

24.964

Phonetic Realization

Implications of Phonetic Detail for Phonological Analyses

Readings for next week:

- Browman & Goldstein (1990)
- Gafos (2002)

The implications of including phonetic detail in phonological representations

- Zhang (2002, 2004), Flemming (2001, 2005) etc formalize phonetically-based phonological analyses by incorporating the relevant phonetic details into phonology and formulating constraints on phonetic detail.
 - The most direct way to formalize phonetically-based analyses.
 - Predicts/accounts for (?) influence of language-specific phonetic detail.
- Detailed phonological representations raise a number of analytical issues that must be addressed:
 - Contrast - how are limitations on possible contrasts accounted for?
 - Neutralization - why is absolute neutralization common? Why isn't near-neutralization common?
 - Phonetic variation vs. phonological constancy - why don't phonological patterns always depend on speech rate/clarity?

Example: Zhang (2002)

- Positional markedness

*CONTOUR(x_i)- $C_{\text{CONTOUR}}(y_j)$:

no contour tone x_i is allowed on a syllable with the C_{CONTOUR} value of syllable y_j or smaller.

- Ranked according to tonal complexity and C_{CONTOUR} values.
- Preference to minimize rhyme duration, subject to strict minimum durations for segments (dependent on prosodic position)

*DUR(τ): for a rime in a prosodic environment, the cumulative duration in excess of the minimum duration for each segment cannot be τ or more.

- Disfavors lengthening rhyme to accommodate contour tone.

Zhang (2002) - constraints

- Correspondence: Corresponding tones must be perceptually similar

$\forall i, 1 \leq i \leq n, \exists$ constraint $\text{PRES}(T, i)$, defined as:

an input tone T_I must have an output correspondent T_O which satisfies the condition $S(T_I, T_O) < i$.

– $S(T_i, T_j)$ is the perceptual similarity of tones T_i, T_j

$\text{PRES}(T, n) \gg \text{PRES}(T, n-1) \gg \dots \gg \text{PRES}(T, 2) \gg \text{PRES}(T, 1)$.

Excerpts from Zhang, Jie. *The Effects of Duration and Sonority on Contour Tone Distribution: Typological Survey and Formal Analysis*. PhD. dissertation, UCLA, 2001. New York, NY: Routledge, 2002.

Sample analysis: Pingyao Chinese (Hou 1980)

contour tone flattening

- Syllables are CVV, CV η , CV \int .
 - vowels are very short in CV \int .
- 3 tones: 13, 35, 53
- On CV \int 13→23, 53 → 54, no 35.

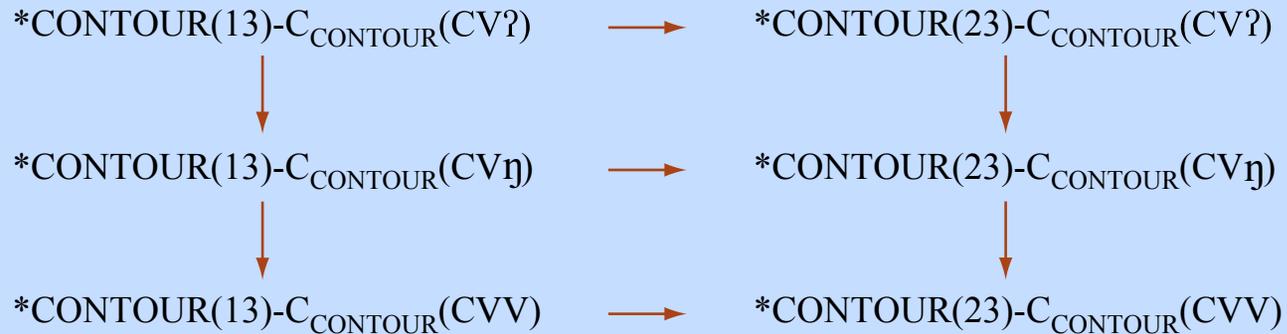
Image by MIT OpenCourseWare. Adapted from Zhang, Jie.
The Effects of Duration and Sonority on Contour Tone Distribution: A Typological Survey and Formal Analysis. New York, NY: Routledge, 2002. Referencing Hou, Jing-Yi. "Pingyao Fangyan de Liandu Biandiao (Tone sandhi in the Pingyao dialect)." *Fangyan (Dialects)* (1980): 1–14.

puu ¹³	'to hatch'
p Λ \int ²³	'to push aside'
puu ³⁵	'cloth'
p Λ \int ⁵⁴	'a musical instrument'
puu ⁵³	'to mend'

- Analyzes flattening, not exclusion of 35 from checked syllables.

Pingyao Chinese contour tone flattening

$C_{\text{CONT}}(\text{CVV}) > C_{\text{CONT}}(\text{CV}\eta) > C_{\text{CONT}}(\text{CV}?)$.



