Feature domains and FAITH-driven transparency in Turkish

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Nov. 20, 2015 at Yale Phonology Reading Group*

1. Introduction

Turkish is well-known as exhibiting a clear pattern of backness harmony (1).

(1) Regular pattern of backness harmony in Turkish

<table>
<thead>
<tr>
<th>Nom.</th>
<th>Dative</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. kadran</td>
<td>kadran-a, *kadran-e</td>
<td>‘clockface’</td>
</tr>
<tr>
<td>b. beden</td>
<td>beden-e, *beden-a</td>
<td>‘body’</td>
</tr>
</tbody>
</table>

→ INTUITION: all agreeing vowels share a single specification of the shared property

Ways to formalize this intuition:
* AUTOSEGMENTAL SPREADING: Clements and Sezer 1982, or in OT, ALIGN (Kirchner 1993, a.o.), SPREAD (Kimper 2011)
* FEATURE DOMAINS: ODT (Cole & Kisseberth 1994), Span Theory (McCarthy 2004), headed feature domains (Smolensky 2006)

All still require a segmental harmony trigger¹, predicting, e.g., that front harmony can't be required if there is no front segment in a word.

Goals of this talk:
* present Turkish data that require a non-segmental front harmony trigger
* propose an analysis based on a new representation of harmony with

¹ feature domains in input (Feature Domain Theory)
* conclude by considering how FDT can describe other harmony systems (recessive-dominant, root-governed, directional, ...)

2. Background: Regular backness harmony in Turkish

8 vowels in a 2 by 2 by 2 vowel space: backness, height, and rounding. Note: This handout uses Turkish orthography.²

All eight vowels participate in backness harmony³: alternate with height- and rounding-matched counterparts.

(2) Vowel inventory of Turkish

<table>
<thead>
<tr>
<th>[-back]</th>
<th>[+back]</th>
<th>Unspecified (archephonemes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[+high]</td>
<td>i</td>
<td>ü</td>
</tr>
<tr>
<td>[-high]</td>
<td>e</td>
<td>o</td>
</tr>
<tr>
<td>[+low]</td>
<td>a</td>
<td></td>
</tr>
</tbody>
</table>

Visible in suffix vowels which harmonize with nearest stem vowel (3).

(3) Normal backness harmony (plural /-lEr/ realized as [ler] or [lar]):

a. Front root:
   i. gün + IEr  →  gün-ler  ‘days’
   ii. gündüz + IEr  →  gündüz-ler  ‘daytimes’

b. Back root:
   i. ay + IEr  →  ay-lar  ‘months’
   ii. ayt + IEr  →  ayt-lar  ‘bears’

c. Disharmonic root:
   i. ka:til + IEr  →  ka:til-ler  ‘murderers’
   ii. kitap + IEr  →  kitap-lar  ‘books’

² IPA equivalents of Turkish letters: vowels: i = /ɯ/, a = /ɑ/, ü = /y/, ö= /ø/; consonants: c = /dʒ/, ç = /tʃ/, and ş = /ʃ/.
³ This paper does not address the rounding harmony that affects high vowels.
3 The puzzle: the apparent failure of harmony

Sometimes suffixes fail to harmonize with the nearest root vowel (4):

(4) Apparent exceptions to harmony

<table>
<thead>
<tr>
<th>Nom.</th>
<th>Dative</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. dikkat</td>
<td>dikkat-e, *dikkat-a</td>
<td>'attention'</td>
</tr>
<tr>
<td>b. kabir</td>
<td>kabr-e, *kabr-a</td>
<td>'tomb'</td>
</tr>
<tr>
<td>c. harf</td>
<td>harf-e, *harf-a</td>
<td>'letter'</td>
</tr>
<tr>
<td>d. rab</td>
<td>rabb-e, *rabb-a</td>
<td>'God'</td>
</tr>
</tbody>
</table>

Previously unnoticed: the vowel failing to trigger harmony is always /a/.

