, which is a [-high] vowel, is realized as [e] when the nearest vowel in the root is a front vowel, as in (9)a-c, but as [a] when the nearest root vowel is a back vowel, as in (9)d-h.

(9) Regular disharmonic roots

a.	<i>Nom</i>	<i>Dat</i>	<i>Gloss</i>
b.	salep	saleb-e	a drink
c.	rahip	rahib-e	'priest'
d.	ansiklopedi	ansiklopedi-y-e	'encyclopedia'

e.	fiyonk	fiyong-a	'bowtie'
f.	düşman	düşman-a	'enemy'
g.	cesur	cesur-a	'brave'
h.	gergedan	gergedan-a	'rhinoceros'

A similar pattern occurs with the few invariant suffixes in Turkish, such as /gen/ '-sided shape' and /stan/ '-nation'. These invariant suffix vowels trigger harmony in any suffixes that follow them, as illustrated in (10).

(10) altı-gen-ler-in-den 'from your hexagons'
 six-sided.PL.GEN.ABL

The result is that alternating suffixes very consistently agree in backness with the nearest invariant vowel.

Opinions vary as to whether harmony is active within Turkish roots (Kabak 2011). In their much-cited 1982 paper, Clements and Sezer claim that harmony in Turkish is not synchronically active in roots. However, the effects of harmony can be seen root-internally when vowel epenthesis occurs, because the epenthetic vowel matches the nearest root vowel in backness and rounding. Vowel epenthesis occurs to repair illegal complex codas (or complex onsets, which only come from loanwords). Turkish permits complex codas that adhere to sonority sequencing, but disallows most others. These illegal consonant clusters occur when a consonant-initial suffix is added to a consonant-final root as in (11), or when a root underlyingly ends with an illegal coda cluster as in (12). In both cases, the cluster is repaired through epenthesis

of a high vowel, which takes both its backness and rounding from the preceding root vowel.

(11) Vowel harmony in epenthesis with 1st sg possessive suffix /m/ (Hankamer 2010):

<i>V-final stem:</i>			
a. /baba + m/	→	baba-m	'my father'
b. /çene + m/	→	çene-m	'my chin'
<i>C-final stem:</i>			
c. /at + m/	→	at-ı-m	'my horse'
d. /karpuz + m/	→	karpuz-u-m	'my watermelon'
e. /kemig+m/	→	kemiğ-i-m	'my bone'
f. /göl+m/	→	göl-ü-m	'my lake'

In addition to consonant clusters arising through affixation, over 200 roots in Turkish that underlyingly end in consonant clusters which do not form acceptable complex codas (Clements & Sezer 1982). In the nominative or when a consonant-initial suffix is present, these complex codas are repaired through vowel epenthesis. The consonant cluster surfaces contiguously with a vowel-initial suffix, such as in the dative.

(12) Harmonic epenthesis in the nominative for roots ending in illegal consonant clusters

<i>Root</i>	<i>Nom</i>	<i>Dat.: +/E/</i>	<i>Gloss</i>
a. /cebr/	cebir	cebre	'algebra'
b. /sabr/	sabır	sabra	'patience'
c. /uğr/	uğır	uğra	'luck'
d. /ömr/	ömür	ömre	'life'

Again, the epenthetic high vowel harmonizes with the root vowel in backness and roundness.

Besides the harmony exhibited by the epenthetic vowel, a further reason to believe that harmony is synchronically active within Turkish roots comes from statistical generalizations about the lexicon. Kabak and Weber (2013) concluded from a corpus study that harmony remains active in roots, contra Clements and Sezer (1982). Additionally, preliminary results from a pilot study by Harrison and Kaun (2001) suggest that Turkish speakers do think of all the vowels in a harmonic word as having one backness specification; changing the backness of the first vowel in a harmonic word prompted Harrison and Kaun's subjects to reharmonize the remaining vowels in the word to match the initial, changed vowel. Reharmonization did not occur with disharmonic roots. In sum, there is evidence from vowel epenthesis, the composition of the lexicon, and psycholinguistic experiments that harmony is synchronically active in Turkish roots. This paper takes the position that harmony is active within roots as well as overtly alternating suffixes.

Having established the regular pattern of harmony in Turkish, we now turn to consider the exceptions.

2.2 The apparent failure of harmony

A sample of roots that fail to trigger harmony in their suffixes is given below, reproduced from (4). In roots like those in (13), the final root vowel is the back vowel

/a/, which regularly triggers back suffixes. So the expected form of the dative suffix is its back allomorph /a/. However, the suffix surfaces instead in its front allomorph /e/; the back version of the suffix is completely ungrammatical to use with these words. This goes for all alternating suffixes, but for purposes of this paper, I will focus on the dative suffix, which does not participate in rounding harmony and so displays the backness alternation more clearly, since it only has two allomorphs, rather than four.

(13) Roots that fail to trigger harmony

<i>Nom.</i>		<i>Dative</i>		<i>Gloss</i>
a. dikkat	→	dikkat-e,	*dikkat-a	'attention'
b. kabir	→	kabr-e,	*kabr-a	'tomb'
c. harf	→	harf-e,	*harf-a	'letter'
d. rab	→	rabb-e,	*rabb-a	'God'

The existence of apparently back roots that require front suffixes is noted in Lewis (1967) and Underhill (1976) as an exception to vowel harmony. Both Lewis and Underhill note that all such words are borrowings from Arabic, and ascribe the requirement for front suffixes to the properties of the Arabic consonants involved. Lewis (1967) implies that these words are exceptional because they are unassimilated—to use modern terms, he proposes a co-phonologies analysis. As we will see, however, this analysis is untenable (§5.3).

To my knowledge, the only existing formal analysis of exceptional disharmonic roots is due to Clements and Sezer (1982; henceforth C&S). Like Underhill and Lewis, C&S ascribe the frontness of suffixes on words like *harf* to their

final consonants being [-back]. C&S present an autosegmental account of diverse disharmonic phenomena in Turkish. They model harmony as the spreading of [+/- back] features from underlyingly specified (“opaque”) segments to underlyingly unspecified segments, according to an association convention (left-to-right, one to one, ...). They directly extend this representation to consonants and exploit this mechanism to account for the exceptionally disharmonic suffixes.

It is not immediately obvious what might justify the ascription of inaudible backness features to consonants, since most consonants in Turkish appear transparent to harmony. They are affected by coarticulation effects (Ni Chiosain & Padgett 2001), but do not display regular alternations between front and back variants. However, the consonants /l k g/ do occur in both front and back realizations. These variants are normally allophonic and predictable from position within the syllable and from the surrounding vocalic context. But the difference between front and back /l k g/ can occasionally be contrastive, as in the minimal pairs below.

(14) Contrastive backness for /k, g, l/ (C&S)

a.	bol	'abundant'	vs.	bol ^ɨ	'cocktail, drink'
b.	kalp	'counterfeit'	vs.	kal ^ɨ p	'heart'
c.	kar	'snow'	vs.	k ^ɨ ar	'profit'
d.	gaz	'gas'	vs.	g ^ɨ avur	'infidel'

Therefore, Clements and Sezer represent unpredictable occurrences of /k g l/ as opaque segments that have [+/- back] attached to them underlyingly, just like vowels. This predicts that word-final /l k g/ should trigger harmony. Thus, if a word ends in

the sequence V[+back]C[-back], the final [-back] consonant is the nearest backness trigger, and spreads its [-back] to suffixes. So suffixes harmonize with the front-valued consonant, and never see the opposite backness value that occurs on the final vowel. Nevins (2010) adopts this approach directly from Clements & Sezer (1982).

Upon first glancing at the data, the consonant-driven harmony approach seems plausible. For example, word-final palatal /i/ reliably triggers front harmony (C&S 1982; Kabak 2011). In the words in (15), the nearest root vowel is a back vowel. But suffixes take on their front allomorphs, harmonizing with the closest back-specified segment in the word, which in these cases happens to be the approximant /i/ rather than a vowel. The fact that suffixes can harmonize with /i/ as well as with vowels supports the idea put forth by Nevins (2010) that any segment contrastive for backness should participate in backness harmony.

(15) /i/ triggers front harmony

<i>nominative</i>	<i>dative</i>	<i>gloss</i>
a. gol ⁱ f	gol ⁱ f-e	'golf'
b. kal ⁱ p	kal ⁱ b-e	'heart'
c. mareşal ⁱ	mareşal ⁱ -e	'marshal'
d. sual ⁱ	sual ⁱ -e	'question'
e. usul ⁱ	usul ⁱ -e	'system'
f. petrol ⁱ	petrol ⁱ -e	'petrol'

Search results in the Turkish Electronic Living Lexicon (TELL), an online corpus of about 30,000 words, also confirm that it is rare for palatal /i/ to be followed by a back vowel, even if it is preceded by a back vowel (only 5 results, all uncommon words).

That is, /l/ reliably acts like a vowel (“opaque”).

Are other consonants reliably opaque? C&S extend their analysis of /l/ to many other consonants which do not exhibit any audible backness contrast. Their account becomes increasingly less convincing when these other consonants are considered. No evidence for /g/ triggering vowel harmony is available, due to its restricted distribution. Due to final-devoicing, /g/ never appears word-finally. Moreover, /g/ never appears intervocalically, because it reduces to a “soft g”, usually realized as a lengthening of the preceding vowel.

Let us turn, then, to /k/. For Clements and Sezer, the final /k/ in (16) has an underlying [-back] that explains the frontness of the suffixes selected. Unlike the frontness of the /l/ in (15), this feature is inaudible when no suffix is present. C&S account for this deceptively with a rule that diassociates [back] from obstruents syllable-finally, resulting in [-back] being left afloat and unpronounced if no suffix is added. This rule has some perceptual basis in that palatalization of an obstruent may be hard to perceive when no vowel follows.

(16) front suffixes after back vowel + /k/ (C&S)

<i>Nom.</i>	<i>Acc.</i>
a. infilʲak	infilʲakʲ-i (C&S) ~ infilʲakɪ (TELL)
b. helʲak	helʲakʲ-i
c. emlʲak	emlʲakʲ-i
d. istimlʲak	istimlʲakʲ-i

In the examples in (16), the palatalization of /k/ only appears with the front suffixes.

Does the frontness of the suffix comes from the /k/, or might the frontness of the /k/ be due to the frontness of the suffix? A clue comes from the TELL results in (17). Unlike C&S, TELL transcribes the words shown in (16) with a velar /k/ in *both* the nominative *and* in the accusative, when palatal assimilation has a chance to occur. Despite the consistent backness of the consonant, the suffixes are still disharmonically [-back].

(17) front suffixes after back vowel + /k/ (TELL)

	Nom.	Acc.
a.	helʲak	helʲak-i
b.	emlʲak	emlʲak-i
c.	istimlʲak	istimlʲak-i

For at least some speakers, then, the /k/ at the end of these exceptional roots remains [+back] in an environment where it might be expected to take on the value [-back] through coarticulation or assimilation. This is clear evidence that these /k/s are not inherently [-back], and consequently that the suffixes cannot depend on the consonant for their frontness.

Indeed, the evidence that /k/ can be opaque is limited. Kabak (2011) reports that /kʲ/ does not trigger harmony regularly; /lʲ/ is the only consonant that regularly does so in Turkish. So according to Kabak (2011), palatal k is not opaque. This claim is supported by the distribution of palatal /kʲ/ in TELL, compared to the distribution of palatal /lʲ/, shown in (18). While it is true that stem-final /kʲ/ is practically never followed by back suffixes (only two results (18)d.ii, which suggests a strong pressure

for a stem-final /k^j/ to spread its [-back] feature), palatal /k^j/ almost⁴ never appears word-finally, making it dubious to propose that stem-final /k^j/ exists underlyingly at all. Moreover, /k^j/ very rarely appears between back vowels even word-internally (18)c.ii, in contrast to /l^j/ which is relatively common between back vowels word-medially (18)a.ii. In short, TELL suggests a fundamental difference in the harmonic behavior of /k~k^j/ compared to /l~l^j/.

(18) Transparent disharmonic consonants in TELL (= represents a morpheme boundary)

- a. Transparent word-medial /l/
 - i. l=E: 503
 - ii. A l^j A: 60
- b. Transparent word-final /l/
 - i. l=E: 315
 - ii. l^j=A: 5
- c. Transparent word-medial /k/
 - i. E k E: 190
 - ii. A k^j A: 4
- d. Transparent word-final /k/
 - i. k=E: 122
 - ii. k^j=A: 2⁵

In addition, these results make clear that disharmonic consonants cannot routinely be represented as opaque, because they often behave transparently, even at the ends of words. This is particularly true of the back variants—an asymmetry that suggests the front variants are more marked.

4 3 TELL results ending in palatal k, of which only 1 takes front suffixes

5 0 for this search but that's because l doesn't show up under A for some reason!

To complete our inventory of roots that take disharmonic suffixes, we now turn to words ending in consonants that are never contrastive for backness. Exceptional front suffixes can also occur following roots that end in /t/, as in (19). Clements and Sezer analyze this /t/ as having a floating [-back], but this feature, again, is not phonetically realized. Also, /t/ is not a backness sensitive consonant in Turkish; it is never audibly contrastive for backness.

(19) front suffixes after /t/

a. dikkat	dikkat-i	'attention'
b. menfaat	menfaat-i	'interest'
c. beraat	beraat-i	'acquittal'
d. l̥iya:kat	l̥iya:kat-i	'merit'
e. saat	saati	'hour'
f. l̥ugat	l̥ugati ~ l̥ugatu	'dictionary'

In principle, the list of consonants that could have a floating [-back] feature attached to them in the C&S analysis is an open set. Indeed, C&S need to posit that an absolute grab-bag of Turkish consonants can have a floating [-back] associated to them. In addition to the floating feature already posited on /k/ (16) and /t/ (19), the consonant driven analysis also requires a floating [-back] to be possible on /r/ (20), /d/ (22), and /b, v, c, h/ (22).

(20) front suffixes after /r/

a. harf	harfi	'letter'
b. harp	harbi	'war'
c. garp	garbi	'west (archaic?)'

The non-occurrence of front suffixes after words that end in a simple coda /r/, rather

than a complex coda /rC/, casts doubt on the claim that the /r/ in the words in (20) is the unifying factor responsible for the front suffixes. If /r/ can have a floating [-back], then why is there no word like *har ~ har-i?

The consonant-driven analysis also requires the possibility of a floating [-back] on /d, b/:

(21) front suffix after /d, b/

a. vaat	vaadi	'promise'
b. rab	rabbi	'God'

At this point, a [-back] has been applied to /b, t, d, k, r, l/: not a natural class. It gets worse, however, because of the data about to be presented in (22). About a dozen Turkish roots end in an underlying consonant cluster that surfaces with a disharmonic epenthetic vowel. Shown in (22), these roots have /i/ as the epenthetic vowel even though the root vowel is /a/. C&S explain the unexpected epenthesis of a front vowel as the result of a floating front feature on the root medial consonant. Thus, they additionally require [-back] versions of: /c, h, v/.