DUR(O) is undominated (no lengthening).

(a) PRES(T, *i*): do not reduce 13 to 23.

(b) PRES(T, *l*): 13 must be faithfully realized.

PRES(T, *i*) >> PRES(T, *l*)

Image by MIT OpenCourseWare. Adapted from Zhang, Jie. *The Effects of Duration and Sonority on Contour Tone Distribution: A Typological Survey and Formal Analysis*. New York, NY: Routledge, 2002.

Pingyao Chinese contour tone flattening

(a) /puu¹³/ → [puu¹³]

puu ¹³	PRES(T, l)	*CONTOUR(13)-C _{CONTOUR} (CVV)
→ puu ¹³		*
puu ²³	*!	
puu ³³	*!	

(b) /pΛʔ¹³/ → [pΛʔ²³]

pΛʔ ¹³	PRES (T, i+l)	*CONTOUR(13)-C _{CONTOUR} (CVʔ)	PRES (T, i)	*CONTOUR(23)-C _{CONTOUR} (CVʔ)
pΛʔ ¹³		*!		*
→ pΛʔ ²³			*	*
pΛʔ ³³	*!		*	

Image by MIT OpenCourseWare. Adapted from Zhang, Jie. *The Effects of Duration and Sonority on Contour Tone Distribution: A Typological Survey and Formal Analysis*. New York, NY: Routledge, 2002.

Xhosa contour neutralization

- Xhosa contrasts HL and H only on stressed penult.
- Elsewhere HL→H

ísìðâyà	'sheep fold'
isìðáyá ésíkhùlù	'big sheep fold'

Image by MIT OpenCourseWare. Adapted from Zhang, Jie. *The Effects of Duration and Sonority on Contour Tone Distribution: A Typological Survey and Formal Analysis*. New York, NY: Routledge, 2002.

- Analyzed along the same lines as allophonic flattening - i.e. neutralization with a level tone is treated as the end point of flattening.

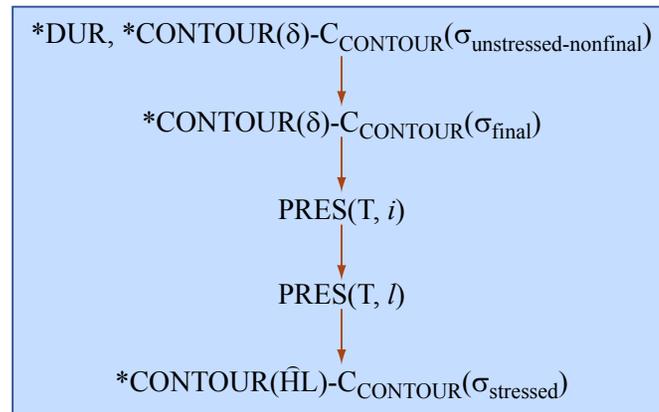


Image by MIT OpenCourseWare. Adapted from Zhang, Jie. *The Effects of Duration and Sonority on Contour Tone Distribution: A Typological Survey and Formal Analysis*. New York, NY: Routledge, 2002.

Xhosa contour neutralization

(a) /ísiḽâyà/ → [ísiḽâyà]

	ísiḽâyà	PRES(T, l)	*CONTOUR(HĪL)-C _{CONTOUR} (σ _{stressed})
→	ísiḽâyà		*
	ísiḽá-yà	*!	
	ísiḽáyà	*!	

(b) /ísiḽâyá ésiḽhùlù/ → [ísiḽáyá ésiḽhùlù]

	ísiḽâyá ésiḽhùlù	*CONTOUR(δ)-C _{CONTOUR} (σ _{unstressed-nonfinal})	PRES(T, i)
	ísiḽâyá ésiḽhùlù	*!	
	ísiḽá-yá ésiḽhùlù	*!	
→	ísiḽáyá ésiḽhùlù		*

Images by MIT OpenCourseWare. Adapted from Zhang, Jie. *The Effects of Duration and Sonority on Contour Tone Distribution: A Typological Survey and Formal Analysis*. New York, NY: Routledge, 2002.

Questions

- What prevents almost levelling HL, resulting in a contrast between H and a slightly falling H tone in unstressed syllables?
- More generally: what prevents such a contrast from arising from faithfulness to the input?
 - /55/ →[55], /54/ →[54]
 - Basic constraints predict that any position that allows a contour tone should also allow all less complex tones.
 - This is the usual objection to enriching phonological representations.