- No words like *hurf-ler to correspond to harf-ler.
- The only previous account (Clements & Sezer 1982; henceforth C&S): final consonant is underlyingly opaque and triggers front harmony.

Note: /k g l/ have front/back variants (5), so some consonants can be harmony triggers – really just /l/, though, since palatal /k/ never surfaces word finally (C&S). I treat front /l/ as a vowel for harmonic purposes and ignore the cases where it triggers harmony because it is the last backness-contrastive segment in the word (6).

(5) Contrastive backness for /k, g, l/ (Clements & Sezer 1982)

| a. bol | 'abundant' vs. bolʲ | 'cocktail'
| b. kar | 'snow' vs. kar | 'profit'
| c. gaz | 'gas' vs. gavur | 'infidel'

(6) word-final /l/ triggers front harmony (C&S 1982; Kabak 2011)

<table>
<thead>
<tr>
<th>Nom.</th>
<th>Dat.</th>
<th>Gloss</th>
</tr>
</thead>
</table>
| a. kalʲp | kalb-e | 'heart'
| b. mareşalʲ | mareşal-e | 'marshal'
| c. sualʲ | sual-e | 'question'

More data: front suffixes required after /a/

In the consonant-driven account, any consonant, including those which are never contrastive for backness, must be able to be underlyingly specified [-back].

(7) front suffixes after /-ak/ (C&S)

<table>
<thead>
<tr>
<th>Nom.</th>
<th>Acc. in C&amp;S</th>
<th>Acc. in TELL(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. infilak</td>
<td>infilak-i (C&amp;S)</td>
<td>~ infilak-i (harmonic)</td>
</tr>
<tr>
<td>b. helak</td>
<td>helak-i</td>
<td>~ helak-i</td>
</tr>
<tr>
<td>c. emlak</td>
<td>emlak-i</td>
<td>~ emlak-i</td>
</tr>
<tr>
<td>d. istimlak</td>
<td>istimlak-i</td>
<td>~ istimlak-i</td>
</tr>
</tbody>
</table>

(8) front suffixes after /-at/

| a. dikkat | dikkat-i | 'attention'
| b. menfaat | menfaat-i | 'interest'
| c. beraat | beraat-i | 'acquittal'
| d. liya:kat | liya:kat-i | 'merit'
| e. saat | saat-i | 'hour'
| f. lugat | lugat-i | 'dictionary'

(9) front suffixes following /-arC/

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

(10) front suffixes following underlying /-ad/

| vaat | vaadi | 'promise' |

Yet more data: Epenthesis of a front vowel after /a/ (11):

- harmonic epenthesis to repair illegal consonant clusters in ~200 roots
- disharmonic epenthesis of [i] in about a dozen roots
- C&S attribute this frontness to the medial root consonants /b c h v/.

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\(^4\) Turkish Electronic Living Lexicon, an online database provided by UC Berkeley.
(11) Disharmonic epenthesis and suffixes with root vowel /a/

<table>
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<th>Root</th>
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</thead>
<tbody>
<tr>
<td>a. /kabr/</td>
<td>kabir</td>
<td>kabr-e</td>
<td>'tomb'</td>
</tr>
<tr>
<td>b. /hacm/</td>
<td>hacim</td>
<td>hacm-e</td>
<td>'volume'</td>
</tr>
<tr>
<td>c. /bahs/</td>
<td>bahis</td>
<td>bahs-e</td>
<td>'bet'</td>
</tr>
<tr>
<td>d. /kavm/</td>
<td>kavim</td>
<td>kavm-e</td>
<td>'tribe'</td>
</tr>
</tbody>
</table>

(12) Consonants do not predict the quality of the epenthetic vowel

<table>
<thead>
<tr>
<th>Environment</th>
<th>Disharmonic root</th>
<th>Harmonic root</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. b _ r:</td>
<td>/kabr/</td>
<td>/sabr/</td>
</tr>
<tr>
<td>b. _ m:</td>
<td>/hacm/</td>
<td>/hasm/</td>
</tr>
<tr>
<td>c. h_s:</td>
<td>/bahs/</td>
<td>/şahs/</td>
</tr>
</tbody>
</table>

→ segment-driven analysis requires a lot of phonetically unmotivated [-back] features on consonants, and doesn't account for the specialness of /a/

Alternative analysis: something about these particular words requires them to take front suffixes – not a characteristic of any of their segments in isolation.

