What cultural evolution tells us about the innateness of language

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What’s wrong with this picture?
What’s wrong with this picture?

vs.

“The big language evolution debate”
Nativism and culture
Nativism and culture

• Chomsky and Pinker:
  • are both nativists
  • neither appear to believe in a significant explanatory role for cultural evolution
Nativism and culture

• Chomsky and Pinker:
  • are both nativists
  • neither appear to believe in a significant explanatory role for cultural evolution

• I want to argue that these two go together

• If you take cultural evolution seriously, it has surprising implications for nativism
What do I mean by innateness?
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- Everything we bring to the task of language learning that is independent of the data
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- The real questions:
  - what is the content of innateness?
  - is it specifically linguistic?
What do I mean by innateness?

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The real questions:
  - what is the content of innateness?
  - is it specifically linguistic?

Linguistic nativism:
  - strong, language-specific constraints
Why believe in linguistic nativism?
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- **UNIVERSALS**
  - The constraints on cross-linguistic variation directly reflect the languages we can acquire
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- **APPEARANCE OF DESIGN**
  - Language structure is adapted to communication. Biological evolution only explanation
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  - The constraints on cross-linguistic variation directly reflect the languages we can acquire

- **APPEARANCE OF DESIGN**
  - Language structure is adapted to communication. Biological evolution only explanation

- **POVERTY OF THE STIMULUS**
  - Given limited evidence, language acquisition would be impossible without significant innate knowledge
Cultural evolution
Cultural evolution

• Taking cultural evolution into account renders all three reasons suspect
Cultural evolution

- Taking cultural evolution into account renders all three reasons suspect

- Cultural evolution:
  - the analog of biological evolution in the domain of socially (rather than genetically) transmitted information

- Arguably, language is the best example in nature of a culturally transmitted system
Iterated Learning

- One mechanism for cultural evolution

- *Iterated Learning*: process whereby a behaviour is acquired through observation of another’s behaviour, who acquired it in the same way
Iterated Learning

• One mechanism for cultural evolution

• *Iterated Learning*: process whereby a behaviour is acquired through observation of another’s behaviour, who acquired it in the same way
Iterated Learning

- Nothing particularly controversial about this
- Nevertheless, it has unexpected properties we are only beginning to appreciate
- How do we study it?
  - Formal models
  - Experimental models with human participants
A formal model of Iterated Learning

Kirby, Dowman & Griffiths (2007), PNAS
A formal model of Iterated Learning

• Is it right to assume that universals are transparently related to innate constraints?

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• Need:
  • a model of innate contributions to learning,
  • and a way of telling what language universals this gives rise to.

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  • and a way of telling what language universals this gives rise to.

• Use *Bayesian* model of learning

Kirby, Dowman & Griffiths (2007), *PNAS*
Bayesian Iterated Learning
Bayesian Iterated Learning

- Learners combine *experience* with innately provided *prior bias* to calculate the probability of each language.
Bayesian Iterated Learning

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- Bayes rule gives us a simple model of such a learner

\[ p(h|d) \propto p(d|h)p(h) \]

- Allows us to provide a model of innateness, \( p(h) \), and predict what language (hypothesis), \( h \), a learner will pick given a given set of data, \( d \)
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Bayesian Iterated Learning

\[ p(\text{h is chosen} | d) \quad p(d | h) \quad p(\text{h is chosen} | d) \]
Bayesian Iterated Learning

- Imagine a chain of these learners, each one’s output the next one’s learning data:

\[ p(h_{\text{is chosen}}|d) \quad p(d|h) \quad p(h_{\text{is chosen}}|d) \]

\[ d_0 \rightarrow h_1 \rightarrow d_1 \rightarrow h_2 \rightarrow \cdots \]
Bayesian Iterated Learning

- Imagine a chain of these learners, each one’s output the next one’s learning data:

\[ \vdots \rightarrow d_0 \rightarrow h_1 \rightarrow d_1 \rightarrow h_2 \vdots \]

- There’s a neat mathematical trick that lets us work out what will happen here to the probability of different languages in the limit
From innateness to universals

- To recap:
  - If we think of innateness in terms of prior bias
  - then we can work out what languages will emerge from iterated learning
From innateness to universals

- To recap:
  - If we think of innateness in terms of *prior bias*
  - then we can work out what languages will emerge from iterated learning