Constraining contrasts

- The argument for limiting the phonetic detail in phonological representations:
 - ‘...[Halle and Stevens] (and SPE) don’t simply have the wrong features in these instances; they will ALWAYS have TOO MANY features because they want to describe exactly how individual sounds are articulated. While we want the phonological features to have some phonetic basis, we also want to distinguish possible contrasts from possible differences.’ (Keating 1984:289)
 - ‘An adequate theory of phonological distinctive features must...be able to describe all and only the distinctions made by the sound systems of any of the world’s languages’ (McCarthy 1994:191)

Constraining contrasts

- The range of attested linguistic contrasts is much smaller than the range of phonetic differences.
- Analysis implicit in Keating, McCarthy:
 - All representable differences are possible contrasts.
 - So impossible contrasts must not be representable.
 - Implication: phonetic detail must be severely restricted to avoid over-predicting the range of possible contrasts.
- Response:
 - This is not the only conceivable theory of contrast.
 - This theory is not applied rigorously by anyone.
 - It is an inadequate theory of contrast.

Alternative theories of contrast

- In OT it is more natural to derive restrictions on possible contrasts from constraints rather than from representations.
 - I.e. representations can encode unattested contrasts, but they are excluded by constraints.
- E.g. Kirchner (1997): if no faithfulness constraint refers to a property (e.g. stop release) then that property cannot (directly) form the basis for a contrast.
 - Cf. no faithfulness to syllable structure.
 - Not easy to apply to Zhang's model.
- Constraints on the distinctiveness of contrasts (Flemming 2004 etc).
 - Preference for maximally distinct contrasts, e.g. *55-53 >> *55-51
 - Some distinctiveness constraints are undominated, e.g. *55-54.
 - This is essentially what Zhang (2002) proposes.
 - Example of this line of analysis below.

Problems with the representational theory of contrast

- All theories allow for the representation of universally non-contrastive properties, e.g. syllable structure, prosodic structure (Steriade 1993).
- Real criterion: representational elements are justified by evidence that they play a role in the formulation of phonological rules/constraints.
- Non-contrastive features are necessary for the formulation of phonological generalizations. E.g. ejectives [tʰ] vs. (pre-)glottalized stops [ʔ^mt].
 - Lombardi (1995) represents both as [+constricted glottis] because they never contrast minimally.
 - But these sounds pattern very differently:
 - Ejectives commonly neutralize with plain stops in ‘coda’, e.g. Klamath, Shapsug, Peruvian Aymara, Maidu (Steriade 1997)
 - Glottalized stops are commonly restricted to coda, e.g. English, Cantonese, Thai.
 - These generalizations cannot be formulated if the two types of sounds are not distinguished.

Problems with the representational theory of contrast

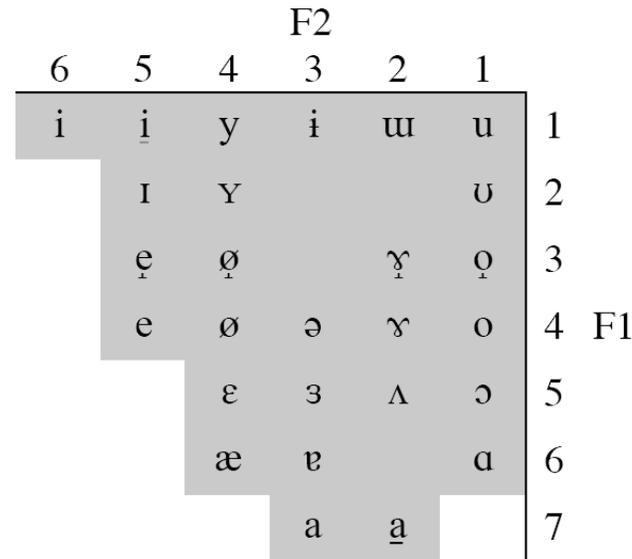
- Cf. Steriade (1993), McCawley (1967) for similar arguments that stop releases are represented in phonology.
- The representational theory does not account for combinatorial restrictions on the contrastiveness of features.
 - [nasal] can be contrastive on vowels and stops, but not on glottal stops or ejectives.
 - Follows from minimum distinctiveness requirements.

Dispersion Theory of Contrast

- Inventories of contrasting sounds are subject to three basic requirements:
 - Maximize distinctiveness of contrasts.
 - Maximize number of contrasts.
 - Minimize articulatory effort.