(22) Roots exhibiting disharmonic epenthesis

<i>Root</i>	<i>Nom.</i>	<i>Ablative</i>	<i>Dative</i>	<i>1.sg.poss</i>	<i>Gloss</i>
a. /kabr/	kabir	kabir-den	kabr-e	kabr-i-m	'tomb'
b. /hacm/	hacim	hacim-den	hacm-e	hacm-i-m	'volume'
c. /rahm/	rahim	rahim-den	rahm-e	rahm-i-m	'womb'
d. /bahs/	bahis	bahis-ten	bahs-e	bahs-i-m	'bet'
e. /kavm/	kavim	kavim-den	kavm-e	kavm-i-m	'tribe'

A wide variety of consonants may flank the disharmonic epenthetic vowel, and they do not definitively predict its frontness, since in other cases a harmonic back vowel can be epenthesized in an identical or similar environment, as shown in (23).

(23) Disharmonic vs harmonic epenthesis in similar environments

	<i>Environment</i>	<i>Disharmonic</i>		<i>Harmonic</i>	
a.	b _ r:	/kabr/	kabir, kabr-e	/sabr/	sabır, sabr-a
b.	_ m:	/hacm/	hacim, hacm-e	/hasm/	hasım, hasm-a
c.	h _ s:	/bahs/	bahis, bahs-e	/şahs/	şahıs, şahs-a

Thus, the roots that take a disharmonic epenthetic vowel challenge any attempt to predict disharmonic behavior based on the consonants involved.

Taking stock, we have seen that disharmonically front suffixes can occur following a wide variety of consonants, but only after one vowel: /a/. The previous autosegmental analysis proposed by C&S does not account for the predominance of /a/, and additionally implies that any consonant in Turkish can occur in three varieties: [-back], [+back], or unspecified. For consonants other than /l k g/, these three variants *always* sound exactly the same. And for all consonants but /l/, all three varieties sound exactly the same *at the end of a word*, which is precisely the environment where C&S crucially need the variety to make a difference. In short, the existing consonant-based analysis of these exceptions lacks phonetic grounding.

(24)

Desirable qualities in an analysis of harmony failure:	C-driven account
no stipulative notation	✗
explains why only /a/ can fail to trigger harmony	✗
uses the same mechanisms to account for regular harmony	✓

This shortcoming is not specific to an autosegmental approach. As discussed in the introduction, current theories of vowel harmony always require a segment as a harmony trigger. But the exceptional cases discussed here lack an audibly front segment to trigger the required front harmony on suffixes. In some cases, a front segment appears earlier in the word, but the most local trigger is back (*dikkat*); in other cases, there is no front segment in the word at all (*harf*). Consequently, any account that tries to pin the frontness of the suffixes to a particular segment in the word will lack phonetic grounding. To avoid this pitfall, a segment-independent model of harmony is necessary. In the next section, I present Feature Domain Theory as such a model.

3 Proposal: Feature Domain Theory

Nothing in the surface phonology uniquely picks out the words that are exceptions to harmony in Turkish. Instead, a theory that accounts for the exceptional behavior of these roots must make reference to their underlying representations. However, these posited underlying representations should not make claims about segmental feature make-up that are not reflected in surface phonology.

An account of these exceptions to vowel harmony should capture the intuition that something about these particular *words* requires them to take front suffixes – not a characteristic of any of their segments in isolation. This intuition accords with the observation that harmony is a characteristic of the word: the requirement of harmony is that all the vowels in a *word* should agree in backness. As discussed in the introduction, evidence from psycholinguistic (Harrison and Kaun 2001; Kabak et al 2010) and articulatory (Boyce 1990) studies converges with the evidence of epenthesis and the distribution of vowels in the Turkish lexicon (Kabak and Weber 2013): harmony in Turkish acts as a word-level phenomenon. The theoretical representation of harmony should capture these facts.

An early theory of vowel harmony that represented harmony as a stem-level feature specification was the root-marker theory of Lightner (1965), which translated the segment-independent “prosodies” of Firthian Prosodic Analysis (cf Ogden and Local 1994) into the generative framework. In the “root-marker” representation, stems in vowel harmonic languages were directly marked with an arbitrary value for

the harmonizing feature. This representation, however, left the root-marker theory unable to account for suffixal harmony triggered by disharmonic roots, which were marked as disharmonic and therefore predicted not to participate in harmony at all (Kabak 2011). The failure of root-marker theories shows that a successful theory of vowel harmony must also capture the fact that the requirement for harmony within a word is violable.

This violability is naturally formulated in a framework like Optimality Theory (henceforth OT; Prince and Smolensky 1993) which makes use of violable constraints. Several OT theories analyze harmony using a featural structure that spans a word: Smolensky's (1993, 2006) domain-based representation of harmony; Span Theory (McCarthy 2004) as adapted by O'Keefe (2007); and Optimal Domains Theory (henceforth ODT; Cole & Kisseberth 1994). All three theories make use of featural domains to represent harmony, an approach which I adopt. To give an idea of the theoretical landscape, this section briefly discusses these previous domain-based models, focusing first on ODT.

Like Span Theory and Smolensky's embedded domains theory, ODT works within OT. ODT differs from autosegmental representations of vowel harmony in that inputs are fully specified⁶ and there is no multiple association between segments⁷ (“anchors”) and features. In addition to creating prosodic structure such as syllables

6 Except when the vowels in question never stand alone without a harmony trigger: “Underspecification is allowed only when the surface specification is always determined by an external source, such as the case of suffix vowels in Turkish” (Cole and Kisseberth 1994).

7 Anchors may also be moras or morphemes to allow for “linked” features and “floating” features (*ibid*).

and feet, **Gen** creates harmonic structures (my term): F-domains. Each of these F-domains must be “sponsored” by an anchor that underlyingly bears feature F.⁸ Instead of the features themselves spreading from anchor to anchor, the F-domains themselves spread, motivated by violable constraints (WIDE SCOPE ALIGNMENT constraints) that require an F-domain and morphological domain to be aligned. Harmony within an F-domain is enforced by the constraint EXPRESSION, which requires every anchor in an F-domain to be affiliated with F. Transparency results from a violation of EXPRESSION.

Similarly, Smolensky (1993, 2006) represents harmony using headed featural domains. As with ODT, the basic idea is that featural domains are constructed by Gen, producing representations like those in (25). A feature domain's value (e.g., [+back] or [-back]) is determined by its head, a segment in it (underlined in (25)). Segments in a domain are required to realize that domain's feature value. Rather than ALIGN being the main motivation for harmony, in Smolensky (2006) harmony is largely driven by the markedness constraint *HEAD, the domain-based equivalent to an OCP constraint in Autosegmental Phonology (Smolensky 2006). Since each domain must have a head, every domain incurs a *HEAD violation, and the number of domains per word is therefore minimized in the optimal candidate.

8 ODT uses privative features.

(25) Turkish harmony with headed feature domains

- a. *harmonic root: violates *Head minimally*
ay₁ +lEr → (a_yı-lar)
- b. *disharmonic root: violates *Head multiple times*
kitap+lEr → (ki)(ta_plar)
- c. *embedded domain: violates *Embed*
dik_kat +lEr → (di_kka_a)t-ler)

For Smolensky (2006), transparency results when segments occur in embedded feature domains, as in (25)c. A segment in an embedded domain realizes the feature value of the innermost domain. Embedding is driven by markedness considerations, since embedding violates *EMBED but can enable a larger domain to satisfy ALIGN without any segments in it violating featural cooccurrence constraints. Under the constraint system of Smolensky (2006), the structure in (25)c would be predicted if the ranking in (26) obtained—that is, if /a/ was systematically transparent because it had no front counterpart in the language.

(26) ALIGN[+BACK], *[-BACK, -HIGH, -ROUND] >> *EMBED

The structure in (25)c for *dikkat* correctly predicts that this word will select front suffixes. The problem is, the constraint ranking in (26) which is needed to obtain the transparent structure cannot be correct for Turkish. This constraint ranking predicts that /a/ will always be transparent and will not have a front counterpart, but in fact /a/ is normally opaque like all Turkish vowels, and alternates systematically with /e/ in suffixes. The problem can be seen clearly by comparing the behavior of *kitap* and *dikkat*. Both contain a front vowel /i/ followed by a back vowel /a/. The back vowel is closest to any suffixes, so both are expected to take back suffixes under

regular harmony. The constraint ranking that will motivate the selection of the correct structure (ki)(t_aplar) will also motivate the selection of incorrect (d_ik)(k_atlar).

Conversely, the constraint ranking that would select the correct (d_ikk(a)t-ler) would favor the incorrect (ki)(t_ap)ler).

The divergent behavior of *dikkat* (requires front suffixes) and *kitap* (requires back suffixes) indicates the need for either a different input structure or a different constraint ranking for these two types of words. A different constraint ranking is only available if *kitap* and *dikkat* belong to different co-phonologies, but this proposal seems suspect for reasons discussed in §5.3--they are both loans from Arabic, there are no differences in stress assignment or clear segmental cues, etc.

In short, ODT, Span Theory, and headed feature domains are all unable to account for exceptional transparency, because they all treat feature domains as prosodic structures, akin to syllables or feet. F-domains are not present in the input, but are constructed by Gen. They are dependent on the segments for their feature values. Consequently, existing domain-based theories cannot explain a word like *harf-ler*, in which the suffix must be incorporated into a [-back] domain, but the root contains no front-valued segment to host this [-back] F-domain. For these domain-based theories, like other theories of transparency (e.g., Kiparsky and Pajusalu 2003, contrastiveness in Nevins 2010), embedding/transparency is always driven by markedness considerations, i.e. feature co-occurrence constraints that correspond to inventory gaps. But to get transparency in *dikkat-ler* (but not in *kitap-lar*),

transparency must be able to result from faithfulness considerations. Moreover, to get front suffixes in *harf-ler*, it must be possible to have an unheaded feature domain.

Therefore, in the spirit of segmentally-independent theories of vowel harmony (Firthian Prosodic Analysis, Ogden and Local 1994; root-markers, Lightner 1965), I extend Smolensky's theory to use HEADLESS FEATURE DOMAINS. Like Firthian prosodies and root markers, these domains are independent of segments and present in the *input* to phonology. This provides the link to morphology that enables the representation of lexicalized exceptions to the usual pattern of vowel harmony. Encoding feature domains in the input to phonology will enable faithfulness to drive transparency in *harf-ler* and *dikkat-ler*. Unheaded feature domains will be subject to the usual faithfulness and markedness constraints of OT, and in fact will replace the segmental feature specifications that are traditional in generative phonology in order to avoid having two independent feature systems (discussed further on the next page).

I term this approach FEATURE DOMAIN THEORY (FDT)⁹. Its key claims are as follows in (27)-(28):

(27) Feature Domain Theory

For a feature F,

- a. every value of F is represented in phonology as an F-domain, in both the input and the output.
- b. F-harmony is the requirement that F-domains coincide with prosodic

⁹ Many, many thanks to Junko Ito for suggesting this name.

categories larger than the syllable—typically the word. This requirement is enforced by Alignment constraints which are high-ranking but not necessarily undominated.

c. F-domains are interpreted according to the algorithm in (28).

(28) Algorithm for interpreting F-domains:

a. *Informally:*

Segments inherit the F-value of the F-domain that contains them. When one domain is embedded in another, the deepest F-domain's F-value wins.

b. *Formally:*

- i. Set Φ = the leftmost unprocessed F-domain that is not contained by any other F-domain. Set α = Φ 's value for F.
- ii. Add α to the featural specification of every segment s that is contained in Φ . If the segment already has an F-value in its featural specification, overwrite it with α .
- iii. Mark the domain Φ as processed (leaving all the segments and domains in it intact).
- iv. Return to (i).
- v. If Φ is null, terminate.

(29) Well-formedness conditions on F-domains (constraints on Gen)

a. An F-domain must dominate at least one segment. No empty domains.

- b. If two F-domains D and D' share some segments, then either D must be embedded in D' or D' must be embedded in D. That is, no overlapping but not embedded domains.

The heart of Feature Domain Theory is the idea that every feature is a featural domain. In a language like Turkish or Finnish that has vowel harmony, some featural domains span entire (harmonic) words; in a language like English or French with no harmonic processes, featural domains coincide with segments. When a featural domain spans multiple segments, an individual segment, if examined in isolation, might appear to be underspecified. However, taken in the context of the morpheme in which it occurs, the segment is specified for that feature, through the featural domain that dominates it. In this sense, FDT, like ODT, uses underspecification only for segments that always take their featural specifications from an external harmony trigger—that is, for alternating suffix vowels in Turkish. At the same time, FDT shares the insight of spreading-based theories of harmony (e.g., autosegmental phonology as embodied in Clements and Sezer 1982) that harmonizing segments share a single feature specification between them, rather than each having its own potentially independent feature specification.

Let me emphasize here that FDT's feature domains are independent of individual segments. That is, FDT introduces a feature-system that is independent of traditional segmental feature specifications. Consequently, maintaining traditional

features on segments while also using FDT's proposed headless featural domains would mean having two independent feature systems—which seems undesirable!

The solution to this problem is that in FDT, membership in a F-domain replaces segmental featural specification in a traditional theory of features. Thus, in a language without harmony, every feature is still a feature domain, but it happens to be a domain that coincides with a segment. So in a language like English, FDT's feature representation is largely isomorphic to traditional featural specifications. Meanwhile, in a language exhibiting harmony along some feature, the domains for that feature will regularly span entire words.

For Turkish, the relevant F-domains are backness domains. FDT says that in Turkish, backness is specified on featural domains that preferentially coincide with words. Every morpheme that does not exhibit backness alternations contains at least one backness domain in the input to phonology. These domains are faithfully preserved in phonology's output. Harmonizing suffixes¹⁰, however, lack underlying backness domains, and must merge into the nearest backness domain of the word to which they attach. This is depicted in (30)-(31).

In a harmonic root, such as *ayl* 'bear' in (30)a, there is only one underlying backness domain. This domain is perfectly aligned with the morpheme. When a suffix like the plural marker *-ler* is added, phonology (the first arrow) incorporates it into the existing backness domain. Phonetics (the second arrow) then interprets the

10 Although invariant suffixes like /gen/, /istan/, /Ebil/, etc. do have underlying backness domains.

backness domain and produces *ayılar* 'bears' with all back vowels.

(30) Harmonic roots: FD perfectly aligned with root

- a. (EyI)_B + lEr → (EyI-lEr)_B → (ayı-lar)_B 'bears'
 b. (gUndUz)_F + lEr → (gUndUz-lEr)_F → (gündüz-ler)_F 'daytimes'

In a disharmonic root like *kitap* (31)a, the same process applies. In the input to phonology, there are already two contrasting backness domains existing side by side. Again, the suffix *-lEr* lacks its own backness domain. Phonology (first arrow) expands the nearest domain, which is [+back], to encompass the suffix. The phonetics (second arrow) applies [-back] to the segments in the first domain, and applies [+back] to all the segments in the second domain, producing *kitaplar* with a sequence of front segments followed by a sequence of back segments.

