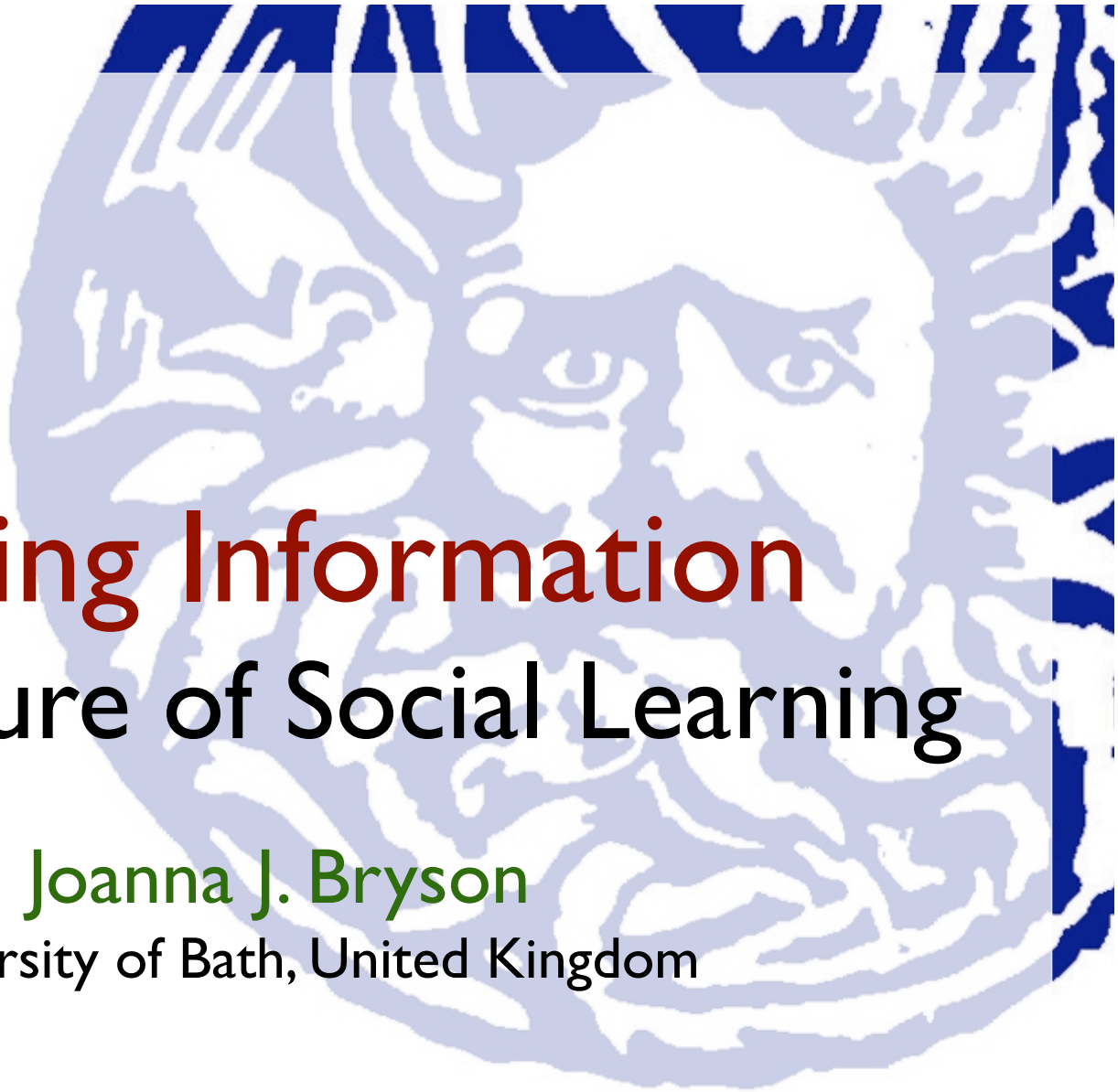


Sharing Information

The Nature of Social Learning

Joanna J. Bryson
University of Bath, United Kingdom

Outline

- Costs & Explanations of Social Learning
- Adaptive Characteristics of Information Transmission
- Culture, Representation and Human Uniqueness

Intelligence as Search

- Intelligence is a search for the next action.
  - Preserving solutions ("good tricks") once found is as important as innovation.
- Evolution (biological or cultural), individual learning (including development), and on-line planning are all mechanisms of search.
  - Adaptive modules extend beyond the individual.
  - Good tricks include representations.

Anil K. Seth, Tony J. Prescott & Joanna J. Bryson, *Modelling Natural Action Selection*, Cambridge University Press, 2011.

What Is Life About?

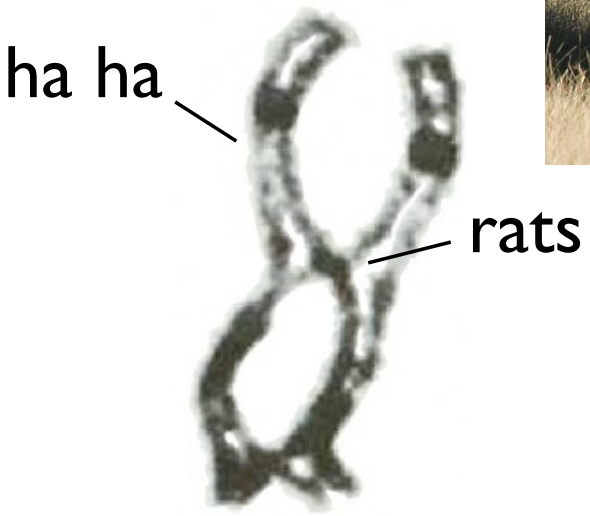
- Life persists–primarily through replication–in a dynamic environment.
- Main mechanism: Darwinian Evolution.
  - Evolution: Change over time resulting in diversity.
  - Darwin explained the diversity of species via variation, selection & transmission.

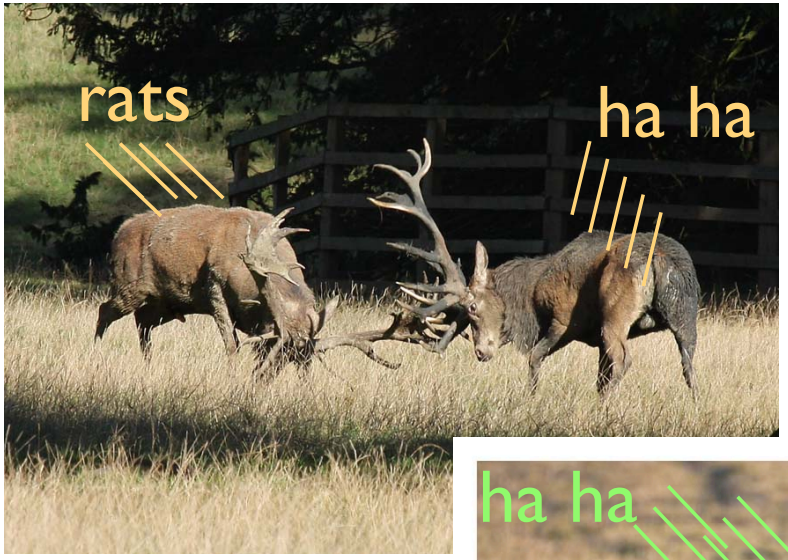
Darwinian Evolution

- Requires variation, selection & transmission.
  - What is transmitted is the replicator.
  - The unit of selection is the vehicle (or interactor.)
  - In the current ecology, most vehicles are composed of many, many replicators.
  - (Variation matters too)