Dispersion Theory of Contrast - OT implementation

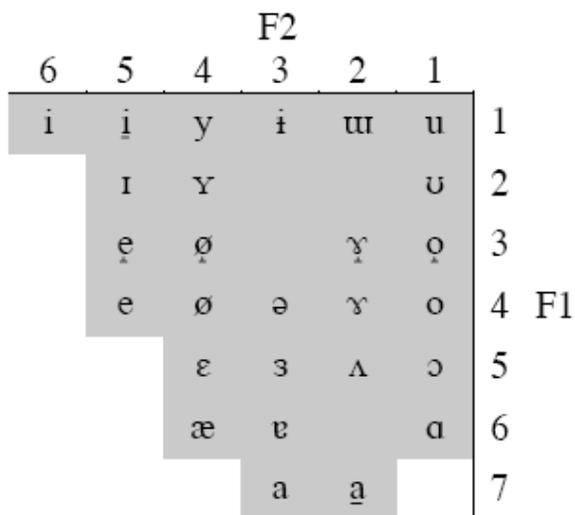
- Distinctiveness is measured in terms of distance in perceptual space



	MINDIST = F1:1	MINDIST = F1:2	MINDIST = F1:3	MINDIST = F1:4	MINDIST = F1:5	MAXIMIZE CONTRASTS
a. i-a						✓✓
b. i-e-a				**	**	✓✓✓
c. i- <u>e</u> -ε-a			***	***	*****	✓✓✓✓
d. i-I- <u>e</u> -ε-a		**	*****	*****	*****	✓✓✓✓✓

Dispersion Theory of Contrast - OT implementation

- Integration of differences on multiple dimensions is not well understood
- here assume distance = largest distance on any dimension.



		MINDIST = 2	MINDIST = 3	MAXIMIZE CONTRASTS	MINDIST = 4	MINDIST = 5
a.	i u a			3!		
b.	i u e o a			5	***	*****
c.	i u e o ε ɔ a		*!*****	7	*****	*****
d.	i u e o a ʌ	*!	*	6	*****	*****
e.	i i u e o a		*!	6	*****	*****
f.	i u e o a			5	***	*****!

Dispersion Theory of Contrast - weighted constraints

- Example of the application of distinctiveness constraints with representation in terms of continuous phonetic parameters (formant frequencies, durations) and weighted constraints: Vowel reduction (Flemming 2005).
- Illustrates derivation of categorical neutralization with detailed representations.

Phonological vowel reduction

- Vowel contrasts are neutralized in unstressed syllables.
- E.g. Southern Italian (Mistretta dialect, Mazzola 1976)

Primary stressed:

i u

e o

a

Elsewhere:

