A Gradient Harmonic Grammar Account of Lexically-Conditioned Phonetic Variation

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Lexically-Conditioned Grammatical Patterns

- Categorical: Japanese phonotactics (Ito & Mester, 1999)
  - Nasal-voiceless obstruent clusters (*mp) banned only in Yamato stratum.
- Variable: Finnish (Anttila, 2002)
  - Variability: vowel mutation (a->o) vs. deletion.
  - Selection of mutation vs. deletion vs. variation is morpheme-specific.

- Defining feature: Non-gradient
  - Input: Conditioned by lexical *categories*.
  - Output: Alternations among *categorically distinct* variants.

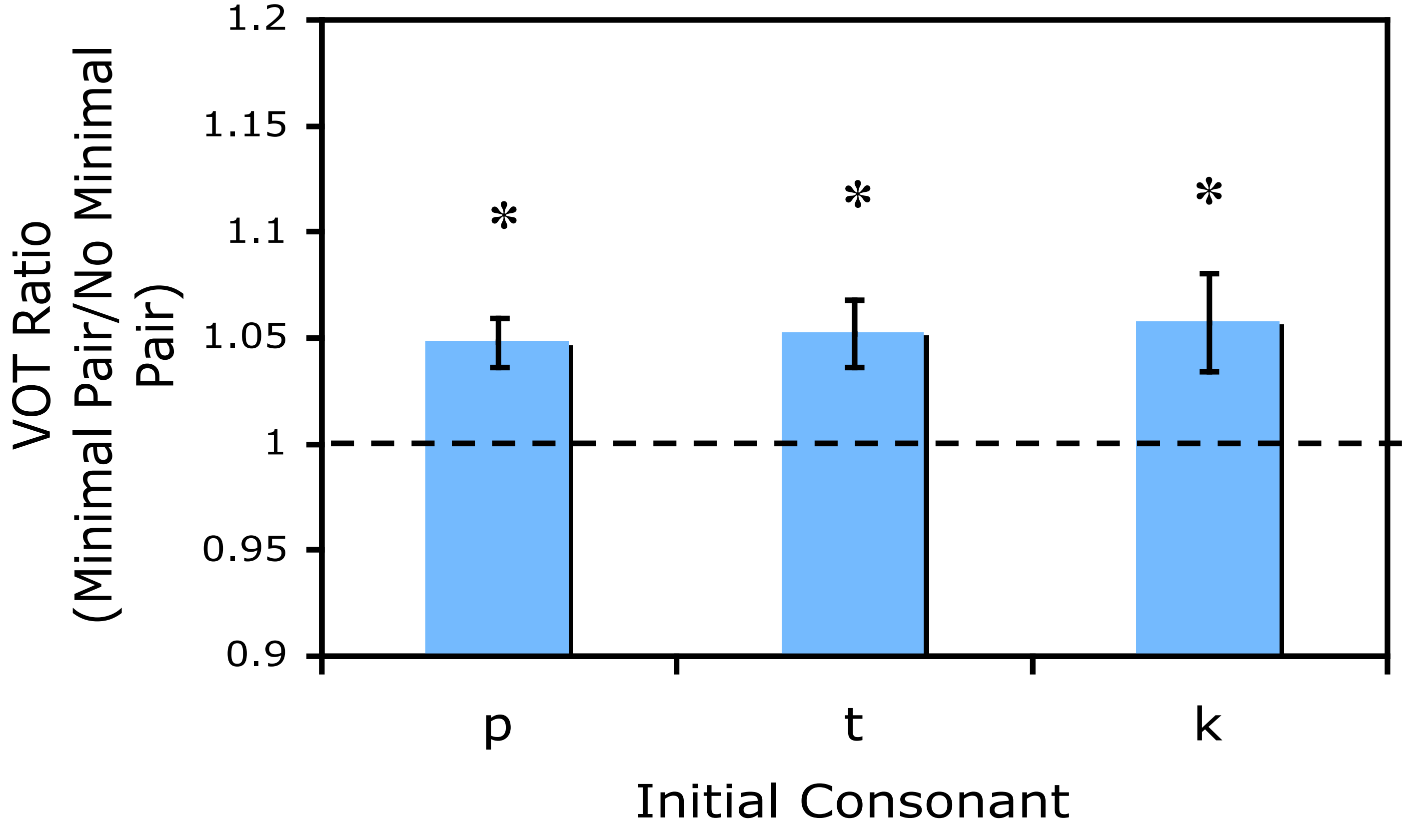
Lexically-Conditioned Phonetic Variation

- Lexical frequency/predictability: High frequency/more predictable forms are *reduced* relative to low frequency/less predictable forms.
  - Shorter durations; more centralized vowels; elision/lenition (and->n; of->uh). (see Aylett & Turk, 2006, for a recent review)

- Neighborhood density: Words phonologically similar to many lexical items are *hyperarticulated* relative to words similar to few lexical items.
  - Vowels in high vs. low density words are less centralized in F1/F2 space
    - (Munson, in press; Munson & Solomon, 2004; Wright, 2004)
  - Similar effects for consonants.