4 Feature Domain Theory

Reasons to consider harmony a characteristic of the word in Turkish:
- domain of harmony = the word (all the vowels in a word should agree)
- statistical generalizations about the lexicon: harmony is active within roots (Kabak & Weber 2013, pace C&S).
- experimental evidence: Turkish speakers...
  - use harmony to segment words (Kabak et al 2010)
  - treat all the vowels in a harmonic word as having one backness specification by reharmonizing in a “language game” (Harrison and Kaun 2001)
  - use one rounding gesture across a whole word (Boyce 1990)
- root-internal epenthesis is harmonic (13)

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

<table>
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<th>Root</th>
<th>Nom.</th>
<th>Dative</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. /cebr/</td>
<td>cebir</td>
<td>cebr-e</td>
<td>'algebra'</td>
</tr>
<tr>
<td>b. /sabr/</td>
<td>sabir</td>
<td>sabr-a</td>
<td>'patience'</td>
</tr>
<tr>
<td>c. /uğr/</td>
<td>uğur</td>
<td>uğr-a</td>
<td>'luck'</td>
</tr>
<tr>
<td>d. /ömür/</td>
<td>ömür</td>
<td>ömür-e</td>
<td>'life'</td>
</tr>
</tbody>
</table>

One existing formalization of word-level harmony: headed featural domains (Smolensky 2006), as in (14).

(14) Turkish harmony with headed feature domains

a. harmonic root: violates *Head minimally
   ayt +1Er → (ayt-lar)

b. disharmonic root: violates *Head multiple times
   kitap+1Er → (k(ı)(tap(lar))

c. embedded domain: violates *Embed
   dikkat +1Er → (dikk(a)t-ler)

• Basic idea: Featural domains are constructed by Gen.
• A feature domain’s value (+/-) is determined by its head, a segment in it (underlined in (14)). Segments in a domain realize its feature value.
• *Head drives harmony.
• Transparency results when segments occur in embedded feature domains (14)c – but embedding is only driven by markedness, for Smolensky.

PROBLEM: For Turkish, there is no markedness reason to construct the output feature domain structure in (14)c, therefore headed feature domains still can’t account for harf-ler and dikkat-ler

• No segment to head a [-back] domain and trigger front suffixes, so no way for Gen to construct an appropriate [-back] domain.
• No motive for embedding /a/ since it normally participates in harmony.

SOLUTION: put embedded feature domains in the input, so faithfulness can drive the transparency of /a/ in words like (dikk(a)t-ler)

→ HEADLESS FEATURE DOMAINS

• independent of segments
• replace traditional segmental features
• present in the input to phonology → faithfulness drives non-participation of /a/ in harf-ler and dikkat-ler
- embedded domains in input result in transparency driven by faithfulness: lexically conditioned transparency

**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 categories larger than the syllable—typically the word.

This requirement is enforced by anti-structure constraints which are high-ranking but not necessarily undominated.

c. F-domains are interpreted according to the algorithm in (16).

**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.
   iv. Return to (i).
   v. If Φ is null, terminate.

**Well-formedness conditions on F-domains (constraints on GEN)**

a. An F-domain must contain 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. No overlapping but not embedded domains.

**Two feature systems?**

- Proposal: In FDT, **membership in a F-domain replaces segmental featural specification** in a traditional theory of features.

- In a language without harmony, F-domains coincide with segments, making them isomorphic to traditional featural specifications. (e.g., in English).

