Within-Colony Social Insect Communication: An Application of Mechanism Design

Introduction

We ask…

Is communication among the social insects fully cooperative?

Introduction

Why not?

1. Incentives largely aligned, but not 100%, b/c foraging dangerous, and SLIGHT preference for sister to die instead.
2. In some species, like members of the the Ponerinae are large incentives problems.
3. We do see noncooperative behavior in other domains; e.g. worker egg laying
4. Communication sometimes appears wasteful, e.g. bees' shaker dance vs piping
5. small conflict may have little impact on aggregate, while still having predictable impact on the behavior of individual workers, e.g. age polyethism.

Introduction

We ask…

What would communication look like IF we take these private incentives into account.

BUT we DON’T IGNORE colony level selection

Aside: Mechanism Design

-Will revenue maximizing auctioneers create efficient Auctions? What features will auctions have? (Myerson '81)

-Why is there so much "money left on the table" in bargaining? Can we design rules for bargaining that always give the item to the person who values it most? (Myerson & Satterthwaite '83)

In general, if individuals are rational, when can we design institutions that are efficient? What features will all institutions that recognize individual rationality share?

Model 1

We assume…

- Patroller privately learns value of food q (from commonly known distribution).
- Patroller sends costless signal σ to forager (from a predetermined set of available signals).
- Forager decides whether to go or not

How do we capture private incentives?

- q normalized so that colony benefits whenever $q \geq 0$.
- Forager has private cost of foraging ε.

Model 1

What choices do each individual make?

- Patroller chooses message to send for each value of q, $\sigma(q)$
- Forager chooses whether to go or not for each signal σ . We will call this function $g(\sigma)$

Model 1

How do we capture individual level selection?

We require…

σ (q) and g(σ) to be best responses to each other.

Model 1

And how do we capture colony level selection?

We let…

Colony level selection choose the set of messages to make available to the patroller and a pair of , $\sigma(q), g(\sigma)$ that are best responses to each other.

Model 1

We ask…

Do we always expect communication to be optimal?

BUT this seems intractable, since potential message space is unlimited

But actually quite simple, with the help of Mechanism Design.

Model 1

It turns out, in some cases THERE CANNOT be any communication!

e.g. ε=.6, q~U[-1,1]

(Why? If forager ever goes, then patroller ought to pretend it is that state whenever q>0. But then forager will assume expected value is .5)

While in other cases communication will look the same as if there is no incentives problem

e.g. ε=.4, q~U[-1,1]

Model 1

In general…

<u>Theorem 1</u>

If $E[q \mid q>0] \geq \varepsilon$ get optimal foraging, otherwise get no foraging.

Model 2

What changes if we allow costly signals?

Model 2

Turns out…

We can actually do BETTER than before.

And we expect costly signalling on many occasions.

E.g.

ε=.6, q~U[-1,1]➔patroller pays .2 whenever q>.2 and forager goes whenever sees patroller burning money.

(Why? Patroller will only pay the cost when above .2, so forager expects q to be .6)

Model 2

In general…

<u>Theorem 2</u>

1. Whenever $E[q \mid q>0]<\varepsilon \Rightarrow$ optimal foraging
2. Whenever $E[q \mid q>0]\geq\varepsilon \Rightarrow$ costly signaling
3. How costly? Pay cost c s.t. $E[q \mid q>c]= \varepsilon$ whenever $q>c$ and 0 otherwise.

Model 3

But these models have so far been unnatural.

-signal structure is always step function.

-can't say anything about variation in forager behavior.

So we add variation in ε.

(note: it must also be assumed that the patroller cannot condition her behavior on each forager's type).

Model 3

And what can we say about all incetive compatible mechanisms now?

<u>Theorem 3</u>

1. As q goes up, more individuals must forage
2. As ε goes up, must be less likely to forage
3. As q goes up, cost of signal must go up.

Evidence?

And how does the real world look?

1. As q goes up, more individuals DO forage
2. Existence of Costly Signalling???
   1. Shaker dance, tandem running vs pheremone trails and piping
3. Cost of signal nondecreasing in q
   1. E.g. shaker dance, motor displays longer and more vigorous
   2. E.g. Piping vs shaking
4. Foraging nonincreasing in ε
   1. E.g. age polyethism

Evidence?

And what testable predictions do we have?

1. Queen ages→ forage less, cost of signal increases.
2. Relatedness drops→forage less, cost of signal increases.
3. Depends on distribution of q

e.g. nest invasions or gems, can have cheap talk, even when costly signalling for other signals within same species.