

Formal and Computational Approaches to Phonology

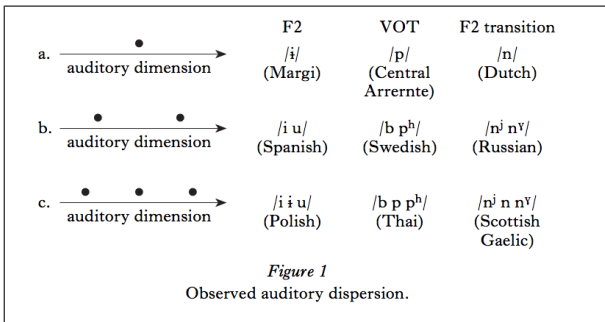
Friday: Auditory dispersion and change

Julian Bradfield and James Kirby

University of Edinburgh

Dispersion

As we saw on days 1 and 3, sound systems seem to like to be **dispersed** evenly throughout the perceptual space.



Typology of dispersion

- ▶ Preference for centre (if 1 category, then centred)
- ▶ Excluded centre (if 2 categories, then not centred)
- ▶ Equal distances (categories prefer to be perceptually distinct)
- ▶ Larger inventory → larger space
- ▶ Fewer categories → more variation
- ▶ Chain shifts (de Boer, Oudeyer)

How might we account for optimal auditory dispersion?

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Several **exemplar-theoretic** implementations exist (Pierrehumbert 2001, Wedel 2006, 2007...).

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Not everyone agrees: 'Sound change through misperception ... can only hope to account for neutralization, not dispersion or enhancement' (Flemming 2005:173).

Goal-oriented: Dispersion constraints

Vanilla OT markedness & faithfulness constraints can't account for 'excluded centre' effects.

Based on the Liljencrants & Lindblom (1972) findings, Flemming (1995 et seq.) introduced MINDIST constraints penalising inventories with small auditory distances between their members.

From Flemming, 2001

| | MINDIST = F1:2 | MINDIST = F1:3 | MAXIMIZE CONTRASTS | MINDIST = F1:4 | MINDIST = F1:5 |
|------------|-------------------|-------------------|-----------------------|-------------------|-------------------|
| a. i-a | | | ✓✓! | | |
| b. i-e-a | | | ✓✓✓ | ** | ** |
| c. i-ɛ-ε-a | | *!*** | ✓✓✓✓ | *** | ***** |

Is there another way?

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But: what if dispersion constraints, while expressing surface-true observations about sound systems, are epiphenomenal of an underlyingly non-goal-oriented mechanism (Padgett 2003)?

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But: what if dispersion constraints, while expressing surface-true observations about sound systems, are epiphenomenal of an underlyingly non-goal-oriented mechanism (Padgett 2003)?

This is B&H's goal (that, and avoiding an exemplar-based implementation).

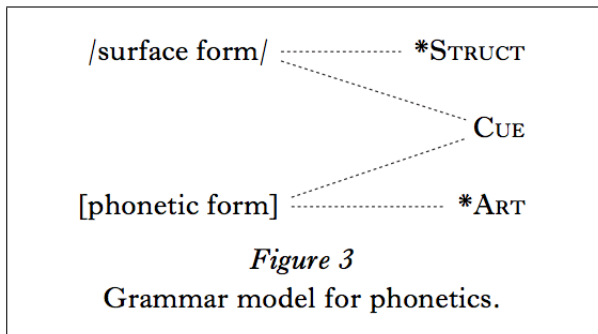
Boersma & Hamann 2008

Want to explain auditory dispersion 'without resorting to exemplar theory' (218).

Instead, use Boersma's bidirectional model (with some notion of articulatory ease):

'Observationally optimising but underlyingly non-teleological.'

Framework: Bidirectional phonetics



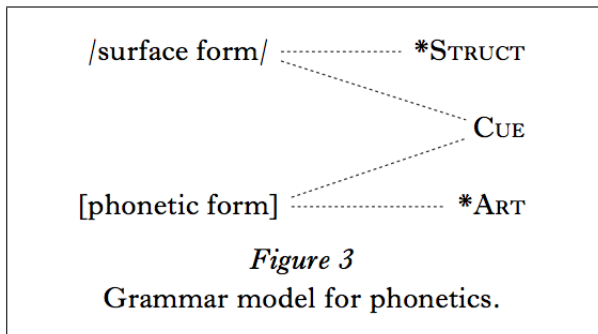
*STRUCT, CUE and *ART are OT-style constraints.