Multiple Levels of Interaction ⇒Cooperation

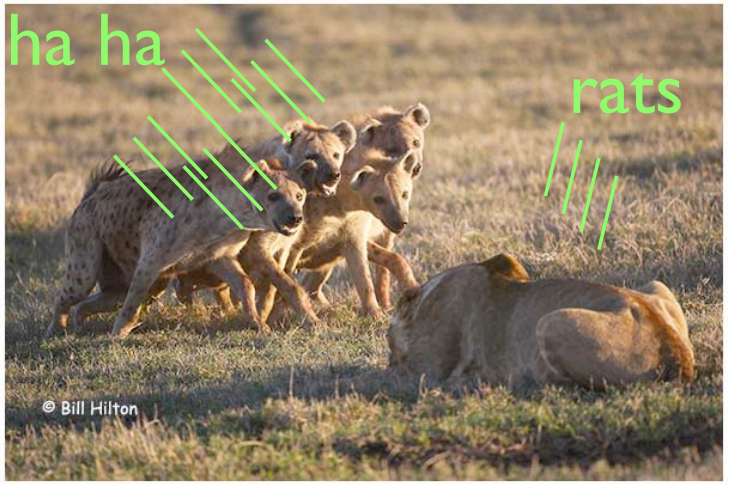
Gene itself





Organism

Group

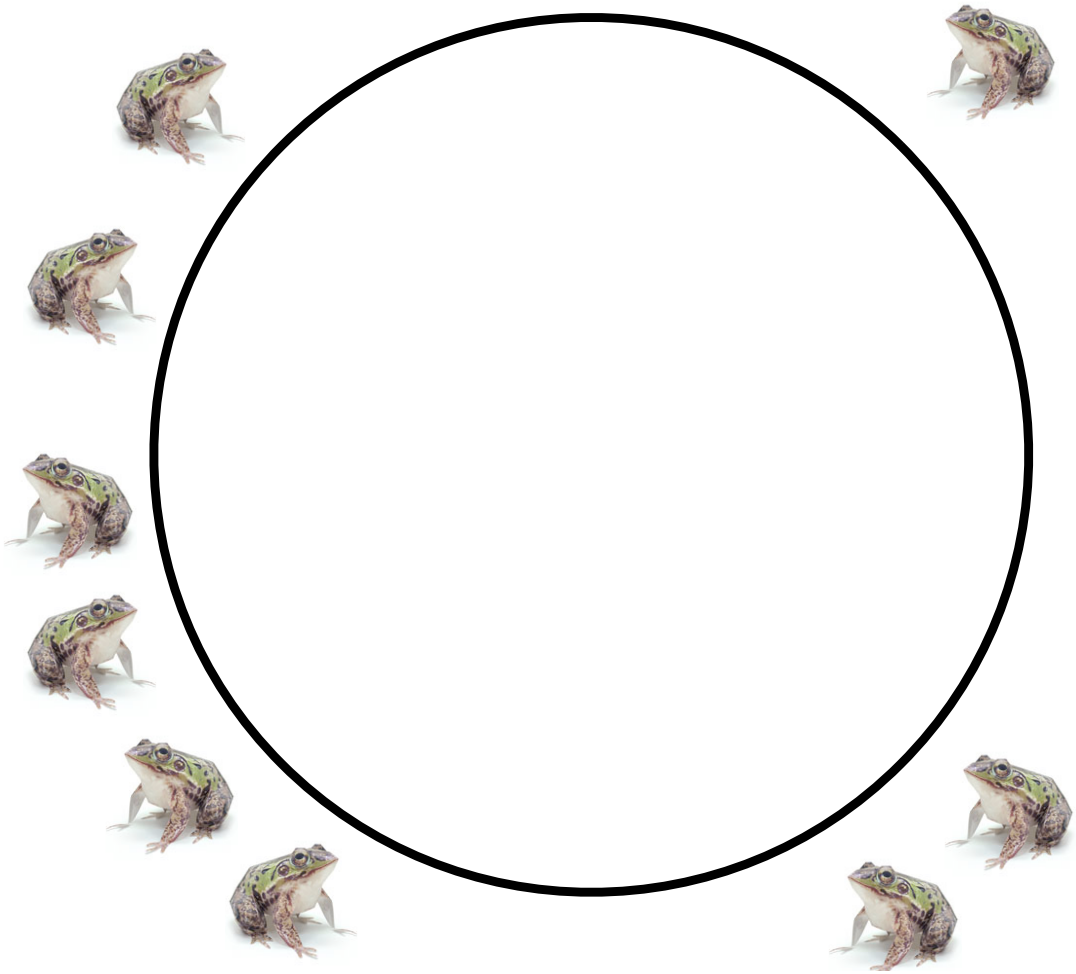


Costs of Socialisation

- Disease & parasites.
- Competition for food, shelter, mates.
- Time spent maintaining social structure.

Traditional Explanation (Galton 1871, Hamilton 1973)

- Aggregation as a form of cover seeking.
- Isolation increases probability of being near a predator.



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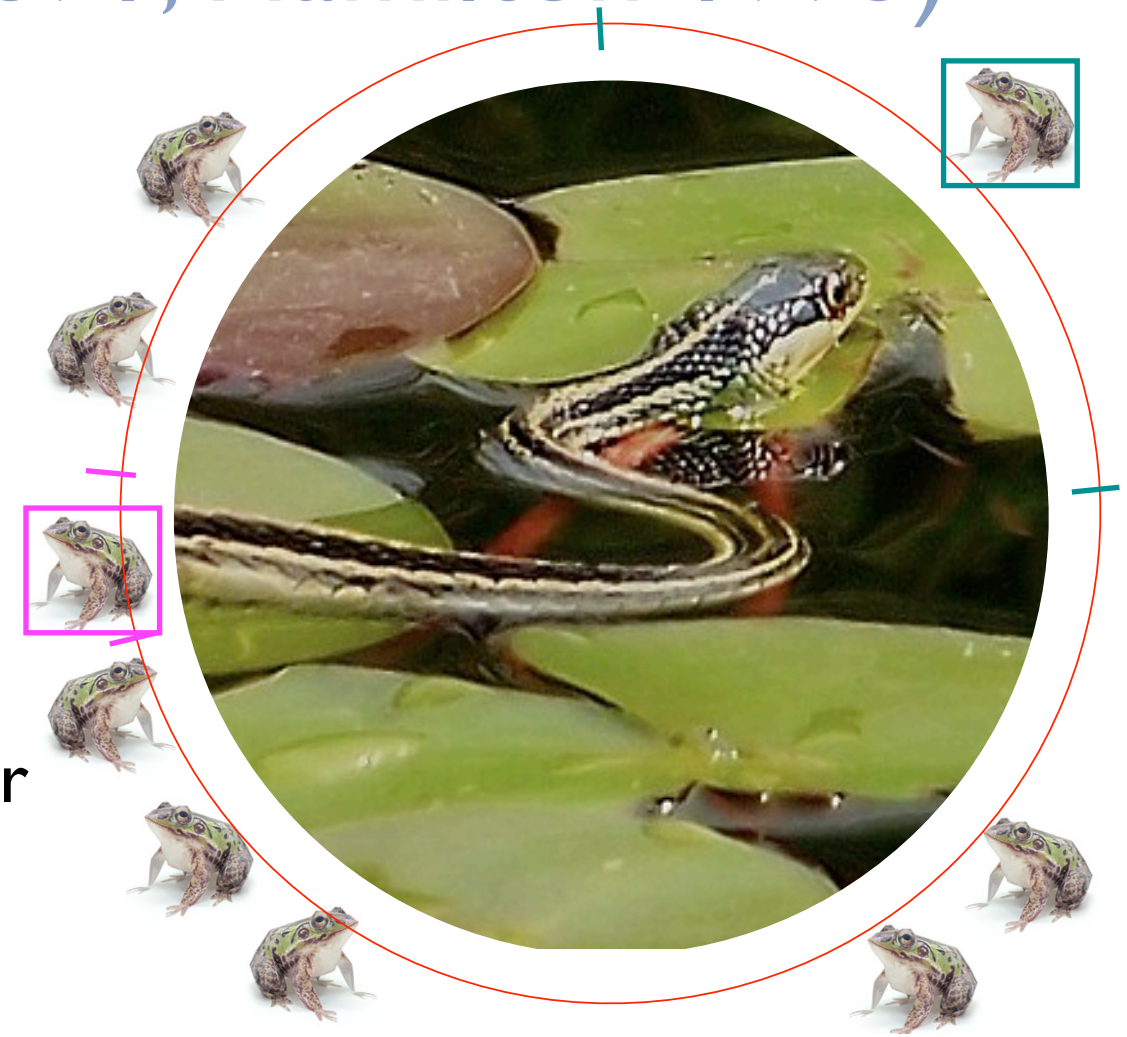
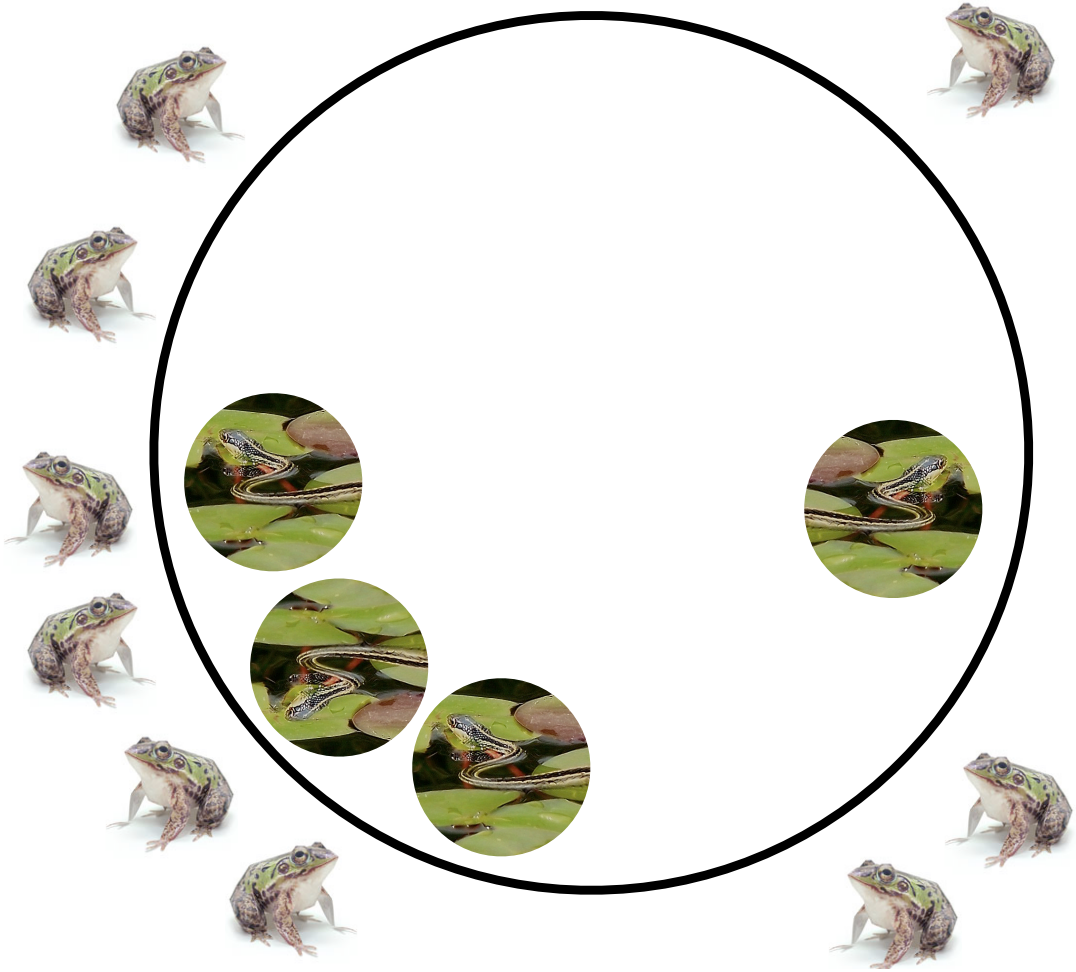


Why not socialise?

- Disease & parasites.
- Competition for food, shelter, mates.
- Time spent maintaining social structure.

Traditional Explanation (Galton 1871, Hamilton 1973)

- Aren't predators a form of parasite?



