Collective and Individual Problem-Solving in Insects

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Insects solving problems?

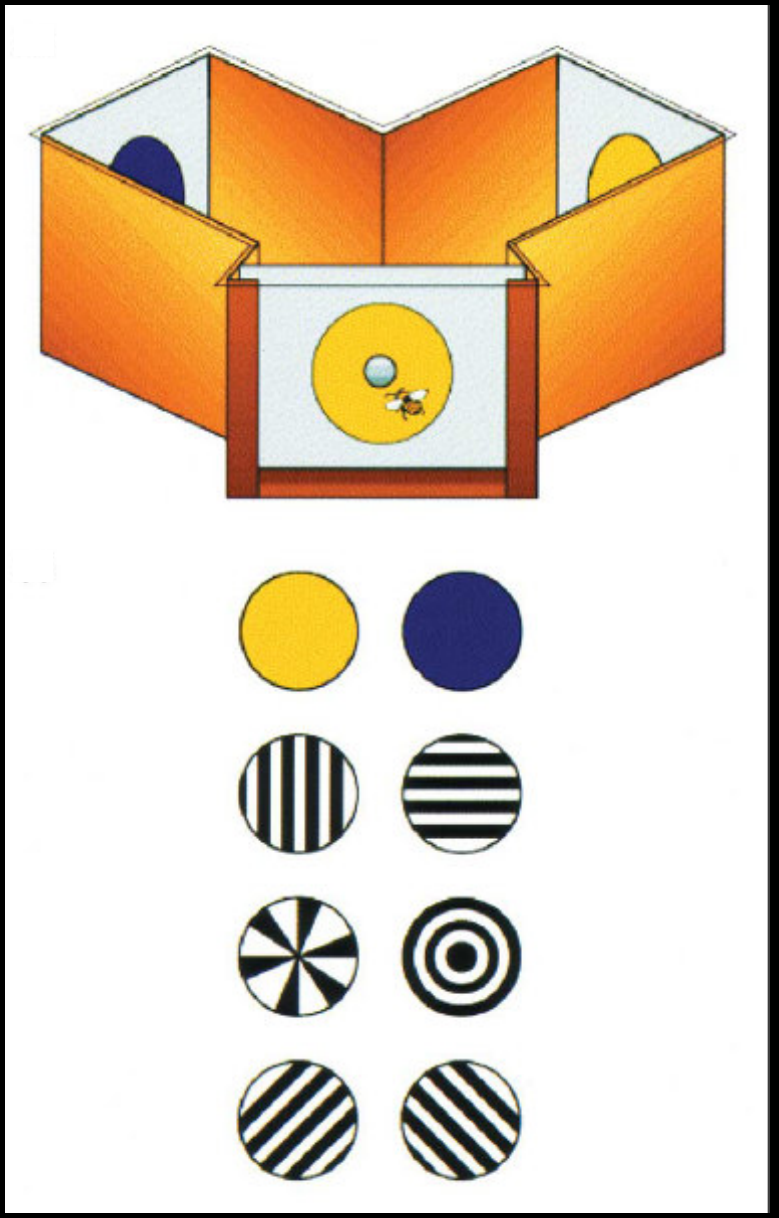
- Are insects really suitable as model systems for research on complex behavior?
- Don’t they have fixed, instinctual, repeatable, machine-like behaviors?

Individual insects

"Delayed matching-to-sample tests":

Learning the concepts 'same' and 'different'

Giurfa (2003)



Learning from each other & teaching

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Worden & Papaj (2005)
Leadbeater & Chittka (2005)

Möglich et al. (1974)