(31) Regular disharmonic roots: multiple FDs side by side

- a. (kI)_F(tEp)_B + lEr → (kI)_F(tEplEr)_B → (ki)_F(tap-lar)_B 'books'
 b. (sE)_B(lEp)_F + lEr → (sE)_B(lEp-lEr)_F → (sa)_B(lep-ler)_F 'drinks'

When a suffix apparently fails to harmonize, as in *harf-ler*, the disharmony between root and suffix vowels results from the nesting of conflicting featural domains. This is depicted in (32): the root as a whole is a [-back] domain, but the final vowel is contained within a [+back] domain. As usual, the phonology

incorporates the underspecified suffix into the nearest featural domain, which in (32) is the [-back] domain that contains the whole morpheme. Consequently, the phonetics applies [-back] to the segments in the suffix. The twist is that the inner [+back] featural domain is interpreted after the outer [-back] domain, and so the final root vowel receives the value [+back]. This is discussed further below.

(32) Embedded featural domains produce disharmonic suffixes

- a. $(dIk(kE)_Bt)_F + lEr \rightarrow (dIk(kE)_Bt-lEr)_F \rightarrow (dik(ka)_Bt-ler)_F$ 'attentions'
- b. $(h(E)_Brf)_F + lEr \rightarrow (h(E)_Brf-ler)_F \rightarrow (h(a)_Brf-ler)_F$ 'letters'

To summarize: Backness is specified on backness domains. In a language which does not exhibit any backness harmony, backness domains are segments. But in a language like Turkish that has backness harmony, backness domains are larger than the segment, and preferentially span entire morphemes. featural domains are present both in the input to the phonology and in the output to the phonology. The phonetics interprets featural domains to provide backness specifications on the individual segments.

The above introduction to FDT referred to the operations of phonology without spelling out what mechanisms exactly were at play. I will now explore the constraint definitions and rankings necessary to model Turkish backness harmony.

3.1 The regular pattern of Turkish backness harmony in FDT

Harmony results from the anti-structure constraint *FEATURE DOMAIN – FDT's equivalent of Smolensky's (2006) *HEAD.

- (33) *F-DOMAIN(back)¹¹ = *FD: Assign a violation for every backness domain within a word. *Penalizes disharmony. Schematically: *(...)*

*FD results in the expansion of an underlying feature domain to include an underlyingly unspecified suffix, like *-lEr* in *ayı-lar*.

Segments present in a featural domain in the input are never removed from it in the output, motivating the constraint *CONTRACT (34), which is undominated in Turkish¹². The counterpart to *CONTRACT, *EXPAND (35), is routinely violated by the incorporation of underlyingly unspecified suffixes into pre-existing featural domains. Thus *EXPAND must be ranked low.

- (34) *CONTRACT: Don't remove segments from a featural domain. For featural domains D in the input and D' in the output, where D' stands in a correspondence relation to D, assign a violation if there is a segment in D that lacks a correspondent in D'.

- (35) *EXPAND: Don't expand a featural domain. For featural domains D in the

11 Note that all constraints in this handout that refer to F-domains (FD), target a particular F(eature) – backness, in this paper. For readability, this indexation to backness is usually left implicit. Thanks to Armin Mester for pointing this out.

12 In a language that does not exhibit vowel harmony, the markedness constraint *EMBED could outrank *CONTRACT. In that case, an input with conflicting embedded domains could be repaired by contracting the outer domain, producing derivations of the form $/(dik(kat))/ \rightarrow [(dik)(kat)]$.

input and D' in the output, where D' stands in a correspondence relation to D, assign if there is a segment in D' that has no correspondent in D.

(36) *CONTRACT >> *EXPAND

*EXPAND is violated whenever a harmonizing suffix is added to a word, since the existing domain expands to incorporate the suffix. Therefore, *EXPAND must be dominated by SPECIFY, which demands that segments be contained in featural domains, as well as *FD, which requires that a word contain the minimal number of featural domains (*FD).

(37) SPECIFY: Every segment must be specified in the output of phonology.

Assign one violation mark for every segment that is not contained in any featural domain

(38) SPECIFY >> *FD >> *EXPAND

(39) Incorporating a suffix into the existing FD violates *FD minimally.

		SPECIFY	DEP(FD)	*CONTRACT	*FD	*EXPAND
	/(EyI) _B +lEr/					
a.	(ay1-lar) _B				*	***
b.	(ay1) _B (-lar) _B		*!		**	
c.	(ay1) _B -lEr	*!			*	

So we see that FDT joins other domain-based theories of harmony in using a representation of harmony that captures the intuition (discussed in the introduction) that all the harmonizing segments in a word seem to share a single feature. Unlike previous theories of harmony, however, FDT does not attribute this shared feature to any particular segment. Rather, the feature is independent of the segment – in a way that even features in “auto-segmental” representations are not. We now turn to FDT’s treatment of regular disharmonic words.

3.1.1 Disharmonic roots in FDT

Disharmonic roots contain multiple conflicting values for the harmonizing feature (backness), and therefore contain multiple backness domains. Since disharmonic roots surface faithfully, faithfulness to underlying featural domains must outweigh the pressure to harmonize within roots in present-day Turkish.

$$(40) (kI)_F(tEp)_B \rightarrow (ki)_F(tap)_B \quad \text{violates } *FD$$

The survival of disharmonic roots in the output means that *FD must be dominated by the following faithfulness constraints:

$$(41) \text{MAX}(FD[\text{BACK}]) = \text{MAX}(FD)$$

Assign one violation mark for every backness domain present in the input that

is not present in the output

$$(42) \text{DEP}(\text{FD}[\text{BACK}]) = \text{DEP}(\text{FD})$$

Assign a violation for every backness domain present in the output that is not present in the input.

$$(43) \text{IDENT}(\text{BK}) = \text{IDENT}(\text{FD})$$

Assign one violation mark for every $[\alpha\text{back}]$ specification that is $[-\text{aback}]$ in the output.

That is, backness domains are never deleted, inserted, or changed. If *FD were to outrank faithfulness to underlying feature domains, all words will be harmonic, because the pressure for one feature domain to span the entire word will outweigh the need to preserve the multiple underlying domains. This situation does not obtain in Turkish, as we see with words like $(ki)_F(\text{tap})_B$.

Ranking faithfulness to underlying feature domains above *FD, as in (44), correctly preserves disharmonic roots. This is illustrated in the tableau in (45).

$$(44) \text{MAX}(\text{FD}), \text{DEP}(\text{FD}), \text{IDENT}(\text{FD}) \gg * \text{FD}$$

(45) Tableau for *kitab*

	/ (ki) _F (tEp) _B /	SPECIFY	DEP(FD)	MAX(FD)	IDENT(FD)	*CONTRACT	*FD	*EXPAND
☞ a.	(ki) _F (tap) _B						**	
b.	(kitep) _F			*!			*	**
c.	(kitap) _B			*!			*	**

If one of the underlying feature domains is eliminated, as in candidates (b) and (c), then the number of *FD violations is minimized and a perfectly harmonic output results. However, these candidates are non-optimal because they violate the high-ranked faithfulness constraint MAX(FD). Instead, the faithful candidate (a) wins, producing the disharmonic surface form (ki)_F(tap)_B.

Suffixes are incorporated into the later harmonic domain, since this minimizes violations of *Expand and avoids violating any of the higher-ranking Faithfulness constraints.

(46) Suffixes are incorporated into the nearest harmonic domain

	/ (ki) _F (tEp) _B +lEr /	SPECIFY	DEP(FD)	MAX(FD)	IDENT(FD)	*CONTRACT	*FD	*EXPAND
☞ a.	(ki) _F (taplar) _B						**	***
b.	(ki) _F (tap) _B (lar) _B		*!				***	
c.	(ki(tap) _B ler) _B						**	*****!

So FDT, like other modern theories of harmony, has no trouble representing disharmonic roots. We now turn to a formal analysis in FDT of the previously problematic data, words like *harf-ler* and *dikkat-ler*.

3.2 Apparent harmony failure as exceptional transparency

On the surface, *dikkat* looks like it should have the same structure as *kitap*: a front domain contain in the front vowel, followed by a back domain containing /a/.

(47) Same sequence of vowels → same structure?

a. (kI)_F(tEp)_B → (ki)_F(tap)_B

b. (dIk)_F(kEt)_B → (dik)_F(kat)_B

However, assigning this structure to *dikkat* makes the wrong prediction about its suffix-taking behavior: it predicts that *dikkat* will behave like *kitap* and take back suffixes. This is shown in (48); compare it to the tableau for *kitap* in (46).

(48) (dik)_F(kat)_B is the wrong structure

		SPECIFY	DEP(FD)	MAX(FD)	IDENT(FD)	*CONTRACT	*FD	*EXPAND
	/ (dIk) _F (kEt) _B + lEr /							
☞ a.	(dik) _F (katlar) _B						**	***
☹ b.	(dik(kat)bler) _B						**	****.***

In (48), the winning candidate (a) incorrectly assigns back suffixes to *dikkat*. The desired winner (b), the embedding candidate, incurs several additional violations of *EXPAND, which prove fatal. Clearly *dikkat* requires a different input structure from *kitab*—namely, an input containing an embedded domain. Such an input structure will allow FAITH as a driving force for transparency.

The principle of EXPRESSION (Cole and Kisseberth 1994) is built into the phonetic interpretation algorithm. Segments in a featural domain must realize the featural specification of that domain. The failure to phonetically realize a feature due to conflicting demands of multiple governing featural domains is anticipated and penalized by *EMBED (49) (Smolensky 2006).

(49) *EMBED: Assign one violation for every segment that is contained in more than one feature domain.

*Penalizes every segment in an embedded domain. Schematically: *(.)*

*EMBED is violated by the /a/ in *harf* or *dikkat*, revealing that it must be ranked below the faithfulness constraints that preserve embedded featural domains. (See §4 for a discussion of the more specific constraint *EMBED[-LOW] (66) is used to inflict heavier penalties on vowels other than /a/ that occur in conflicting featural domains. *EMBED[-LOW] is undominated, which ensures that only the low vowel /a/ is able to

occur in embedded featural domains.) I have adopted Smolensky (2006)'s formulation of *Embed with no changes, but the particular formulation of this constraint is not crucial to the analysis. Formalizing the constraint on embedding in this particular way has two major consequences: first, structures involving a greater number of embedded segments will receive more violations; second, a sound embedded into multiple domains with the same feature value, e.g., (((a)_B)_B)_B, will get the same violations as one embedded in conflicting domains.

(50) FAITH(FD) >> *EMBED

	/(dIk(kEt) _B) _F /	SPECIFY	DEP(FD)	MAX(FD)	IDENT(FD)	*CONTRACT	*EMBED	*EXPAND	*FD
a.	(dik(kat) _B) _F						***		**
b.	(dik) _F (kat) _B					*!***			**
c.	(dik(ket) _F) _F				*!		***		**
d.	(dikket) _F			*!					*

Suffixes must be incorporated into the nearest featural domain, not an embedded featural domain, both because of *EXPAND and because of *EMBED. Pulling a suffix into a embedded domain, as in (51)b, results in twice the number of *EXPAND violations as pulling it into the outermost domain as in (51)a.

(51) *Expand prevents suffixes from being pulled into embedded domains.

		SPECIFY	FAITH(FD)	*EMBED	*EXPAND	*FD
	/dIk(kEt) _B F+E/					
☞ a.	(dik(kat) _{BE}) _F			***	*	**
b.	(dik(kata) _B) _F			****!	**	**

The losing candidate (dik(kata)_B)_F is harmonically bounded by the winning candidate, showing that embedding will always result in disharmony between the embedded vowel and any suffixes.

Introducing underlying embedded domains, then, allows the transparency of /a/ in certain Turkish words to fall out naturally from the previously defined constraint set. FDT can account for *harf-ler* and *dikkat-ler* easily where other domain-based theories could not because in FDT, domains themselves are targets for faithfulness since they are present in the input, not just constructed by Gen.

Having shown how FDT accounts for patterns of harmony and apparent disharmony in suffixes, we now turn to address harmony and apparent disharmony in vowel epenthesis. The next section shows that this same constraint set and input representation accounts for the apparently disharmonic epenthesis.

3.3 Epenthesis in FDT

There is one more pattern of apparent disharmony to analyze: words like *kabir* ~ *kabr-e* 'tomb (+dat)', which exhibit front vowels in epenthesis and in their suffixes

even though the root vowel is the back vowel /a/. In this section, I will analyze *kabir*~*kabre* as exhibiting covert harmony, just like *harf*~*harf-e* but with the effect of syllable structure playing a crucial role.

Recall that Turkish allows complex codas, as in *harf-ler*. However, complex codas that would violate sonority sequencing are repaired by epenthesis of a high vowel, which takes its backness and rounding values from the root vowel. This is shown in (52), reproduced from (12):

(52) Harmonic epenthesis in nom. for roots ending in illegal consonant clusters

<i>Root</i>	<i>Nom</i>	<i>Dat.:</i> +/E/	<i>Gloss</i>
a. /cebr/	cebir	cebre	'algebra'
b. /sabr/	sabır	sabra	'patience'
c. /uğr/	uğır	uğra	'luck'
d. /ömr/	ömür	ömre	'life'

These roots display epenthesis in the nominative, as well as with consonant-initial suffixes. With vowel initial suffixes, however, epenthesis is unnecessary since the final consonant in the root is syllabified as an onset to the following syllable.

Epenthesis repairs sonority sequencing violations. Thus it shows that the sonority sequencing principle (SSP) outranks Dep-V. Moreover, the choice of epenthesis rather than deletion as a repair strategy shows that Max-C also dominates Dep-V. This gives us the following ranking of syllable-structure constraints:

(53) SSP, MAX-C >> DEP-V, *COMPLEXCODA

SSP is undominated,¹³ as is MAX-C. Conveniently, the high ranking of MAX-C relative to DEP-V corresponds to the high ranking of *CONTRACT (which penalizes the removal of a segment from a feature domain) relative to *EXPAND (which penalizes the addition of segments to a feature domain). Note that the violations of Max will be a subset of the violations of *CONTRACT, and violations of Dep will be a subset of the violations of *EXPAND.¹⁴ Consequently, MAX-C and DEP-V are redundant in the constraint system here and are omitted from tableaux.

(54) Harmonic epenthesis falls out from FDT

	/(cEbr) _F /	SSP	MAX(FD)	IDENT(FD)	*CONTRACT	*EMBED	*EXPAND	*FD	DEP
☞ a.	(cebir) _F						*	*	*
b.	(ceb) _F				*!			*	
c.	(cebr) _F	*!						*	

Thus, the addition of the SSP to the constraint system is all that is needed to produce harmonic epenthesis in FDT.

