A Computation-Enabled Biological Perspective on Cultural Variation

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Even Tortoises Use Culture if It’s Available

Anna Wilkinson, Karin Künstner, Julia Müller & Ludwig Huber; in prep.
Outline

- Why culture should be adaptive (CS theory).
- Culture is adaptive (simulations.)
  - What limits the extent of its use:
    - Transmission probability; Stability; Cognitive strategy.
- Applications:
  - Conservation; Tracking cultural change; Understanding cultural variation.
Definition of Culture

- **For this talk:** Behaviour acquired from conspecifics by non-genetic means (Bryson 2008, 2009; Richerson & Boyd 2005).

- “Neo-diffusionist” — Kashima, yesterday.
Culture is Concurrency

• If each agent has a 1% chance of discovering a skill (e.g. making cheese) in its lifetime and there are 4000 agents, probably some agents will know the skill.

• If it is easier to learn the skill from a knowledgeable agent than by discovery, then selective pressure for culture.

• Individual & social learning both take time, but probably different amounts.
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Evolving Language

Two questions --- pick one:

• If language is useful, why are we the only species that has it?

• If language isn’t useful, why do we have it?

(Knight, Studdert-Kennedy and Hurford 2000)
Evolving Language

• Two questions --- pick one:
  • If language is useful, why are we the only species that has it?
  • If language isn’t useful, why do we have it?

(DeSalles 2000, 2004; Buckley & Steele 2002)
Evolution of Language

• If language isn’t useful, why do we have it?

• Language is costly signaling (DeSalles 2000, 2004; Buckley & Steele 2002 for review).

• Communicating valuable information is not in itself adaptive.

• Demonstration of fitness, prestige.

• Then why can women & children talk?
Trade-Offs Concerning Culture: A Simulation

Čače & Bryson (2005 AISB, 2007 Springer), Bryson, Bilovich & Čače (Submitted)

- Environment
- Agents’ Attributes
- Agents’ Behavior
- Results & Analysis
Environment

- Torus-shaped space (surface of a donut).
- Discrete patches of food, but agent’s location is continuous.
- \( N \) types of food, \( N-1 \) of which require special knowledge for eating.
- The one easy food is also the most common; exists in fixed proportion.
- Communication is about food processing.
Attributes of the Agents

• **Species**: either *talker* (altruist) or *silent* (free-rider.) Permanent, inherited.

• **Location**: $x, y$. **Age**: $0$-$\text{MaxAge}$ cycles.

• **Energy level**: moving & breeding costs, eating gains, born with 20% of parent’s.

• **Knowledge**: 5% discover 1 thing, all may overhear. Maximum $N$ things known.
How the Agents Behave

- If possible, eat food from present location
- Food regrows slowly; max one type of food in each place, may not know how to eat it.
- If you have enough energy, reproduce (lose 20% of energy to offspring, share location & species).
- If no energy or too old, die.
- Age, lose energy & move in a random direction.
- If talker, speak. Everyone near listens & learns.
Basic Results: Altruists & Knowledge

A graph showing the proportion of talkers and average knowledge over cycles.
Cost (in energy $\Rightarrow$ reproduction)

talker (altruist) silent (free-rider)

Number of Extra Food Types Known

Average Energy

<table>
<thead>
<tr>
<th>Number of Extra Food Types Known</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td>341</td>
<td>269</td>
<td>166</td>
<td>68</td>
<td>13</td>
</tr>
</tbody>
</table>
Knowledge (average & standard deviation)

talker (altruist) silent (free-rider)
Trade-Offs Favouring Culture

- The longer you live & faster you share the more society knows & the faster sharing fixates.
- The denser the society / higher the carrying capacity of the environment, the more society knows & the faster sharing fixates.
- The more food that can’t be exploited without knowledge, the faster sharing fixates.
Max lifespan 40 versus 50 cycles
1:8 (top) vs. 1:16 plants “special”; 32 trials each
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Model of Cultural Stability

Bryson (AACC 2008)

• Environment

• Agents’ Variable State
  • static, run-dependent, dynamic

• Agents’ Behaviour
Environment

- Continuous torus-shaped space again.