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Individual insects

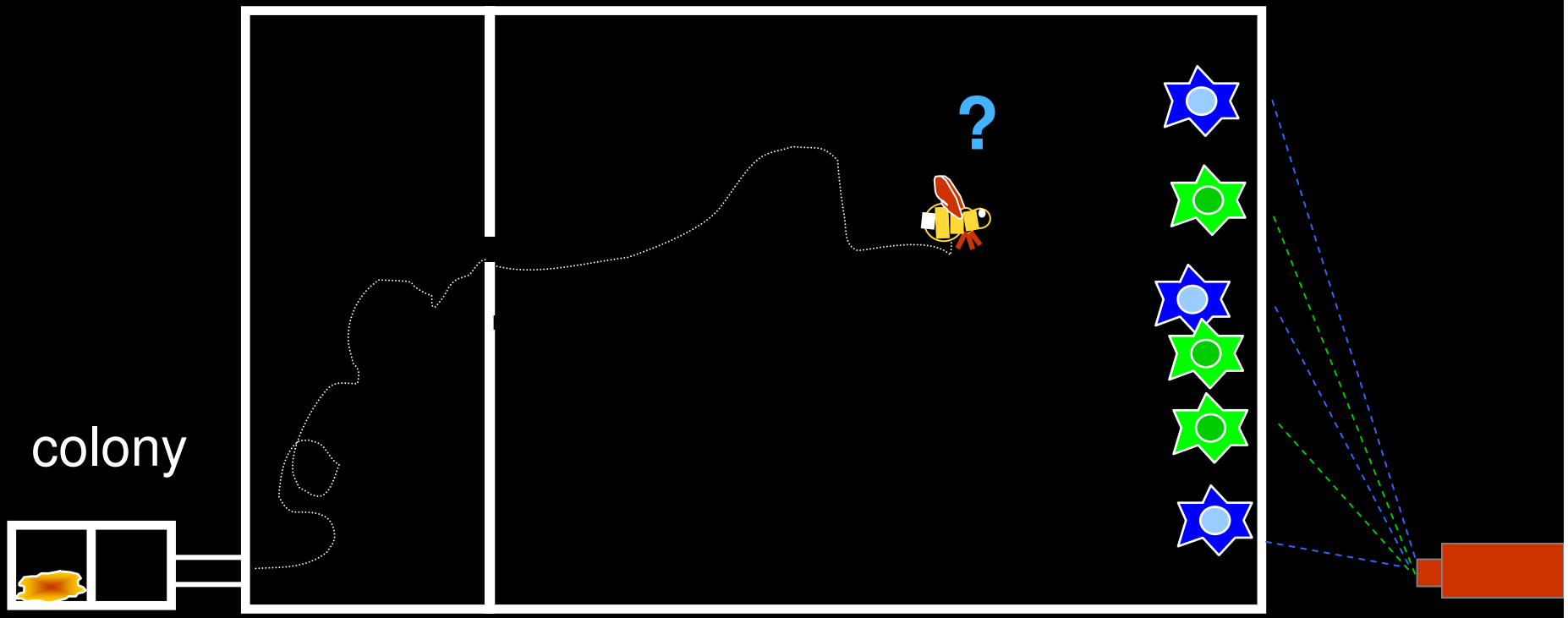
Sand pellets as sponges

Tool use in ants

Stones as ammunition

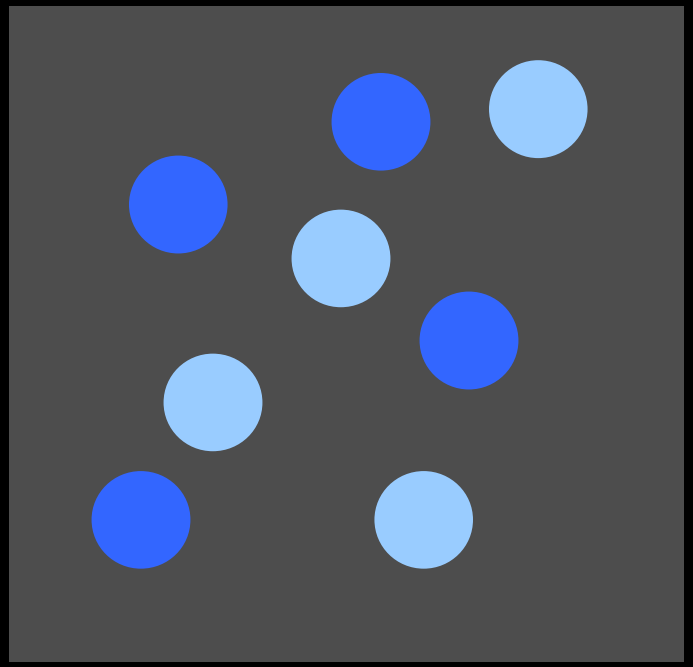
Grasso et al. (2004)

