Evolution of Signaling: Part II

Models and Simulations in Philosophy
December 9th, 2013

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The puzzle consists of three different questions:

- Definition: What makes a signal meaningful?
- Evolution: How did meaningful signals evolve?
- Stability: Why are signals stable?

Question: How did Lewis answer these three questions?

Definition:

Definition: Lewis [2008]: Signals have meaning when they form part of a **signaling system**.

Evolution:

Evolution: Common knowledge allows agents to solve coordination problems. What are three ways by which common knowledge is acquired?

Review

Evolution: Common knowledge allows agents to solve coordination problems. What are three ways by which common knowledge is acquired?

Agreement, Salience, and Precedent.

Stability:

Stability: A convention is a Nash equilibrium, and so if you expect everyone else to conform, then it is rational for you to conform.

Today:

- Millikan's and Skyrms' criticisms/improvements to Lewis' solutions to the three questions.
- More on population level models of evolution of signaling [Skyrms, 2010].

Today's Class

Today: On the evolution of signaling systems, which are particular types of convention

Outline

1. Review and Preview

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2. Signaling Games

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3. Criticisms of Lewis
   - Definition
   - Evolution
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Review: What's a signaling game? What's a signaling system?

Example: What was the signaling system reached by these adorable creatures?

Definition

Although it was not discussed much in the assigned readings (except by reference), both Millikan and Skyrms do propose amendments to Lewis' game-theoretic analysis of meaning as arising from signaling systems.

Skyrms: Meaning can arise in non-signaling systems.

Definition of Meaning

Skyrms: Meaning can arise in non-signaling systems.

- In some cases, signals carry some (but not all) information about the state of the world.
- In chapter 3 of [Skyrms, 2010] there is a tentative proposal for measuring *how much* information is contained in a signal in these cases.

Miilikan: For signals to have meaning, they must be intentional.

- Smoke does not mean "there's a fire", nor do fossils mean "there were animals here millions of years ago."
- Meaningful signals must have the ability to be false, and/or
- meaningful signals must have been designed ...

Definition

In my usage, natural signs contrast with "intentional signs," which, following Franz Brentano's technical usage of the term "intentionality," are signs that can be false or that may sometimes signify nothing real. By intentional signs I mean those that have been "designed," in accordance with human or animal purposes, or by learning mechanisms, or by natural selection, to be interpreted according to predetermined (semantical) rules to which targeted interpreters are cooperatively adjusted

[Millikan, 2004], pp. 3.

I don't know which definition Millikan takes to be primary.

Last week, we briefly discussed Skyrms' criticisms of Lewis' solution to the evolution problem. What were they?

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1. The three mechanisms for acquiring common-knowledge mentioned by Lewis (agreement, salience, and precedent) are not applicable in explaining the origins of signaling.
2. Common knowledge is unnecessary for conventions:
    - Population models (e.g. replicator dynamics) show that differential reproduction can produce conventions (Today)
    - Agents can also learn conventions (Mostly Next week)

[Millikan, 2005] also thinks common knowledge is unnecessary for conventions.

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Many conventions are learned and maintained unconsciously. E.g.,

- Distances between conversational partners.
- Most of language!

Millikan: Rationality and expectations of players is not always the best explanation for stability of conventions.

- Precedent is often enough to maintain conventions given our (and other animals') tendency to imitate others.
- Other times, strong sanctions are imposed to maintain conventions.

See more in [Millikan, 2005].

Skyrms likewise criticizes Lewis' solution to the stability problem.

To understand the criticisms, it is best to review the replicator dynamics.

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- **Population Model:**

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- **Population Model:** Replicator Dynamics
- **Network Models:** Lattice, Small-Worlds, Bounded Degree, and Dynamic

The replicator dynamics has been a faithful go-to population model.

Let's try it again.