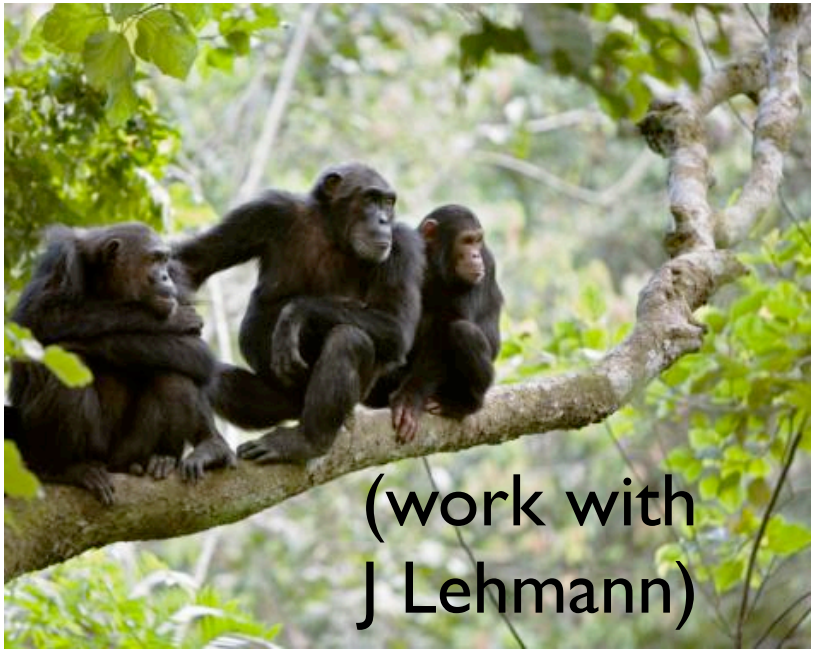
Talk Theses

- Sharing information (and therefore behaviour) is an adaptive strategy, fundamental to sociality and cognition.
- Species and cultures both
  - describe a space of possible solutions,
  - search within that space individually.

Novel Explanation

- Animals aggregate to share / exploit information.
- Threats, Opportunities, Behaviour.

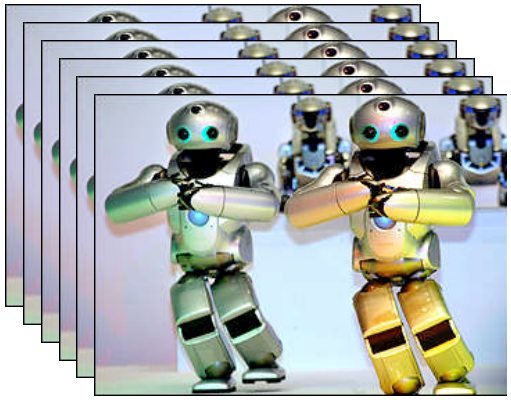
photo: Petra Kaczensky

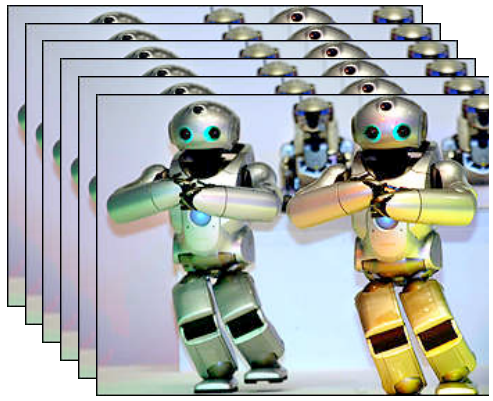


If information sharing is part of a species' adaptive repertoire, then populations may collapse even in numbers sufficient for genetic sustainability.

A Computational Advantage

- If every agent has a 1% chance of discovering a skill in its lifetime (e.g. making yogurt), & there are 2000 agents, then at any instant some agents probably have that skill.
- If it is easier to learn the skill from a knowledgeable agent than by discovery, then there is selective pressure for culture.





History of Social Learning Research

- In the mid-1990s many people doubted social learning occurred except in humans.
  - Altruism impossible to evolve.
  - Correspondence problem too hard.
  - No evidence from nature.
- Note: Rizzolatti didn't solve correspondence, but showed nature has.

History of Social Learning Research

- In the mid-1990s many people doubted social learning occurred except in humans.
  - Altruism impossible to evolve
  - Correspondence problem too hard.
  - No evidence from nature.

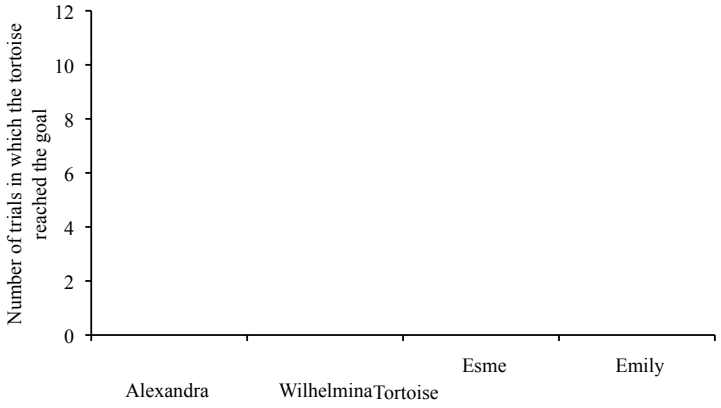
Culture in non-human primates

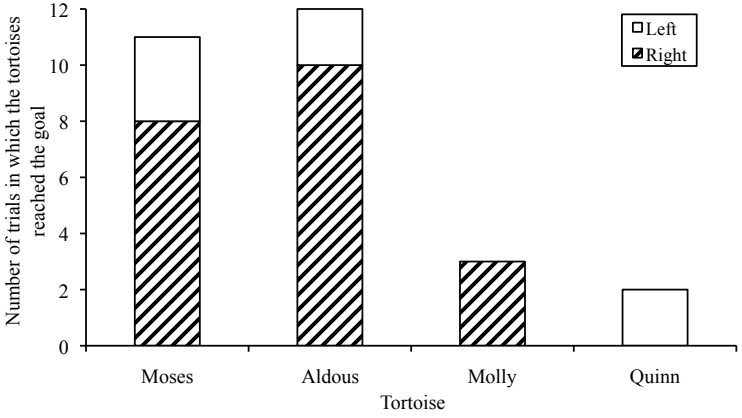
Chimpanzees (Whiten, Goodall, McGew, Nishida, Reynolds, Sugiyama, Tutin, Wrangham, & Boesch Nature 1999, p . 684).

Macaques (de Waal & Johanowicz 1993); Capuchins (Perry *et al* 2003); Orangutans (van Schaik *et al* 2003).

Solitary Tortoises Use Culture if It's Available

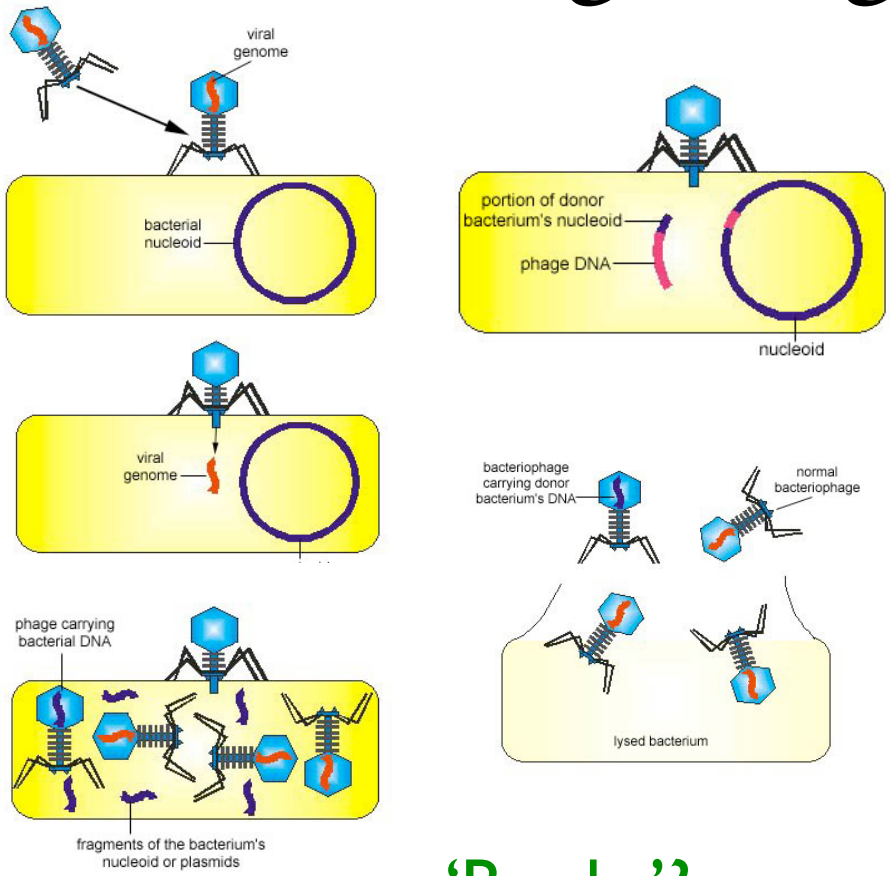
Social Learning in a Non-Social Tortoise
Anna Wilkinson, Karin Künstner
Julia Müller& Ludwig Huber 2010.





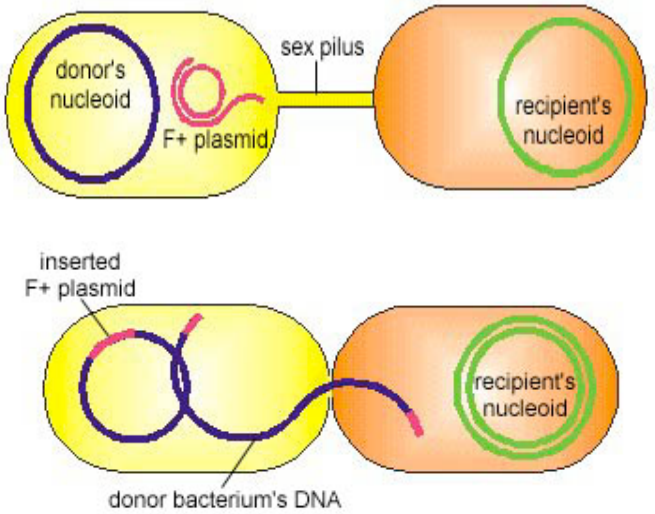
Even Bacteria Share Info

MGEs: e.g. Phages & Plasmids



'Books'?

One on One 'speech'?