Target selection by individual bees

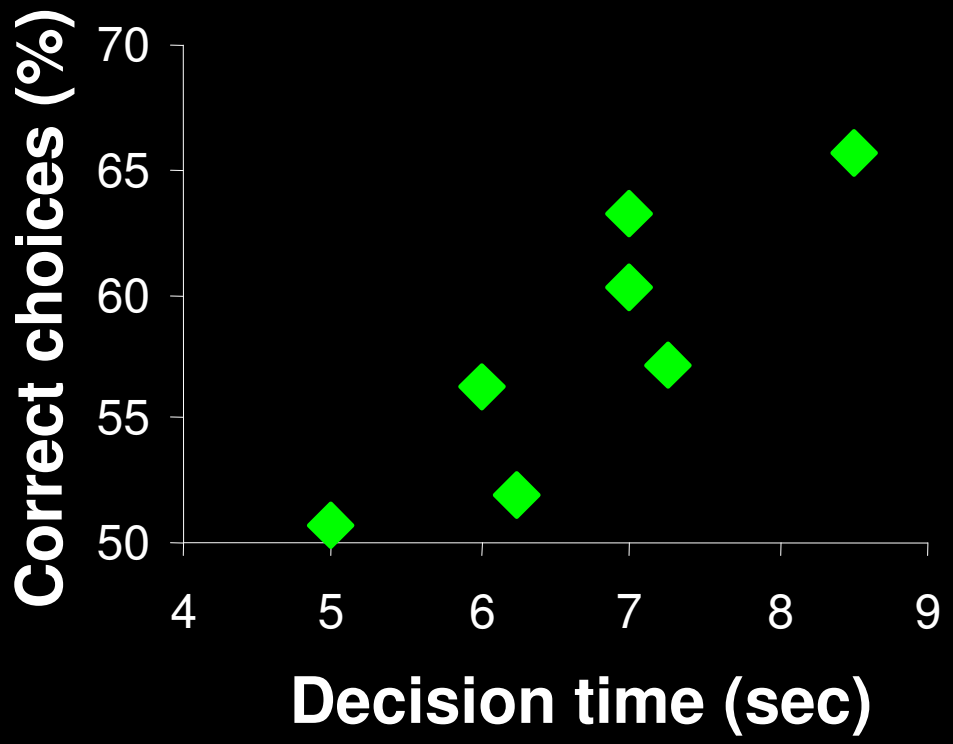


Bees are trained to target color and rewarded there

Accurate decisions come at a cost



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

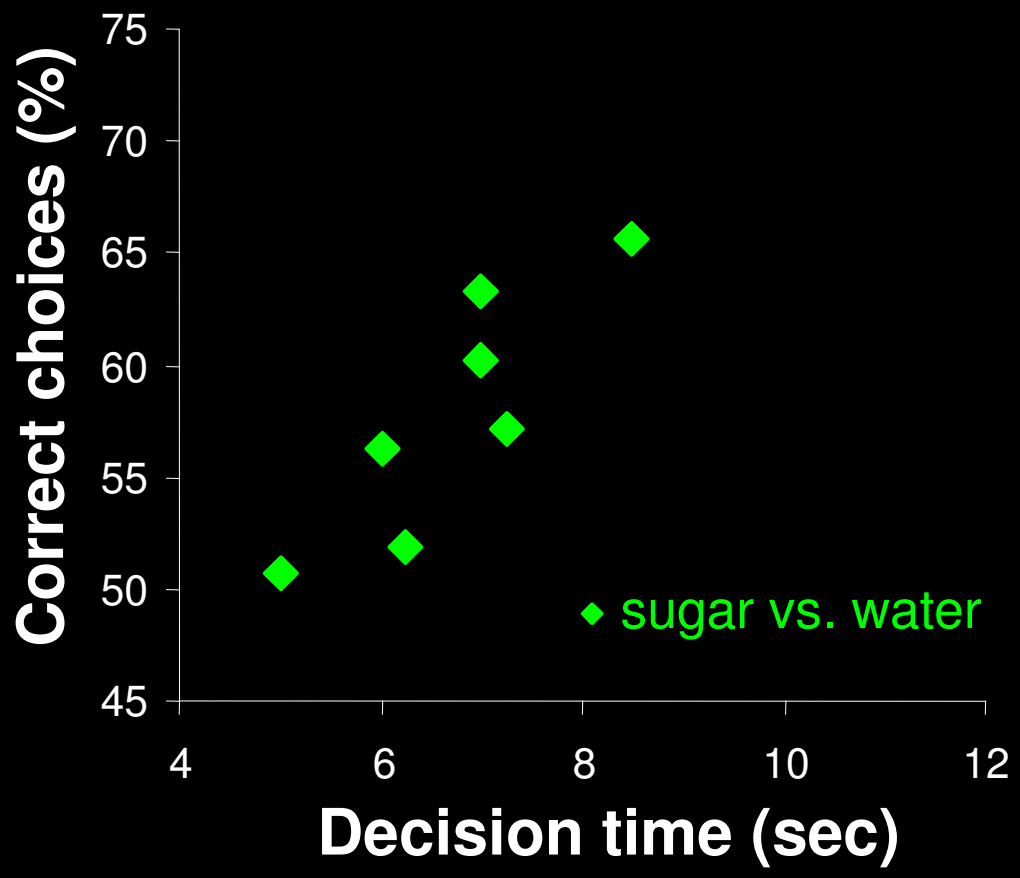


Each dot is one individual bee

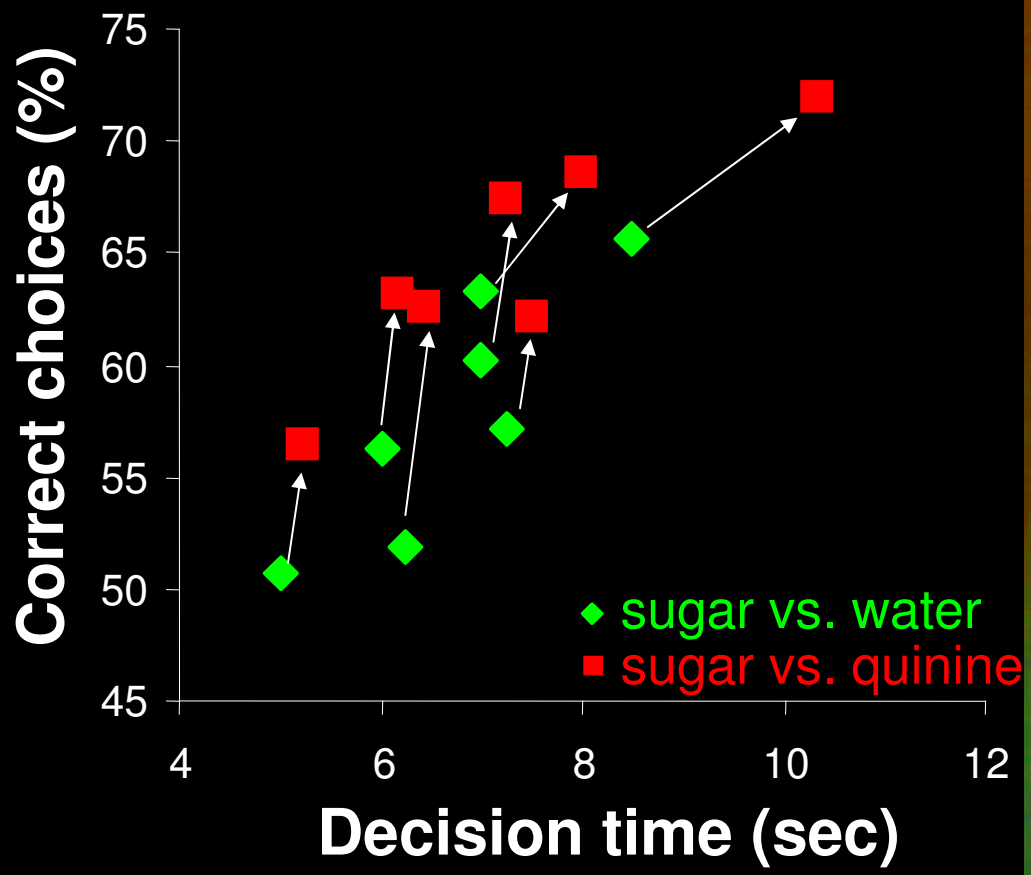
Nature 424: 388

Individual insects

- sugar vs. quinine: making errors more costly



Individuality & flexibility



… more time for better decisions.

Nature 424: 388

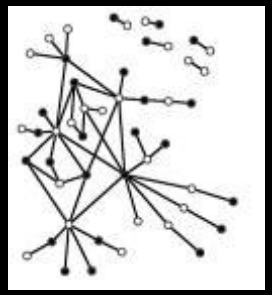
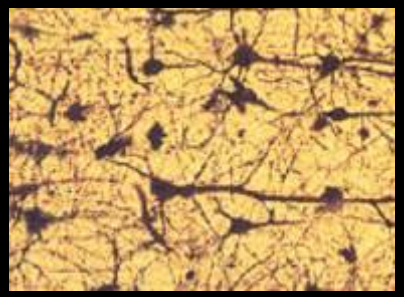
Social insects

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

Complex systems:
common problems & solutions?