![Diagram showing the relationship between Innateness and Universals](image)
A simple example: regularity
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- Model language as a set of meanings
A simple example: regularity

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- Meanings can be expressed regularly, or irregularly
A simple example: regularity

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- Start with the assumption that there is a slight innate bias in favour of regularity
  - We can vary the strength of this bias
  - It’s reasonable to assume this isn’t language specific
A simple example: regularity

- Model language as a set of meanings
- Meanings can be expressed regularly, or irregularly
- Start with the assumption that there is a slight innate bias in favour of regularity
  - We can vary the strength of this bias
  - It’s reasonable to assume this isn’t language specific
- What happens?
Probability of language by type: strong bias
\( (\alpha=1, \varepsilon=0.05, 4 \text{ meanings, 4 classes}) \)
Probability of language by type: strong bias
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Probability of language by type: strong bias
(\(\alpha=1\), \(\varepsilon=0.05\), 4 meanings, 4 classes)

Prior

m=10

regular

irregular
Probability of language by type: strong bias
($\alpha=1$, $\varepsilon=0.05$, 4 meanings, 4 classes)

- Regular:
  - aaaa
  - aaab
  - aabb
  - aabc
  - abcd

- Irregular:
  - m=10
  - m=6

Prior
Probability of language by type: strong bias
($\alpha=1, \varepsilon=0.05, 4$ meanings, $4$ classes)
Probability of language by type: strong bias
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Strength of language universal depends on amount of data seen
Probability of language by type: weak bias
($\alpha=40$, $\varepsilon=0.05$, 4 meanings, 4 classes)
Probability of language by type: weak bias
($\alpha=40$, $\varepsilon=0.05$, 4 meanings, 4 classes)

Strength of language universal independent of strength of innate preference!
• What’s innate matters, but you can’t predict language universals from innateness

• Equally, you can’t infer innateness from universals.

• Strong universals do not imply strong innate constraints

• Neatly predicts Dediu & Ladd’s (2007) genes/tone correlation
Linguistic adaptation
Linguistic adaptation

• Language is *adapt*ing culturally

• The languages we see are the ones optimised for transmission
  • No need for natural selection
Linguistic adaptation

- Language is *adapting* culturally
- The languages we see are the ones optimised for transmission
  - No need for natural selection
- The tougher the transmission “bottleneck”, the more pressure there is to adapt
  - Turns the poverty of the stimulus problem on its head
  - Explains the frequency/irregularity correlation in morphology
Irregularity by frequency
($\alpha=1$, $\varepsilon=0.05$, 8 meanings, 4 classes)

- $m=10$
- prior
Irregularity by frequency
($\alpha=1$, $\epsilon=0.05$, 8 meanings, 4 classes)

Irregularity changes with frequency even though innate preference is uniform.
Beyond formal models
Beyond formal models

• Can we replicate the modelling results in the lab?
Beyond formal models

• Can we replicate the modelling results in the lab?
• Is our model of learning reasonable?
• Can this kind of evolution happen in a reasonable time-scale?
• Can cultural adaptation happen without human intention?
An experimental paradigm

Cornish, K. Smith, Tamariz, A. Smith, Flaherty, Beqa
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• Participants exposed to artificial language made up of picture/string pairs (typically initially random)
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• Tested on full set of “meanings”
An experimental paradigm

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• Participants exposed to artificial language made up of picture/string pairs (typically initially random)
• Try and learn this
• Tested on full set of “meanings”
• Output on test used as input language for next participant
Explorations
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• We can vary the same parameters as in the formal models:
  • How much of the language the subjects are exposed to
  • Frequency of meanings
  • Structure of meaning space

• What are the results?
Explorations

• We can vary the same parameters as in the formal models:
  • How much of the language the subjects are exposed to
  • Frequency of meanings
  • Structure of meaning space

• What are the results?
  • Language adapts
Study 1: Emergence of structure

Cornish (2006); Kirby, Cornish & Smith (forthcoming)
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- Meanings are moving coloured shapes
- 3 x 3 x 3 meaning space
- Initial language completely random (and hard to learn!)