Lexically-Conditioned Phonetic Variation

- Voiceless stops in words that have a minimal pair neighbor (e.g., cod-god) show enhanced VOTs relative to stops in phonetically matched words that do not (e.g., cop-*gop).
  (Baese & Goldrick, 2007)



Lexical and Phonetic Gradience

- Current grammatical accounts of lexical effects on sound patterns capture categorical phenomena.

- Understanding lexically-conditioned phonetic variation requires incorporating gradience.
  - Conditioning factors (frequency, density) are gradient.
  - Phonetic effects (vowel space dispersion; VOT expansion) are gradient.

Gradient Harmonic Grammar Account of Lexically-Conditioned Phonetic Variation

- Gradience of phonetics.
  - Output candidates allow for gradient activation.
  - (following Flemming, 2001; Gafos, 2002, and other work in Articulatory Phonology)

- Gradience of conditioning lexical factors.
  - Variation in activation of representations in the lexicon.
  - Focus: Neighborhood density.

- Lexically-conditioned phonetic variation
  - Constraint interaction in Gradient Harmonic Grammar is sensitive to gradient variation in activation of <u>both</u> input and output representations.
  - (see Gafos & Benus, 2006, for an alternative approach within a dynamical systems framework)

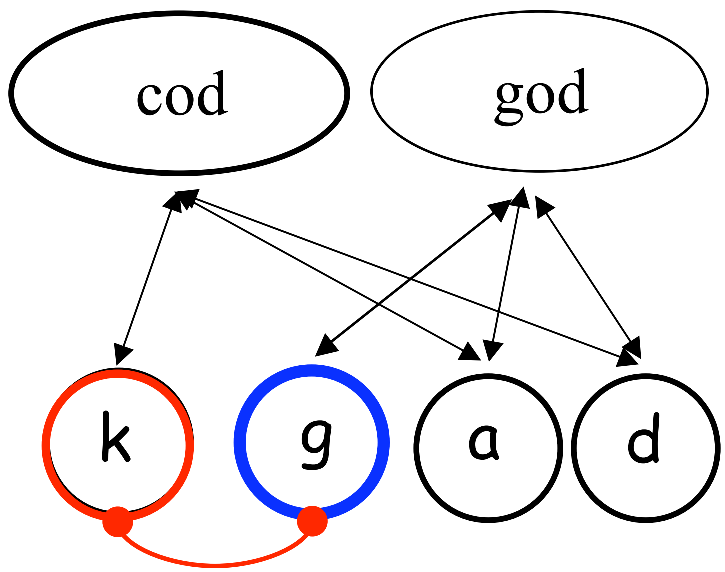
Gradient Lexical Factor: Neighborhood

Feedback activates lexical representation of neighbor.

Non-target phonological representations become active.

Contrasting, highly similar segments compete for same position in string.

(Meyer & Gordon, 1985; Yaniv et al., 1990)



To resolve competition, target segment must grow in activation so as to inhibit competitor.

- Enhanced activation: *Stronger* input to Harmonic Grammar
  - Word without minimal pair neighbor: Weaker competition, so no need to enhance activation of input.

