# Formal and Computational Approaches to Phonology

Friday: Auditory dispersion and change

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## 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?

## Dispersion

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

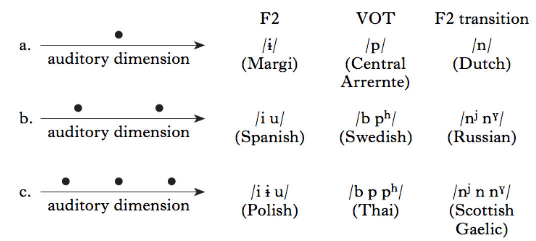



*Figure 1*
Observed auditory dispersion.

## Non-goal-oriented: Innocent misperception

Ohala (1981), Blevins (2004), etc.: sound change is caused by reanalysis of imperfectly transmitted (perceived) sounds.

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

Pierrehumbert (2001) suggests automatic shifting of auditory vowel prototypes to regions where they are less likely to be confused.

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

## Goal-oriented: Dispersion contraints

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-e̞-ɛ-a | | *!** | ✓✓✓✓ | *** | ***** |

## 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.'

## Is there another way?

Along with Padgett (2001), Sanders (2003), these works evaluate not input forms, but entire inventories or languages.

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).

## Framework: Bidirectional phonetics

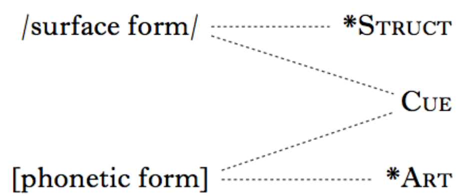



*Figure 3*
Grammar model for phonetics.

*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

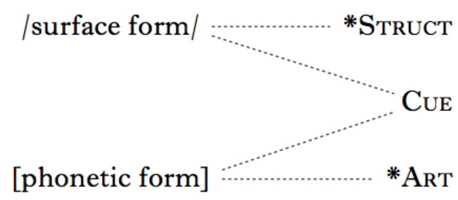


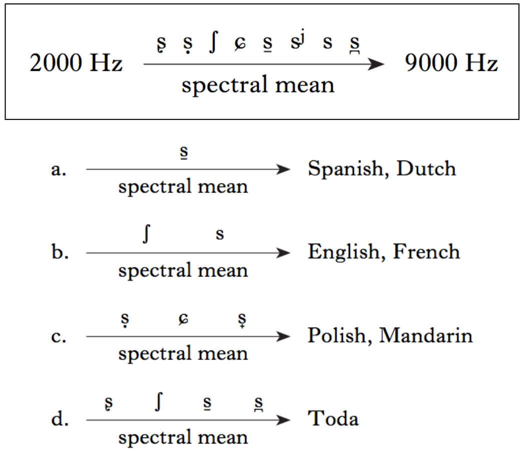

*Figure 3*
Grammar model for phonetics.

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

## Case studies: sibilant dispersion

Primary acoustic continuum:

spectral centre of gravity or spectral mean

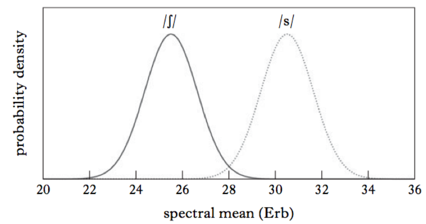



## Types of constraints

- STRUCT constraints (e.g. ONSET): evaluate phonological form only
- CUE constraints (e.g. *[long vowel duration] /obs, −voice/): evaluate relation between phonetic and phonological form
- ART constraints (e.g. *31 Erb): evaluate phonetic form only
- Here, we'll mainly be concerned with the (somewhat arbitrarily discretized) CUE and ART constraints

## Learning a perceptual grammar

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




. . . 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]/ʃ/ | *[26·6]/ʃ/ | *[26·5]/ʃ/ |
|---|---|---|---|---|---|---|
| a. /s/ | | *! | | | | |
| ☞ b. /ʃ/ | | | | | * | |

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?)

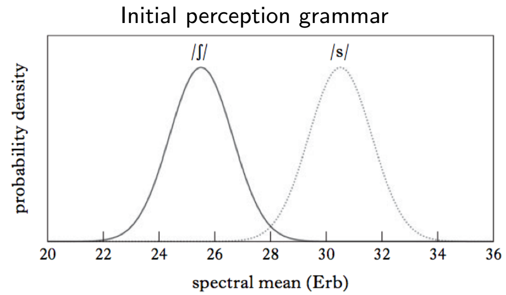
Learner optimally re-ranks cue constraints consistent with input (via the GRADUAL LEARNING ALGORITHM)

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

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

## A side-effect: prototypes

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

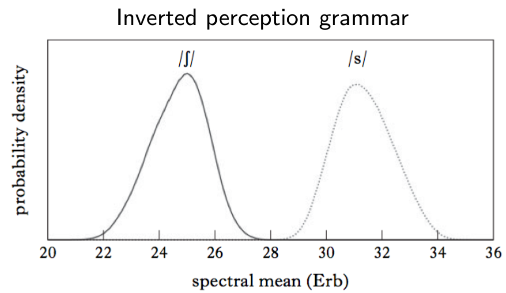



## Demo: English perception

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:



## *ART(iculatory) constraints

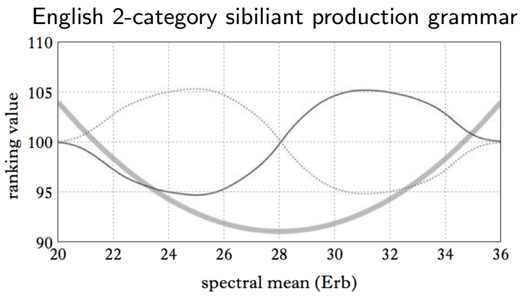
Thus B&H introduce (universally ranked) articulatory constraints:

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

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

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

Old Polish had an asymmetric sibilant inventory /ʃ $s^j$ s/ (Carlton 1991)

Modern Polish has a basically symmetric sibilant inventory /ṣ ɕ s̪/

Around the 13th century, [$s^j$] > [ɕ] . . .

. . . 300 years later, [ʃ] > [ṣ]

- (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?

## Summary

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

## Standard Eastern Norwegian

- Starting from CScand /s̠ ʃ ʂ/, predicts [s̟ ɕ ṣ] instead of [s̟ ç ṣ]
- Fails to predict attested mergers of /ʂ/, /ʃ/ > [ṣ] and /ʂ/, /ç/ > [ç]

From Williams, in prep.

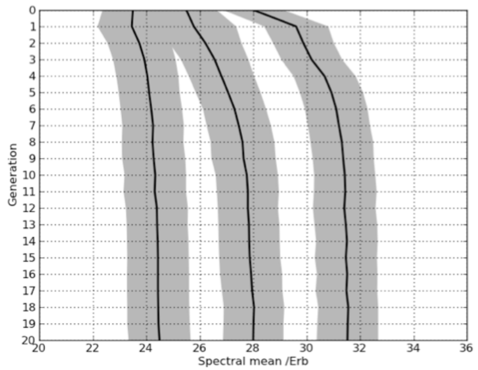



*Figure 3*
The evolution of the three initial standard eastern Norwegian sibilants over 20 generations.