Images from Bharat Kumar Chimanlal Patel

Mobile Genetic Elements (MGEs)

- Traditionally seen as parasites on a cell's reproductive capacity.
- Provide instructions for defence against environmental toxins e.g. heavy metals, antibiotics.
- Regulate extent of public goods production, 'altruism' – increase relatedness primarily at social behaviour loci.

work with Sam Brown

Nogueira *et al*. (2009) *Current Biology*
Rankin *et al*. (2010) *Heredity*

Outline

- Costs & Explanations of Social Learning
- Adaptive Characteristics of Information Transmission
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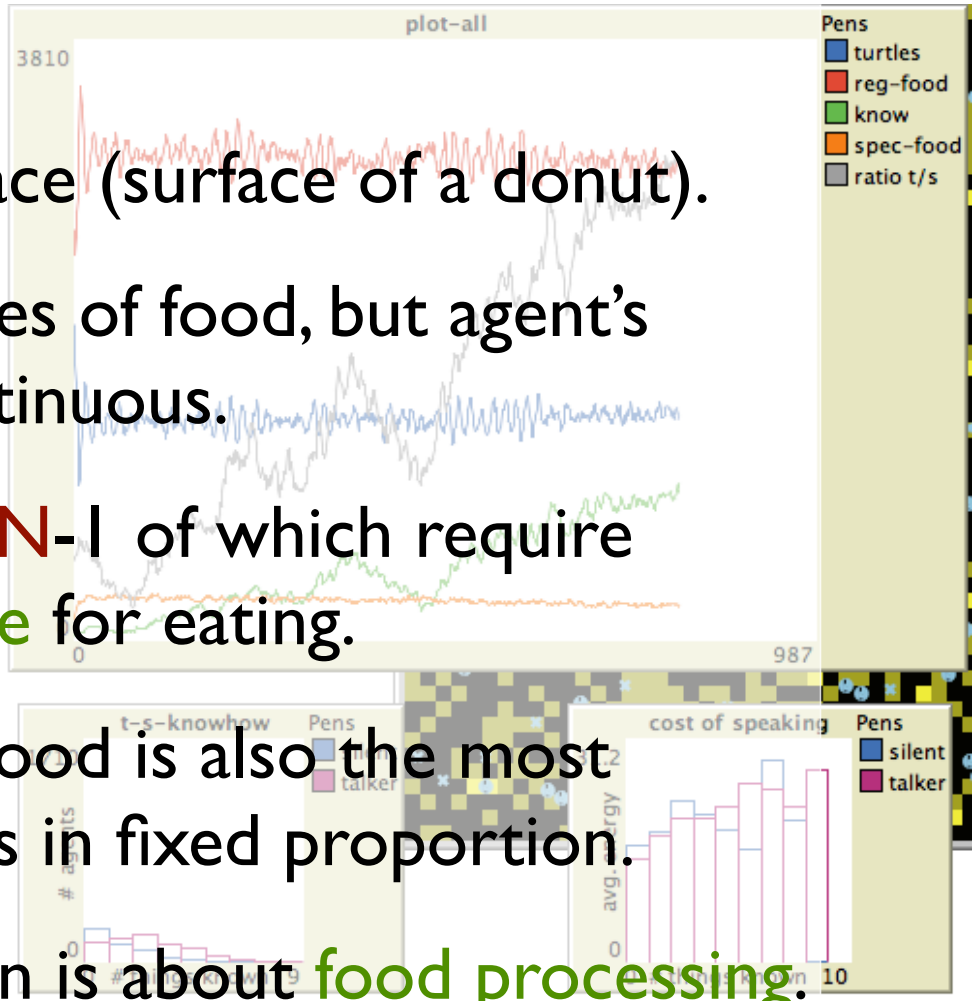
Explaining Selection for Culture

Čače & Bryson (2007 Springer), Bryson, Lowe, Bilovich & Čače (*under revision*)

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

Environment

NetLogo



- 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.

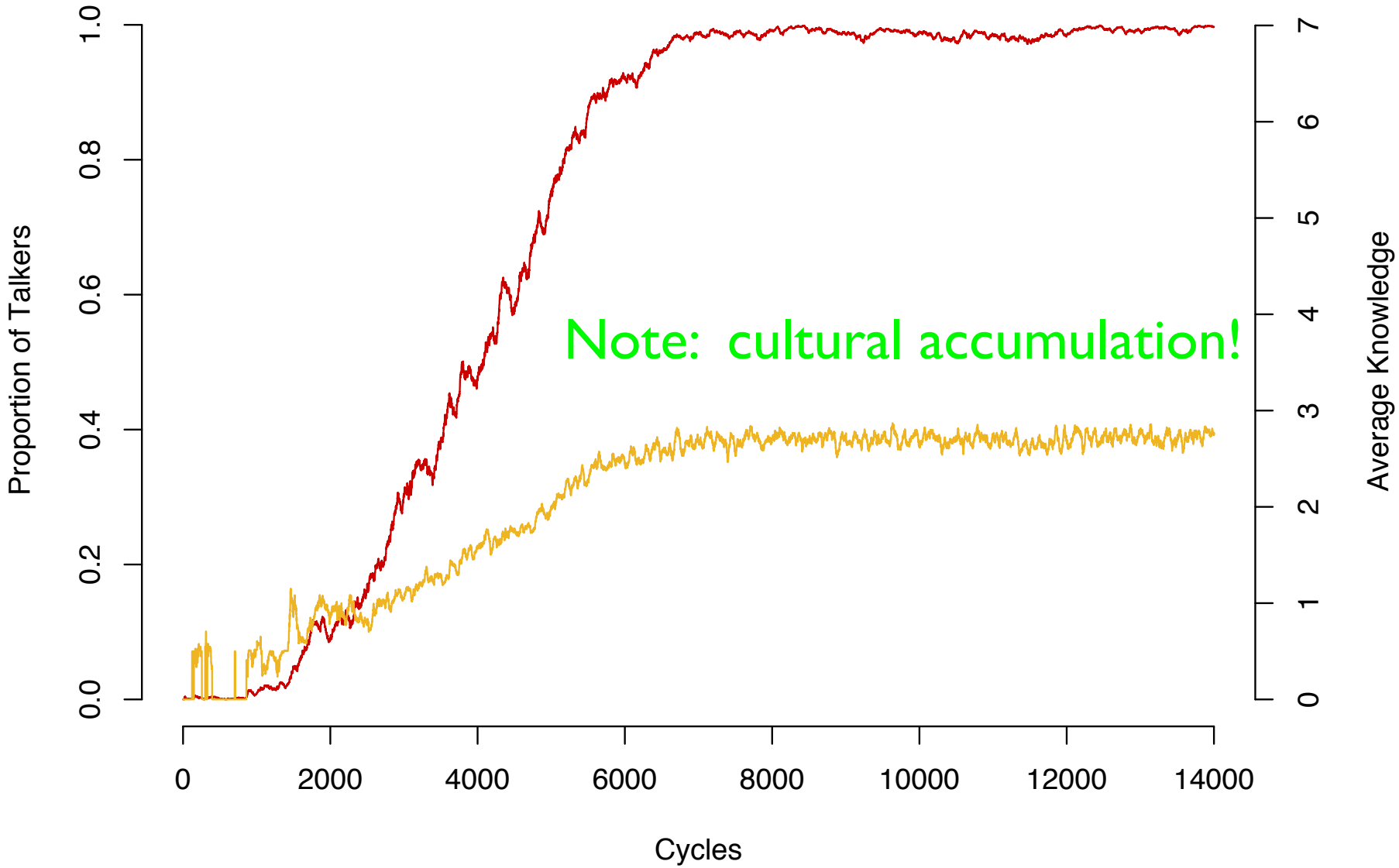
Attributes of the Agents

- Species: either talker (altruist) or silent (free-rider.) Permanent, inherited.
- Location: x, y. Age: 0-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

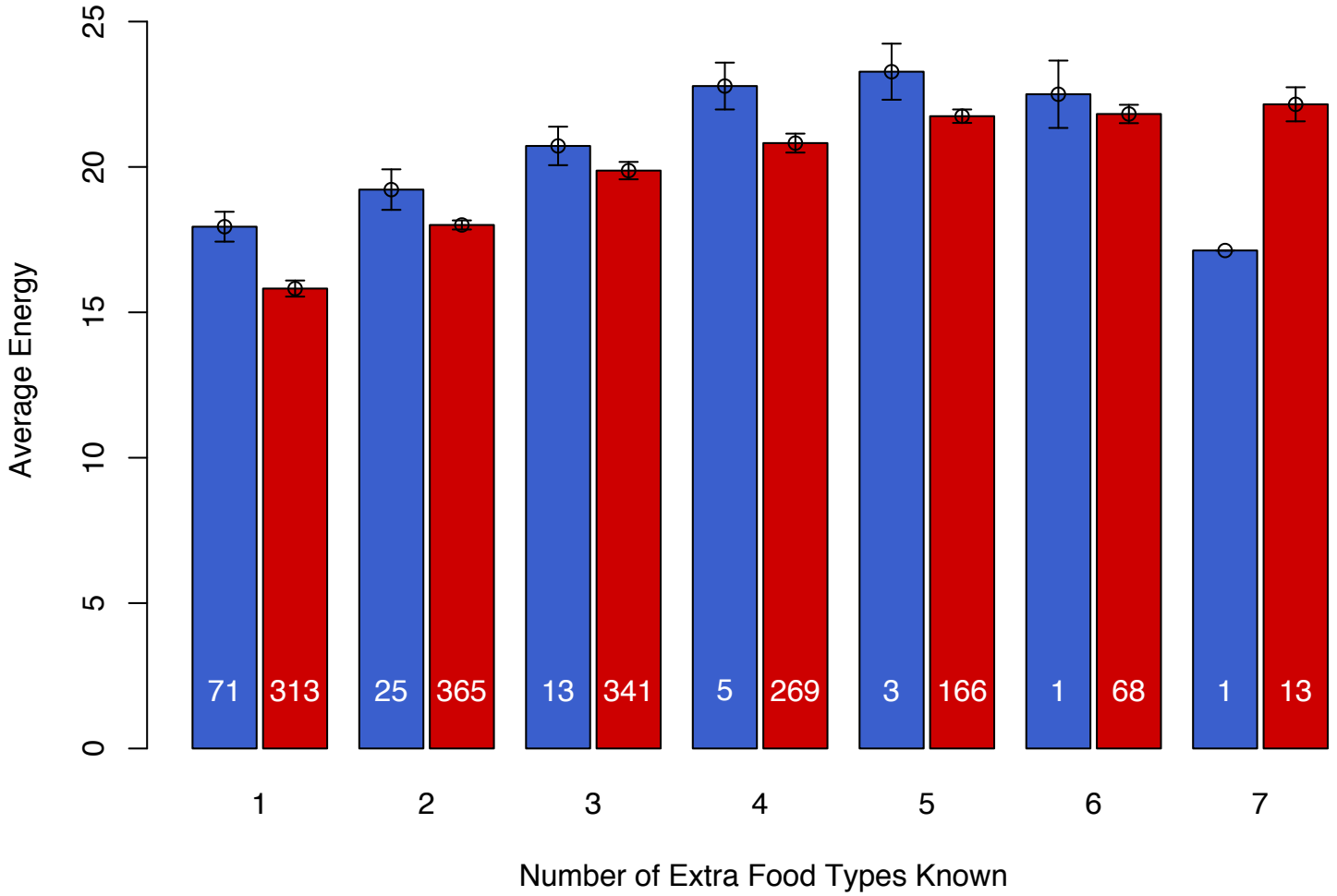
- If possible, eat food from present location
  - Food regrows slowly; max one type of food in each place, may not know how to eat it.
- If you have enough energy, reproduce (lose 20% of energy to offspring, share location & species).
- If no energy or too old, die.
- Age, lose energy & move in a random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