i u

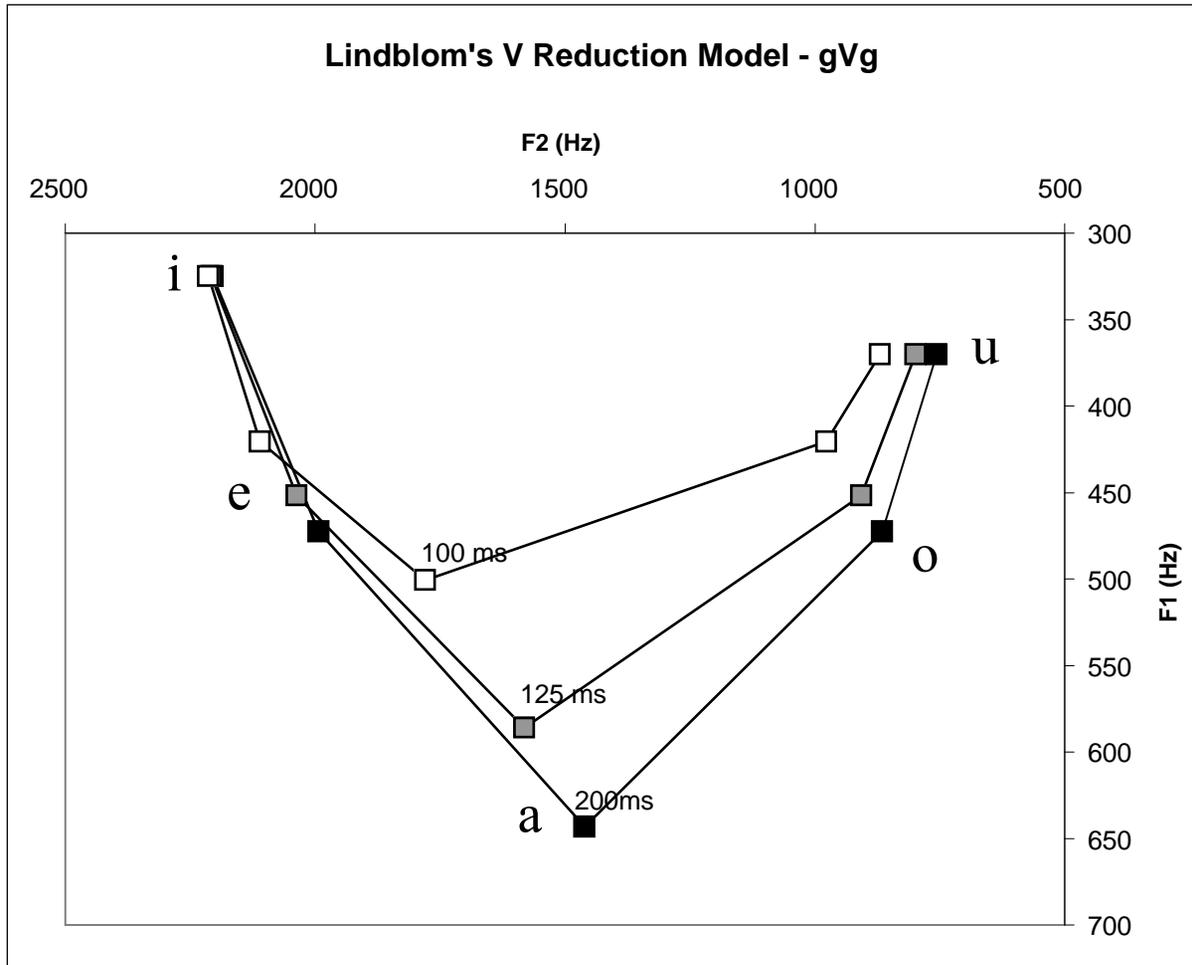
a

	<u>stressed vowels</u>		<u>unstressed vowels</u>	
[i]	vîni	‘he sells’	vinímu	‘we sell’
[e]	véni	‘he comes’	(vinímu	‘we come’)
[a]	ávi	‘he has’	avíti	‘he has’
[o]	móri	‘he dies’	(murímu	‘we die’)
[u]	úʃi	‘he boils’	uʃímu	‘we boil’

Outline of an analysis of vowel reduction

- Vowel reduction is fundamentally motivated by undershoot in short unstressed syllables.

Phonetic vowel reduction - Undershoot

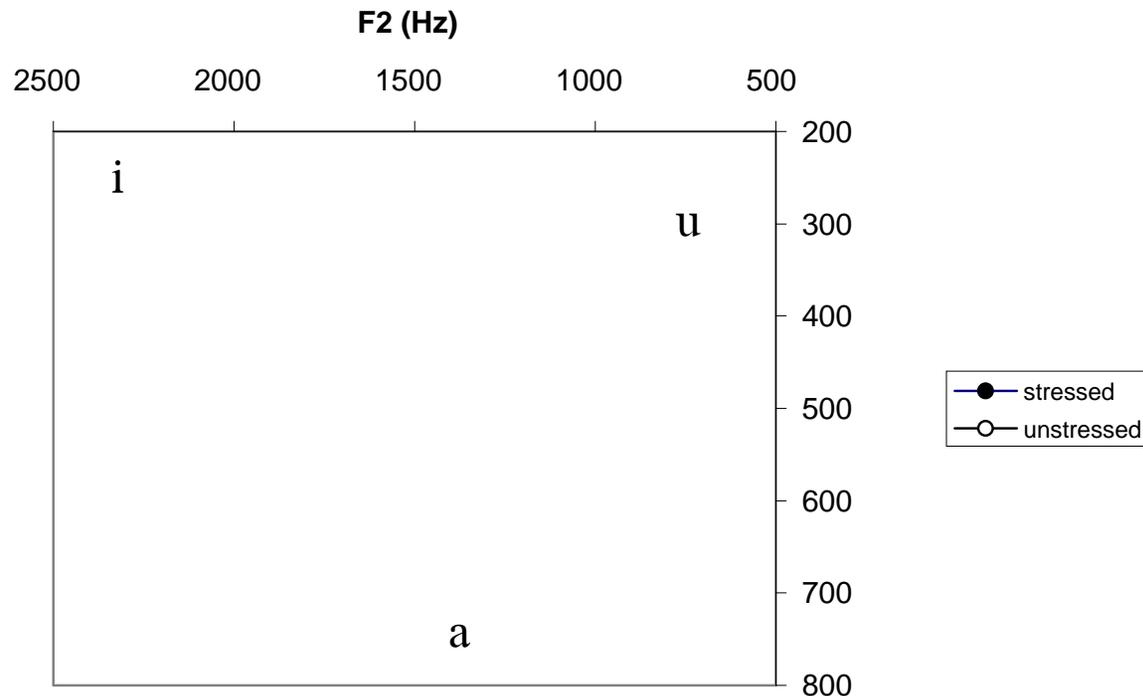


Outline of an analysis of vowel reduction

- Vowel reduction is fundamentally motivated by undershoot in short unstressed syllables.
- Short duration of unstressed vowels increases the effort required to achieve distinct vowel qualities, particularly low vowels (Lindblom 1963).
- Contrasts are subject to distinctiveness constraints, so neutralization occurs where phonetic reduction would otherwise render contrasts insufficiently distinct.