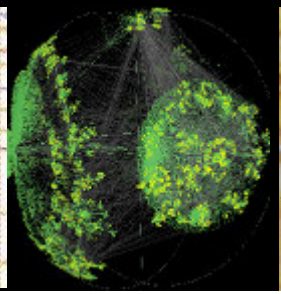


task allocation


information flow



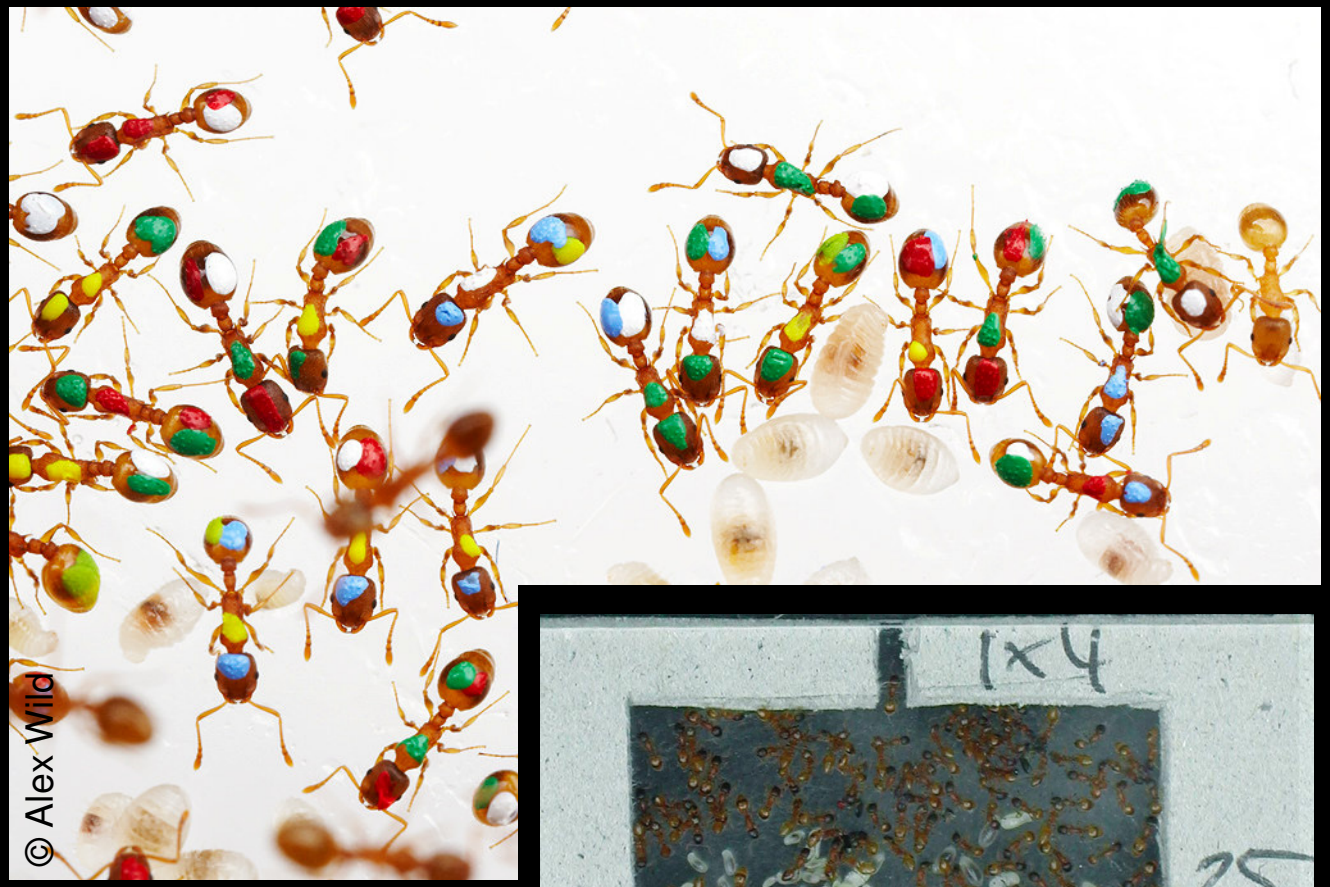


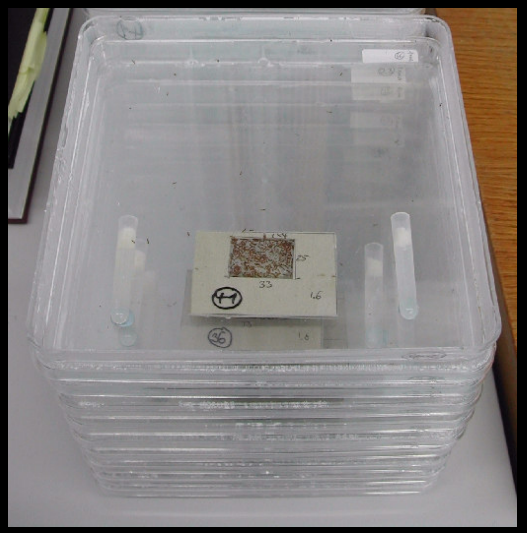

minimization of delays

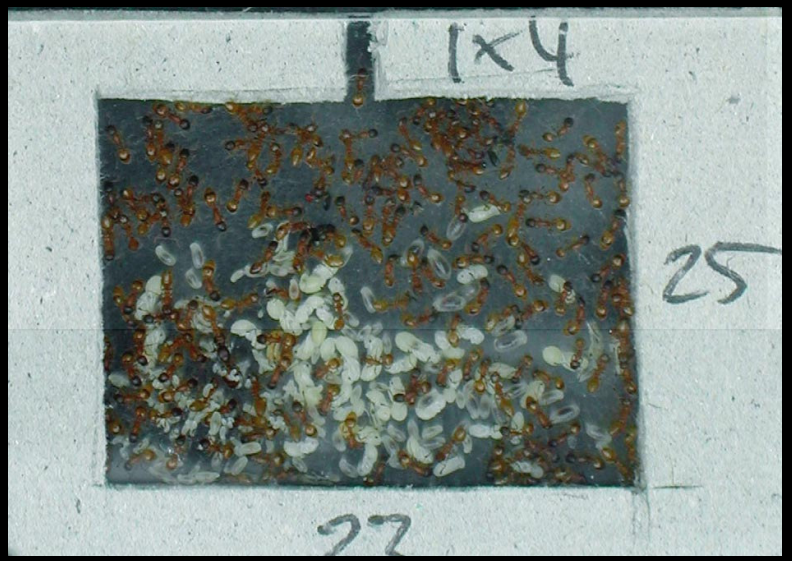
Collective behavior

Temnothorax ants

Collective behavior







Temnothorax ants

Colony emigrations

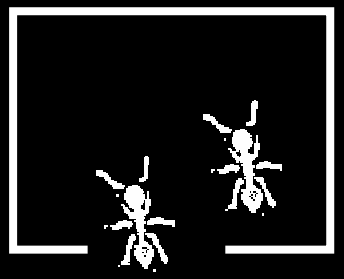
If the nest is destroyed, a new one has to be found

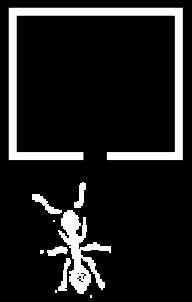
→ comparison