**4.1 Harmony with harmonic roots**

(18) **Harmonic roots: FD coincides with root**

a. \((EyI)_{\text{y}} + 1\text{Er} \rightarrow (ayi-lar)_{\text{y}}\), 'bears'

b. \((gUndUz)_{\text{y}} + 1\text{Er} \rightarrow (gündüz-ler)_{\text{y}}, 'daytimes'\)

In a harmonic root, such as ayi 'bear' (18a):

- only one underlying backness domain which spans the whole word
- When plural marker -\(1\text{Er}\) is added, phonology incorporates it into the existing backness domain.
- Phonetics interprets backness domain: aylar (all back vowels)

Backness harmony is motivated by markedness constraints (19)-(20):

(19) **WORD~FD(BACK) = WD~FD:** Every word should have a corresponding backness domain. Assign one violation mark for every word that is not completely spanned by a single backness domain.  
*Penalizes disharmony. Schematically: *(...)...*  

(20) **FD(BACK)~WORD = FD~WD:** Every backness domain should correspond to a word. Assign a violation for every backness domain within a word that does not span the whole prosodic word.  
*Penalizes embedding or disharmony. Schematically: *(...)(...)*  

For Turkish, (19)-(20) play the same role so I will just make reference to FD~WD.

5 The equivalent of Align for Smolensky (2006). Also note that all constraints in this handout that refer to F-domains (FD), target a particular F(eature) – backness, in this talk. For readability, this indexation to backness is usually left implicit. Thanks to Armin Mester for pointing this out.
FD~Wd and DEP (21) motivate violations of the faithfulness constraint

*EXPAND (22) when suffixes are added. (*EXPAND’s counterpart *CONTRACT (23) is unviolated and undominated.)

Note: I assume input underspecification on harmonizing suffixes but this is not crucial.

(21) **DEP(BACK):** Assign a violation for every backness domain present in
the output that is not present in the input.

(22) **EXPAND(BACK):** Don't expand a backness domain. For backness
domains D in the input and D' in the output, where D' stands in a
correspondence relation to D, assign a violation if D' contains more
segments than D.

Schematically: \( \ldots(\ldots) \rightarrow \ast \ldots(\ldots) \)

(23) **CONTRACT(BACK):** Don't remove segments from a backness domain.
For featural domains D in the input and D' in the output, where D'
stands in a correspondence relation to D, assign if D' contains fewer
segments than D.

Schematically: \( \ldots(\ldots) \rightarrow \ast \ldots(\ldots) \)

(24) **CONTRACT >> FD~Wd >> *EXPAND**

(25) Incorporating a suffix into the existing FD avoids violating FD~Wd

<table>
<thead>
<tr>
<th></th>
<th>/hEvE/)B+1Er/</th>
<th>DEP(FD)</th>
<th>*CONTRACT</th>
<th>FD~Wd</th>
<th>*EXPAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (hava-lar)B</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. (hava)B+1Er</td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. (hava)B(-lar)B</td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td>**</td>
</tr>
</tbody>
</table>

4.2 Harmony with disharmonic roots

Disharmonic roots: multiple F-domains side by side in the input (26).

(26) Regular disharmonic roots violate FD~Wd

a. (kI)(tEp)+lEr \rightarrow (ki)(tap-lar) ‘books’
b. (sE)Ep+lEr \rightarrow (sa)lep-ler ‘drinks’

Faithfulness to underlying featural domains preserves disharmonic roots. Thus
FD~Wd must be dominated by MAX (27), for the ranking in (28):

(27) **MAX(BACK):** Assign a violation for every backness domain present in
the input that is not present in the output

(28) MAX, DEP *CONTRACT >> FD~Wd >> *EXPAND

(29) MAX(BK) requires disharmonic roots to surface faithfully

<table>
<thead>
<tr>
<th></th>
<th>/kI(tEp)B/</th>
<th>MAX(FD)</th>
<th>FD~Wd</th>
<th>*EXPAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (kI)(tap)B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. (kitep)B</td>
<td>*!</td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. (kıtap)B</td>
<td>*!</td>
<td>**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3 Explaining the puzzle: covert harmony

When a suffix apparently fails to harmonize, as in dikkat-lar (30):