•Acoustic data confirm that neutralizing reduction is accompanied by phonetic reduction:

Italian (Albano Leoni et al 1995), Catalan (Herrick 2003), Russian (Padgett and Tabain 2003), Bulgarian (Lehiste and Popov 1970), Brazilian Portuguese (Fails and Clegg 1992).

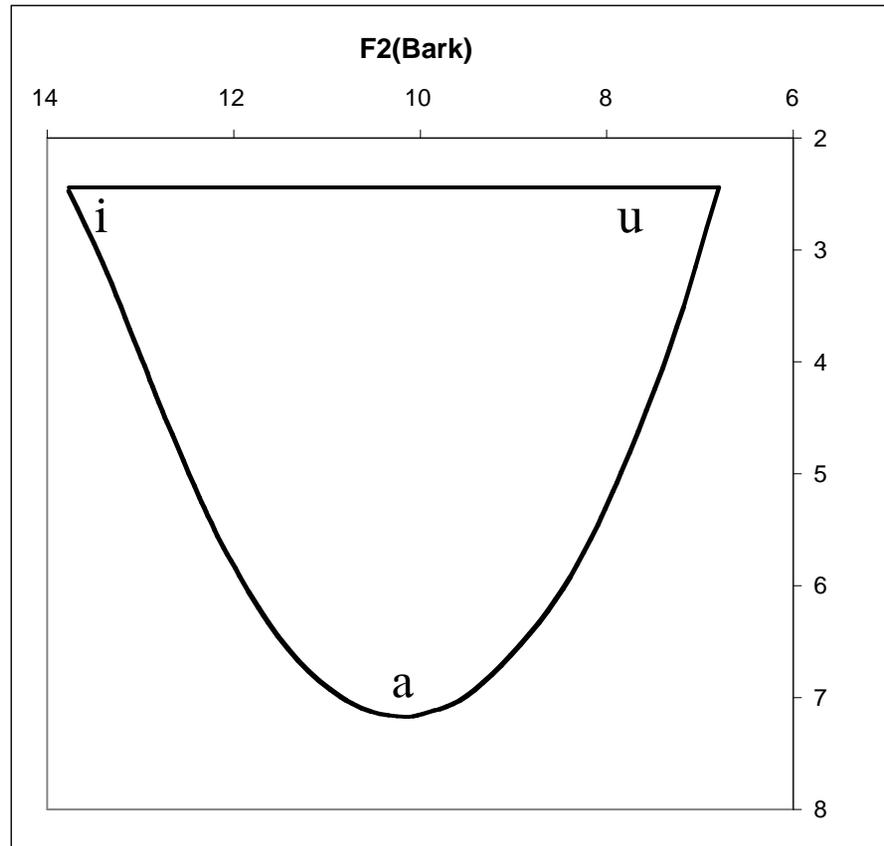


Implementation of the model of vowel reduction

- Stressed and unstressed inventories of contrasting vowel categories are selected from a space of possible vowels so as to best satisfy constraints on contrasts:
 - Maximize distinctiveness of contrasts.
 - Maximize number of contrasts.
 - Minimize articulatory effort.
- Effort minimization implies undershoot.

Model of vowel reduction

- The vowel space is modeled on Liljencrants and Lindblom (1972).

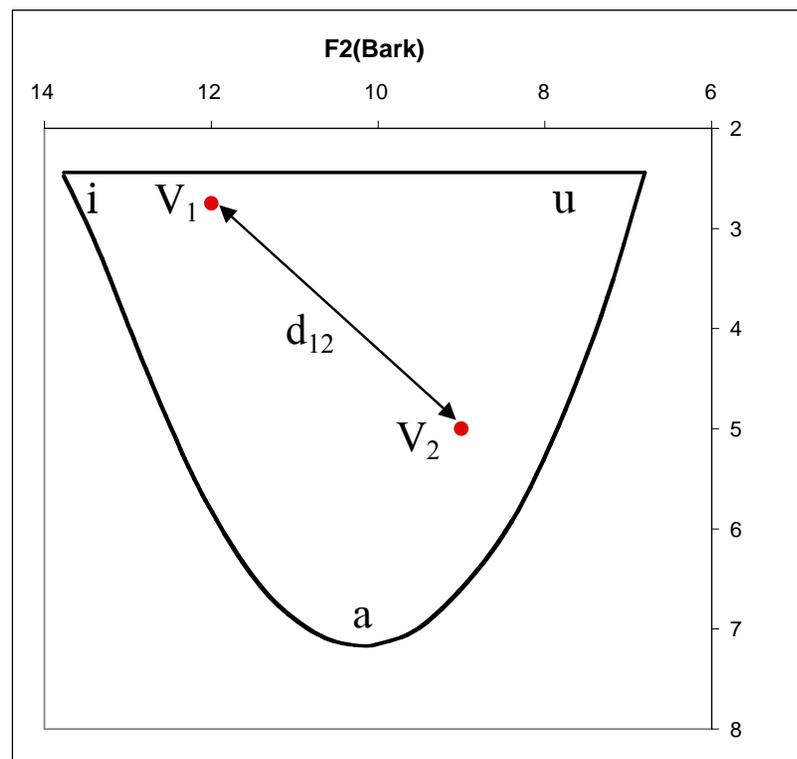


i. Maximize the distinctiveness of contrasts

- Distinctiveness of the contrast between V_i and V_j is the (weighted) distance between the vowels in formant space.