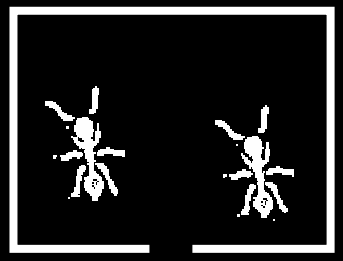
→ consensus decision

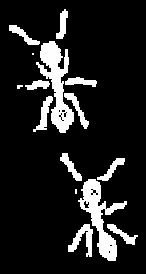
→ transport

Colony emigrations



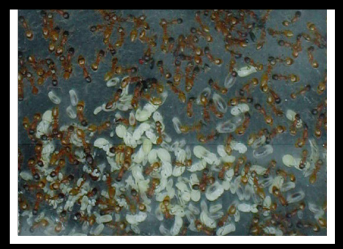




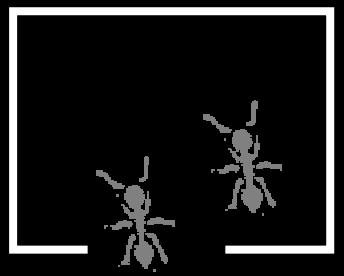


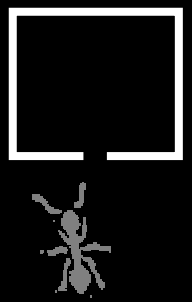
1. Search
2. Recruitment
3. Quorum attained: **decision**
4. Transport

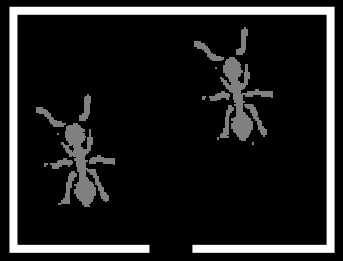
Nigel Franks,
Stephen Pratt

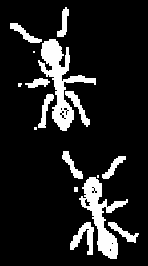


Why wait for a quorum?









Tandem runs are slow!