- root as a whole is a [-back] domain, final vowel is in a [+back] domain.
- As usual, phonology incorporates suffix into nearest featural domain
- Consequently, the phonetics applies [-back] to the segments in the
  suffix.
- The embedded /a/ is unable to trigger harmony (looks transparent)
  because the inner [+back] featural domain is interpreted after the outer
  [-back] domain, so that the final root vowel receives the value [+back].
(30) Embedded featural domains produce disharmonic suffixes
   a. \((dIk(kEt)_e, + lEr) \rightarrow (dIk(kat)_a, ler)\) → 'attentions'
   b. \((h(E)_e, rf) + lEr \rightarrow (h(a), rfler)\) → 'letters'

Embedding one domain in another violates *EMBED (Smolensky 2006):

(31) *EMBED: Assign one violation for every backness domain that is contained within another backness domain.
   *Penalizes every segment in an embedded domain. Schematically: *\((.())\)

(32) FAITH(FD) >> *EMBED

(33) FAITH(FD) preserves an embedded domain

<table>
<thead>
<tr>
<th></th>
<th>DE(FD)</th>
<th>MAX(FD)</th>
<th>CONT-CONTRACT</th>
<th>FD-WD</th>
<th>EMBED</th>
<th>EXPAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>((dIk(kEt)_e, rE))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>((dIk(kat)_a, ler))</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>((dIk(kat)_a, ler))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Transparency results from *EXPAND:
- Adding suffix to embedded domain, (34)b: two *EXPAND violations
- Adding suffix to outermost domain, (34)a: only one *EXPAND violation

(34) *EXPAND require suffixes to be incorporated into the outermost domain

<table>
<thead>
<tr>
<th></th>
<th>FAITH(FD)</th>
<th>FD-WD</th>
<th>EXPAND</th>
<th>EMBED</th>
<th>EXPAND</th>
<th>EMBED</th>
</tr>
</thead>
<tbody>
<tr>
<td>((dIk(kEt)_e, + lEr))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>((dIk(ket)_a, re))</td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>((dIk(ket)_a, re))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Summary: key claims of Feature Domain Theory

- Backness is specified on backness domains.
  - Language without backness harmony: backness domains = segments
  - Language with backness harmony (e.g. Turkish): backness domains larger than segment, preferentially span entire words.
- Featural domains: headless, present in both input and output of phonology.
- The phonetics interprets featural domains to provide backness specifications on the individual segments.

5. /a/ is special

Observation to account for: The final vowel in roots exhibiting covert harmony is always /a/. No *hurf-ler, *horf-ler or *hırf-ler to correspond to harf-ler.

Solution: undominated markedness constraint *EMBED[-low]

(35) *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: *\((\text{....}(i), \text{...})\)

*EMBED[-low] is unviolated, therefore undominated: only the low vowel /a/ is able to occur in embedded featural domains.
- *EMBED[-low] outranks FAITH(Backness Domain) and IDENT constraints governing height
- If the input contains a high vowel in an embedded domain as in (36), the output will either:
  - alter the height and rounding of the vowel to make it an /a/ as in the winning candidate (with the given constraint ranking) or delete the embedded domain as in candidate b (if IDENT(round))

6. Covert harmony words are borrowed from Arabic which lacks /o/ and /ı/, so the lack of horf-ler and hırf-ler is not particularly surprising.
7. Because /e/ can surface allophonically as the low vowel [æ], IDENT(low) must be ranked quite low. See §5.2.
8. In FDT, every Ident(F) is actually Ident(F-domain). For the problem at hand, other F-domains behave in a way that is isomorphic to traditional segmental feature
or IDENT(high) is ranked as high as FAITH(BD) instead of being ranked low like IDENT(low))

(36) A non-low vowel cannot surface in an embedded domain

(37) Vowel inventory of Turkish

<table>
<thead>
<tr>
<th>[-back]</th>
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<th>Unspecified (archephonemes)</th>
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</thead>
<tbody>
<tr>
<td>[+high]</td>
<td>i</td>
<td>ü</td>
</tr>
<tr>
<td>[-high]</td>
<td>e</td>
<td>ö</td>
</tr>
<tr>
<td>[+low]</td>
<td>[æ]</td>
<td>a</td>
</tr>
</tbody>
</table>

5.1 Phonetic grounding for lower markedness requirements on /a/?

Embedding results in a conflict ([+back] within [-back]). Why does /a/ suffer less from this conflict than, e.g., /u/?