$$d_{ij} = \sqrt{(a(x_i - x_j))^2 + (y_i - y_j)^2}$$

Where x_n is F2 of V_n in Bark
 y_n is F1 of V_n in Bark
 $a < 1$



i. Maximize the distinctiveness of contrasts

- Overall distinctiveness cost of a vowel system depends on the minimum distance found in either inventory.

$$\text{Cost: } \frac{1}{d_{\min}^2} \quad \text{where } d_{\min} = \min_{i \neq j} d_{ij}$$

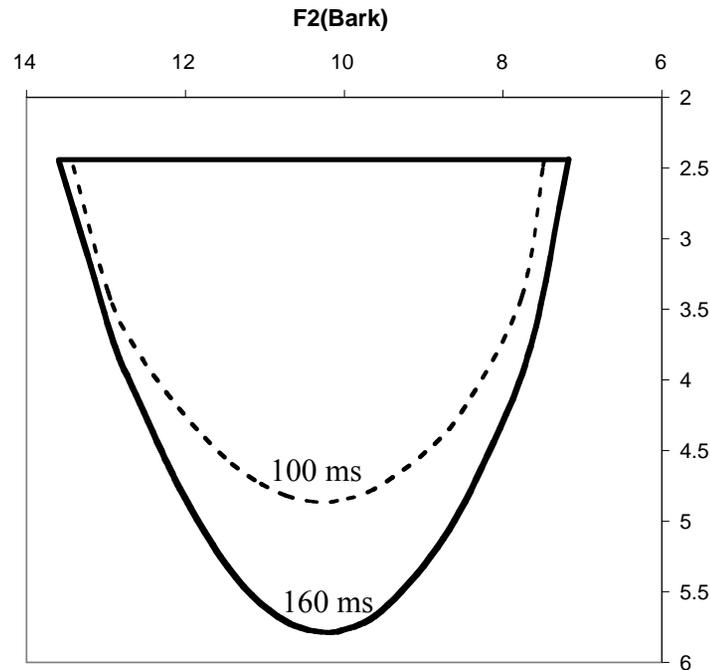
ii. Maximize the number of contrasts

- maximize the number of vowels in the stressed and unstressed vowel inventories.

Cost: $\frac{1}{n_{ave}^2}$ where $n_{ave} = \frac{n_{stressed} + n_{unstressed}}{2}$

iii. Articulatory effort

- The space of possible vowels contracts as vowel duration is reduced, following the undershoot functions proposed by Lindblom (1963)
- Consonants are assumed to assimilate partially to the vowel target in F2, but not in F1.



Overall cost function

- The optimal vowel system is the one that best satisfies these constraints:

$$\underset{v}{\text{minimize}} \frac{1}{d_{min}^2} + \frac{w_n^2}{n_{ave}^2}$$

(subject to vowel space constraint)

- Optimal solutions found using Matlab optimization routines.
- Multiple runs with different random starting configurations.

