From alarm calls to language: using simulations to look at evolutionary plausibility and cognitive complexity

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Outline

Language is weird, and has mysterious origins.

Alarm calls in putty-nosed monkeys.

Simulations model plausible evolutionary paths.

Simulations can place bounds on cognitive complexity.

Modelling monkey alarm calls.

Modelling the evolution of language.

Language is weird

Some of the questions:

1. Why do we spend so much of our time talking?
2. Why do we offer information for free?
3. Conversely, why do so many conversations involve minimal information exchange?
4. Why is our language so richly compositional?
5. Why are we capable of such complicated Gricean tricks in understanding each other?

The mysterious origins of language

Explaining language is nearly synonymous with explaining what's special about the human lineage amongst the other primates.

So where does language come from?

1. Cooperative referential communication just happened because it was good for the group?
2. Co-opted from cognitive skills in another domain:
    1. Machiavellian intelligence (Whiten & Byrne).
    2. Social intelligence (Dunbar).
    3. By-product of cognition for tool use (Greenfield).
3. A form of sexual selection (Miller).
4. Driven by status competition (Dessalles, Locke).

Explanations in biology

Tinbergen's four questions:

Evolutionary explanations

1. Function
2. Phylogeny

Proximate explanations

3. Mechanism
4. Ontogeny

"Big theories" about language origins address its function. Both function and mechanism are accessible to computational modelling.

Alarm calling in putty-nosed monkeys

Much to be worried about...

