Phonetic Universals –
Abstraction vs detail and -etics vs -ology

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Whence universals?

Universal(ist)s come in all shapes and sizes – from strong Chomskyan to the weakest of statistical tendencies. Whence do they arise?

- unambiguously physiological (e.g. human pitch range)
- artefacts of motor development (prevalence of labials?)
- apparently phonetically motivated (\([p^h] \rightarrow [f]\))
- based on general cognitive motivations such as maximise difference between distinct entities
Universals of vowel systems

Where on the scale are the universal tendencies in vowels?
Is detailed phonetics of vowels important?
Or are they a consequence of abstract principles?
Starting point for today: Bart de Boer’s thesis.

- Simulate development of vowel systems among speaker population.

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Abstracting de Boer’s model

- Adopt the general framework (imitation games etc.) – but throw away phonetic detail.
- Vowels are simply points in 3-D space shaped like the printed vowel chart. (i.e. less front/back space for low vowels, rounding less important)
In more detail

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  - \(S\) chooses a vowel, ‘speaks’ it to \(L\) (all randomly).
  - \(L\) matches ‘heard’ vowel to one of its own, says that back.
- \(S\) communicates ‘extra-linguistically’ whether it heard what it originally said.
- On success, agents move vowels to be slightly closer to each other.
- On failure, \(L\) adds a new vowel based on what it heard.
- After many interactions, look at agents’ ‘vowel spaces’.
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- After many interactions, look at agents’ ‘vowel spaces’.
For example . . .

- 20 agents for 10000 interactions, parameters set to merge articulatory nearby vowels (in a cube). Run.
- The same, but vowels merged in perceptual space (vowel chart). Run.
- The same, with stronger mutual accommodation between speakers. Run.
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Now for something different . . .
Phonetic vs phonological universals

Many universalist phonologists believe in features (à la SPE). Features are phonology . . .
Recent study by Boersma and Chládková connected feature structure and vowel perception maps.
Boersma and Chládková 2010

Simulation framework is agents learning a 5-vowel system via an OT phonological grammar in Boersma’s interconnecting module version.

- Learners learning points in vowel space have ‘diagonal’ perceptual boundaries between vowels.
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- Learners learning categorical features (high/back etc) have horiz./vert boundaries.
- In reality, the latter happens (Savela 2009).
- They suggest this is evidence for features.

Moreover ...
B&C on Spanish and Czech

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This talk provides perceptual, computational and phonological evidence that the seemingly similar Spanish and Czech vowels are in fact represented as different sets of feature bundles:

<table>
<thead>
<tr>
<th></th>
<th>Spanish</th>
<th>Czech</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>central</td>
<td>back</td>
</tr>
<tr>
<td>e</td>
<td>central</td>
<td>front</td>
</tr>
<tr>
<td>i</td>
<td>low</td>
<td>mid</td>
</tr>
<tr>
<td>o</td>
<td>mid</td>
<td>high</td>
</tr>
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</tr>
</tbody>
</table>

We first simulate by computer how learners with these two feature systems will come to divide up the F1-F2 space perceptually; we call the virtual baby with the lefthand feature system S, that with the righthand system C. We teach S and C an identical language environment, namely the distributions that are painted as grey disks in the pictures below. The grammar model is that of Boersma (1997, 2007), in which cue constraints form the interface between phonology and phonetics. The cue constraints employed here are special: instead of arbitrary and exhaustive, they are phonetically-based. That is, they do not, as usual, connect (all) values of all auditory continua (here, F1 and F2) to all phonological elements (here: low, mid, high, front, central, back), but they connect (all) F1 values only to the height features low, mid, and high, and (all) F2 values only to the place features front, central, and back. Examples of such constraints are *

/low [F1=550 Hz], which militates against connecting a sound with an F1 of 550 Hz to the feature low, and *

/back [F2=1100 Hz].

The acquisition procedure follows Boersma (1997): a learner is fed pairs of auditory form (F1 and F2 values) and phonological surface form (a height and a place feature), using Stochastic OT and the Gradual Learning Algorithm. Once S and C have learned from the data, their cue constraints come to be ranked in such a way that their perceptual behaviour comes to look like this:

S:

C:

The patterns of diagonal, horizontal and vertical boundaries are very different in the two virtual learners. These patterns turn out to correspond to the perception patterns that we find in an identification experiment with 38 real Spanish and 50 real Czech listeners. This provides evidence that S is Spanishlike and C is Czechlike, therefore that the table above is correct for Spanish and Czech. We additionally provide phonological evidence for the features in the table, from palatalization and umlaut (přehláska) in Czech, and from synchronic nonfossilized processes and loanword adaptation in Spanish.

We conclude that two phonetically similar vowel inventories, which have traditionally been transcribed as phonologically identical, in fact reflect strikingly different phonological structures. A more general conclusion is that if you detect non-optimalities in the perception of phoneme inventories (such as the horizontal boundary between /o/ and /u/ in both pictures; an optimal, i.e. confusion-minimizing, boundary would have been diagonal), you can draw inferences about the language’s feature structure.

Perceptual differences in five-vowel systems reflect differences in feature structure

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- But phonology suggests Czech /a/, /e/ are [back] and [front], but Spanish /a/, /e/ are [central]
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This is what the simulation does with Czech and Spanish featuraly specified targets.
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- It’s also what B&C find in real speakers!
But is there a phonetic explanation?

We set up a simulation using learning via imitation game again, but:

- We distinguish children from adults (don’t learn) and have a dynamic population.
- The agents have a richer notion of vowel: articulatory prototype, and perceptual regions (convex polygons extended as they hear new exemplars).
- But the vowels are still simple and abstract (no phonetic detail, just $F_1$ and $F_2$).
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We seed the initial adult population with Czech or Spanish articulatory prototypes, and ask: Is it stable? What are the perceptual boundaries do the agents develop?
Four simulations

All specified by initial articulatory prototypes:

- A pure 5-vowel system \textit{Run}.
- with slightly raised e,o \textit{Run}.
- A Spanish 5-vowel system \textit{Run}.
- A Czech 5-vowel system \textit{Run}.

![Diagram of S and C vowel systems]
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appropriate different perceptual boundaries can arise as purely emergent phonetic consequences of vowel positions – no features in sight!