The same grammar is used in **both** production and comprehension

...

Why should we model phonetics with constraints?

Framework: Bidirectional phonetics



'The output of the perception process tends to be restricted by the same structural constraints that have been proposed for phonological production' (227)

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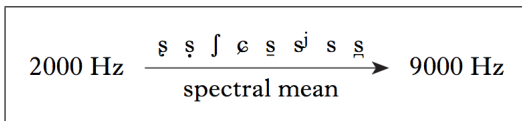
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- ▶ Here, we'll mainly be concerned with the (somewhat arbitrarily discretized) CUE and ART constraints

Case studies: sibilant dispersion

Primary acoustic continuum:

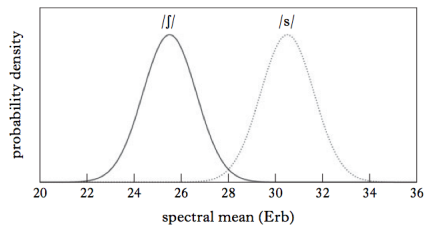
spectral centre of gravity or spectral mean



- a. $\xrightarrow{\text{ʃ}} \text{Spanish, Dutch}$
spectral mean
- b. $\xrightarrow{\text{ʃ} \quad \text{s}} \text{English, French}$
spectral mean
- c. $\xrightarrow{\text{ʃ} \quad \text{ʒ} \quad \text{ʃ}} \text{Polish, Mandarin}$
spectral mean
- d. $\xrightarrow{\text{ʃ} \quad \text{ʒ} \quad \text{ʃ} \quad \text{ʒ}} \text{Toda}$
spectral mean

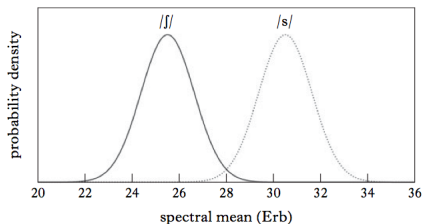
Learning a perceptual grammar

Given a fixed distribution of tokens along an acoustic dimension. . .



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. . . learn the optimal ranking of cue constraints for distribution:

(2) *A perception tableau for classifying tokens with a spectral mean in English*

| | [26·6 Erb] | *[26·5]/s/ | *[26·6]/s/ | *[26·7]/s/ | *[26·7]/j/ | *[26·6]/j/ | *[26·5]/j/ |
|--------|------------|------------|------------|------------|------------|------------|------------|
| a. /s/ | | | *! | | | | |
| b. /j/ | | | | | | * | |

Such learners display **maximum-likelihood** behaviour wrt input.

Lexicon-driven perceptual learning

A crucial element of the algorithm: learners given true URs, but needs to learn ranking of cue constraints (is this realistic? why or why not?)

Learner optimally re-ranks cue constraints consistent with input (via the GRADUAL LEARNING ALGORITHM)

(3) *A learner's perception tableau with reranking of cue constraints*

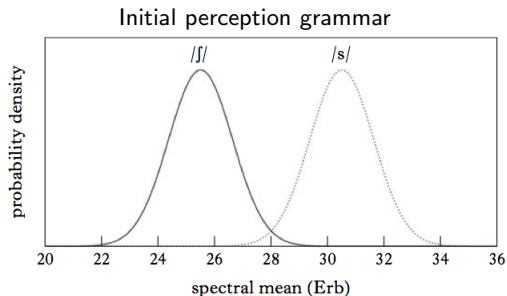
| | [26·6 Erb] | *[26·5]/s/ | *[26·7]/f/ | *[26·6]/f/ | *[26·5]/f/ | *[26·6]/s/ | *[26·7]/s/ |
|----------|------------|------------|------------|------------|------------|------------|------------|
| ✘ a. /s/ | | | | | | ← * | |
| ✓ b. /f/ | | | *!→ | | | | |

Demo: English perception

What are the properties of an optimal English OT listener?