- But no food! This time, 2D models social space, not physical space.

- Each agent has 8 neighbours.

- In adaptive condition (below) may have fewer, but never more.
Agents’ Variable State

- **Location** \((x, y)\) -- run-dependent!
  Determines neighbours

- **Age.**

- **Knowledge** -- set of modules (one per context) & possible actions / values for these contexts.
## An Agent’s Brain

<table>
<thead>
<tr>
<th>Context</th>
<th>action 1</th>
<th>action 2</th>
<th>action 3</th>
<th>action 4</th>
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<tr>
<td>Context 1</td>
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<td>1</td>
</tr>
<tr>
<td>Context 2</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Context 3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>
Behaviour (per cycle)

• Environment sets a context randomly.

• Each agent expresses the action it thinks is appropriate for that context.

• All eight neighbours record this action.

• Agent may make a mistake, all neighbours will record the mistake.

• The appropriate action is what you’ve seen most in this context.

• In case of tie, pick randomly from leaders.
• Agents age and die, are replaced with entirely naive “children”. No gene transmission, only neighbour transmission.

• At the beginning of the simulation, each culture is seeded with a bias towards the action with the same index as the module.

• Can choose to have a condition where another cultural value is “adaptive”. A wrong value reduces chance of reproduction, right value can also seed one empty neighbouring space.
Slightly unstable; displays subcultures.
Same run with slight drop in noise.
Surprisingly stable subcultures after selection event
Simulation ‘Analysis’: Stability vs. Innovation

• Too much stability (too little noise) leads to no uptake of innovation.

• Too little stability leads to even adaptive innovations (and culture in general) getting lost.

• Fairly stable cultures still experience local “speciation” (sympatric?)
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Cognition

• Cognition is the time-consuming computation an individual does to create intelligent behavior.

• Not every aspect of intelligent behavior is computed ‘on demand’ (in real time).

• Intelligence also derives from our genes and our pre-processed experiences.
Cognition

• **Cognition** is the *time-consuming computation* an individual does to create intelligent behavior.

• Some intelligence derives from our *genes* and our *pre-processed experiences*.

• Some intelligent behaviour requires *new search* among limited alternatives.

*Trade offs → Variation*
Hinton & Nowlan (1987) Replication & Extension to Individual Variation
(c.f. Maynard Smith 1987)

Fitness: Agents more likely to reproduce during part of their life they have the exact right genome

(Richards & Bryson in prep; Paenke, et al 2006)
Only think when you don’t know what’s going on.

• Cognition is costly.
• Time, errors metabolism.
• Extent of investment can be determined from experience of mother (maternal effects) or individual.

Conservation

(Jenks, Lehmann & Bryson 2009)

individual
chase runners
territory + chase
(Bryson, Kaczensky & Grove in prep)
Tracking Culture via Large Corpus Semantics

• Human semantics can be replicated by statistical learning on large corpora (Finch 1993, Landauer & Dumais 1997, McDonald & Lowe 1998, Bilovich & Bryson 2008).

• Only information gathered on each word’s ‘meaning’ is what words occur in a small window before and after it.

• Normally just choose 75 fairly frequent words to watch out for.
Culture like you artists mean it

- Bilovich & Bryson (2008)
  - Goal: replicating Banaji implicit language bias data. RTs show implicit correlation between black, left, bad, violence, etc.
  - Cultural stereotypes in an AI (corpus-based) agent?
text: British National Corpus
Avri Bivolich May
2006
dissertation
text: bible
Avri Bivolich
May 2006
dissertation
text: Shakespeare
Reliably high levels of altruistic punishment are thought to explain human cooperation (Boyd 2006).

But some cultures invest heavily in anti-social punishment (Hermann, Thöni & Gächter 2008)
Flexibility Trade-Off for Social Norms?

- Appears to be variation in the extent to which cooperative equilibria can be discovered / changed.