Optimal inventories

$$a = 0.14,$$

$$k_1 = 1.5,$$

$$\beta_1 = 0.008,$$

$$k_2 = 1.5,$$

$$\beta_1 = 0.01,$$

$$c = 0.27,$$

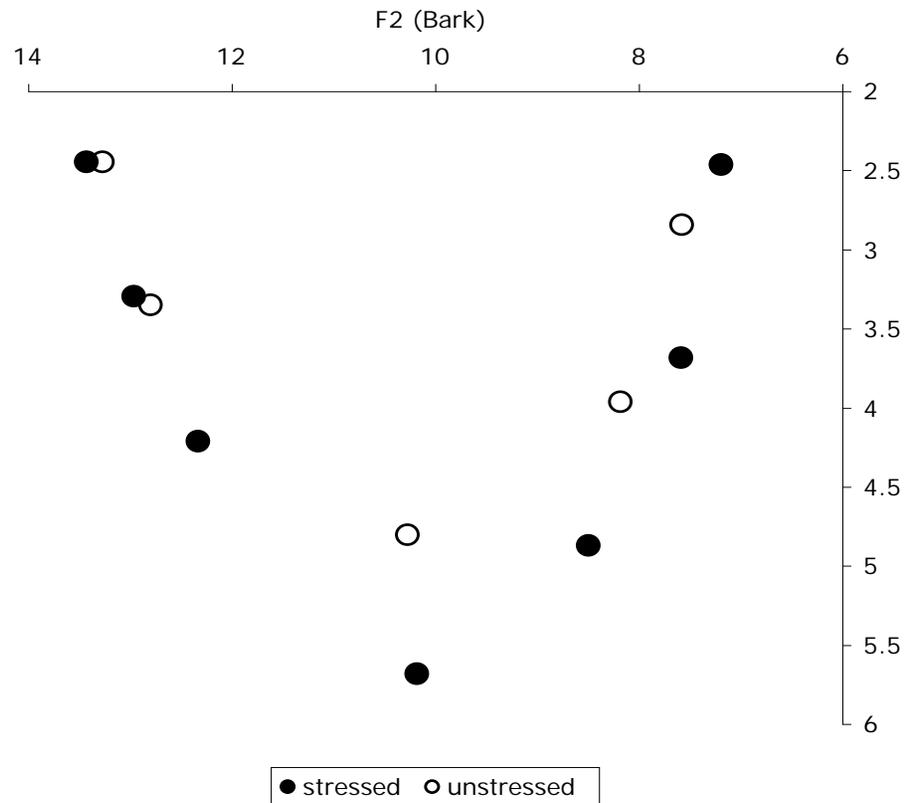
$$F2_l = 1400 \text{ Hz},$$

$$w_n = 6$$

Durations:

stressed 160 ms

Unstressed 100 ms



Dispersion Theory of Contrast - weighted constraints

- Although a continuous space of possible vowels is permitted, distinctiveness constraints derive discrete vowel categories.
- Distinctiveness constraints can also give rise to categorical neutralization: where effort constraints would make a contrast insufficiently distinct, it is optimal to neutralize it.
 - so categorical neutralization can arise from a process of which could in principle produce any amount of reduction along continuous dimensions.

Dispersion Theory of Contrast

- According to Flemming (2001), phonetics/phonology selects an optimal set of possible words, specified in phonetic detail, subject to effort constraints, distinctiveness constraints etc.

Dispersion Theory of Contrast

An alternative organization (Flemming 2006):

- An inventory of basic contrasts is derived from the interaction of segment-internal effort constraints and distinctiveness constraints.
 - essentially as illustrated above for vowel inventories.
 - segments are specified in phonetic detail - targets.
- Input forms are constructed from sequences of segments drawn from the basic inventory.
- Phonetic realization component supplies the (hypothetical) phonetic realization for input sequences
 - interaction of timing, effort, and correspondence constraints
 - Along the lines of the model presented last week - inventory supplies targets.
 - undershoot applies here.
- Minimum distance constraints evaluate contrasts with realizations of neighboring inputs to ensure that they are adequately distinct.
 - insufficiently distinct contrasts are neutralized. E.g. vowel reduction.

Issues

- Detailed phonological representations raise a number of analytical issues that must be addressed:
 - Contrast - how are limitations on possible contrasts accounted for?
 - Neutralization - why is absolute neutralization common? Why isn't near-neutralization common?
 - Phonetic variation vs. phonological constancy - why don't phonological patterns always depend on speech rate/clarity?

The stability of phonology

- Most neutralization processes are not ‘undone’ no matter how carefully or slowly you speak.
- If vowel reduction depends on vowel duration, then shouldn’t vowel reduction be blocked in slow speech?
- Basic explanation:
 - Contrasts serve to distinguish words.
 - If a contrast is permitted at any rate of speech, it can distinguish words in the lexicon.
 - Neutralizing a contrast only at higher rates of speech is effectively realizing a contrast with zero distinctiveness in fast speech.
 - If the contrast is permitted at all, then listeners have to try to discriminate it.
 - So to avoid perceptual difficulties at normal rates of speech, a language must eschew contrasts that could be realized adequately in slow, careful speech.

Implementation

- Flemming (2001) proposes that contrasts should be evaluated based on the effort-distinctiveness trade-off across a range of speech rates/styles.
- Most other researchers have proposed that constraints are evaluated with respect to a fixed ‘canonical’ rate and style (Steriade 1997, Kirchner 1998, Zhang 2002).
- This implies that even with full phonetic detail in the phonology, the output of the phonology is not the realization of a form on a particular occasion - rate/clarity effects must still be supplied.
 - Another phonetic implementation component?
- In the model sketched above, utterance realization could be governed by the same phonetic realization component that is used in phonological derivation.
 - Phonetic realization is parameterized for rate etc.
 - Evaluation of contrasts employs particular ‘canonical’ parameter values.
 - Utterances are derived with utterance-specific parameter values.

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