Basic Results: Altruists & Knowledge



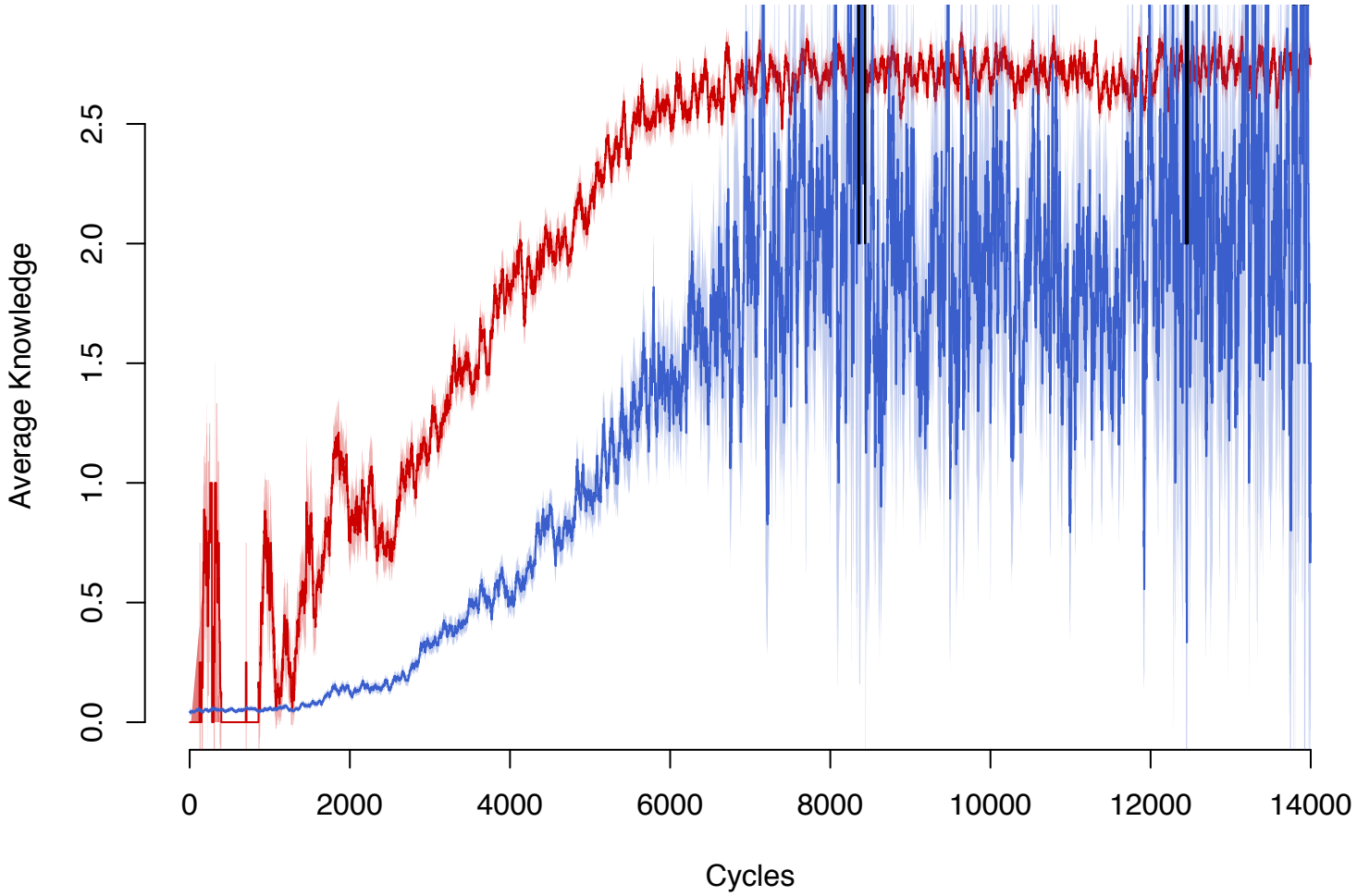
Cost (in energy ⇨ reproduction)

talker (altruist) silent (free-rider)



Knowledge (average & standard deviation)

talker (altruist) silent (free-rider)



Summary of Results

- It is adaptive though costly to share food-processing behaviour.
- A Simpson's Paradox resolved by proximity to similar individuals: determines knowledge.
  - Unlimited motion or transmission eliminate this effect, but these are also totally unrealistic.

viscosity

Evolving Altruism Does Not Require

- Punishment,
- Tagging / kin recognition,
- Explicit multi-level structure,
- Hard boundaries between groups,
- Memory of individuals / tit for tat.

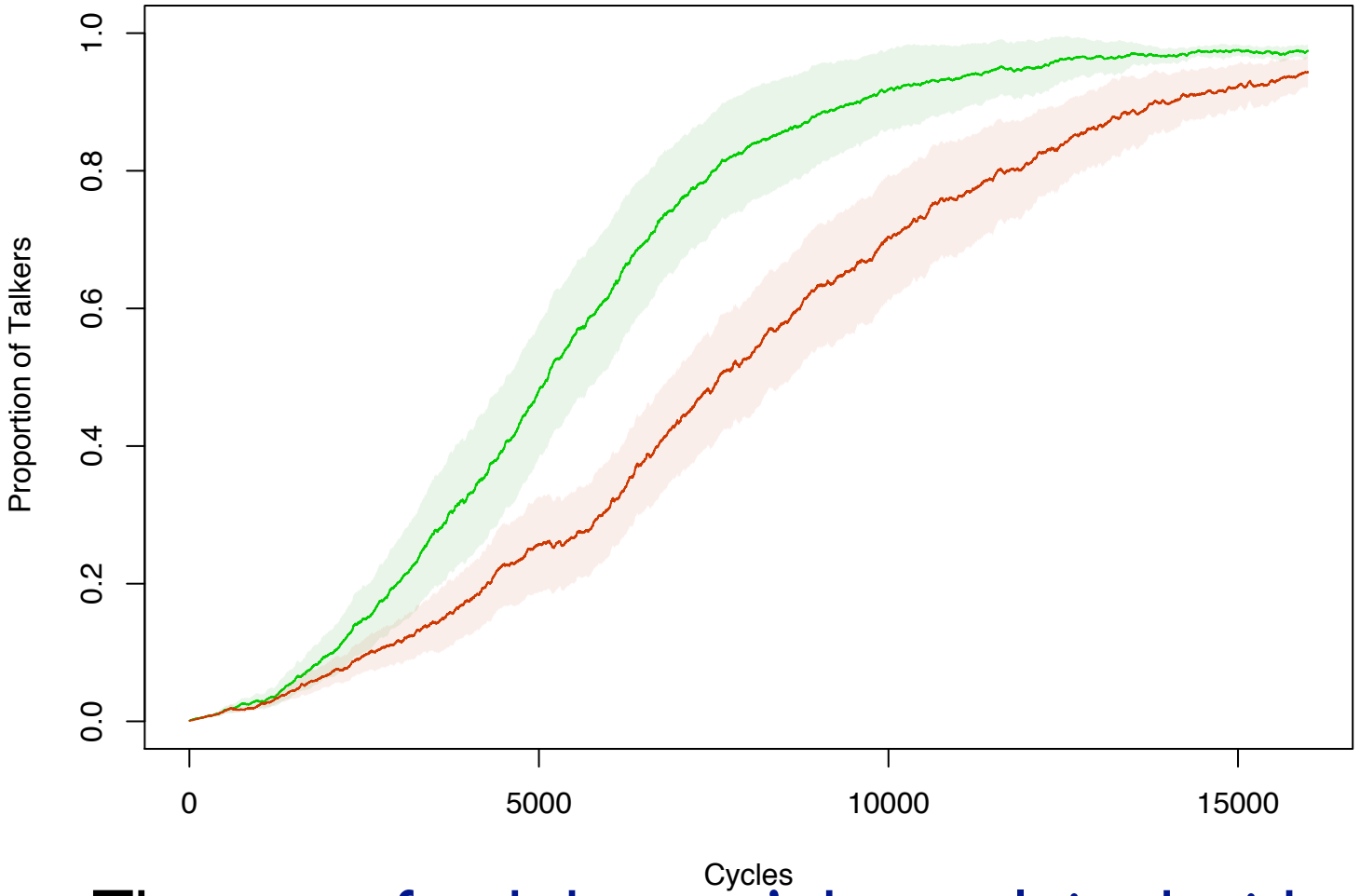
Joanna J. Bryson, Will Lowe, Avri Bilovich and Ivana Čače, "Factors determining the extent of a species' reliance on socially-acquired behaviour", *under revision*.

- What limits the size of culture?
- Why don't tortoises have laptops?

Biological tradeoffs determine amount of information transmittable per generation.

Cultural evolution determines quality of information.

1:8 (top) *vs.* 1:16 plants "special"; 32 trials each



- The more food that can't be exploited without knowledge, the faster sharing fixates.

