Collective and Individual Problem-Solving in Insects

Anna Dornhaus
Ecol & Evol Bio, University of Arizona (Tucson)
Insects solving problems?

- Are insects really suitable as model systems for research on complex behavior?

- Don’t they have fixed, instinctual, repeatable, machine-like behaviors?
“Delayed matching-to-sample tests”:
Learning the concepts ‘same’ and ‘different’

Giurfa (2003)
Learning from each other & teaching

Worden & Papaj (2005)
Leadbeater & Chittka (2005)
Möglich et al. (1974)
Tool use in ants

Sand pellets as sponges

Individual insects

Stones as ammunition

Morrill (1972)

Grasso et al. (2004)
Target selection by individual bees

Bees are trained to target color and rewarded there.
Accurate decisions come at a cost

Bees are trained to target color; targets and distractors only slightly different

Each dot is one individual bee

Nature 424: 388
Individual insects

- sugar vs. quinine: making errors more costly
Individuality & flexibility

... more time for better decisions.
Social insects

- **Social**: colony sizes of 1 - 10 million
- **Cooperative**: most individuals are non-reproducing workers – ‘superorganisms’
- ‘**Complex systems**’ – patterns created by interaction, without central control
Collective behavior

Complex systems: common problems & solutions?

- Task allocation
- Information flow
- Minimization of delays
Collective behavior

Temnothorax ants
Collective behavior

Temnothorax ants
Collective decisions

Colony emigrations

If the nest is destroyed, a new one has to be found

→ comparison

→ consensus decision

→ transport
Colony emigrations

1. Search
2. Recruitment
3. Quorum attained: decision
4. Transport

Nigel Franks, Stephen Pratt
Why wait for a quorum?

Tandem runs are slow!

Delay before start of carrying a disadvantage?
Individual scouts make their own decisions if in a hurry

Individual decisions: scouts start carrying even though they have not encountered ANY other ant in the new nest (quorum threshold of 1). (Fisher’s Exact Test, n=16)
... which is fast but faulty

Median, quartiles, range of 16 colonies; each tested once in each condition; Wilcoxon Tests.

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Even more ants involved if speed not important

**Quorum threshold**

- Destroyed nest, harsh conditions
- Destroyed nest
- Intact nest (mediocrce)

**Forward tandem runs**

- Destroyed nest, harsh conditions
- Destroyed nest
- Intact nest (mediocrce)

\[ p < 0.05 \]
\[ p < 0.01 \]
Two strategies

I’ll do it myself!

Call a meeting!
Two strategies

- Low quorum threshold (sometimes $=1$: individualistic decision-making)
- Quick decision
- Error prone

- High quorum threshold: collective decision-making
- Takes time
- Accurate decisions
- Favored in benign conditions

Anim Behav 67: 959-963
Proc. R. Soc. Lond. B 270: 2457-2463
Collective decision

1. Search
2. Recruitment
3. Quorum attained: decision
4. Transport
Collective decision

1. Information collection
2. Recruitment
3. Activation

Alternative 1

Alternative 2

decision

Collective decisions
Decision-making in the brain

1. Information collection
2. Recruitment
3. Activation threshold: decision
Decision-making in the brain

1. Information collection
2. Recruitment
3. Activation threshold

Alternative 1

Alternative 2

inhibition

sensory information

Collective decisions
Collective decisions

Ant colonies
- populations of ants committed to each site
- as information is collected, active population committed to ‘correct’ alternative increases
- decision is made when active population exceeds a threshold
- threshold $\rightarrow$ speed & accuracy of decision

Brain
- populations of neurons committed to each alternative
1. Individual & collective decision-making
   – flexible choice of speed over accuracy when necessary

2. Communication: push or pull
3. Division of labor
4. Spatial sorting
5. Optimal search
6. Colony size

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Communication systems in social insects

• usefulness of information depends on environment

• collective behavior can often be optimized and sophisticated without coordination
Collective strategies

- May be surprisingly intricate
- May be surprisingly non-intuitive

→ to understand their evolution, careful, quantitative measurement of costs and benefits under different conditions necessary
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