13 Although an appendix /s/ seems to be possible: no epenthesis in *boks* 'boxing', *raks* 'dance' (Clements and Sezer 1982)

14 This is a side effect of the particular constraint definitions employed here; alternative definitions of *Expand and *Contract could be employed if this overlap turns out to make incorrect predictions. E.g., the prediction under the current definition of *Expand is that a language that disallows the expansion of a feature domain will also prohibit epenthesis. This is probably undesirable as a universal prediction.

The constraint ranking needed for overtly harmonic epenthesis also accounts readily for apparently disharmonic epenthesis. The data to be accounted for appear below, reproduced from (22):

(55) Apparently disharmonic epenthesis

<i>Root</i>	<i>Nom.</i>	<i>Ablative</i>	<i>Dative</i>	<i>1.sg.poss</i>	<i>Gloss</i>
a. /kabr/	kabir	kabir-den	kabr-e	kabr-i-m	'tomb'
b. /hacm/	hacim	hacim-den	hacm-e	hacm-i-m	'volume'
c. /rahm/	rahim	rahim-den	rahm-e	rahm-i-m	'womb'
d. /bahs/	bahis	bahis-ten	bahs-e	bahs-i-m	'bet'
e. /kavm/	kavim	kavim-den	kavm-e	kavm-i-m	'tribe'

Disharmonic epenthesis—or rather, covertly harmonic epenthesis—is predicted in roots with embedding. That is, when the root vowel /a/ appears in an embedded [+back] domain, while the whole word is a front domain. In this analysis, *kabr-e* is exactly like *harf-e*, except that without a vowel-initial suffix, the root /kabr/ has an illicit SSP-violating coda that needs to be repaired, yielding nominative *kabir*. This is illustrated in the tableau in (56).

(56) Covertly harmonic epenthesis falls out from embedding

	/k(E) _B br _F /	SSP	*EMBED(-LOW)	MAX(FD)	IDENT(FD)	*CONTRACT	*EMBED	*EXPAND	*FD	DEP
☞ a.	(k(a) _B bir) _F						*	*	**	*
b.	(kebir) _F			*!				*	*	*
c.	(kabır) _B			*!				****	*	*
d.	(k(abı) _B r) _F		*!				***	***	**	*

Furthermore, the frontness of suffixes on words exhibiting disharmonic epenthesis also falls out from the constraints already established. The case of *kabr-e* is exactly the same as *harf-e*, as shown in (57).

(57) *kabr-e* is exactly parallel to *harf-e*

	/k(E) _B br _F +E/ or /h(E) _B r _F +E/	SSP	*EMBED(-LOW)	MAX(FD)	IDENT(FD)	*CONTRACT	*EMBED	*EXPAND	*FD	DEP
☞ a.	(k(a) _B bre) _F or (h(a) _B rfe) _F						*	*	**	
b.	(kebre) _F or (herfe) _F			*!				*	*	
c.	(kabra) _B or (harfa) _B			*!				****	*	
d.	(k(abra) _B) _F or (h(arfa) _B) _F						**!	***	**	

The difference between *kabir* ~ *kabr-e* and *harf* ~ *harf-e* is entirely due to the relative

sonority of the consonant clusters in these roots. FDT represents their behavior using embedding.

3.4 Richness of the base and lexicon optimization

An ever-present concern in OT is Richness of the Base. Given a wildly non-optimal input, will the system yield a reasonable output? For example, what happens to a redundantly specified word in FDT?

For example, the word *kabahat* 'blame' takes front suffixes: *kabahat-i*, **kabahat-i*. Its structure is ambiguous. Some of the possible structures that yield the same correct surface string are shown below:

(58) [kabahat - i]

- | | | |
|---|---|--|
| a. /((k(a) _B b(a) _B h(a) _B t) _{F+I} / | → | (k(a) _B b(a) _B h(a) _B t - i) _F |
| b. /((k(a) _B b(aha) _B t) _{F+I} / | → | ((k(a) _B b(aha) _B t - i) _F |
| c. /((kakahat) _B) _{F+I} / | → | ((kakahat) _B - i) _F |

Given the ranking below, the third structure, (kakahat)_B - i)_F, is least marked since it incurs only two *FD violations. However, ranking *Embed higher would prefer (k(a)_Bb(a)_Bh(a)_Bt - i)_F instead. The present analysis has not made use of ALIGN at all, but introducing an alignment constraint would again favor candidate (a) which perfectly aligns the edges of every morpheme with the edge of a FD.

(59) *FD >> *EXPAND, *EMBED

(60) ALIGN(MORPHEME, FD) = ALIGN: Assign a violation for every segment that

intervenes between the d edge of a FD and the nearest d edge of a morpheme.

Align the edge of every feature domain to the edge of a morpheme.

(61)

	/kabahat + I/	*FD	*EMBED	ALIGN
a.	((kabahat) _B - i) _F	**	*****	
	(k(abaha) _B t - i) _F	**	*****	**
b.	(k(a) _B b(a) _B h(a) _B t - i) _F	***!*	***	** *****

The ranking *FD >> *EMBED, *EXPAND prefers to minimize the number of backness domains even at the expense of increasing the amount of embedding. Given the definition of a FD below in (62), this ranking then predicts that the domains will all expand to be aligned with the edges of the word: [(((kabahat)_B)_B)_B]_F, and thereby collapse into a single domain. Then the distinction will be imperceptible and unlearnable. Coextensive domains could be considered to collapse into a single domain for free.

(62) DEFINITION OF A FEATURE DOMAIN: an ordered set of segments; a feature; and a value for that feature.

By the definition in (62), if two domains for the same feature F span the same set of segments in a word and share the same value for F, *they are the same object*.

The discussion above has clear implications for the representation of words like those in the dataset below (63) which contain multiple /a/s which are apparently all transparent, since the words take or can take front suffixes.

(63) Words containing multiple /a/s that take front suffixes for at least some speakers – results from TELL

Multiple /a/	front suffixes for speaker 1	front suffixes for speaker 2	front suffixes for my consultant
yaşa-y-i	✓ / ?		
fera:gat-i	✓		?
kabahat-i	✓	✓	✓
anasaat-i	✓		
belahat-i	✓		?
ifa:kat-i	✓		?
kanaat-i	✓		✓
sarahat-i	✓		?
tala:kat-i	✓		?
refa:k ^ɰ at-i	✓		
zanaat-i	✓		?
çalışaat-i		✓	✓

Section 4.1 will deal further with the question of richness of the base and what the proposed constraint system will do with an input that is impossible as a surface form.

We have now discussed FDT's treatment of all the observed cases where suffixes apparently fail to harmonize. FDT allows us to analyze these cases as covert harmony. In addition, we have seen that the proposed constraint system for Turkish can handle unexpected inputs in a graceful way. What remains to be explained, however, is why only /a/ is able to be transparent in Turkish. That is, why is /a/ the only vowel able to be embedded in a front domain? The next section addresses this question.

4 Transparent /a/ and its cross-linguistic implications

The claim of this paper is that /a/ is the only vowel in Turkish which is able to be transparent (i.e., embedded in a backness domain). It is worth noting, however, that previous reports are in conflict regarding the occurrence of unexpectedly back suffixes following front root vowels. Lewis (1967) reports that “Arabic words ending in q, even if they have a front vowel in the last syllable, take back-vowel suffixes: [Arabic] *shawq* 'desire' > [Turkish] *şevk*, acc *şevki*” (20). In accordance with this claim, Clements and Sezer (1982) does not constrain the possible occurrences of covert harmony (for them, “consonant conditioned vowel harmony”) at all. At the time of their writing, however, the use of back suffixes after front root vowels had already been reduced to possible variants in the idiolects of some older speakers. Meanwhile, Underhill (1976) and Kabak (2011) report that systematic, non-idiolectal exceptions to the normal pattern of vowel harmony always involve front suffixes

following a back vowel, not back suffixes following a front vowel.

Whatever the historical status of the use of back suffixes following front vowels, however, it is clear that there has been a major asymmetry in the preservation of covert harmony in Turkish. As we have seen with *harf-ler* and *dikkat-ler*, the use of front suffixes after a back root vowel has persisted in the everyday vocabulary to this day. But front vowels embedded in back domains have been un-embedded – or rather, the outer back domain has been lost, so that words like *şevk* which formerly might have taken back suffixes now take front suffixes. The contrasting treatment of embedded front and back domains is shown below.

(64) *Diachronic change in şevk-lar*:

- a. Arabic input: (shawq)_B
- b. Adapted as: (ş(e)_Fvk)_B + back suffixes: (ş(e)_Fvk-lar)_B
- c. Present day – loss of outer back domain: (şevk)_F, (şevk-ler)_F

(65) *Diachronic stability in harf-ler*

- a. Arabic input: (harf)_F
- b. Adapted as: (h(a)_Br)_F + front suffixes: (h(a)_Brf-ler)_F
- c. Present day – preservation of outer front domain: (h(a)_Brf-ler)_F

What explains the preservation of covert front harmony when covert back harmony has been lost? Moreover, what explains the previously unnoticed generalization that

covert harmony always involves an embedded /a/? There are no words **hurf-ler*, **horf-ler* or **hurf-ler* to correspond to *harf-ler*. That is, the systematic use of front suffixes after back root vowels has only survived in Turkish for words containing /a/, not other back vowels, most notably /u/. Why is it that the only transparent vowel in Turkish is /a/? What predictions does this analysis of the Turkish data make for transparency cross-linguistically?

4.1 Formalization: *Embed[-low]

It is simple to constrain the formal system of FDT to only allow /a/ as a transparent vowel: assign a worse violation to a mid or high vowel that occurs in an embedded backness domain than to a low vowel in an embedded backness domain. This mechanism works because /a/ is the only low vowel in the Turkish phoneme inventory. The constraint *EMBED[-LOW] in (66) will assign the necessary fatal violations to embedded mid or high vowels.

(66) *EMBED[-LOW]: Assign a violation for every segment specified [-low] that contained in two backness domains.

*Penalizes high or mid vowels in embedded domains. Schematically: *(...(i)...)*

(67) *EMBED[-LOW] >> *EMBED

The ranking in (67) captures the fatal markedness of embedding a high or mid vowel

in backness domains in Turkish. This ranking assigns a higher level violation to any vowel other than /a/ that occurs in conflicting featural domains. *EMBED[-LOW] is phonetically justified by the fact that low vowels are less contrastive for backness than mid or high vowels, due to the fact that the lower part of the vowel space is more constricted in the front/back dimension. The motivation for *EMBED[-LOW] will be discussed further in section 4.3. For now, we focus on the formal implementation of the proposed solution.

We know that *EMBED[-low] is unviolated, therefore we can conclude that it is undominated. This ranking yields the desired result that only the low vowel /a/ is able to occur in embedded backness domains, as illustrated in (68).

(68) Tableau for hypothetical / $(h(U)_{Bf}f)_F$ /

		$(h(U)_{Bf}f)_F$	*EMBED[-low]	MAX[round]?	FAITH(BD)	*EMBED	*EXPAND	*FD	IDENT[low]	MAX[round]?
☞	a.	$(h(a)_{Bf}f)_F$						**	*	*
☞	b.	$(h(ü)_{Bf}f)_F$			*!			*		
	c.	$(h(u)_{Bf}f)_F$	*!			*		**		

If *EMBED[-low] and MAX(round)¹⁵ outrank MAX(Backness Domain), an input embedded domain containing a high vowel will be deleted in the output, as shown in

15 In FDT, every Max(F) is actually Max(F-domain)¹⁵. But for the problem at hand, other F-domains behave in a way that is isomorphic to traditional segmental feature specifications, so the present representation is harmless.

(68)b. This incurs a Max(FD) violation but produces a harmonic, entirely front word. On the other hand, if *EMBED[-low] does not dominate FAITH(Backness Domain) but does dominate IDENT constraints governing height¹⁶ and rounding, then the embedded vowel would instead be changed to become a low vowel to avoid violating *EMBED[-low]. This is shown by candidate (a).

Adding *EMBED[-LOW] as an undominated constraint in the Turkish constraint system enables FDT to capture the generalization that only /a/ is allowed to be transparent in Turkish. For Turkish, the only transparent vowel is /a/, and the only low vowel is /a/ also. Thus, the constraint *EMBED(BACK)[-LOW] was sufficient to rule out the embedding of all other vowels in surface forms, while allowing the embedding of /a/. But the invention of a new constraint does not explain what makes /a/ a better transparent vowel articulatorily or perceptually. Moreover, the introduction of *EMBED[-LOW] raises the question of what the new constraint predicts for transparency cross-linguistically. Why should there be a constraint banning the transparency of non-low vowels, when cross-linguistically /i, e/ are very common as transparent vowels (Kramer 2003)? We now turn to these questions.

4.2 Systematic transparency in current theories

Like Turkish, Finnish and Hungarian exhibit backness harmony. Unlike Turkish, Finnish and Hungarian treat /i, e/ as transparent vowels. Both /i, e/ are allowed to

¹⁶ Because /e/ can surface allophonically as the low vowel [æ], IDENT(low) must be ranked quite low. See §5.2.

appear in both front roots and back roots, and they are 'invisible' to harmony, which 'passes through' to affect harmonizing vowels on the other side of /i, e/. That is, /i, e/ in Finnish and Hungarian consistently fail to trigger [-back] suffixes. This is a case of SYSTEMATIC TRANSPARENCY (although the Hungarian includes some interesting exceptions, as will be discussed).

The behavior of /a/ in Turkish resembles the behavior of /i, e/ in Finnish and Hungarian, but also differs in important ways. As we have seen, Turkish /a/ sometimes acts invisible to vowel harmony, and is followed (in these cases) by front suffixes, as in *dikkat-ler*. So in these cases, /a/ is transparent. However, the transparent cases are exceptional, because Turkish /a/ usually participates in vowel harmony and mandatorily triggers [+back] on suffixes (/kitap-lEr/ → [kitap-lar] 'books') and epenthetic vowels (/sabr/ [sabr] 'patience'). Thus, Turkish /a/ is not systematically transparent like Finnish /i, e/, but it is transparent in exceptional words. I refer to this as EXCEPTIONAL TRANSPARENCY. Under the FDT analysis, exceptional transparency in Turkish results from /a/ being a back domain that is embedded in a front domain. The frontness of suffixes falls out from the normal procedure of FDT, where suffixes are incorporated into the nearest backness domain, and receive their backness from it. In this view, front suffixes after transparent /a/ still obey harmony, but the harmony is not obvious. Instead, it is COVERT HARMONY, and indeed, under FDT all transparency can be considered covert harmony.