Replicator Dynamics

The replicator dynamics is the following equation:

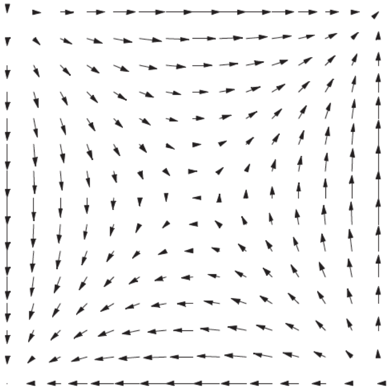
$$p_{t+1}(s) = p_t(s) \cdot \frac{F_t(s)}{F_t(\text{AVE})}$$

where

- Let $p_t(s)$ be the proportion of individuals in the population employing strategy s at time t.
- Let $F_t(s)$ be the fitness of the strategy, which is (recall) its expected payoff when paired with a random other agent from the population.
- Let $F_t(\text{AVE})$ be the average fitness of all strategies.

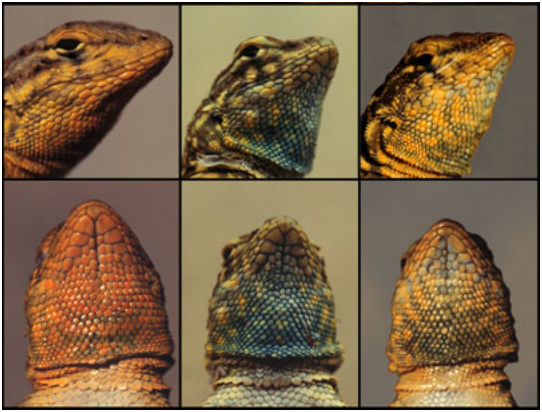
The equation tells us how the population changes over time.

Replicator Dynamics



Simple case: two equally probable states, two signals, two acts ⇒ The population moves towards a signaling system.

How the populations changes over time can be distinctly more complicated . . .



What's the story with these lizards?

Orange = Aggressive. Try to guard and take over large areas.

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Yellow = Sneaky but not aggressive. Can infiltrate poorly guarded relationships.

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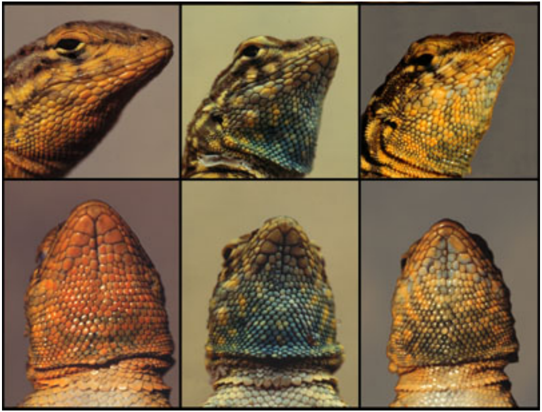
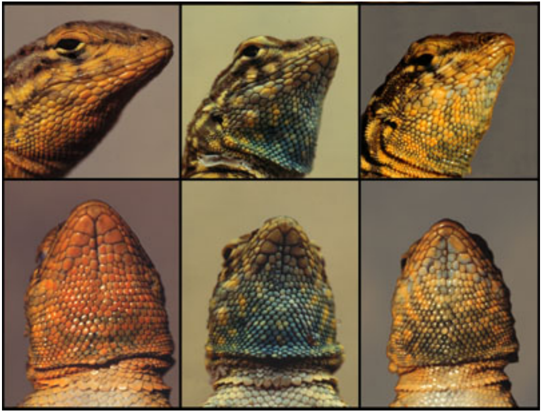
Yellow = Sneaky but not aggressive. Can infiltrate poorly guarded relationships.

Blue = Can guard mates from less aggressive males due to limited area.