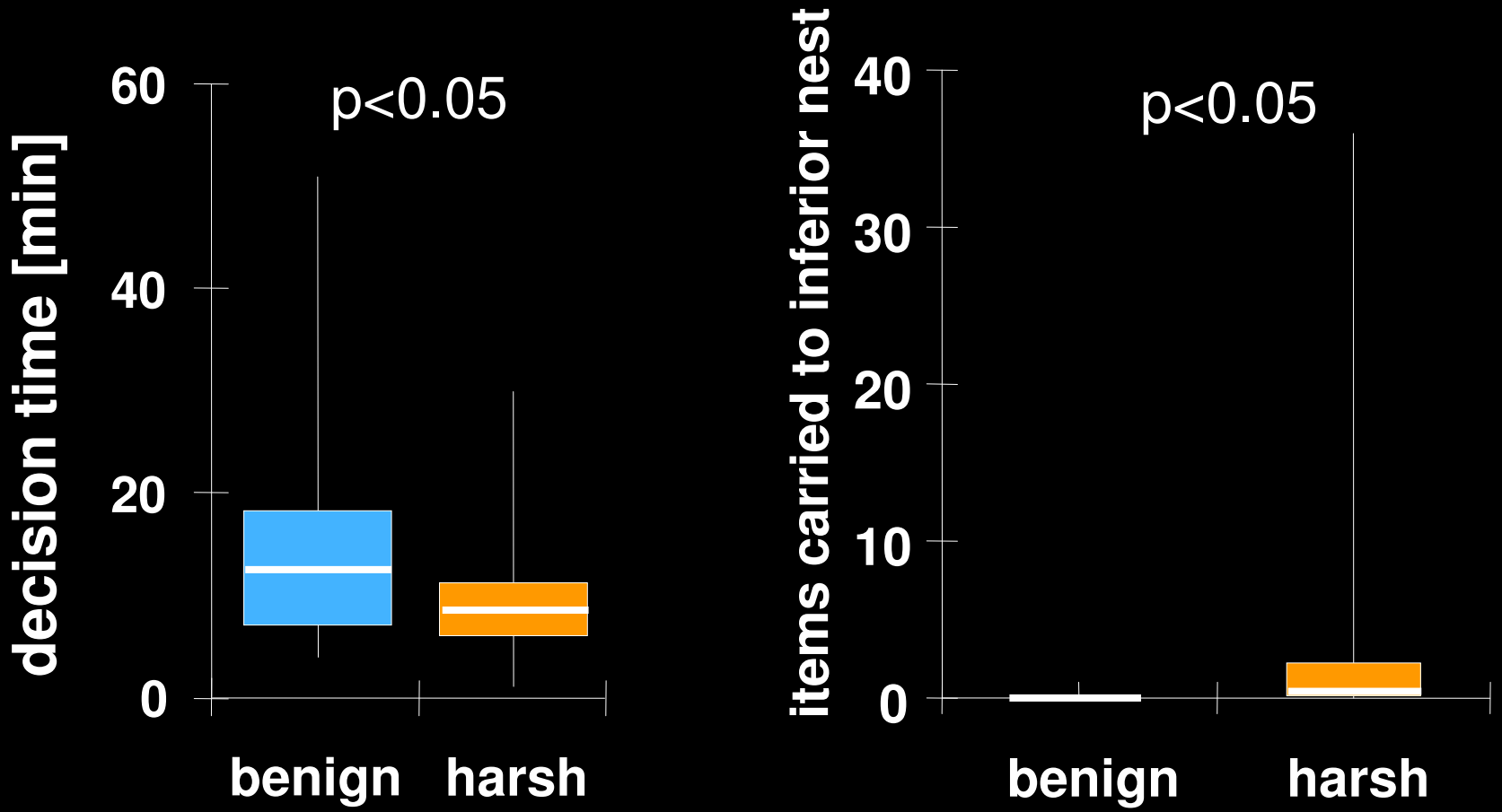
()