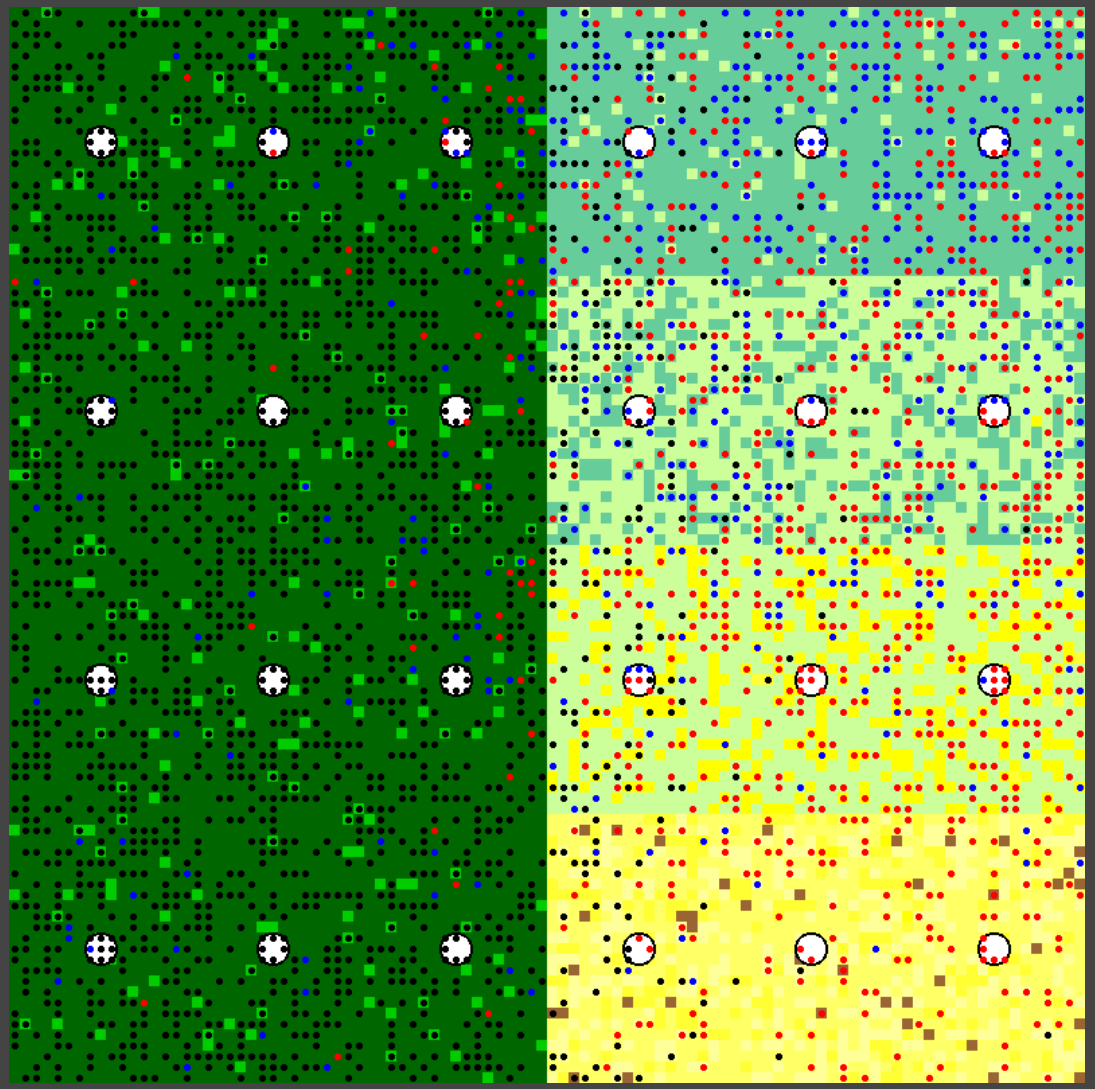
Alarm calling in putty-nosed monkeys

Live in family groups in the Nigerian rainforest. One dominant male, many females and young.

Preyed on by leopards and eagles. Males give "hack!" and "pyow!" alarm calls in response to these predators.

Evidence for referential calling: hack = eagle, pyow = leopard. Seems possibly relevant to the evolution of language.

Individual-based evolutionary simulations



Why simulate?

Because theories are under-determined by the available data. Note the wide range of theories about language origins: they can't all be correct.

Simulations can never be a substitute for empirical data.

Simulations are "opaque thought experiments" that extend knowledge by showing what follows from a set of assumptions.

Help to reduce the vast set of candidate explanations.

Using simulations to test the evolutionary plausibility of a theory

1. Individuals embodied as a genetically specified set of choices from a menu of available strategies (cf. game theory).
2. Model their environment to the desired level of detail.
3. Run a genetic algorithm from a reasonable ancestral strategy, e.g., non-communicative origins.
4. Does the theorized behaviour in fact evolve in the model?

An example: rats learning from each other about food.

Note that we do not wait for complex behaviour to emerge from a "primordial soup" as in some Artificial Life work.

Evolution of communication: what counts as a plausible theory?

Evolution is just variation, selection and heredity. Why is it hard to see whether a theory is evolutionarily plausible?

Evolution of social behaviour always involves a complicated cycle of interacting strategies between at least two types of agents (e.g., signaller and receiver).

Early ethologists notably got the story wrong when talking about aggressive signals evolving for the good of the group.

Evolution of communication: what counts as a plausible theory?

Fully formed communication systems do not just leap into existence. Why be the first speaker when no listeners exist yet, etc.

We need a plausible story about "how to get there", that takes fitness costs and benefits into account at all stages.

Starting points include:

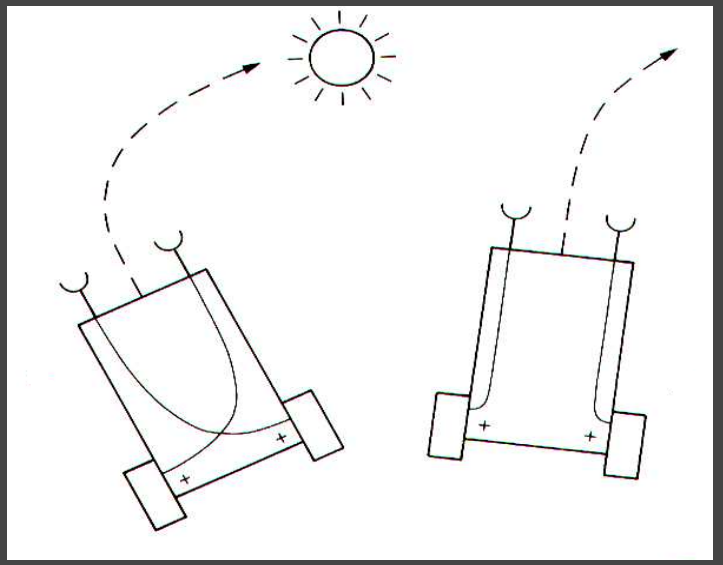
1. Accidental influence.
2. Manipulation of others' pre-existing behavioural dispositions by a "signaller".
3. Exploitation of others' behavioural cues by a "receiver".

Simulations and cognitive complexity

Simulations can compare the plausibility of different theories about the function of a behaviour.

Can also be used to put a lower bound on the complexity of the cognitive machinery required to perform a particular behaviour, by giving an existence proof.

Braitenberg, among others, gives us reasons to suspect that the complexity of evolved cognitive mechanisms may be lower than they appear from the outside:



Cognitive complexity and monkey alarm calls

What sort of complexity are we talking about?

Dennett's *Kinds of Minds* gives a good starting point:

1. Darwinian creatures: hard-wired responses.
2. Skinnerian creatures: can learn from experience.
3. Popperian creatures: capable of building internal representations of their world in order to make better decisions.
4. Gregorian creatures: capable of self-referential manipulation and restructuring of their Popperian models.

Cognitive complexity and monkey alarm calls

Putty-nosed monkeys capable of Popperian model-building, but *do they do this when making and responding to alarm calls?*

How do monkeys represent other monkeys in their models of the world? Dennett on levels of intentionality:

1. Zero-order system: the Darwinian/Skinnerian case.
2. First-order system: signaller believes that there is a predator nearby and decides to signal (receiver monkey not seen as a cognitive agent).
3. Second-order system: signaller believes the receiver is not aware of the predator.
4. Third-order system: signaller believes that the receiver will recognize that the signaller has seen a predator.

Cognitive complexity and monkey alarm calls

What level of cognitive complexity is the minimal one required by the monkeys to get by in their environment?

How does this match up with what they actually do?

Cognitive complexity: an example

Consider the design of a robot that can drive a car.

Handling traffic lights is easy: some perceptual filtering needed, but the behavioural policy for each colour of traffic light is straightforward.

In this, our robot could be a hard-wired "Darwinian" agent.

What about flashing headlights?

Needing to interpret the variable meanings intended by other drivers requires a much richer cognitive system.

Modelling monkey alarm calls

The core problem is anti-predator vigilance.

Model of the environment needs to capture their physical niche: rainforest canopy, 3-D movement, limited visual range.

The social structure of monkey groups is relevant.

Behavioural strategies: calling, being silent, etc.

Cognitive options: hard-wired rules, first-to-third-order intentionality, etc.

Observe the course of evolution: what kind of mind needed?

Modelling the evolution of language

The ecological niche: group-living primates with a range of resource types, predators, potential social structures, cooperative behaviours, etc.

Cognitive "equipment" that might be selected for:

1. Speech
2. Ability to learn arbitrary sequences
3. Internal representations of the world
4. Recursive operations on those representations
5. Rich representations of the internal states of others

Modelling the evolution of language

Test the relative plausibility of the "big theories" of language origins; for example:

1. Could cognitive systems originally adapted for keeping track of social relationships be co-opted for language?
2. Is sexual selection a plausible explanation for the "runaway" character of our linguistic abilities?

Even stronger support if the theory could also account for non-linguistic outcomes in other primates.

Simulation would be speculative but difficult to see any other way to combine all these factors.

Further reading

http://www.ecs.soton.ac.uk/people/jn2/publications

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