Transparency is a much-debated topic in the vowel harmony literature, since it

raises the question of whether harmony can be considered a truly local phenomenon (as in Ni Chiosain and Padgett (2001)), or whether some form of gapping or skipping must be allowed. The copious literature focuses on systematic transparency, like Finnish and Hungarian /i, e/. Accounts of systematic transparency normally make crucial use of inventory-related constraints. Transparent vowels are said to be transparent because of feature co-occurrence constraints that prevent them from taking on the [+back] value that they “should” take on. The reliance on feature-cooccurrence constraints is a feature common to diverse theories of transparency and harmony (Smolensky 2006, O’Keefe 2007, Kramer 2003, Kiparsky and Pajusalu 2003, and others). That is, systematic transparency results from inventory gaps, which translate into markedness constraints that are undominated in the language (cf Kiparsky and Pajusalu 2003). Thus, transparent vowels always bear the unmarked feature value (“the unmarkedness property”), because there is no equivalent feature-cooccurrence markedness constraint ruling out the unmarked version of the vowel.

For example, in the case of transparent /i, e/ in Hungarian and Finnish, their back unrounded counterparts /ɪ, ʏ/ do not exist in the vowel inventory. Since there is no back vowel that matches /i, e/ in both rounding and height, they cannot participate in backness harmony. This inventory gap is usually considered the reason that /i/ is transparent to backness harmony in both languages (Kiparsky and Pajusalu 2003, Kramer 2003, Smolensky 2006, and others). The theory predicts that a language with transparent /ɪ, ʏ/ would be impossible, since these are marked.

A complementary perspective on transparency is offered in Gafos and Dye (2011), which addresses articulatory and acoustic properties of transparent vowels. Phonologically, transparent vowels are non-participants in harmony. Articulatorily, however, they may participate in harmony to some degree. For example, /a/ in Kinande has been analyzed as transparent to ATR harmony, but an articulatory study (Gick et al 2006) found that /a/ does undergo ATR harmony. Similarly, in Hungarian, an ultrasound study found that transparent vowels in roots that trigger back harmony are articulated farther back than those in roots that trigger front harmony, even when no other vowels are present to directly cause coarticulation (Gafos and Benus 2003). Because of these findings, Gafos and Dye (2011) suggest that transparent vowels actually participate in harmony articulatorily, while remaining non-participants acoustically—that is, their phonological percept remains constant despite the change in their articulation. This type of articulatory assimilation combined with perceptual faithfulness is only possible for vowels that are relatively more “stable,” in the sense of Stevens (1972, 1989). To quote Gafos and Dye (2011):

Stevens (1972, 1989) promotes the idea that the relation between acoustic and articulatory dimensions of phonetic form displays discontinuous characteristics. In ‘stable’ regions of an abstract articulatory-acoustic space, change along an articulatory dimension does not result in significant change in acoustics. In ‘unstable’ regions, however, comparable articulatory change can cause significant difference in acoustics.

In this model, transparent vowels must be acoustically stable vowels. Acoustic stability enables articulatory flexibility, and these are the properties of transparent

vowels.

4.3 Turkish /a/ and the markedness theory of transparency

How does exceptional transparency in Turkish fit with the existing theories about systematic transparency? Kiparsky and Pajusalu (2003) formulate three empirical generalizations about systematic transparency. They formulate a typology of transparency and opacity that predicts these properties, and derives transparency and opacity from markedness constraints. Markedness constraints alone are not enough to drive exceptional transparency, however, which suggests that not all of these generalizations will necessarily hold for exceptional transparency. Kiparsky and Pajusalu's (2003) generalizations are quoted below:

Unmarkedness. Neutral vowels bear an unmarked value of the harmonizing feature. For example, the unmarked value of backness is [–Back] for unrounded nonlow vowels, and [+Back] for other vowels. For front/back harmony systems, therefore, neutral vowels can be one of *i, e, a, o, u*, but not *ɪ, ø, ä, ö, ü*. In the languages we focus on here, the neutral vowels are *i* and *e*; Seto furnishes an instance of neutral *o*.

Uniformity. All neutral vowels with a given value [α F] of the harmonic feature will be either opaque or transparent. In Seto, for instance, [–Back] neutral vowels are transparent, and [+Back] neutral vowels are opaque.

Asymmetry. Transparent vowels have a predictable feature value; in front/back harmony systems it is [–Back].

(Kiparsky and Pajusalu 2003).

These generalizations turn out not to all be true for the exceptional transparency observed in Turkish. Kiparsky and Pajusalu (2003) state in the passage quoted above that systematically transparent vowels in front/back harmony systems are predictably [-back], but Turkish exceptional transparency involves /a/, a vowel that is [+back] (at least phonologically), violating the Asymmetry generalization. I will argue, however, that the Unmarkedness property still holds for exceptional transparency, and that it is a natural consequence of the family of *Embed constraints (further articulated in §4.4 and §4.5). As for Uniformity, Turkish exceptional transparency does not directly shed any light on its role, since it only involves one neutral vowel, but the contrasting behavior of palatalized consonants ([-back], usually opaque) and velar consonants ([+back], often transparent) suggests that Turkish conforms to the Uniformity generalization.

The core idea behind Kiparsky and Pajusalu (2003) is that transparency is driven by markedness. Inventory requirements, implemented as undominated feature-cooccurrence constraints, provide a clear markedness motivation for systematic transparency. However, this explanation is not available for exceptional transparency, because exceptional transparency involves the transparency of a vowel that normally participates in harmony. In the Turkish case, /a/ normally alternates with /e/ and its allophone [æ]. So clearly [e] and [æ] are not prohibited in Turkish phonology, and there is no inventory gap to motivate the occasional transparency of /a/. This lack of markedness-driven motivation for the exceptional transparency, as well as its

lexically-conditioned nature, motivate the proposal that exceptional transparency is driven by faithfulness: in the underlying representation of the words that display transparency, the surface-transparent /a/s are embedded in front domains. Covert harmony, driven by faithfulness, results.

If transparency and covert harmony can be driven by faithfulness, what constrains the vowels that can be transparent? Why should only /a/ be transparent in Turkish, and what vowels should be potentially transparent in other vowel harmony systems?

There are two possible and probably conspiring factors for why /a/ would be transparent in Turkish, rather than other vowels. The first factor, the subject of this section, is inventory considerations. The other factor, which the next section addresses, is perceptual / articulatory considerations: as a low vowel, /a/ is less contrastively [+back] than the other vowels of Turkish. I focus here on the inventory considerations.

Looking a little closer at the Turkish vowel inventory, we find a connection between the shape of the inventory and the position of the vowel /a/, whose transparency is allowed even though other vowels are prohibited from being transparent. As noted above, /a/ is the only phonemic low vowel of Turkish. Other vowels alternate with exactly height-matched counterparts, but /a/'s front counterpart, while phonologically height-matched to /a/, phonetically is mis-matched. The vowel inventory is reproduced below for reference.

(69) Vowel inventory of Turkish

	[-back]		[+back]
[+high]	i	ü	ɪ u
[-high]	e	ö	o
[+low]			a

Unlike the other Turkish back vowels, /a/ lacks an exactly height-matched front counterpart phoneme; it alternates with the mid-vowel /e/.

This observation suggests that features that are not regularly active in a language's phonology can still play a role in the type of phonological exceptions that survive. That is, [low] isn't active in the regular phonology of Turkish. There are no minimal pairs distinguished by [+low] vs [-low]. Nonetheless, in determining the types of exceptions in Turkish, [+low] seems to play a role. So even though feature-cooccurrence constraints did not play a direct role in motivating Turkish exceptional transparency, the shape of the inventory is still crucial in determining which vowels survive as transparent.

Cross-linguistically, **systematic transparency** occurs when a vowel lacks a harmonic counterpart which shares with it all of the features that are contrastive *in that language*. i.e. for front harmony, /i/ [+high, -round, -back] will be transparent when the language uses [high], [round] and [back] contrastively, and lacks a phoneme /ɪ/ [+high, -round, +back], differing from /i/ only in its value for [back]. Meanwhile, cross-linguistically, **exceptional transparency** will involve a vowel which lacks a

harmonic counterpart which shares with it all of the features that is contrastive *in some language*. In Turkish, the exceptionally transparent vowel is /a/ because /a/ is the vowel that lacks a phonemic counterpart that is distinguished from it only by being [-low] instead of [+low]. The feature [low] is not contrastive in Turkish, but it is contrastive in other languages, such as English which phonemically distinguishes /e/ [-high, -low] from /æ/ [-high, +low].

This claim predicts, for example, that Finnish would not have exceptional transparency on /a/, because /a/ does have an exactly height-matched counterpart phoneme /æ/ in the Finnish vowel inventory. Likewise, it is predicted to be impossible for /i/ to be the most commonly transparent vowel in a language with the same inventory as Turkish. (Such a language would be the opposite of real Hungarian where /i/ is normally neutral but exceptionally triggers back harmony.) The transparency of /i/, exceptional or systematic, is anti-predicted for the Turkish vowel inventory because: /i/ [+high, -round, -back] has an exact counterpart /ɪ/ [+high, -round, +back] differing only in backness (the harmonizing dimension).

The inventory dimension to the analysis of why /a/ is able to be exceptionally transparent connects to the pattern that backness harmony typically features /i, e/ as systematically transparent vowels. As discussed above, the consensus in various theories (Kiparsky and Pajusalu 2003, Nevins 2010, Kramer 2003, Smolensky 2006...) is that language-wide transparency results from inventory imbalance. The transparent vowels are those which lack appropriate counterparts with which to

alternate, due to an undominated featural cooccurrence constraint in that language. Incorporating such constraints, FDT can obtain this result as well. Moreover, systematic transparency need not be derived from underlying embedded domains, as shown in existing domain-based theories (Smolensky 2006, Cole and Kisseberth 1994, O'Keefe 2004). Rather, it can result from the interaction of feature cooccurrence constraints and Alignment constraints. The fact that /i, e/ are commonly transparent in backness harmony is unproblematic for FDT's account of transparency, since in FDT terms, the fact that only /i, e/ can be transparent in Hungarian can be derived from the ranking in (70):

(70) ALIGN-R[+BACK], *I, FAITH-FD-STEM, *EMBED(Ü, Ö) >> *EMBED, MAX-FD, *EXPAND

*EMBED(ü) and *EMBED(ö) will be justified in the next section, and the details of the analysis of Hungarian will be discussed further in the case study in §4.6.

4.4 Turkish /a/ and perceptual stability of transparent vowels

In the absence of inventory asymmetries and accompanying feature cooccurrence constraints, phonetic reasons for transparency may emerge. This section discusses how the exceptional transparency of Turkish /a/ fits with Gafos and Dye's (2011) observations about the relationship between transparency and perceptual stability.

Recall that transparent vowels always bear the unmarked value for the feature

over which harmony occurs—the unmarkedness property of transparency (Kiparsky and Pajusalu 2003). When harmony and transparency are derived by markedness, as in pre-existing theories of harmony, the unmarkedness property falls out from the fact that constraints against marked values exist but constraints against unmarked values do not. However, to account for the exceptional transparency seen in Turkish, I have proposed that transparency can also be driven by faithfulness considerations (in FDT). What is to prevent the embedding of a marked vowel like /ü/ and its resulting transparency? In the current formulation of FDT, only *EMBED[-low] rules out the embedding of /ü/. But *EMBED[-low] can be ranked low, as in Hungarian where /i/ and /e/ are regularly embedded. This calls for the expansion of the *EMBED family to introduce various constraints that penalize the embedding of marked vowels—*EMBED[MARKED], so to speak. The inclusion of *EMBED[MARKED] constraints in the hierarchy predicts that a language that allows a marked vowel to be embedded will also allow less marked vowels to be embedded, since there is no constraint that favors the embedding of marked vowels over the embedding of unmarked vowels. The interaction of embedding and alignment may conceal the embedding of all but the unmatched vowels of an inventory, however. The case study on Hungarian provides tableaux to illustrate this.

*EMBED[MARKED] unpacks into several hierarchies of constraints. Each feature F in which the embedding is occurring must have its own hierarchy of *EMBED(F-DOMAIN)[MARKED] constraints. These constraints will be in fixed ranking

or a stringency relationship based on the relative perceptual stability of the embedded material under articulatory variation induced by F. This proposal relies upon the phonetic grounding for transparency proposed in Gafos and Dye (2011). Drawing on Stevens (1989) quantal theory of speech, Gafos and Dye (2011) claim that transparent vowels are those that have a stable percept because of the part of the articulatory space they occupy. The idea is that transparent vowels do participate in harmony articulatorily, but not acoustically, because in the part of the vowel space the transparent vowel occupies, the small articulatory shift caused by (co)articulatory participation in harmony is not enough to trigger a categorically perceivable acoustic shift. This is possible for certain acoustically stable vowels (such as /i, e/ for backness harmony) but not possible for the less stable vowels. For example, in backness harmony, /i/ is the best candidate for transparency because the percept of /i/ will remain stable under the greatest retraction in articulation. Gafos and Dye report that “following any given back vowel, a high front vowel like /i/ is most retractable, a mid front vowel like /e/ is somewhat retractable, and the high front round /y/ is minimally retractable.” This naturally translates into a fixed hierarchy of constraints on embedding, as in (71).

(71) *EMBED(y, +back) >> *EMBED(e, +back) >> *EMBED(i, +back)

(72) *EMBED(α , β): Assign a violation for every instance of α embedded in a domain of type β .

That is, the shorthand *Embed(marked) used above unpacks into a series of constraints on embedding vowels of various stability levels, where embedding a less stable vowel incurs a higher penalty than embedding a more stable vowel. This particularly makes sense if we interpret the domains of FDT as representations of gestures, similar to the phonological units in Articulatory Phonology (Browman and Goldstein 1993). The Gafos and Dye (2011) model of transparency involves overlapping gestures, and in FDT's representation of transparency this overlap is directly represented using embedding. This analysis of transparency allows for a genuinely local harmony process, since nothing is neutral on the gestural level. It has this in common with other theories of strict locality in harmony, such as Ni Chiosain and Padgett (2001).

My extension of the Gafos and Dye (2011) model is that transparent vowels are those that are still recognizable as themselves even when the gestural requirements of their context distort their articulation. The stability of their percept might come from any or all of three factors, all of which apply to Turkish /a/. First, there is the source of stability that Gafos and Dye (2011) discuss. The transparent vowels may inherently be in an acoustically stable part of the articulatory space (cf quantal theory) – this is the case for the systematically transparent vowels of, e.g., Hungarian and Finnish. I predict that /a/ is more “front-able” than other back vowels, although I am not aware of experimental evidence that directly demonstrates this.