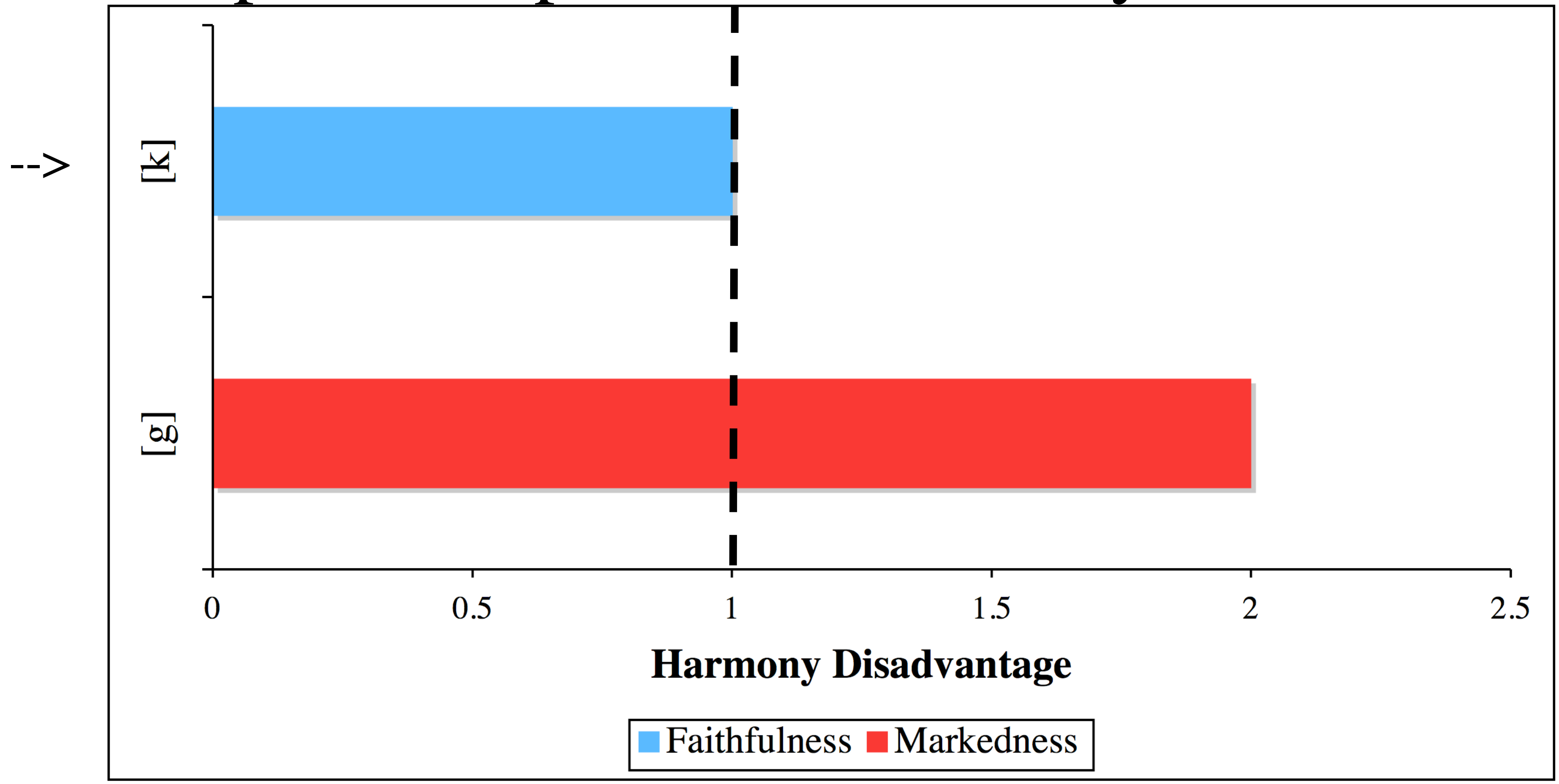
Harmonic Grammars

- Connectionist precursor to Optimality Theory
  - (Legendre et al. 1990; Smolensky & Legendre, 2006; see also Pater et al., 2007)

- Output of grammar is candidate with highest *harmony*.
  - Harmony = sum of weighted constraint violations.

/g/	*[+voi]:–2	ID(voi):–1	HARMONY
--> [k]		–1	–1
[g]	–2		–2

Graphical Depiction of Harmony Differences



/g/	*[+voi]:–2	ID(voi):–1	HARMONY
--> [k]		–1	–1
[g]	–2		–2

Gradient Harmonic Grammars

- Representations: Gradient patterns of activation in range {0,1} over sets of symbolic representational units.
- Default activation levels: 0.1 / 0.9.
  - [+voi]: 0.9 Neutral articulation level for voiced
  - [+voi]: 0.99 Hyperarticulated voiced
- As in connectionist networks (Smolensky, 2006) Harmony reflects gradient activation levels.
  - *[+voi]: Weight: –1
  - Output: [+voi]:0.9 Harmony ≈ –1 * 0.90 ≈ –0.90
  - Output: [+voi]:0.99 Harmony ≈ –1 * 0.99 ≈ –0.99
- Critical factor for lexically conditioned phonetic variation: Gradience in input influences calculation of Harmony.

Calculating Harmony: Faithfulness

- Constraint: ExpressVoice: Weight = –4.1
  - Penalizes outputs that do not maximally express input.
  - Following example above (cop/cod) assume voiceless input.