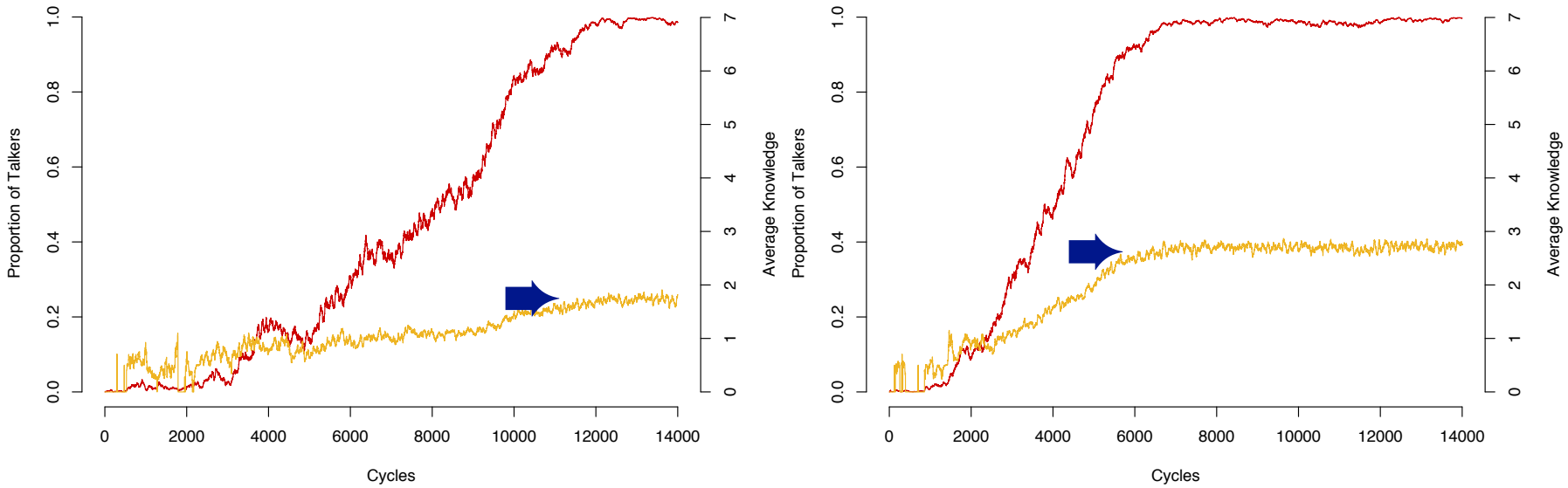
Trade-Offs Increasing the Size of Culture

- 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.

Joanna J. Bryson, Will Lowe, Avri Bilovich and Ivana Čače, "Factors determining the extent of a species' reliance on socially-acquired behaviour", *under revision*.

Max lifespan 40 versus 50 cycles

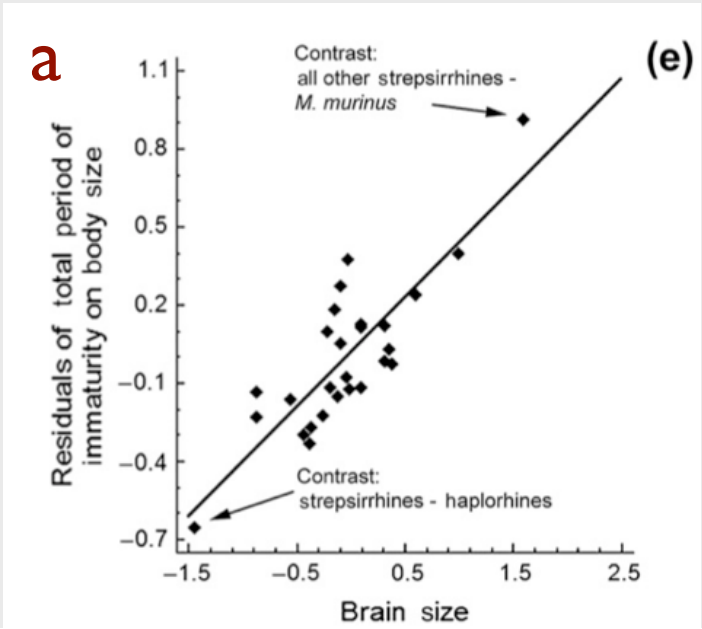
Longer life increases cultural accumulation & selective pressure for culture.



Note also more knowledge when higher proportion of altruists / density of speakers.

40 50

a



b

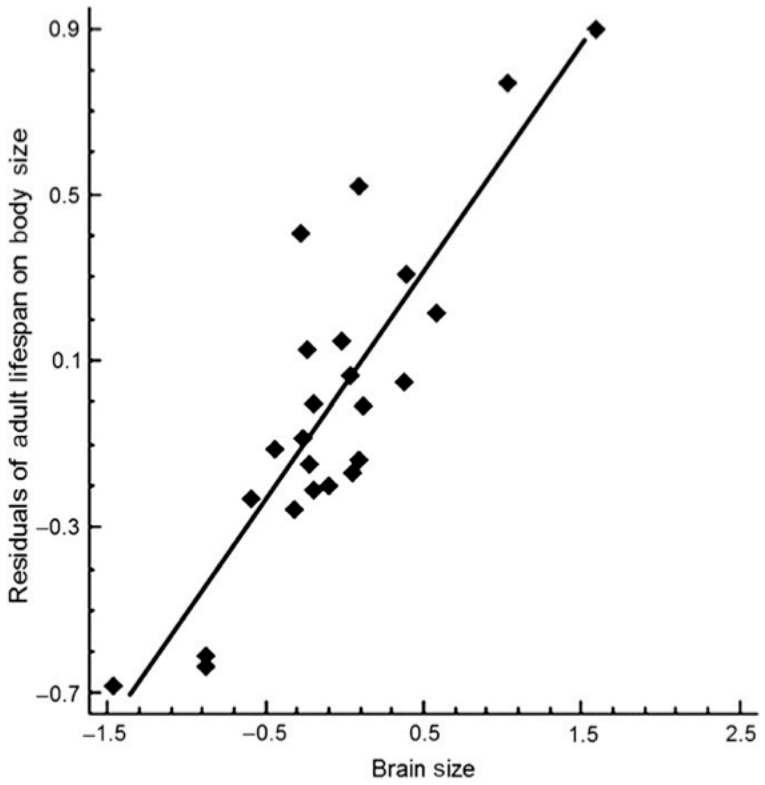
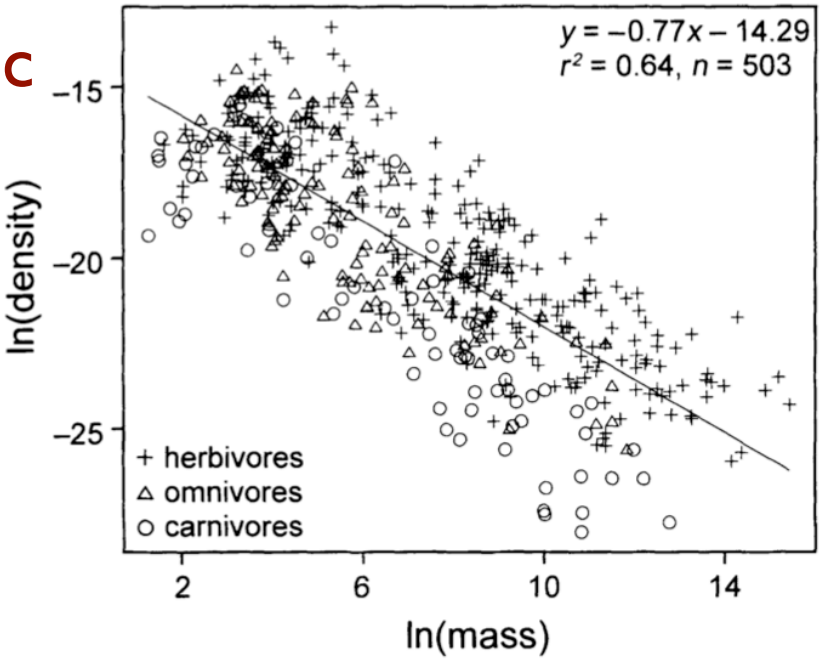


Fig. 5. Plot from the multiple regression analysis of maximum adult lifespan on body and brain size. The y-axis represents the residual variation in adult lifespan after the effect of body size has been removed. The x-axis plots the

c



Big brains correlate w/ long life, slow maturation, big size & sparseness.

a, b Barrickman, Bastian, Isler & van Schaik (2008): y axes are residuals.

c Brown, Gillooly, Allen, Savage & West (2004)

Tradeoffs

- One we know:
  - Lifespan correlates with size. Size trades off against population density.
- One I suspect:
  - Lifespan trades off against biological evolution.

work in progress

Outline

- Costs & Explanations of Social Learning
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- What limits the size of culture?
- Why don't tortoises have laptops?

Biological tradeoffs determine amount of information transmittable per generation.

Cultural evolution determines quality of information.

The Size of a Culture

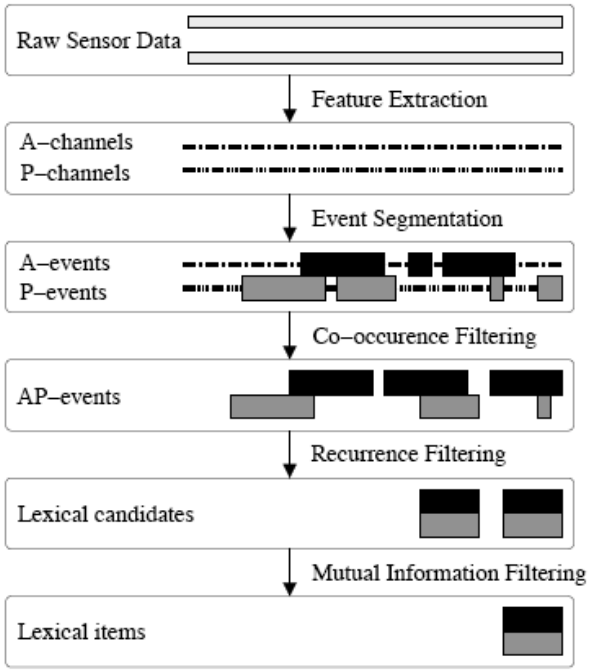
The amount of information that can be transmitted between generations

+

Innovation

Social Learning of Real-Time Behaviour

Even in VR, intractable without an enormous amount of prior information. (Wood & Bryson 2007)