The second factor connects to inventory. Systematically transparent vowels

completely lack harmonic counterparts in the inventory. Exceptionally transparent vowels have harmonic counterparts, but occur in a less crowded part of the vowel space such that they are less likely to be confused with a neighboring phoneme, since they would have to move really far acoustically / articulatorily to be confusable. In the case of Turkish /a/, from an inventory perspective, its height is what makes it more perceptually stable. Because it's the only low vowel, there is no other low vowel to confuse /a/ with; /a/ would have to raise as well as front or round in order to be perceived as one of the other phonemes. (Even Turkish [æ] is higher than /a/ and is described by some as a low mid vowel.) In contrast, /i/ would be a poor candidate for transparency in Turkish from an inventory perspective on confusability, since it differs from /ɪ/ only in backness.

A third factor that could make a vowel friendly to embedding is its contrastiveness for the embedding feature. This is an articulatory argument, more than a perceptual one. If a vowel is already less contrastive for the relevant feature, it will be articulatorily less taxing to produce it in its usual fashion in an embedded context. For example, low vowels are less contrastive for backness than high vowels, making it articulatorily less taxing to produce *i-a-i* than *i-u-i*. Indeed, while the Turkish low vowel is phonologically [+back] in Turkish, patterning with undeniably back vowels such as /u, o/, it is variously transcribed as the central /a/ (Zimmer and Orgun 1999) and as the back /ɑ/ (Kabak 2011). Therefore an [i-a-i] (disharmonic) sequence will be perceptually more similar to an [i-æ-i] (harmonic) sequence than an [i-u-i] sequence

will be to an [i-ü-i] sequence.

The low incidence of backness contrast in low vowels crosslinguistically seems to reflect the fact that low vowels are not as contrastive in the front back dimension as higher vowels. In the UCLA Phonological Segment Inventory, there are only about 20 languages with backness contrast in low vowels, compared to almost all languages in the database showing a backness contrast among the mid or high vowels (Maddieson 1984). The impoverished backness contrast among low vowels results from their articulatory properties – the jaw can only move so much, so the lower part of the vowel space is inherently more constricted in the front-back dimension (Grant McGuire, p.c.). This means /a/ is better able to simultaneously realize both [-back] and [+back] features than other vowels – in gradient phonetic terms, not to say a vowel should be able to *phonologically* be both front and back. But FDT's embedded representation suggests overlapping [+back] and [-back] gestures for an /a/ embedded in a front domain.

To conclude this section, there are both perceptual and articulatory reasons that /a/ is closer to neutral in terms of backness than the other vowels in Turkish. First, by hypothesis, /a/ is more perceptually stable under fronting than the other back vowels. Second, because of the shape of the inventory, /a/ is less confusable with other phonemes since it is farther away from them articulatorily and presumably acoustically as well. Thirdly, /a/ represents less of an articulatory burden because, as a low vowel, it is inherently not very contrastive for backness. Both the perceptual and

articulatory factors form the basis for the constraint *EMBED(back)[-low]. The general principle I propose is that, with respect to the relevant harmony process, a vowel that can be transparent should be phonetically more neutral and acoustically more stable than the vowels that cannot be transparent. Formally, this is enforced by the family of *EMBED(UNSTABLE) constraints, which exist in a fixed ranking based on the perceptual stability of the embedded segment under the embedding feature.

4.5 Predictions of FDT

My analysis of exceptional transparency piggy-backs on Benus and Gafos / Benus and Dye 's reports about the articulatory and perceptual basis for transparency. Some contradictions to Kiparsky and Pajusalu's typology of (systematic) transparency occur, but this is to be expected given that the phenomenon in question is a somewhat different from the one they analyze, being *exceptional* transparency. This section discusses some predictions of FDT.

Prediction 1. /a/ is perceptually more stable than other Turkish back vowels. Experimental evidence to support this claim would be good. Even modeling as in Stevens (1989) would provide good confirmation. Conducting an acoustic experiment or modeling project is beyond the scope of this paper, but the claim is at least indirectly supported by the fact that the low back Turkish vowel is variously transcribed as central vs back (though of course phonologically it is [+back]).

Prediction 2. Like systematic transparency, exceptional transparency will

have some connection to the inventory. e.g. a gap in terms of a non-contrastive feature. Cross-linguistically, exceptional transparency is likely to involve a vowel whose harmonic counterpart differs from it in one or more of the additional features that are contrastive *in some human language*. This creates more room for articulatory assimilation without a perceptual shift. I propose that the "unmarkedness property" (Kiparsky and Pajusalu 2003), a side effect of this fact, will hold for exceptional transparency as well as systematic transparency. When an inventory gap exists, the phoneme present in the inventory is the less marked sound, so of course the transparent phoneme will bear the unmarked value.

Prediction 3: Like systematic transparency, exceptional transparency will have some connection to articulatory flexibility / perceptual stability. A vowel that is able to persist in an embedded context over time will be perceptually stable even with more articulatory assimilation (coarticulation). Formally in FDT, this is enforced by the family of *EMBED constraints. These must penalize: perceptually bad transparency (that is, every kind of unstable embedding - e.g. embedding /ɪ/ or /ü/ in conflicting backness domains bc they will be hard to recognize), articulatorily bad transparency (embedding highly contrastive vowels, like i in a [+back] domain, because producing them really faithfully will involve major articulatory deviation). The effect of these constraints is overruled by inventory considerations in languages that lack the opposing value counterparts.

4.6 Case study: Hungarian

FDT makes possible two major claims about harmony: that transparency can be motivated by faithfulness, and that harmony need not be triggered by a segment. The first claim accounts for the discrepancy between words like *kitap-**lar*** and words like *dikkat-**ler***, while the second accounts for Turkish words like *harf-**ler***. Since Hungarian displays systematic rather than exceptional transparency, it has no problem equivalent to *kitap* vs *dikkat*. However, Hungarian does have words which seem to lack an appropriate segmental trigger for the observed value of harmony—equivalents of *harf-**ler***.

Kramer (2003) refers to the vowels in words of the *harf-**ler*** type as “Trojan vowels.” For Kramer, these are vowels that are usually transparent to harmony, but which exceptionally do trigger harmony with the opposite value from what is expected. A prime example is Hungarian's class of exceptional roots containing the vowel /i/ which trigger back harmony. Hungarian exhibits backness harmony in a system similar to Turkish. However, Hungarian has lost the high back unrounded vowel that should be the direct counterpart to /i/. This diachronic change has had two consequences. First, /i/ is now regularly a transparent vowel, and can intervene in a back root between a triggering back vowel and a suffix, as in *radir-**nak*** in (73)a. Secondly, some roots which historically were pronounced with the back vowel /ɨ/ and regularly triggered back harmony, today are pronounced with the front vowel /i/ but still trigger back harmony. An example is *hid* (73)c, which contrasts with regular

transparent /i/ in viz (73)b in triggering back harmony on its suffixes.

(73) Hungarian (Ringen & Vago 1998)

<i>Nom.</i>	<i>Gloss</i>	<i>Dat.</i>	
a. radir	'eraser'	radir-nak	<i>normal transparency of /i/</i>
b. viz	'water'	viz-nek	<i>suffix /nek/ is underlyingly front</i>
c. hid	'bridge'	hid-nak	<i>exceptional /i/ triggers back harmony</i>

The Hungarian pattern is easily formalizable in FDT in an analysis very similar to that provided for Turkish. However, to guarantee that /i/ is transparent throughout the whole language (systematic transparency), feature-valued *EXPAND or ALIGN must come into play. Here, I will follow Smolensky (2006) in using ALIGN, but this is not crucial for the analysis. In addition, because of the inventory gap, we need the feature-cooccurrence constraint *₁:

(74) *[+high, +back, -round] = *₁ : No high, back unrounded vowels.

(75) ALIGN(+back): Assign a violation for every segment intervening between the right edge of a [+back] domain and the right edge of the word.

In addition, since Hungarian suffixes have underlying backness specifications that emerge when they stand without a stem, Faith-root will also be necessary to overwrite the suffixes' backness specifications. The constraint ranking below can account for Hungarian harmony:

(76) ALIGN(+back), *₁, Faith-FD-stem, *Embed(ü), *Embed(ö) >> *Embed, Max-

FD, *Expand

In the FDT analysis, Hungarian *hid* is like Turkish *harf* but with a front domain [i] embedded in a back domain:

(77) $(h(I)_{Fd})_B + (nEk)_F \rightarrow (h(I)_{FdnEk})_B + \cancel{(nEk)_{FR}} \rightarrow (h(i)_{Fdnak})_B$ 'bridge.DAT'

$(h(I)_{Fd})_B + (nEk)_F$	ALIGN (+BK) * _I *EMBED (Ü, Ö)	FAITH-FD-STEM	*EMB	MAX-FD	*EXP
a. $(h(i)_{Fdnak})_B$			*	*	***
b. $(h(i)_{Fd})_B(nEk)_F$	*!***		*		
c. $(hidnak)_B$	*!	*		*	***

This ranking will systematically create transparency when a high unrounded vowel appears in a back domain. That is, it generates markedness-driven transparency.

(78) Embedding driven by *_I

$(rEdIr)_B + (nEk)_F$	ALIGN (+BK) * _I *EMBED (Ü, Ö)	FAITH-FD-STEM	*EMB	MAX-FD	*EXP
a. $(rad(i)_{Frnak})_B$		*	*	*	***
b. $(rad(i)_{FIR})_B(nEk)_F$	*!***		*		
c. $(radırnak)_B$	*!			*	***

It will also prevent illicit input embeddings from surfacing. Depending on the relative

rankings of Faith-FD-stem, *Contract, and *Embed, either the unembedded candidate (b) will win, or the super-embedded candidate (c), which is segmentally identical to another unembedded candidate (ri)_F(darnak)_B, will win.

(79) Only /i, e/ can be embedded

(rId(E) _{BR}) _F + (nEk) _F	ALIGN (+BK)	*I	*EMBED (Ü, Ö)	FAITH -FD- STEM	*EMB	MAX -FD	*EXP
a. (rid(a) _{BR} nek) _F	*!****				*	*	***
b. (ridernek) _F				*	*	**	****
c. (ri(darnak) _B) _F					*****	*	*** ****

The same pattern obtains with /e/, which is systematically transparent and yet varies as to which suffixes it triggers. To quote Gafos and Dye (2011), “*szél* triggers a front while *cél* triggers a back suffix: *szél-nek* ‘wind-DATIVE’ vs. *cél-nak* ‘aim-DATIVE”

Gafos and Benus (2003) found that there are articulatory differences in production of /i/, /e/ in different harmony triggering contexts, even in the bare forms where coarticulation with neighboring vowels cannot play a direct role. This is experimental evidence for FDT's representation of *hid-nak* vs *viz-nek*, supporting the claim that there must be a difference in the underlying representations of words that trigger different harmony values.

4.7 Case study: Covert harmony in Japanese

Japanese offers another example of /i/ being harmonically exceptional. In Sino-Japanese roots of the form /CVk/, the back vowels /a u o/ require the back epenthetic vowel /u/, while the front vowel /e/ requires a harmonically front epenthetic vowel /i/. Only /i/ allows a genuine contrast between /i/ and /u/ as epenthetic vowels; i.e., only /i/ can occur in embedded featural domains.

(80) Japanese (Ito and Mester 2015)

a. /hok/	[hoku]	'north'
b. /sek/	[seki]	'stone'
c. /sik/	[siki]	'ceremony'
d. /zik/	[ziku]	'axle'

(81) /i/ unembedded vs. embedded

a. (sik) _F	→	(siki) _F
b. (z(i) _F k) _B	→	(z(i) _F ku) _B

The constraint ranking will be very similar to Hungarian, but less complex since no affixes are involved, only epenthesis driven by syllable-structure constraints (NoCoda >> Dep-V).

5 Alternative analyses of exceptional transparency in Turkish

Let's take stock of what has been proposed. To account for Turkish words like *harfler*, I propose a new representation of vowel harmony, Feature Domain Theory. In FDT, backness in Turkish is specified on featural domains, which normally coincide with roots. Vowels within a featural domain take their backness from it. Most suffixes

lack their own featural domains and merge into that of the word to which they attach. When a suffix apparently fails to harmonize, the disharmony results from the embedding of conflicting featural domains: the root as a whole is a front domain, but the final vowel is contained within a back domain (e.g., (dik(ka)_{BT})_F, (h(a)_{BT})_F). As usual, suffixes take on the backness of the root; consequently they conflict with the vowel. This is exceptional, lexically-conditioned transparency.

Since vowels must realize the backness of the featural domains that contain them, nesting featural domains are usually ruled out. However, /a/ is special, because there is both phonetic and phonological support for re-categorizing /a/ as a quasi-front vowel. /a/ is more central than the other back vowels /u o ɯ/, and unlike the other Turkish back vowels, /a/ lacks an exactly height-matched front counterpart phoneme; it alternates with the mid-vowel /e/. Since /a/ can occur within front roots, this analysis of vowel harmony can model the selection of front suffixes by *harf* and *dikkat* without the need to posit phonetically unrealized front features on consonants, or any other additional apparatus.

As illustrated above with Hungarian and Japanese, this proposal extends straightforwardly to account for so-called Trojan vowels (Kramer 2003) in languages like Hungarian and Japanese, as well as systematic transparency. Which vowels can be transparent in a language will be constrained by the family of *Embed constraints, which preclude the embedding of unstable, marked constraints. These interact with feature cooccurrence constraints and Alignment constraints to produce systematic or

exceptional transparency. Thus, Feature Domain Theory offers a mechanism for representing both exceptions to vowel harmony and the regular cases of harmony in a unified fashion.

However, proposing a theory of such scope as FDT on the basis of exceptions to vowel harmony, which by their nature are relatively few in number, may be met with some suspicion. This section tries to show that FDT is a more appealing explanation for the Turkish data than the possible segment-dependent analyses, such as an /a/ based account with chain-shift (§5.1), or default front-suffixes inserted as a last resort (§5.2), or cophonologies (§5.3). It concludes with a theoretical comparison (§5.4).

5.1 Underlying /æ/ and low-vowel chain shift

Having established that /a/ is special in Turkish, it is tempting to propose that the exceptional behavior of words like *harf* results from a special feature on the vowel /a/, and nothing else. This would mean that /a/ sometimes has a [-back] feature, rather than the usual [+back], and in these exceptional cases, /a/ triggers front harmony. Perhaps [a] in those cases is underlyingly /æ/, and the front harmony reflects this underlying front-ness, rather than surface backness. This hypothesis improves on the consonant-based account (Clements and Sezer 1982) by only proposing an inaudible front variant of one phoneme, not dozens. It has the additional benefit of (seemingly) not requiring any extra theoretical machinery. As we will see, however, some

additional theoretical apparatus is still necessary with this proposal.

The first major problem with this proposal is that the vowel in exceptional words is only very subtly different from the vowel in regular back-harmony words. E.g., the /a/ in *harf-ler* 'letters' and the /a/ in *zarf-lar* 'envelopes' are barely distinguishable. Moreover, Turkish does have [æ], as an allophone of /e/, and it often appears before a sonorant coda (82). If [æ] can surface as an allophone of /e/, why would /æ/ surface as [a] in /harf/?

