Formal and Computational Approaches to Phonology

Wednesday: Vowel Simulations

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And now for something completely different . . .

So far, we've been looking at 'pure', traditional, phonology: discrete, categorical, abstract systems.

Now we turn to the connexion of such phonology to real(?), continuous phonetics.

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Questions of interest: why do languages so often produce vowel systems like those we saw on Monday (not Swedish!)? Is it a natural consequence of . . . of what?

How do we model such a thing?

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Perceptual: how do we perceive vowels? Do we actually hear formants? (If so, how do we deal with variation?) Calling neuroscientists . . .

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- speakers map from perception to articulation by 'talking to themselves': trying to find articulations that produce the same percept.

It is interesting to observe that in his actual thesis (rather than the published book), he started with a much more detailed physical model. It didn't work ...

Phonetics, Phonology and Learning

We also have to model the process of learning a phonology.

How does a child convert the heard sound into its own articulatory instructions?

How does it know when it's correctly making some distinction that the adult makes?

(And how does all this work given that child voices are very different from adult voices? Let's not go there.)

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    - if $v == v'$, L marks v' as more successful, and perhaps moves it towards v; otherwise
    - L marks v' as less successful, and creates a new vowel phoneme based on v.

Noise, variation and tidiness

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To avoid proliferation of closely spaced vowels (Swedish!), speakers periodically tidy up by merging vowels that are perceptually close (by parameter).

Demo

Discussion

If the demo went well, we saw vaguely natural-looking vowel systems emerging.

- What have we learned from doing this?
- Did we have a falsifiable hypothesis? What was it?
- How does the success (or otherwise) of our ‘experiment’ depend on
  - the architecture of the model
  - the parameters within the decided architecture
- Whatever we’ve learned, how do we transfer it back to the real world?
- Compare and contrast with, e.g., an astrophysics simulation of galaxy formation; a predator–prey simulation in population dynamics; an economic forecasting model; etc. etc.

Simplifying the model

Suppose we abandon the relatively realistic modelling of articulatory, acoustic and perceptual domains, and just say that vowels are points in the unit cube, with a perceptual distance metric which squashes (a) backness when low (b) rounding compared to other dimensions (like the IPA vowel cuboid).

How much changes?

Demo

- 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.

Now what have we learned?

Getting a bit more phonological . . .

An interesting use of simulations is to try to support the psychological reality of phonological concepts.

Boersma and Chládková 2010

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- In reality, the latter happens (Savela 2009).
- They suggest this is evidence for features.

Moreover . . .

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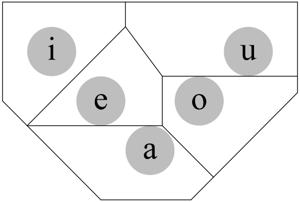

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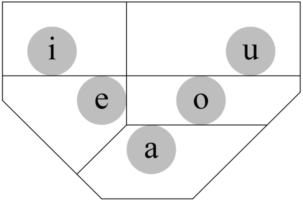

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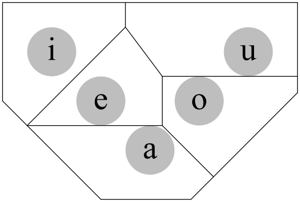

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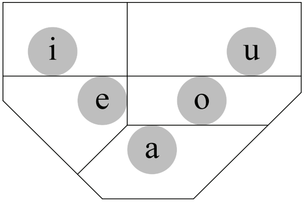

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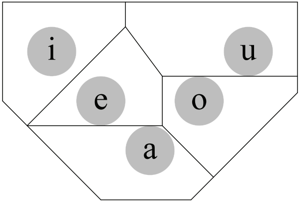

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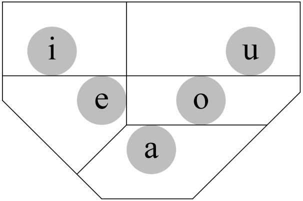

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- It's also what B&C find in real speakers!

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).
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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:

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- with slightly raised e,o Run.
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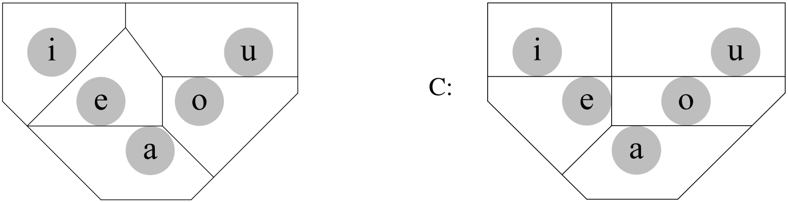

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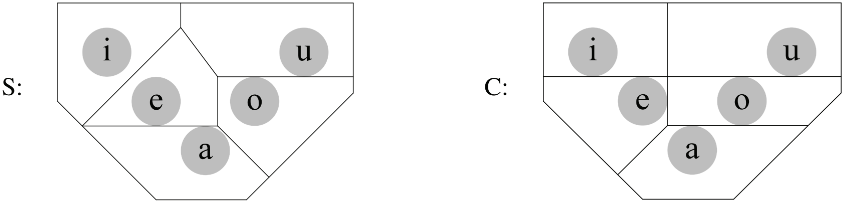

appropriate different perceptual boundaries can arise as purely emergent phonetic consequences of vowel positions – no features in sight!