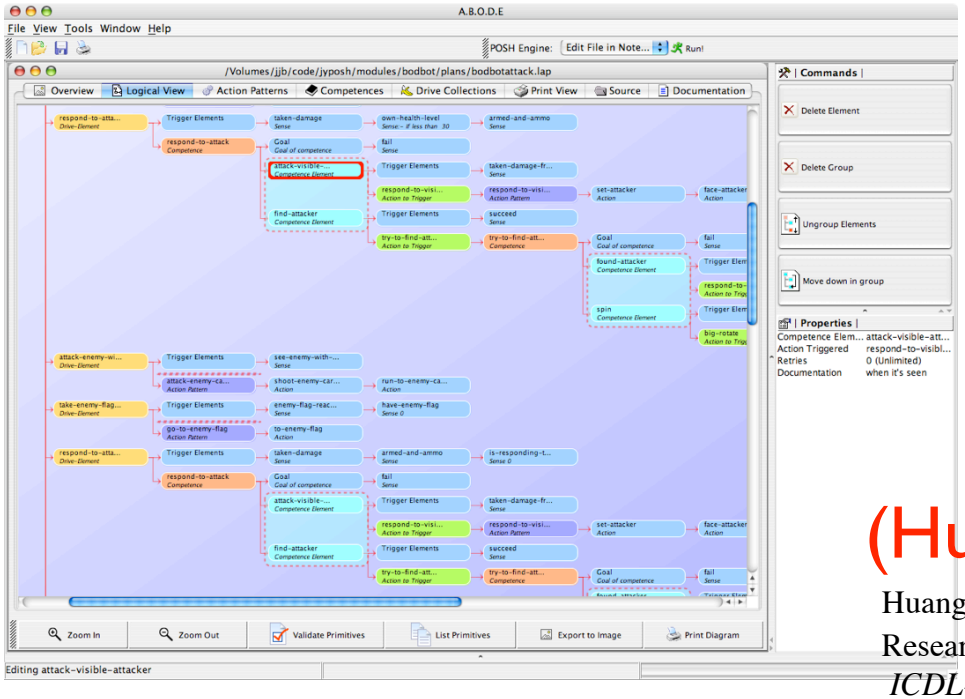


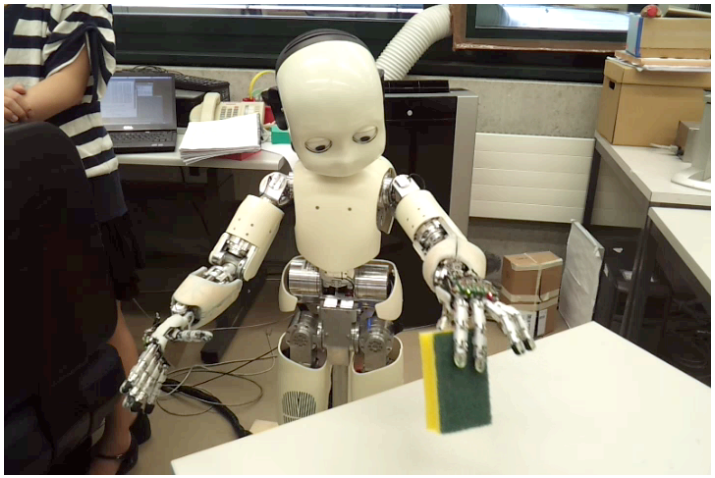
Extension of Roy 1999 (PhD) to realtime planning.

Mark A. Wood and Joanna J. Bryson, "Skill Acquisition Through Program-Level Imitation in a Real-Time Domain", *IEEE Transactions on Systems, Man and Cybernetics Part B—Cybernetics*, **37**(2):272–285, April 2007.

Learning is Hard ∴ Requires Massive Priors

Behaviour Oriented Design facilitates integrating expectations, planning and learning (Bryson 2000-2011)





(Huang, Leake & Bryson 2011)

Huang, Leake & Bryson, "Humanoid Robots and Cognitive Systems Research: An Epistemological Case Study Based on the iCub" *ICDL-EpiRob*, Frankfurt, August 2011.

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Cultural Evolution

- The size of culture is limited by biological constraints—e.g. evolutionary tradeoffs.
    - These change relatively slowly, though they do (co)evolve.
- The extent of culture—the amount of information / behaviour it contains, increases as representations become more efficient (Kirby 1999, Bryson 2010).

Joanna J. Bryson, "Cultural Ratcheting Results Primarily from Semantic Compression", in *Proceedings of the Evolution of Language 2010*, Smith et al (eds.), World Scientific, pp. 50–57,

Why are humans special? (Bryson 2008, 2009,2010)

- Humans are the only primate species capable of precise vocal imitation (Fitch 2000; 2007).
- Communicates lots of information, including volume, pitch, timbre and time.
- Allows redundant encoding to preserve important details while others can mutate ⇒ cultural evolution.

Joanna J. Bryson "Representations Underlying Social Learning and Cultural Evolution" *Interaction Studies*, **10**(1):77–100, March 2009.

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).
- C.f. Wray (2000) on the evolution of language from phrases, Kirby (2000) on cultural selection for language efficacy.

Kirby's Iterated Learning

- The size of culture transmitted (# of phrases heard from parent) is the bottleneck in IL.
- Kirby became famous because a fixed size selects for* increased semantic compression (regularity), thus increasingly more can be communicated between generations — greater extent.

*assuming the representation allows for its evolution

Why Humans are Special (Bryson EoL 2010)

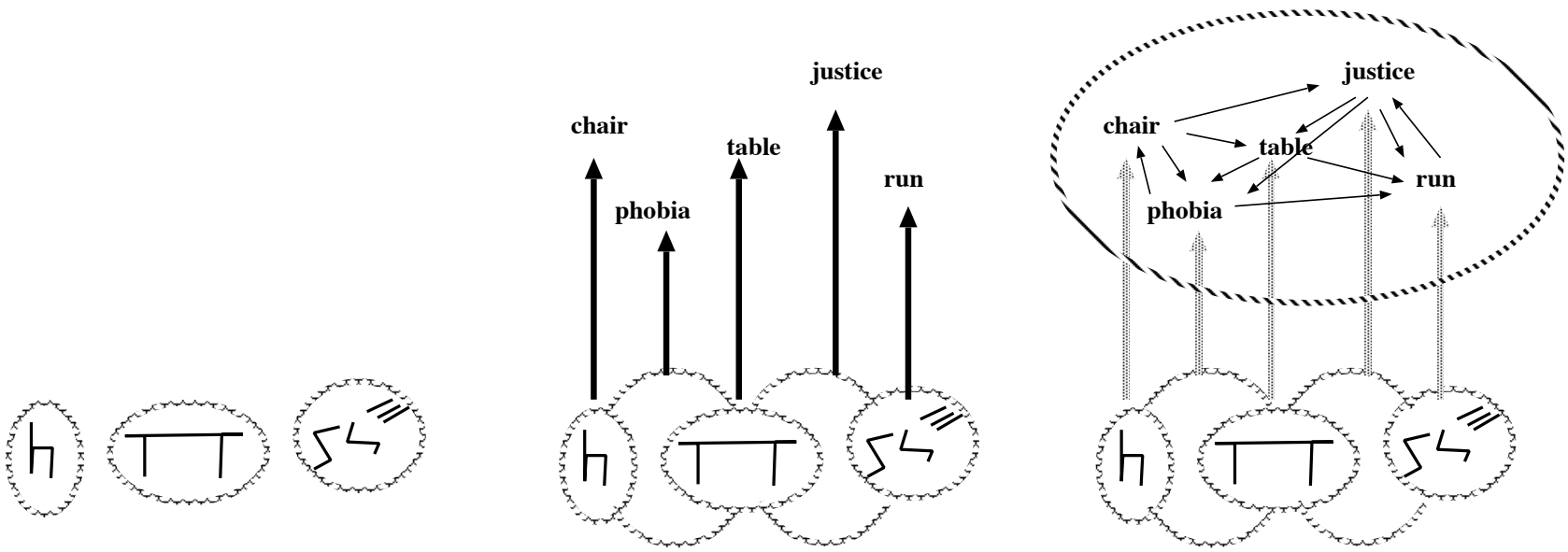
	temporal imitation	no temporal imitation
big brains, memories	people	non-human apes
no big brains, memories	birds, seals	most things

Getting Culture from Large Corpus Semantics

- Human semantics can be replicated by statistical learning on large corpra (Finch 1993, Landauer & Dumais 1997, McDonald & Lowe 1998, Bilovich & Bryson 2008).
- The only information gathered on each word's 'meaning' is what words occur in a small window before and after it.
- Normally just use 75 fairly frequent words to watch out for.

Joanna J. Bryson "Embodiment versus Memetics", *Mind & Society*, **7**(1):77–94, June 2008.

Deacon's (1997) Theory of Semantics



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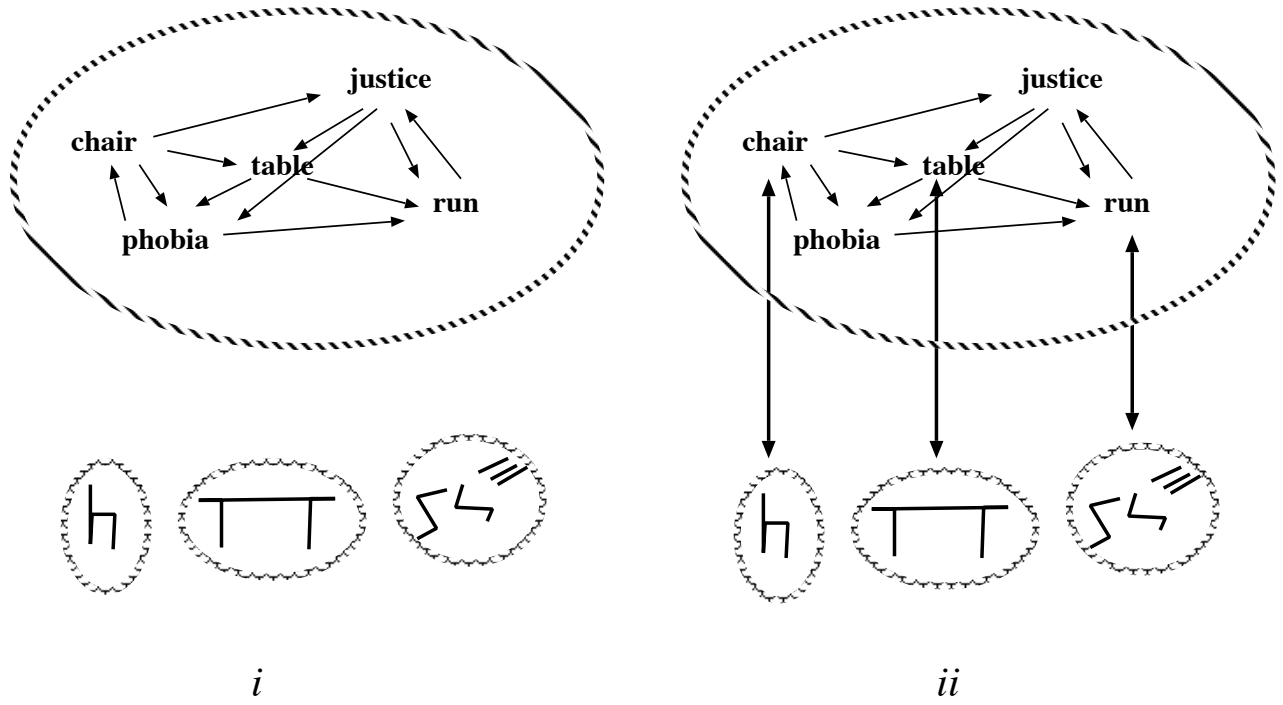
Bryson's Theory of Semantics



i *ii*

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

Tracking Cultural Change

- 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?