- phonetically, low vowels are less contrastive for backness than higher vowels, because low vowels have less articulatory space in the front/back dimension (Grant McGuire, p.c.). i.e., /u/ is really back whereas /a/ is just kind of back → worse to have /u/ in [-back] domain.⁹ Like /i/ and /e/, /a/ may be more perceptually stable under differing articulations (cf Kiparsky & Pajusalu 2003).
- phonological motive pertaining to the shape of the Turkish vowel space. /a/ lacks an exactly height-matched front counterpart phoneme; it alternates with the mid-vowel /e/.

5.2 An /a/-based account?

what if: the exceptional behavior of words like harf results from a special feature on the vowel /a/, and nothing else?

- i.e., /a/ sometimes has [-back] feature, rather than the usual [+back], and in these exceptional cases, /a/ triggers front harmony.
- Underlyingly /æ/? But can’t have * [+low, +front] to rule it out.

(38) [æ] as an allophone of /e/

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

Because of the allophonic alternation [e]~[æ], an /a/-based account requires a chain-shift (→ constraint conjunction) AND some form of serialism (→ Harmonic Serialism, which has trouble with chain-shifts).

6. Conclusion

Feature Domain Theory:

- extends headed feature domains (Smolensky 2006)
- innovates in proposing underlying, unheaded featural domains → FDT represents every feature as a domain (which may or may not contain multiple segments), thus replacing traditional feature theory.
- accounts for apparent failures of harmony as transparency driven by faithfulness harmony
- cf. other cases of “Trojan vowels” (Kramer 2003), such as Hungarian /i/ (normally transparent) which sometimes requires back suffixes.
Implications of FDT for harmony systems in general

- harmony arises when a feature domain spans a word (in whole or part), driven by high-ranking FD~Wd markedness constraints
  - ex. FD(back)=wd, FD(round)=wd, FD(nasal)=wd...
- a feature like voicing for which no harmony systems exist: no FD(voice)=wd constraint to motivate harmony

In FDT, what ranking is necessary for harmony to occur at all?

- harmony to resolve underspecification: 
  - w=FD >> *Expand, or Dep >> *Expand (39) (contrast (40))
- harmony to eliminate underlying disharmony within the word: 
  - w=FD >> Max, *Expand (41) (contrast (42))

(39) Harmony resolves underspecification: w=FD >> *Expand

<table>
<thead>
<tr>
<th>(Eyl)B+Er/</th>
<th>w=FD</th>
<th>Dep(FD)</th>
<th>*EXPAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (ayi-lar)B</td>
<td>*</td>
<td><img src="image-url" alt="" /></td>
<td></td>
</tr>
<tr>
<td>b. (ayi)B(-ler)F</td>
<td><img src="image-url" alt="" /></td>
<td><img src="image-url" alt="" /></td>
<td></td>
</tr>
</tbody>
</table>

(40) Harmony does not resolve underspecification: *Expand >> w=FD, Dep

<table>
<thead>
<tr>
<th>(Eyl)B+Er/</th>
<th>*EXPAND</th>
<th>Dep(FD)</th>
<th>w=FD</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (ayi-lar)B</td>
<td><img src="image-url" alt="" /></td>
<td><img src="image-url" alt="" /></td>
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</tr>
<tr>
<td>b. (ayi)B(-ler)F</td>
<td><img src="image-url" alt="" /></td>
<td><img src="image-url" alt="" /></td>
<td></td>
</tr>
</tbody>
</table>