- Looking to understand (simulate) differences and collect further data (work in progress with Herrmann).
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Conclusions

- **Diffusive perspective can do useful work.**
- **AI can be used to understand, track and even reflect culture & cultural change.**
Thanks!

Ivana Čače
Rob Jenks
Avri Bilovich
Marios Richards
Petra Kaczensky
Will Lowe, James Steele, Anna Wilkinson
A Computation-Enabled Biological Perspective on Cultural Variation

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• **Modeling** doesn’t investigate the world; it investigates our theories.

• **Simulations** are useful because our brains aren’t big enough to see all our theories’ consequences (Kokko 2007)
Biology & Cognition

Just as natural processes determining cognition impact politics & economics; natural processes determining biology impact cognition.

(D’Amato 1998, Behavioural Pharmacology)
Why are humans special?

Warning: Speculation starts here.
(Bryson, 2008; 2009)

• Humans are the only species who can do precise vocal imitation (Fitch 2000; 2007).

• Communicates lots of information, including volume, pitch, timbre and time.

• Humans can precisely imitate temporal sequence events of up to 3 seconds — length of phrases? (Pöppel 1994).
Why should temporal imitation matter?

- More information contained in the ‘genetic’ substrate.
- Allows for more variation while providing redundancy, robustness -- assists GAs (Baluja 1992; Weicker & Weicker; 2001; Miglino & Walker 2002).
Why don’t birds talk?

• They can’t hold 2\textsuperscript{nd} order representations

• Primates have uniquely complicated social organisations. (Harcourt 1992).

• Almost all species remember how group-mates behave with respect to themselves (tit-for-tat).

• But only primates behave as if they keep track of each other’s social behaviour.
<table>
<thead>
<tr>
<th></th>
<th>ego</th>
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<tbody>
<tr>
<td>Roy</td>
<td>5</td>
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<tr>
<td>Thelma</td>
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Why don’t birds talk?

- They can’t hold 2\textsuperscript{nd} order representations!
- Primates have uniquely complicated social organisations. (Harcourt 1992).
  - Almost all species remember how group-mates behave with respect to themselves (tit-for-tat).
  - But only primates behave as if they keep track of each other’s social behaviour.

**Hypothesis:** These 2\textsuperscript{nd} order representations are the basis of compositionality in language.
Why Humans are Special (Bryson 2008, 2009)

<table>
<thead>
<tr>
<th></th>
<th>temporal imitation</th>
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</thead>
<tbody>
<tr>
<td>second-order representations</td>
<td>people</td>
<td>non-human primates</td>
</tr>
<tr>
<td>no second-order representations</td>
<td>birds, seals</td>
<td>most things</td>
</tr>
</tbody>
</table>
Consequences: Stability vs. Innovation

- New simulation of Sperber & Hirschfeld (2004,2006) -- the interaction between massive modularity and culture, given noisy transmission (Bryson AAAI 2008).

- Meaningless set of norms set initially.

- Agents express (random one-of) behavior they’ve most often witnessed neighbors express in the same context.
Analysis

• Classic Simpson’s Paradox.

• When two knowledge communities meet, local surge in population and knowledge, until new resources are exploited to regrowth rate.

• If free-riders still present, will invade and destroy knowledge communities --- but not enough to change the probable outcome.
Altruistic Communication

- Communicating behaviour can be adaptive.
- Accelerated cultural evolution may precede & help explain language and the hominid explosion.
- Requires viscosity, that the altruistic act increases resources, and population oscillations (Mitteldorf & Wilson 2000).
- All common!
Hypotheses

• Language evolved *memetically*.
  
  • Wray (1998), Kirby (1999, 2006),
  
  • “Embodiment vs. Memetics” Bryson (EoL 2004, *draft*)
  
• Human intelligence *co-evolved* with language.
  
  • Carruthers (2003), Spelke (2002), Knight (2006).
Deacon’s (1997) Theory of Semantics
Bryson’s Theory of Semantics

Steels EoL 2006 plenary: coevolution of words & meaning (de Boer, Belpaeme)