- Harmony contribution:
  - Weight *
    - Constraint strength
  - (1 – activation of [–voi]) *
    - Prefers hyperarticulated to normal articulation level
  - Activation of /k/
    - ➢Preference is stronger if input is more highly activated (e.g., cod vs. cop)

Calculating Harmony: Markedness

- Constraint: MinimizeEffort: Weight = –1
  – Penalizes outputs with high levels of activation.

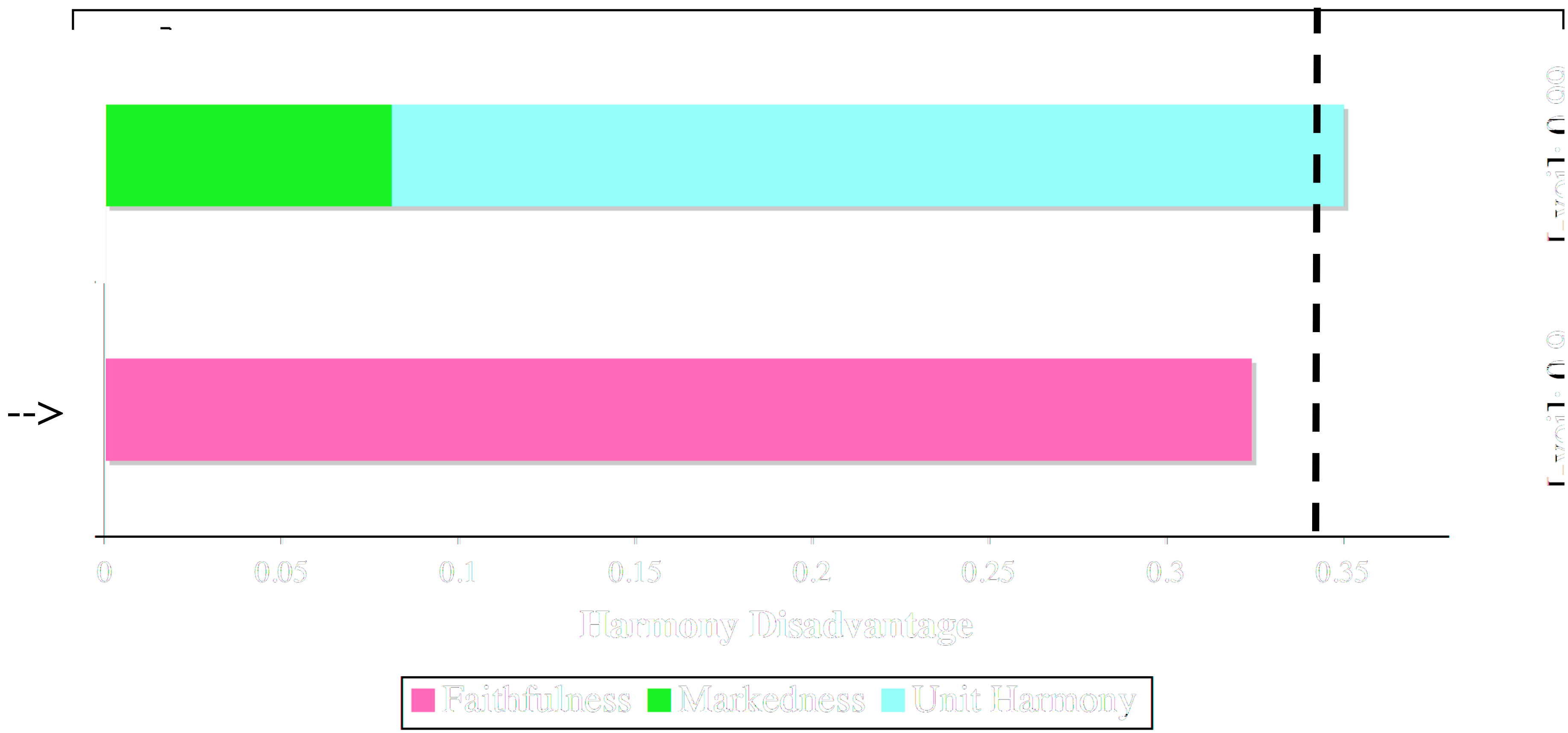
- Harmony contribution:
  – Weight *
    - Constraint strength
  – (activation of [–voi]) *
    - Prefers normal articulation level to hyperarticulated
  – 0.9
    - General 'bias value' for markedness constraints (maintain symmetry with Faithfulness constraints)

