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?

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 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

<table>
<thead>
<tr>
<th></th>
<th>MinDist = F1:2</th>
<th>MinDist = F1:3</th>
<th>Maximize Contrasts</th>
<th>MinDist = F1:4</th>
<th>MinDist = F1:5</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. i-a</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>b. ø</td>
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<td></td>
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<tr>
<td>c. i-ø-a</td>
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</tbody>
</table>

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).

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

![Grammar model for phonetics.](image)

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

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

Case studies: sibilant dispersion

Primary acoustic continuum:
- spectral centre of gravity or spectral mean

![Spectral mean distribution.](image)

Learning a perceptual grammar

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

![Probability distribution.](image)

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

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

| Spectral Mean (Erb) | English
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>20</td>
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<td>34</td>
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<tr>
<td>36</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Token</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>[s]</td>
<td>*</td>
</tr>
<tr>
<td>[f]</td>
<td>*</td>
</tr>
<tr>
<td>[θ]</td>
<td>*</td>
</tr>
</tbody>
</table>

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)

![A learner’s perception tableau with reranking of cue constraints](image)

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:

![Initial perception grammar](image)

A side-effect: prototypes

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

![Inverted perception grammar](image)
*ART(icalatory) constraints

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

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

<table>
<thead>
<tr>
<th></th>
<th>30</th>
<th>31</th>
<th>32</th>
<th>33</th>
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</thead>
<tbody>
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<td>a.</td>
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<td>b.</td>
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<td>f.</td>
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<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>g.</td>
<td>.</td>
<td>.</td>
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<td>.</td>
</tr>
</tbody>
</table>
```

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

Simulating sound change: English

- Stable English
- Exaggerated English
- Skewed English

Simulating sound change: Polish

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

Modern Polish has a basically symmetric sibilant inventory /s/ . . .

Around the 13th century, [ʃ] > [s] . . .

. . . 300 years later, [ʃ] > [s]

- (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 /s / s/, predicts [s ç s] instead of [s ç s]
▶ Fails to predict attested mergers of /ø/, /ʃ/ > [s] and /ø/, /ɛ/ > [ɛ]

From Williams, in prep.

The evolution of the three initial standard Eastern Norwegian syllables over 10 generations.