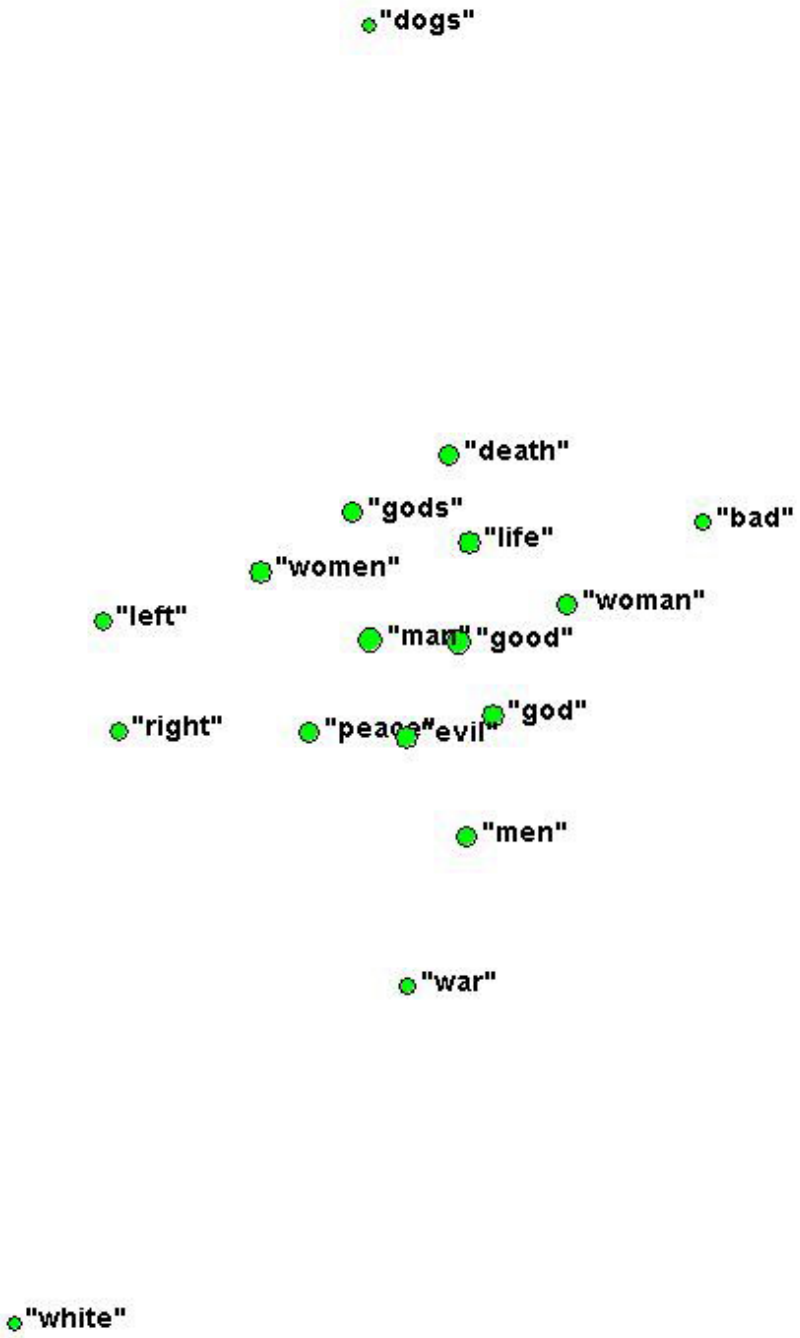
Avri Bilovich and Joanna J. Bryson, "Detecting the Evolution of Semantics and Individual Beliefs Through Statistical Analysis of Language Use", *Proceedings of the Fall AAAI Symposium on Naturally-Inspired Artificial Intelligence*, J. Beal, P. Bello, N. Cassimatis, M. Coen and P. Winston (eds), pp. 21–26,

Avri Bivolich
May 2006 UG
dissertation

text: British
National
Corpus

Avri Bivolich May
2006
dissertation

text: bible



Avri Bivolich
May 2006
dissertation

text: Shakespeare

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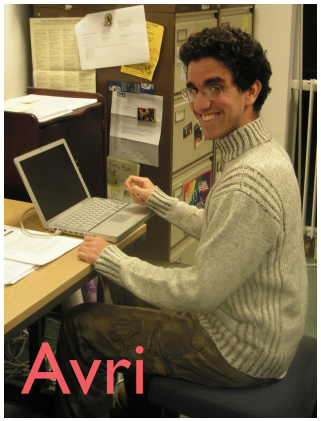
Conclusions

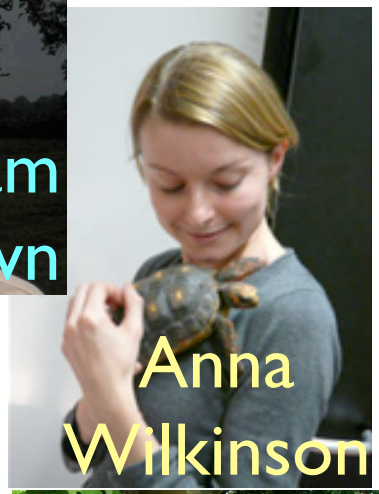
- Social learning is a key adaptive mechanism for acquiring behaviour.
- The extent of a species' predisposition to use it is determined by a number of adaptive tradeoffs and representations.
  - Humans, as apes with vocal imitation, are more extreme than unique.
- Utilising cultural knowledge may require more systems AI than people want to know.

Thanks!

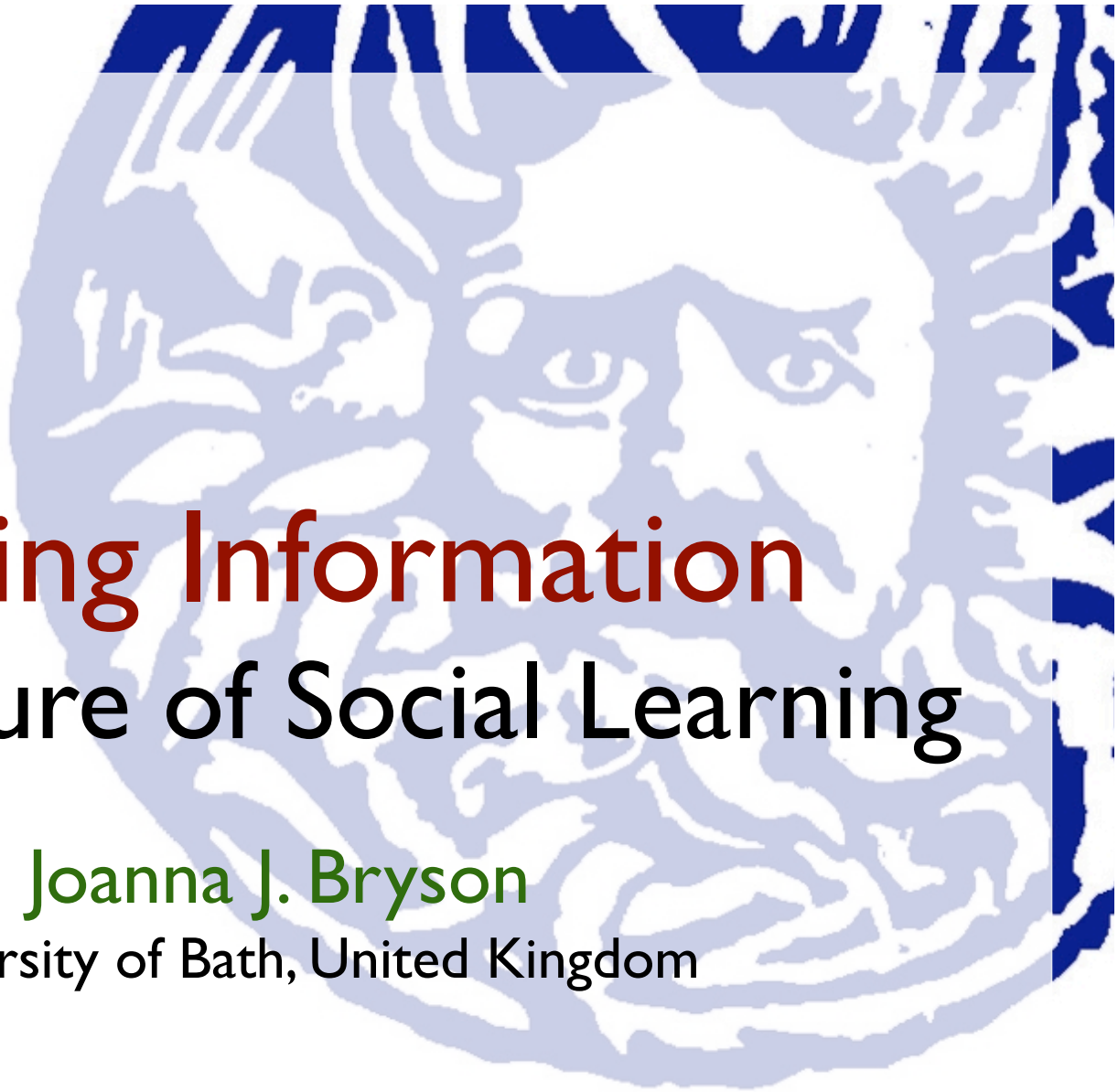


Artificial Models of Natural Intelligence:

Gideon Gluckman
Jason Leake
Dominic Mitchell
James Mitchell
Simon Perkins
Marios Richards
Karolina Sylwester
Daniel Taylor



Konrad Lorenz Institute for Evolution & Cognition Research
The Nuffield Foundation
US Air Force Office of Scientific Research



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