Calculating Harmony: Unit Harmony

- Assumption: Neutral activation level is 0.9 / 0.1
  - NOT 1.0 / 0.0

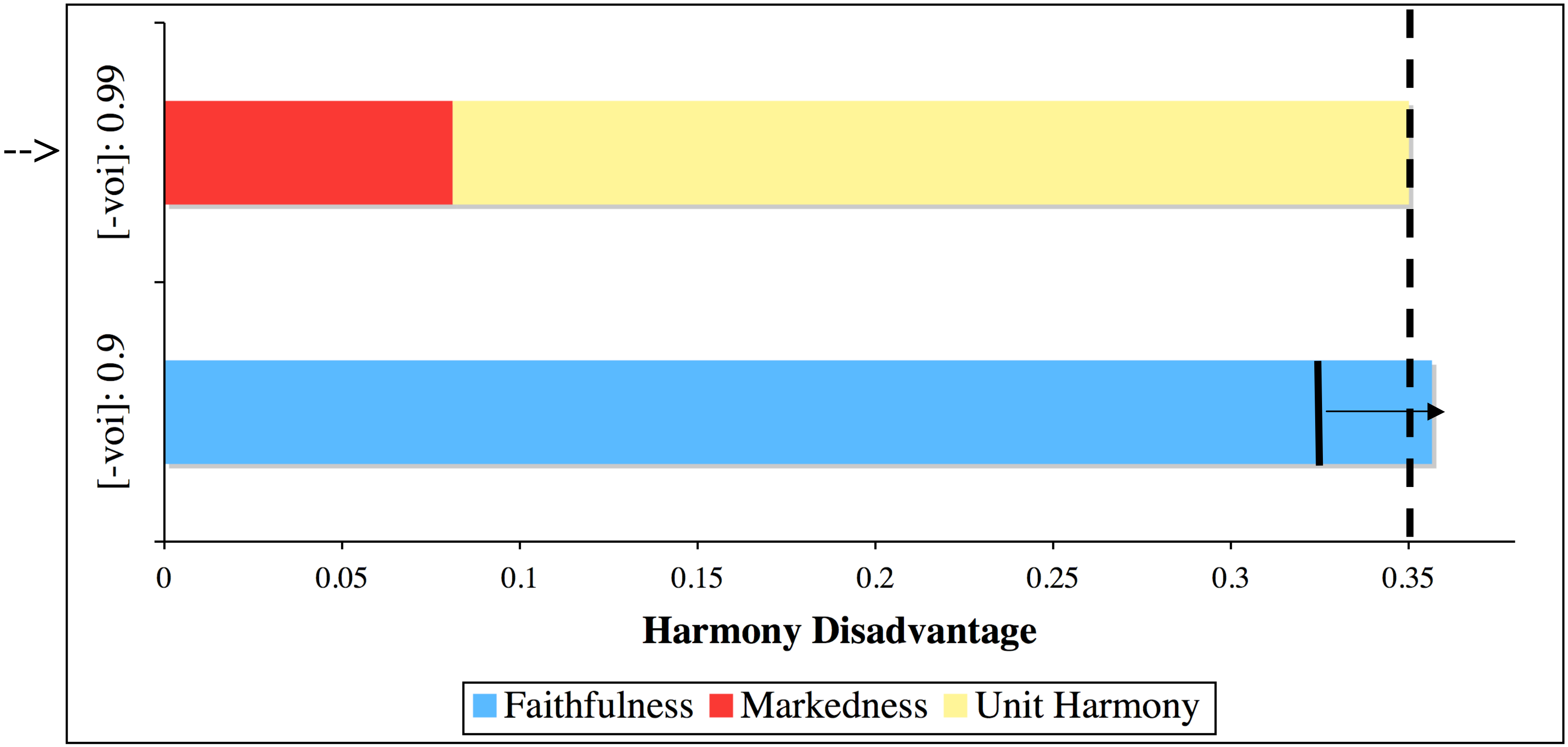
- To enforce the neutral activation level: *Unit* harmony term
  - Penalizes outputs with extreme values.
  - Penalizes **both** 1.0 and 0.0
  - See Appendix D for details.

Weakly Activated Input->Normal Articulation



- Although Faithfulness prefers hyperarticulated candidate, the combined influence of Markedness and Unit Harmony prevent it from being the most harmonic form.
- (see Appendix B for Tableaux)

Strongly Activated Input->Hyperarticulation



- Because harmony is weighted by activation of input, increasing the input's strength increases the impact of Faithfulness.
- Hyperarticulated form is now more harmonic.

Lexically Conditioned Phonetic Variation

- Because Harmony is sensitive to gradient activation levels, changes to the activation of input representations alters the harmony of output forms.

  – Neighbors increase activation of phonological representations in the lexicon.