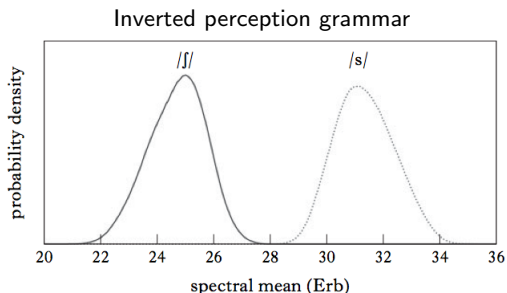
A side-effect: prototypes

When just cue constraints are involved, the listener-turned-talker tends to prefer to produce tokens at the periphery:



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*ART(iculatory) constraints

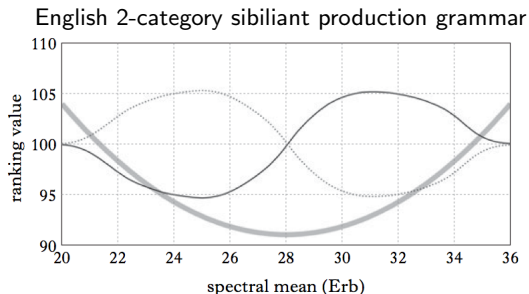
Thus B&H introduce (universally ranked) **articulatory** constraints:

(5) *A production tableau with cue constraints and articulatory constraints*

| /s/ | *31 ·2 | *31 ·1 | *31 ·0 | *30 ·9 | *30 ·6 | *30 ·8 | *30 ·7 | *30 ·7 | *30 ·8 | *30 ·6 | *30 ·9 | *31 ·0 | *31 ·2 | *31 ·1 |
|--------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| | | | | /s/ | /s/ | /s/ | /s/ | /s/ | /s/ | /s/ | /s/ | /s/ | /s/ | /s/ |
| a. [30·6Erb] | | | | *! | | | | | * | | | | | |
| b. [30·7Erb] | | | | | | * | * | | | | | | | |
| c. [30·8Erb] | | | | | | *! | | * | | | | | | |
| d. [30·9Erb] | | | | *! | | | | | | | * | | | |
| e. [31·0Erb] | | | *! | | | | | | | | | * | | |
| f. [31·1Erb] | | *! | | | | | | | | | | | | * |
| g. [31·2Erb] | *! | | | | | | | | | | | | * | |

Notice how the cue constraints can be re-ranked among the articulatory constraints.

*ART(iculatory) constraints



‘While the bidirectional use of cue constraints causes the categories to drift apart auditorily, the presence of the articulatory constraints checks this expansion and drives the production distributions back towards the centre of the spectral mean continuum.’

Simulating sound change: English

- ▶ Stable English
- ▶ Exaggerated English
- ▶ Skewed English

Simulating sound change: Polish

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Modern Polish has a basically symmetric sibilant inventory /ʂ ʂ̣ ʂ̨/

Around the 13th century, [sʲ] > [ʂ̣] ...

... 300 years later, [ʃ] > [ʂ̨]

▶ (demo)

Discussion

- ▶ Why does the B&H learner have these properties?
- ▶ What assumptions of the model drive this behaviour?
- ▶ Where do cue constraints come from?
- ▶ Does the B&H model make different predictions from exemplar-theoretic models?
- ▶ Are there prima facie counterexamples? How do confusable/unstable scenarios arise in the first place?
- ▶ What about merger? How could this be implemented?

Standard Eastern Norwegian

- ▶ Starting from CScand / \underline{s} ʃ ξ /, predicts [$\underset{+}{s}$ \varnothing $\underset{+}{s}$] instead of [$\underset{+}{s}$ $\underset{+}{\zeta}$ $\underset{+}{s}$]
- ▶ Fails to predict attested mergers of / ξ /, /ʃ/ > [$\underset{+}{s}$] and / ξ /, / ζ / > [$\underset{+}{\zeta}$]

From Williams, in prep.

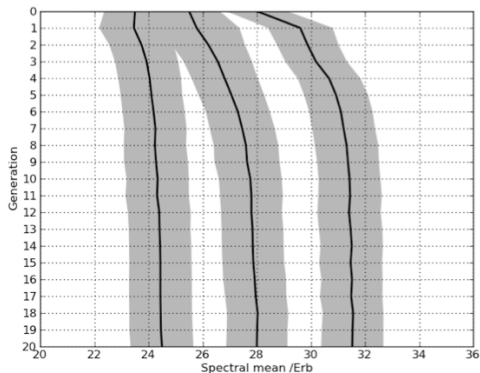


Figure 3

The evolution of the three initial standard eastern Norwegian sibilants over 20 generations.

Summary

- ▶ Optimal dispersion effects can emerge 'innocently'
- ▶ Bidirectionality predicts listener-oriented effects
- ▶ Suggests a larger role for general constraint-based theories of language processing