(41) All words are harmonic: w=FD >> Max, *Expand

<table>
<thead>
<tr>
<th>(/kI)_(tEp)B/</th>
<th>w=FD</th>
<th>MAX</th>
<th>*EXPAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (ki)_(tap)B</td>
<td><img src="image-url" alt="" /></td>
<td><img src="image-url" alt="" /></td>
<td></td>
</tr>
<tr>
<td>b. (kitap)B</td>
<td><img src="image-url" alt="" /></td>
<td><img src="image-url" alt="" /></td>
<td></td>
</tr>
<tr>
<td>c. (kitep)F</td>
<td><img src="image-url" alt="" /></td>
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</tr>
</tbody>
</table>

(42) Disharmony possible: Max >> FD~Wd

<table>
<thead>
<tr>
<th>(/kI)_(tEp)B/</th>
<th>MAX</th>
<th>w=FD</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (ki)_(tap)B</td>
<td><img src="image-url" alt="" /></td>
<td><img src="image-url" alt="" /></td>
</tr>
<tr>
<td>b. (kitap)B</td>
<td><img src="image-url" alt="" /></td>
<td><img src="image-url" alt="" /></td>
</tr>
<tr>
<td>c. (kitep)F</td>
<td><img src="image-url" alt="" /></td>
<td><img src="image-url" alt="" /></td>
</tr>
</tbody>
</table>

Assuming FD~Wd >> Max, what rankings produce different types of harmony?

- root-governed harmony: Max-root >> Max (43)
- dominant-recessive harmony, say with + dominant: 
  - *Expand(-) >> *Expand (44)
- directional harmony, say R→L but not L→R: 
  - *Expand(L) >> *Expand (45)

(43) Root-governed harmony: Max-root >> Max

<table>
<thead>
<tr>
<th>(/(+))Root (-)Suffix/</th>
<th>MAX-Root</th>
<th>w=FD</th>
<th>MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (+)</td>
<td><img src="image-url" alt="" /></td>
<td><img src="image-url" alt="" /></td>
<td></td>
</tr>
<tr>
<td>b. (+)(-)</td>
<td><img src="image-url" alt="" /></td>
<td><img src="image-url" alt="" /></td>
<td></td>
</tr>
<tr>
<td>c. (-)</td>
<td><img src="image-url" alt="" /></td>
<td><img src="image-url" alt="" /></td>
<td></td>
</tr>
</tbody>
</table>

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10 See Smolensky (2006) for accounts of systematic transparency and opacity using embedded feature domains in conjunction with language-specific featural co-occurrence constraints.
(44) Dominant-recessive harmony, [+] dominant

<table>
<thead>
<tr>
<th></th>
<th>Expand</th>
<th>Expand</th>
</tr>
</thead>
<tbody>
<tr>
<td>[(-]Root (+)Suffix/</td>
<td><em>boxes</em></td>
<td>*EXPAND</td>
</tr>
<tr>
<td>☞ a. (++)</td>
<td>*!</td>
<td>*</td>
</tr>
<tr>
<td>☞ b. (--)</td>
<td>*!</td>
<td>*</td>
</tr>
</tbody>
</table>

(45) Right-to-left harmony: *Expand(L) >> *Expand

<table>
<thead>
<tr>
<th></th>
<th>Expand</th>
<th>Expand</th>
</tr>
</thead>
<tbody>
<tr>
<td>[(+]Root (--)</td>
<td><em>boxes</em></td>
<td>*</td>
</tr>
<tr>
<td>☞ a. (--)</td>
<td>*!</td>
<td>*</td>
</tr>
<tr>
<td>☞ b. (++)</td>
<td>*!</td>
<td>*</td>
</tr>
</tbody>
</table>

What rankings produce systematic transparency? (ex. /i/ and /e/ in Finnish):
- As in a dominant-recessive system, *Expand[-back] >> *Expand
- high ranking *Embed[+round, -back]
- low ranking Dep and *Embed.

References


TELL. http://linguistics.berkeley.edu/TELL/