  – Harmony contribution of Faithfulness constraints increases.

  – Can cause a hyperarticulated output representation to be more harmonic than one with normal articulation levels.

Implications for Theories of Phonetic Variation

- Above: Neighborhood density induces hyperarticulation
  - Expanded vowel space, enhanced VOTs.

- Neighborhood density also enhances *coarticulation*
  - E.g., greater nasalization on /ae/ in ‘ban’
  - Similar results for V-V coarticulation (Scarborough, 2003, 2004)
  - Not clearly predicted by simple hyperarticulation theory
    - In anticipatory nasalization, why are features of consonant hyperarticulated, rather than hyperarticulating properties of the target vowel /ae/?

- In Gradient Harmonic Grammar, this can be understood as a consequence of constraint ranking.

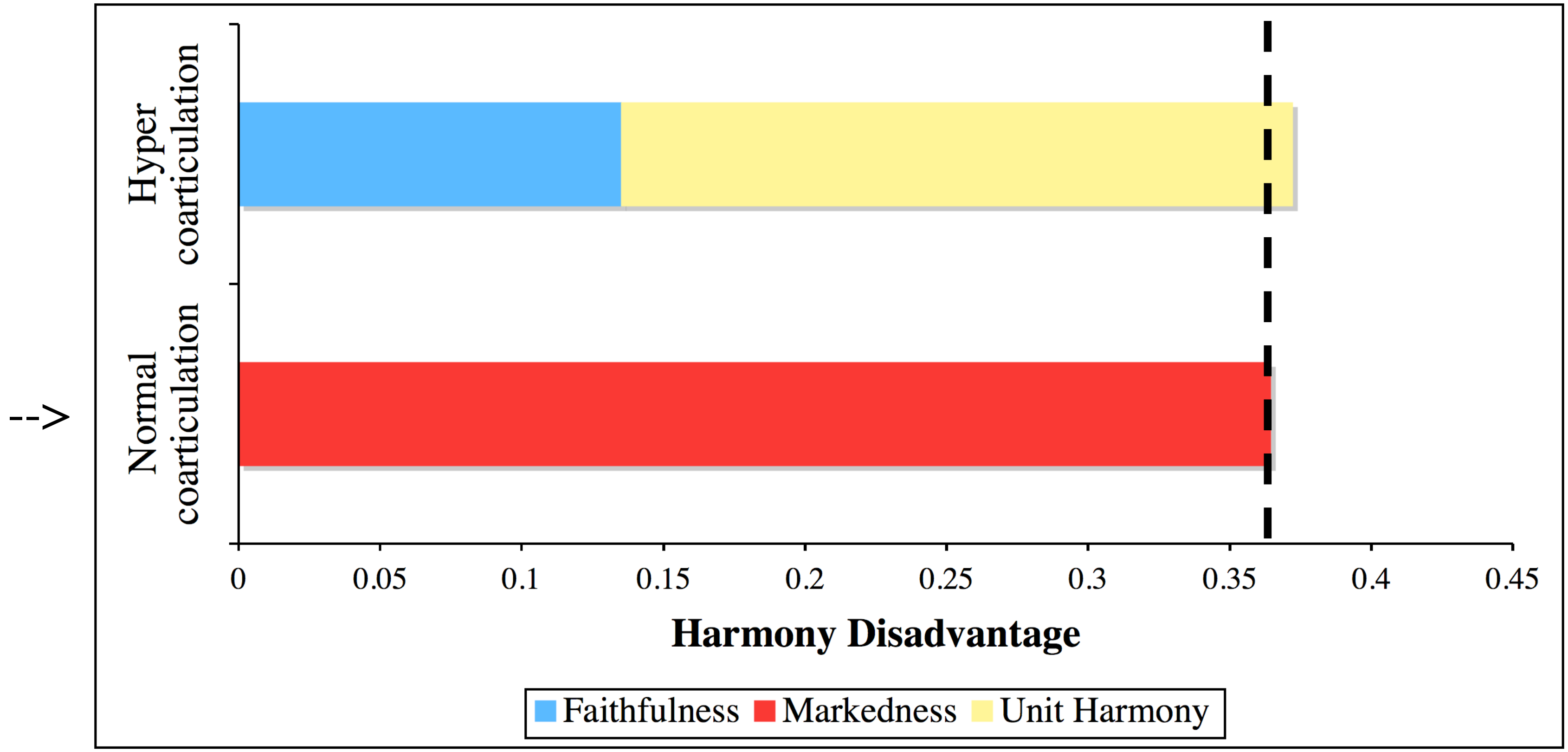
Case Study: Anticipatory Nasalization

- Trigger of nasalization: Consonant features
  - Phonetic realization of consonant reflects underlying nasality.
  - i.e., ExpressNasal > MinimizeEffort
  - Following above, causes hyperarticulation for words in dense neighborhoods.