(82) [æ] as an allophone of /e/

- | | | | |
|----|---------|----------|-----------------|
| a. | gün-ler | [günlær] | 'days' |
| b. | döner | [dönær] | (type of kabob) |
| c. | erken | [ærkæn] | 'early' |
| d. | gel | [gæɫ] | 'come!' |

If the vowel were underlyingly /æ/, it should surface as [e], if anything, to preserve its frontness—a feature which is phonologically important in Turkish, unlike the low/mid vowel distinction that is preserved by the /æ/ → [a] mapping.

(83) *[ER]: Assign one violation for every mid unrounded vowel in a syllable with a [+sonorant] coda

(84) *FROLO: Assign a violation for every low front vowel

(85) *FroLo must be low ranking to get the pronunciations in (82)

			IDENT (BACK)	IDENT (HIGH)	IDENT (ROUND)	IDENT (LOW)	*FROLO
	/(gEl) _F /	*[ER]					
☞ a.	(gæ) _F					*	
b.	(göl) _F				*!		
c.	(gil) _F			*!			
d.	(gal) _B		*!			*	
e.	(gel) _F	*!					

Suppose we put aside FDT and just use traditional segmental feature specifications. Given the ranking in (85) which is necessary to predict the actual pronunciations of the words in (82), an input vowel /æ/ should surface as a front vowel, either as [æ] or [e], depending on the relative rankings of Ident(low) and *FroLo, and the syllabic context.

(86) Input /æ/ should surface as a front vowel in *dikkat*

	/dikkæt/	*[ER]	IDENT (BACK)	IDENT (HIGH)	IDENT (ROUND)	IDENT (LOW)	*FROLO
☞ a.	dikkæt						*
☞ b.	dikket					*	
c.	dikkat		*!				

(87) Input /æ/ should surface as a front vowel in *harf*

	/hærf/	*[ER]	IDENT (BACK)	IDENT (HIGH)	IDENT (ROUND)	IDENT (LOW)	*FROLO
☞ a.	hærf						*
b.	harf		*!				
c.	herf	*!				*	

Another variant on this proposal is that the exceptional /a/ is an underlyingly central vowel, which triggers front harmony. Again, this would not require any morpheme marking. This proposal faces the same objections: if the vowel in *harf*, *dikkat*, etc is underlyingly central, and this centrality triggers front harmony, why doesn't it surface as a front vowel instead of a basically back vowel? A segment that is [-back, +front] to the harmony process should also be [-back, +front] phonetically.

It is true that we can get around the objections raised above by employing a chain-shift analysis of low vowels in Turkish. Suppose that *harf* takes front suffixes because it underlyingly contains /æ/, as proposed above:

(88) /hærf/ → [harf]

Meanwhile, underlying /er/ sequences often surface as [ær] due to lowering before sonorant codas.

(89) Nonce /herf/ → [hærf]

That is, $e \rightarrow \text{æ} / _ r$, while $\text{æ} \rightarrow a / _ :$ a “regular chain shift” in Lubowicz (2011)’s typology, since both processes are independently motivated. Lowering before rhotics and liquids is common cross-linguistically, and can be phonetically / articulatorily motivated (Bradley 2011). Bradley formalizes lowering before /r/ with the constraint *Distance-/er/. Additionally, backing $\text{æ} \rightarrow a$ is motivated by the markedness of the low front vowel – this makes sense because /æ/ is cross-linguistically less common than /a/ (Maddieson 1984).

As shown above, ranking Ident(back) above Ident(low) and *FroLo (to prevent /er/ from surfacing as [ar]) predicts that /dikkæt/ → [dikkat] (86) and /hærf/ → [hærf] (87). To force the /æ/ → [a] mapping, we need a different ranking:

(90) *DISTANCE-/ER/ >> *LOFRO, IDENT(LOW) >> IDENT(BACK)

Note that Ident(back) is now ranked at the bottom. This ranking is surprising given that we expect Ident(back) to be ranked relatively high in Turkish so that disharmonic words will be preserved faithfully despite the pressure for vowels to harmonize in backness. However, this ranking does correctly derive the desired /dikkæt/ → [dikkat].

(91) /æ/ → [a]

	/dikkæt/	*DISTANCE-/ER/	IDENT (LOW)	*LOFRO	IDENT(BACK)
	dikket		*!		
	dikkæt			*!	
→	dikkat				*

(92) /ær/ → [ar]

	/hærf/	*DISTANCE-/ER/	IDENT (LOW)	*LOFRO	IDENT(BACK)
	herf	*!	*		
	hærf			*!	
→	harf				*

However, this ranking by itself predicts the incorrect /er/ → [ar] as well.

(93) Incorrect prediction: /er/ → [ar]

	/-ler/	*DISTANCE-/ER/	IDENT (LOW)	*LOFRO	IDENT(BACK)
	ler	*!			
☹	lær		*	*!	
→	lar		*		*

To circumvent this ranking paradox, we can use local constraint conjunction to assign a worse violation to a segment that violates both Ident(back) and Ident(low) simultaneously. This yields the constraint-ranking illustrated in the tableau in (95), which successfully derives the chain shift.

(94) IDENT(BACK)&IDENT(LOW) >> *LOFRO

(95) Chain shift: /er/ → [æɹ]

	/-ler/	*DISTANCE -/ER/	IDENT(BACK) &IDENT(LOW)	IDENT (LOW)	*LOFRO	IDENT (BACK)
	ler	*!				
→	læɹ			*	*	
	lar		*!	*		*

(96) Chain shift: /æɹ/ → [a]

	/hæɹf/	*DISTANCE -/ER/	IDENT(BACK)& IDENT(LOW)	IDENT (LOW)	*LOFRO	IDENT (BACK)
	herf	*!	*	*		
	hæɹf				*!	
→	harf					*

So it is not so difficult to get /e/ to surface as [æ] while /æɹ/ surfaces as [a].

However, this “solution” still leaves the problem of why a word that on the surface has back vowels would require front suffixes. OT treatments of harmony do

not make reference to underlying feature values; the whole point of parallel evaluation is producing a surface-optimal output, and harmony is always treated as driven by markedness. Putting front suffixes on [harf] even if it was underlyingly /hærf/ does not improve markedness.

(97) Chain shift does not derive *harf-ler*

	/hærf-lEr/	*DISTANCE -/ER/	IDENT (BACK) & IDENT (LOW)	IDENT (LOW)	*LOFRO	IDENT (BACK)	AGREE or ALIGN
→	harf-lar					*	
☹	harf-ler					*	*!

With these constraints, *harf-ler* is harmonically bounded by *harf-lar*. In order to derive *harf-ler*, some additional theoretical machinery is still necessary. One option is to use serialism to derive harmony with the UR rather than the SR. However, this would mean taking on the theoretical problems of serialism (e.g., deriving non-myopic harmony – see Walker (2010)).

An alternative would be to follow Nevins (2010) and propose that front suffixes are default in Turkish, and appear when no suitable harmony trigger is available. In this case, we would still need a mechanism for why this [a] or /æ/ cannot trigger harmony at all – what makes it transparent. This would again require additional theoretical apparatus.

Yet another alternative would be a word-level Preserve-Contrast (Lubowicz 2003) strategy where front suffixes are used on /hærf/ ~ [harf] to prevent neutralization of the contrast with hypothetical /harf/, as suggested in the tableau below.

(98) A Preserve-Contrast approach

	Scenarios	PC(æ/a)	PC(æ/e)	*DISTANCE -/ER/	*LOFRO	HARMONY	FAITH
chain shift, disharmonic	harf-E → harf-a hærf-E → harf-e herf-E → hærf-e				*	*	**
chain shift, harmonic	harf-E → harf-a hærf-E → harf-a herf-E → hærf-e	*			*		**
faithful, harmonic	harf-E → harf-a hærf-E → hærf-e herf-E → herf-e			*	*		
one shift, harmonic	harf-E → harf-a hærf-E → hærf-e herf-E → hærf-e		*		**		*
one shift, disharmonic	harf-E → harf-a hærf-E → hærf-a herf-E → hærf-e				**	*	*

This contrast would only be maintained when suffixes are present, however, creating an additional complication for the constraint ranking. To my knowledge Preserve

Contrast is supposed to operate on the level of segmental contrasts; it is not immediately clear whether it is legitimate to extend the existing theory to induce disharmony. A full analysis in the Preserve Contrast framework is beyond the scope of this paper. Like the other possible approaches mentioned above, however, attributing the frontness of the suffixes on *harf* to Preserve Contrast requires an extension of the prevailing theoretical framework. Thus the chain-shift argument against FDT from theoretical parsimony fails.

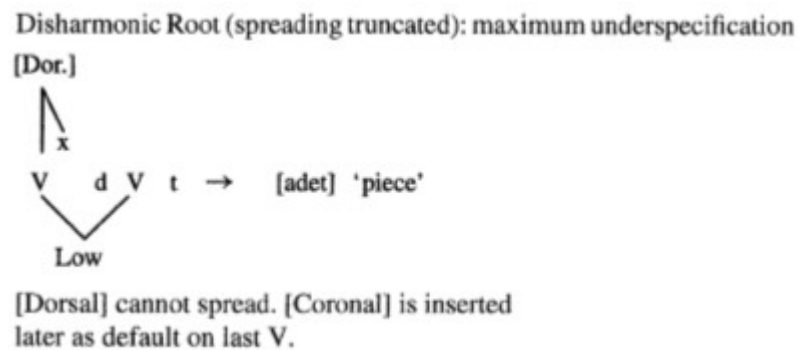
5.2 Front suffixes as default

I have argued above that the exceptional front-suffixing behavior of words like *harf-ler* and *dikkat-ler* cannot be due to the /a/ in those words being an under-cover front vowel. Additionally, standard explanations for why a vowel is transparent (e.g., high markedness of its harmonic counterpart, inventory considerations) are unavailable for Turkish because these explanations derive transparency across the entire language, but /a/ is normally opaque in Turkish, and only transparent in the exceptional cases considered here.

But for the sake of argument, let's suppose that some unspecified alternative explanation for why /a/ can be transparent were to emerge. For example, we could adopt the harmony truncation proposed for disharmonic Turkish roots like *kitap* 'book' (normal back harmony) by Kabak and Vogel (2011). In this representation, spreading is autosegmental feature-sharing, and for backness, only [+back] (or [Dorsal]) can be

specified underlyingly. This is in order to avoid underlying specification of the unmarked [Coronal] feature (for [-back] segments). Underspecified vowels are assigned the default, unmarked value [Coronal] or [-back]. Disharmonic roots appear when a root is “prespecified” to contain a “truncation” marker. At the point in the word at which it (silently) appears, this marker makes the usual spreading impossible—it truncates it (99).

(99)



Nevins (2010) proposes a theory of harmony in which only segments that are contrastive for the harmonizing feature participate, but harmony always copies the nearest harmonizing feature. In the Search and Copy algorithm, the “needy” (underspecified) vowel initiates a search to have its feature value checked. This search may be parameterized, for instance, to only look at contrastive feature values, thus enabling transparency of vowels that lack harmonic counterparts. If the Search fails to return a result, a default value is inserted as a last resort. This default value is

determined by a parameter setting for the language. Under the Search and Copy theory of harmony, we might propose that the selection of front suffixes after /a/ in Turkish occurs because there is no backness donor found and the default value of [-back] is inserted as a last resort. Kabak and Vogel (2011) also propose [-back] (for them, CORONAL) as the default value in their description of a representation for harmony blocking in disharmonic words.¹⁷ However, a problem for the Search and Copy approach is the existence of “exceptional exceptions” below: cases where more than just /a/ would have to be transparent.

There are actually some attested cases of covert harmony with words that contain back vowels other than /a/. TELL contains some examples for which only one of the two speakers used front suffixes (100)

(100) Exceptional exceptions

Front suffixes on a word that contains /o u ı/	Sp. 1	Sp. 2
lugat-i		✓
yalova-y-i		✓
muvakkat-i		✓
sihhat-i		✓
hovarda-y-i		✓
kitcanaat-i	✓	
muaccat-i	✓	

¹⁷ They do not discuss the data in this paper but their analysis extends straightforwardly to it; however, their analysis involves prespecified blocking which is unrestricted to any particular segmental context, thus failing to account for the regularity that harmony failure always involves the transparency of an immediately adjacent /a/.

These examples show front suffixes appearing after a word that contains a back vowel other than /a/. Consequently, the Search and Copy algorithm would be expected to find the [+back] on this additional back vowel, and copy it to the suffix. In the case of *lugat-i* 'dictionary', for example, even if the algorithm was pre-set to have to skip this /a/ as transparent in this word, having passed over /a/ it would then reach /u/, another [+back] vowel. Since /u/ is not systematically transparent in any subpart of the lexicon, there is certainly no reason for the algorithm to skip /u/. For the Search and Copy algorithm with last-resort default value insertion, then, these words would have to be truly exceptional and simply not subject to the Search and Copy algorithm (at least for these speakers).

In contrast, FDT has no problem with these words. For the speakers that give them front suffixes, they simply involve multiple back domains, one of which is embedded. To take the example of *muvakkat-i*, FDT would assign this underlying structure:

$$(101) (mUvEk)_B((kEt)_{B-I})_F \rightarrow (muvak)_B((kat)_{B-i})_F$$

Note the complexity of the structure. An apparently harmonic sequence of surface [+back] vowels *u...a...a* is broken up into distinct harmonic domains, which seems hard to learn. Most likely the high markedness and low learnability of these structures contributes to their being marginal. Dictionaries do not list these words as requiring front suffixes, and my consultant rejected the use of front suffixes on these

words. So unlike the cases discussed in the rest of this paper, the exceptionality of these words is idiolectal; for most speakers, they behave regularly and take back suffixes.

There are a very few additional examples of unexpected front suffixes that immediately follow a vowel other than /a/. Kabak (2011) cites *ma:l̥um-dü* 'it was inevitable' as a common variant on the harmonic *ma:l̥um-du*. Kabak (2011) notes a pattern which Underhill (1976) observes: all exceptions involve unexpected front suffixes, never unexpected back suffixes¹⁸. This is good for the “default front suffix” view, and suggests that the FDT analysis should incorporate an asymmetry between [-back] and [+back], such as rating [-back] as less marked, ranking *Embed[-back] >> *Embed[+back], or (similar to Hungarian) ranking Align[-back] >> Align[+back]. I leave this for further investigation.

5.3 Cophonologies

The previous section considered the possibility that certain /a/s are exceptional and that their exceptionality is the reason for the surprising selection of front suffixes by words like *harf* and *dikkat*, and rejected the proposal that an /a/-based analysis was more theoretically economical than FDT. This section considers another alternative to FDT: that the exceptionality of *harf*, *dikkat*, et al. is the result of cophonologies or indexed constraints in Turkish.