Orange < Yellow < Blue < Orange



Orange $<$ Yellow $<$ Blue $<$ Orange
Rock $<$ Paper $<$ Scissors $<$ Rock

	Orange	Yellow	Blue
Orange	$\langle 1, 1\rangle$	$\langle 0, 2\rangle$	$\langle 2, 0\rangle$
Yellow	$\langle 2, 0\rangle$	$\langle 1, 1\rangle$	$\langle 0, 2\rangle$
Blue	$\langle 0, 2\rangle$	$\langle 2, 0\rangle$	$\langle 1, 1\rangle$

What does the replicator dynamics tell us will happen if the population starts out with $P(O)$ many orange throats, $P(B)$ many blue ones, and $P(Y)$ many yellow ones?

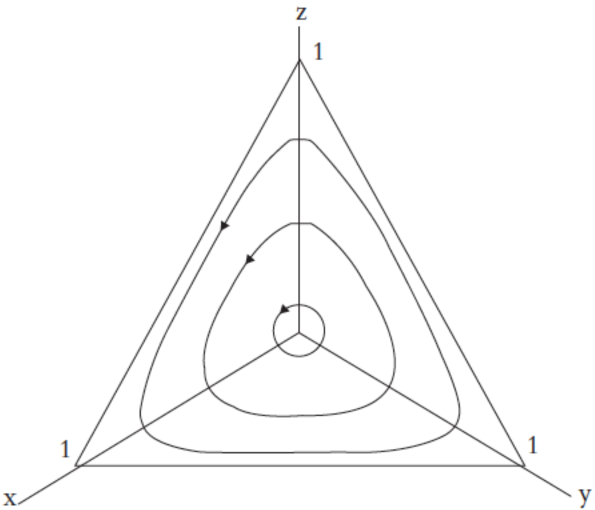


Figure 4.1: Cycles in rock-scissors-paper.

Moral 1: The Nash equilibrium is unstable to any small changes to the population: if the $\frac{1}{3}$-balance is broken at all, then the frequencies of various mating strategies in the population begins to cycle.

That's what's observed in real life.

We're often bad at estimating expected offspring. What if we change the payoffs slightly, say by some small number ϵ?

	Orange	Yellow	Blue
Orange	$\langle 1-\epsilon, 1-\epsilon \rangle$	$\langle 0, 2 \rangle$	$\langle 2, 0 \rangle$
Yellow	$\langle 2, 0 \rangle$	$\langle 1-\epsilon, 1-\epsilon \rangle$	$\langle 0, 2 \rangle$
Blue	$\langle 0, 2 \rangle$	$\langle 2, 0 \rangle$	$\langle 1-\epsilon, 1-\epsilon \rangle$

All points go to center.

I tried to write a program for you last night, but it took me too much time. I'll send you one later.

Moral 2: The populations' dynamics change radically if the payoff matrix changes slightly.

Here's Skyrms' criticism of Lewis' solution to the stability and evolution problem:

Lewis' analysis involving traditional game theory is inadequate because it ignores the dynamics of the population in three ways ...

Evolution:

1. Conventions must be reachable by evolution.
   - RPS shows that some Nash equilibria are never the limit of the replicator dynamics.
   - What about other coordination equilibria?

Stability:

2. Conventions ought to be stable under small changes in the population.
   - Moral 1 shows that's not always the case with Nash equilibria.
   - What about coordination equilibria?

Stability:

3. Conventions ought to be stable under small changes in the payoffs (in cultural evolution, players' preferences).
    - Moral 2 shows us that's not always the case with Nash equilibria.
    - What about coordination equilibria?

How well do Skyrms' models explain the evolution and stability of signaling?

Thus far, we've only seen successes in simple cases, namely, the game with two equiprobable states, two signals, and only one-to-one signaling strategies.

You Tell Me! How does the story get more complicated in other cases? What factors are important and why?

Does Signaling Always Emerge?

You Tell Me! How does the story get more complicated in other cases? What factors are important and why?

Things that matter:

- Differences between likelihood of states of the world.
- How many signals are available
- Strategies that can be used

Programming Concepts: Debugging and the Behaviorspace

References I

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