Effect on Nasalization Target: Vowel Features

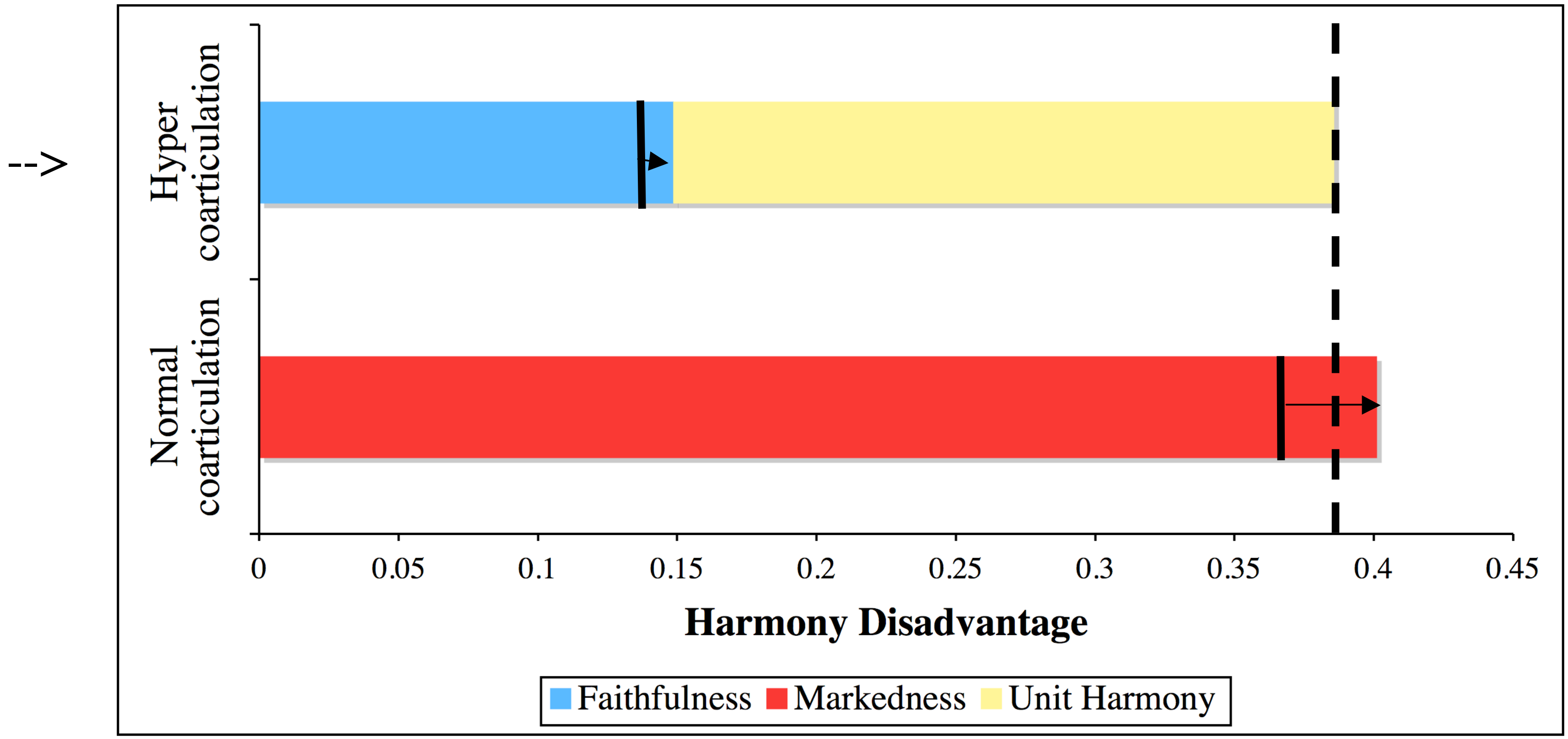
- Harmony contribution of faithfulness constraint (ExpressOral) increases due to enhanced activation of vowel input (see above).
- Harmony contribution of markedness constraint: *V[oral]N:
  - Weight * [1–activation of nasal feature on vowel] *
  - ➢ Activation of nasal feature on consonant
    - Harmony contribution of markedness <u>also</u> increases due to hyperarticulation of nasal features on consonant.
- Both are strengthened; which dominates?
  - Because coarticulation is present:
    - *V[oral]N > ExpressOral
  - ➢ Same proportional strengthening of Markedness and Faithfulness will provide a greater numerical benefit to Markedness.