18 C&S 1982 cite some idiolectal variants in which back suffixes are used after front vowels, but TELL, dictionaries, my consultant and Kabak (2011) all concur that the C&S examples are marginal.

The theory of cophologies, pioneered by Orgun (1996) and developed by subsequent authors, including Inkelas and Zoll (2007), involves multiple constraint rankings within one language. Words belong to one cophology or another based on their morphological features. A related but competing theory is indexation of constraints (e.g., Ito and Mester 1999), where there is a single constraint ranking for a language but some constraints target specific classes of words only. Both of these approaches can provide explanations for the exceptional behavior of a class of words in a language.

Clearly in the normal phonology of Turkish, /a/ functions as an opaque back vowel: it triggers back harmony on alternating suffixes and on epenthetic vowels that follow it (e.g., *kitap* → *kitap-lar*, *ay* → *ay-lar*). But in the troublesome words like *harf-ler*, /a/ acts as a transparent or perhaps front vowel. Could the disparate behavior of /a/ in the exceptional cases be the result of different constraint rankings in different co-phonologies? I will argue, however, that their solutions are not appropriate for the Turkish data examined here.

The problem is that the classes picked out by cophologies or indexed constraints are supposed to be distinguished by clear phonological or morphological markers. These do not exist for the words in question in Turkish. While the exceptional words are all loans from Arabic (C&S 1982, Lewis 1967), the language is full of countless other Arabic loans in which /a/ is opaque as usual, rather than transparent as in *dikkat*. So indexed constraints could not simply target all Arabic

loanwords. Conceivably the class of exceptional words could be those loans which are unassimilated (as Lewis (1967) claims). However, the exceptional cases include not only rarely used words but also extremely common words like the examples this paper has focused on, *dikkat* 'attention, caution' and *harf* 'letter'. Moreover, there are no clear segmental cues to mark these words as being more foreign (contra Lewis (1967)). We find near-minimal pairs of which one exhibits the usual opaque /a/ but the other, the unusual transparent /a/:

- (102) Near-minimal pairs
a. exceptional: *harf-ler* 'letter'
b. regular: *zarf-lar* 'envelope', *sarf-lar*

We might suspect /ikk/ or /kk/ of being markers for an exceptional cophonology. Searching TELL for words containing /ikk/ turns up just three morphemes that internally contain /ikk/: *dikkat* 'caution', *rikkat* 'softness' and *sikke* 'coin stamp'. All take front harmony, so this tiny data set suggests that the sequence /ikk/ in a morpheme is a good cue that front harmony will be required. Since most of the exceptional harmonizers do not contain /ikk/, however, this cue is clearly insufficient to pick out the entire cophonology or stratum we would like to distinguish.

Searching TELL for /kka/ turns up 23 matches of which *dikkat*, *rikkat* and the derivatives of *dikkat* are the only covert harmonizers, so /kka/ is not a good cue to front harmony. Likewise, /kk/ yields 83 matches of which just shy of half (41) exhibit front harmony – /kk/ on its own does not predict front harmony at all.

Another suspect might be the Arabic ending /-at/. However, TELL provides 373 matches ending in *-at*, of which only 44 take front suffixes. The long /-aat/ is a better candidate as a cue for transparency: TELL yields 17 examples of words ending in /-aat/ in the nominative and taking front suffixes (ex. *saat*, *ziraat*, *itaat*), out of 22 matches for /-aat/. But even /aat/ is not a reliable cue for front suffixes:

(103) Words ending in -aat which take back suffixes

- a. *müracaat*
- b. *mümanaat*
- c. *icraat*
- d. *mutavaat*

It is especially notable that (103)a-c take back suffixes, because not only do they end in /-aat/ but they even contain front vowels.

Also note that *saat(-i)* 'hour, clock' can combine with morphemes from other languages in compounds: *ampersaat* (+French *amper* 'amp'; 'amp hour'), *anasaat* (+native Turkish *ana* 'mother': 'central clock'). These derivatives still take exceptional front suffixes. A cophonologies or constraint indexation approach would have to account for this mixing of morphological classes.

In short, a cophonologies or constraint indexation analysis would require classes that lacks phonological and morphological distinguishing markers. Moreover, speakers I consulted do not report words like *harf* and *dikkat* as “feeling” different, although they were clearly aware of the distinction between native Turkish words and Arabic or Persian loans. Taken together, this evidence suggests a cophonologies or

indexed constraint account is inappropriate for the Turkish data.

5.4 Theoretical comparison: FDT and other theories of vowel harmony

This section briefly compares FDT to existing theories of vowel harmony, and discusses their similarities and differences, concluding that FDT extends previous theories in a way necessary to represent the cases of exceptional transparency in Turkish that are presented in this paper.

One of the first analyses of Turkish vowel harmony is the root-markers approach of Lightner (1965), in which each root is marked as front or back. FDT uses the insight of root markers that harmony is represented on the word level, not the segment level. However, FDT is dramatically more flexible than root markers, able to represent disharmonic roots and invariant suffixes, since the constraints that require domains to correspond to words are violable. In this, FDT resembles other domain-based theories of harmony situated in Optimality Theory (Prince and Smolensky 1993).

Current domain-based theories are Cole and Kisseberth (1994)'s ODT, Smolensky (2006)'s headed feature domains, and McCarthy (2004)'s Span Theory. These theories all make use of feature domains that prefer to span whole words. However, as discussed in section 3, existing domain based theories must derive transparency from markedness only, and the exceptional Turkish data presented in this paper present an insurmountable problem for a markedness-dependent account of

transparency. Span Theory, ODT and headed feature domains all maintain that the backness of a featural domain is determined by backness of the segment that “heads” (Smolensky 2006), “sponsors” (McCarthy 2004), or “anchors” (Cole and Kisseberth 1994) the domain, i.e., the rightmost underlyingly backness-specified segment in the domain. This conservative headedness requirement is good for the regular cases, but constrains the representation such that it cannot accommodate the exceptions. In contrast, since FDT has the option of motivating embedding and transparency with faithfulness, the possibility of exceptional transparency falls out naturally from FDT.

The unheaded feature domains proposed by FDT may recall the prosodies of Firthian Prosodic Analysis, a non-generative strand of phonology. Firthian Prosodic Analysis (FPA) conceives of phonology/phonetics in a radically different way from traditional feature theory. FPA diverges from generative phonology and feature theory much more dramatically than FDT does; however, FDT and FPA have in common a conception of the phonological equivalent of phonetic features as being independent of individual segments. For FPA this is expressed in the fundamental independence of prosodies (which express syntagmatic relations) from phonematic units (which express paradigmatic relations) (Ogden and Local 1994). For FDT, this is expressed as the independence of feature domains from individual segments -- the proposal of unheaded feature domains. That is, FDT's feature domains have a conceptual ancestor in FPA's prosodies.

Many current theories of vowel harmony resemble FDT in that they function

within Optimality Theory, using violable constraints. The declarative identity approach to vowel harmony (Bakovic 2000), implemented with the constraint AGREE that requires adjacent vowels to have identical values for the harmonizing feature, would require suffixes on exceptional roots to agree with the root as usual. Like ODT, AGREE has no mechanism for representing exceptions. The same goes for approaches based on underspecification and ALIGN constraints, such as Kirchner (1993). These approaches use feature spreading to derive harmony, and featural co-occurrence restrictions to block spreading. But the exceptional words investigated in this paper lack an appropriate feature to spread onto their suffixes. There is no room in the underlying representation to model exceptions.

An autosegmental approach or its direct adaptation in Nevins's (2010) Search and Copy attributes the front suffixes on exceptional words to the presence of an (inaudible) [-back] feature on the final consonant in the word. This analysis completely misses the generalization that all the exceptions involve /a/ as the final vowel. Analyzing the exceptional suffixation pattern as consonant-driven harmony can represent the exceptional words, but only at the expense of positing inaudibly different front and back variations on all the consonants in the Turkish inventory. As discussed in Section 2.2, this approach lacks phonetic grounding and makes incorrect predictions, failing to address the important generalization that only words ending in /a/ exceptionally take front suffixes.

To summarize, all of the above-mentioned theories derive transparency from

constraints on featural co-occurrence (Cole & Kisseberth 1994, Kirchner 1993, Kimper 2011), or by making reference to contrastiveness (Nevins 2010). This leaves no room for lexical exceptions, which seems like a mistake given that many languages contain classes of words whose phonological behavior used to be transparent but has become opaque through diachronic changes.

(104) Summary

Desirable qualities in an analysis of apparent harmony failure	C-based	/a/-based	FDT
no stipulative notation	✗	✗	✓
explains why only /a/ can fail to trigger harmony	✗	✓	✓
uses the same mechanisms for regular harmony	✓	✓	✓

6 Conclusion

Motivated by a pattern of exceptional transparency in some Turkish roots, this paper has proposed Feature Domain Theory. FDT extends the theory of headed feature domains developed by Smolensky (2006). Headed feature domains in previous theories are only targets for markedness constraints, not faithfulness, since they are entirely built by Gen. FDT innovates by proposing underlying, unheaded featural domains. These are similar to Firthian prosodies in being independent of individual segments, and similar to the phonological units of Articulatory Phonology in being gestures that span multiple segments. FDT's feature domains are present in the input, making them targets for faithfulness as well as markedness. Thus, exceptional

transparency as in *harf-ler* can be captured by using a marked structure (embedding) in the input. Normal harmonic processes remain in force. But since embedding is preserved by faithfulness constraints, the suffix harmonizes not with the linearly-nearby but embedded /a/. Instead it covertly harmonizes with the outermost domain, which is [-back]. This is exceptional transparency, and it obeys many of the same principles that govern systematic transparency.

FDT, then, uses the same constraint ranking and representational mechanisms to account for overt and covert harmony in Turkish. A thorough account of harmony in Turkish must somehow distinguish the roots that trigger overt harmony on suffixes from those that trigger what I've termed covert harmony. The previous consonant-based analysis (C&S 1982) does this by marking the final consonant in the covert-harmonic roots. A vowel-driven account would mark the vowel in these words as exceptional. Both of these approaches pin the surprising front harmony on individual segments. But given that these individual segments do not themselves phonetically realize their supposed frontness, a segmental explanation seems suspect.

Instead, FDT takes a structural approach to covert harmony. Roots exhibiting covert harmony are front roots containing an embedded back domain. This analysis avoids the problematic attribution of frontness to a segment that does not sound “front.” It treats the frontness as a property of the root as a whole, and the covert harmony as the result of a more complex feature domain structure. In order to achieve this result, FDT requires feature domains to be independent of individual segments.

Therefore, FDT represents every feature as a domain. A feature domain may contain multiple segments—as with backness domains in a harmonic word in Turkish—or a single segment—as with backness domains in an English word, or height domains in Turkish. Thus, FDT's feature domains replace traditional feature theory.

In FDT, as in previous domain-based accounts of harmony (Smolensky 1993, 2006; O'Keefe to 2007; Cole and Kisseberth 1994), harmony is driven by a markedness constraint that prefers the minimal number of feature domains per word. For FDT, this constraint is *FD. Of course, each feature behaves differently even within a language; no language has harmony over all features at once. So constraints on feature domains are cued to particular features. The active version of *FD in Turkish is *FD(back).

Harmony arises when *FD is high-ranked for some feature, driving a feature domain to span a word (in whole or part)¹⁹. This paper examined backness harmony driven by *Domain(back); nasal harmony would be motivated by *Domain(nasal), and rounding harmony by *Domain(round). A feature like voicing for which no harmony systems exist lacks a corresponding *FD constraint. That is, there is presumably no *Domain(voice) constraint to motivate the unattested voicing harmony. Alternately, *Domain(voice) may exist, but there may be no corresponding Align(voice) constraints.

Harmony along a feature leads to word-spanning feature domains. These large

¹⁹ See Smolensky (2006) for accounts of systematic transparency and opacity using embedded feature domains in conjunction with language-specific featural co-occurrence constraints.

feature domains posited by FDT reflect articulatory realities. The data is clearest with rounding harmony. Boyce (1990) found that when English speakers pronounce a word with multiple round vowels, there is a “valley” in the rounding – that is, each round vowel receives its own rounding gesture, as expected given that English does not have rounding harmony. In contrast, Turkish speakers use a single rounding gesture for a word with multiple round vowels, as predicted by FDT since Turkish does exhibit rounding harmony. This kind of evidence has motivated previous arguments that harmony is strictly local for Turkish (Ní Chiosáin and Padgett 2001). Even though most consonants do not obviously participate in backness harmony, coarticulation effects make it sensible to say they are still affected by that harmony process. FDT represents this directly, since segments that are not contrastive for backness will still be contained in backness domains.

Unlike previous domain-based theories of harmony, FDT claims that feature domains are not special to languages exhibiting harmony. What distinguishes harmonic languages from non-harmonizing languages is the size of domains and their ability to expand. A non-harmonizing language like English still has feature domains, but these domains are segment-sized. Essentially, the FDT representation of non-harmonizing features isomorphic to traditional feature theory. One difference, however, would occur when adjacent segments are locally required to agree in place (in+possible → impossible), voicing (cleave+t → cleft), etc. because of coarticulation effects. There, the agreeing segments would be represented as contained in a single

place domain, since lexicon optimization (Ito, Mester and Padgett 1995) in conjunction with *FD will drive segments that agree for a feature to be pulled into the same feature domain.

There are a number of remaining issues. First, the phonetic basis of /a/'s transparency would be better established by experimental evidence. An experiment along the lines of Gafos and Benus (2003) for Hungarian, conducted to compare Turkish words like *harf* (front harmony) vs. *zarf* (back harmony), could substantiate or cast down upon the claims of FDT. Another open question best answered experimentally is whether the pattern examined in this paper is productive for Turkish speakers. My consultant reported intuitions regarding the acceptability of exceptional transparency for words he had never seen before, suggesting that there might be a lexical similarity effect at work.

A Turkish data question has to do with directionality. Harmony in Turkish has been argued to be strictly progressive (although epenthesis in loanwords complicates the picture – see Kabak 2011). The current analysis eschews any directionality. However, this may not be desirable when invariant suffixes are taken into account, since these always trigger harmony on the suffixes that follow them, but never on those that precede them. In all likelihood, the constraint system proposed here should have Align-right incorporated into it.

The topic of Alignment in turn raises the question of whether Turkish harmony displays an asymmetry analogous to that in Hungarian, where Align[+back]

outranks Align[-back]. This may connect to the asymmetrical behavior of palatal [-back] consonants, which are almost always opaque, compared to velar [+back] consonants, which are often transparent. I leave an investigation of the constraints on embedding disharmonic consonants in Turkish, and their interaction with coarticulation, to future work.

Most important, future work should seek out other cases of exceptional transparency to determine what patterns hold cross-linguistically, and validate or invalidate the predictions made in this paper. In all likelihood, it will turn out that the current formulation of FDT overgenerates and more constraints are needed, but no conclusions can be drawn without more data.

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