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Study 1: Emergence of structure

- Meanings are moving coloured shapes
  - 3 x 3 x 3 meaning space
- Initial language completely random (and hard to learn!)
- Over generations of participants, language becomes gradually easier to learn
- Compositional structure emerges

Cornish (2006); Kirby, Cornish & Smith (forthcoming)
Example initial language

<table>
<thead>
<tr>
<th>Lumonamo</th>
<th>Kinahune</th>
<th>Lahupine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nelu</td>
<td>Kanehu</td>
<td>Namopihu</td>
</tr>
<tr>
<td>Kapihu</td>
<td>Humo</td>
<td>Lahupiki</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Moki</th>
<th>Luneki</th>
<th>Lanepi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalu</td>
<td>Mola</td>
<td>Pihukimo</td>
</tr>
<tr>
<td>Nane</td>
<td>Kalakihu</td>
<td>Mokihuna</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kilamo</th>
<th>Kahuki</th>
<th>Neluka</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilu</td>
<td>Neki</td>
<td>Pinemohu</td>
</tr>
<tr>
<td>Luki</td>
<td>Namola</td>
<td>Lumoka</td>
</tr>
</tbody>
</table>
Example final language
(10 “generations” later)

<table>
<thead>
<tr>
<th></th>
<th>n-ere-ki</th>
<th>l-ere-ki</th>
<th>renana</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n-ehe-ki</td>
<td>l-aho-ki</td>
<td>r-ene-ki</td>
</tr>
<tr>
<td></td>
<td>n-eke-ki</td>
<td>l-ake-ki</td>
<td>r-ahe-ki</td>
</tr>
<tr>
<td></td>
<td>n-ere-plo</td>
<td>l-ane-plo</td>
<td>r-e-plo</td>
</tr>
<tr>
<td></td>
<td>n-eho-plo</td>
<td>l-aho-plo</td>
<td>r-eho-plo</td>
</tr>
<tr>
<td></td>
<td>n-eki-plo</td>
<td>l-aki-plo</td>
<td>r-aho-plo</td>
</tr>
<tr>
<td></td>
<td>n-e-pilu</td>
<td>l-ane-pilu</td>
<td>r-e-pilu</td>
</tr>
<tr>
<td></td>
<td>n-eho-pilu</td>
<td>l-aho-pilu</td>
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</tr>
<tr>
<td></td>
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<td>l-aki-pilu</td>
<td>r-aho-pilu</td>
</tr>
</tbody>
</table>
Study 2:
Frequency/irregularity

Beqa (2007); Beqa, Kirby & Hurford (forthcoming)
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- Meanings are actions performed by male or female agents
- Half meanings are frequently seen, other half infrequent

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Study 2: Frequency/irregularity

- Meanings are actions performed by male or female agents
- Half meanings are frequently seen, other half infrequent
- Initial language consists of verbs, half inflecting for gender regularly, half suppletives
- Over generations:
  - language becomes easier to learn
  - *infrequent* irregulars regularise

Beqa (2007); Beqa, Kirby & Hurford (forthcoming)
Frequency/irregularity

Frequent
- vipirir / vipirar ➔ rivipir / rivipar
- tada / sinefu ➔ tada / senoufe
- ridetir / ridetar ➔ ravipir / ravipar

Infrequent
- gidu / riwe ➔ riwa / riwe
- livove / domipu ➔ rimipir / rimipar
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  → ravipir / ravipar

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- livove / domipu
  → rimipir / rimipar
Pulling it all together
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• Language is culturally transmitted
  • Surprisingly little investigated in the literature
Pulling it all together

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- Reduces three different sources of support for linguistic nativism:
Pulling it all together

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• Reduces three different sources of support for linguistic nativism:
  • strong universals do not imply strong constraints
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• Reduces three different sources of support for linguistic nativism:
  • strong universals do not imply strong constraints
  • appearance of design does not imply natural selection
Pulling it all together

• Language is culturally transmitted
  • Surprisingly little investigated in the literature

• Reduces three different sources of support for linguistic nativism:
  • strong universals do not imply strong constraints
  • appearance of design does not imply natural selection
  • stimulus poverty actually drives cultural adaptation, reducing the problem innate knowledge is presumed to solve
A final note...
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• I am not denying innateness
  • It’s just not necessarily strongly constraining or language specific
A final note...

- I am not denying innateness
  - It’s just not necessarily strongly constraining or language specific

- I am not denying a role for biological evolution

- The real question is revealed: *How did humans end up being the only species able to transmit a symbolic system culturally?*