Weakly Activated Input->Normal Coarticulation



- Although Markedness prefers hyper coarticulation candidate, the combined influence of Faithfulness and Unit Harmony prevent it from being the most harmonic form.
- (see Appendix C for Tableaux)

Strongly Activated Input->Hyper Coarticulation



- Increase in input increases impact of faithfulness, but also causes hyperarticulation of nasal—providing an even bigger numerical benefit to markedness.

Gradient Harmonic Grammar

- Incorporating gradience into grammar
  - Gradience in representations in both input (modulation by lexical factors) and output (phonetic variation).
  - Gradience at both levels influences constraint interaction.

- Provides an account of Lexically-Conditioned Phonetic Variation
  - Influence of lexical factors on expression of underlying features
  - Influence of lexical factors on coarticulation

- Gradient representations may provide a means to capture opaque process interactions (see Appendix A for discussion).

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- Sound Lab and Phonatics Discussion Group at Northwestern
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  - **http://ling.northwestern.edu/~goldrick**

Appendix A: Implications for Theories of Opacity

- Variation in activation as a model of phonological opacity.
- ‘Counterbleeding’
  - Since harmony is determined by multiplying activations, partially activated structures can influence harmony.
  - Prediction: Phonetics should reflect partially activated structures.
    - See Benus & Gafos (2007): ‘Transparent’ vowels in Hungarian
- ‘Counterfeeding’
  - A weakly activated structure may have less of an influence on harmony than a strongly activated structure.
  - Prediction: Phonetics should reflect weakening.
    - See Gouskova & Hall (in press): Epenthetic vowels in Lebanese Arabic.

Appendix B: Hyperarticulation Tableaux

Tableau B1. Input without minimal pair neighbor (e.g., cop)

Weight	–4.1	–1		
Input with no minimal pair /k/:0.9	Express Voice	Minimize Effort	Unit Harmony	**Total Harmony**
Non-voiceless output [–voice]:0.1	–3.321	–0.090	–1.104	–4.515
--> Voiceless output [–voice]:0.9	–0.369	–0.810	–1.104	–2.283
Hyperarticulated voiceless output [–voice]:0.99	–0.037	–0.891	–1.373	–2.301

Appendix B: Hyperarticulation Tableaux

Tableau B2. Input with minimal pair neighbor (e.g., cod)

Weight	–4.1	–1		
Input with minimal pair /k/:0.99	Express Voice	Minimize Effort	Unit Harmony	**Total Harmony**
Non-voiceless output [–voice]:0.1	–3.653	–0.090	–1.373	–5.116
Voiceless output [–voice]:0.9	–0.405	–0.810	–1.373	–2.588
--> Hyperarticulated voiceless output [–voice]:0.99	–0.040	–0.891	–1.642	–2.573

Appendix C: Hyper Coarticulation Tableaux

Tableau C1. Input in sparse neighborhood (e.g., strand)

Weight	–2.7	–1		
Input in sparse neighborhood /aen/:0.9	*V[oral]N	Express Oral	Unit Harmony	**Total Harmony**
No coarticulation [+nas]:0.1	–2.187	–0.090	–1.104	–3.381
--> Normal coarticulation [+nas]:0.75	–0.608	–0.675	–0.867	–2.150
Hyper coarticulation [–voice]:0.9	–0.243	–0.810	–1.104	–2.157

Note: Candidates show [nas] of vowel. For all candidates, consonant [nas] = 0.9

Appendix C: Hyper Coarticulation Tableaux

Tableau C2. Input in dense neighborhood (e.g., band)

Weight	–2.7	–1		
Input in dense neighborhood /aen/:0.99	*V[oral]N	Express Oral	Unit Harmony	**Total Harmony**
No coarticulation [+nas]:0.1	–2.406	–0.099	–1.642	–4.147
Normal coarticulation [+nas]:0.75	–0.668	–0.742	–1.405	–2.815
--> Hyper coarticulation [–voice]:0.9	–0.267	–0.891	–1.642	–2.800

Note: Candidates show [nas] of vowel. For all candidates, consonant [nas] = 0.99

Appendix D: Unit Harmony Function

- From Movellan & McClelland (1993)
- For unit i with activation $a_i = -[a_i \ln(a_i) + (1-a_i)\ln(1-a_i) - \ln(0.5)]$
- Total unit harmony is sum over all units
  - Including ‘bias’ unit for markedness constraints (e.g., 0.9 term in MinimizeEffort constraint)

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