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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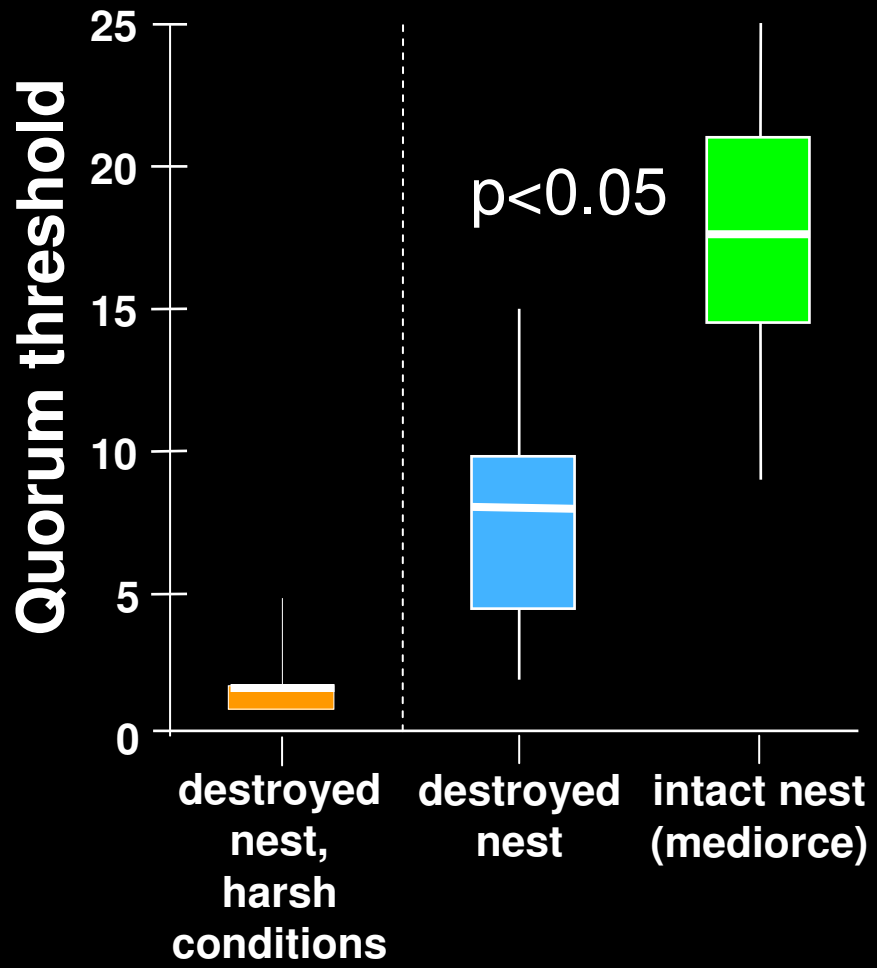
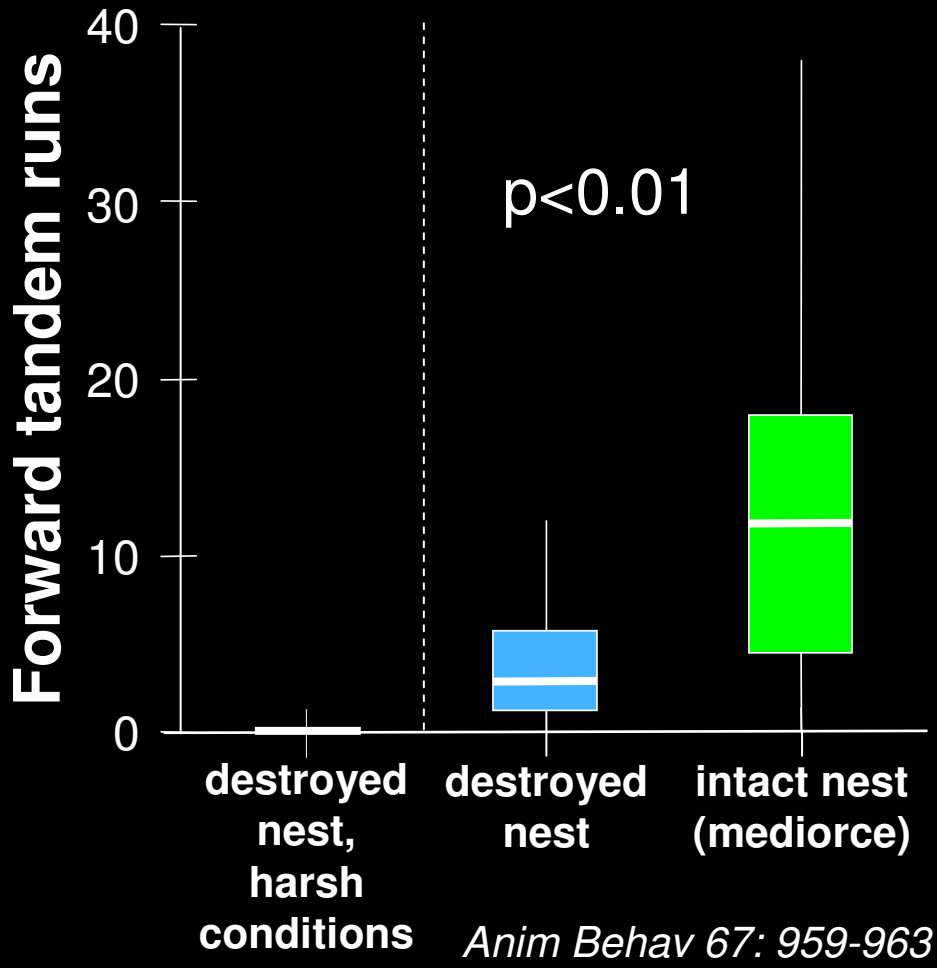
Even more ants involved if speed not important





Anim Behav 67: 959-963

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 theshold: collective decision-making
- Takes time
- Accurate decisions
- Favored in benign conditions

Anim Behav 67: 959-963
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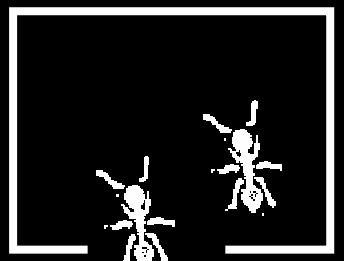
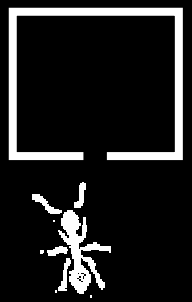
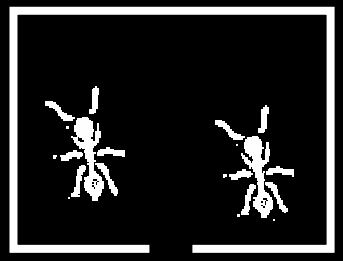
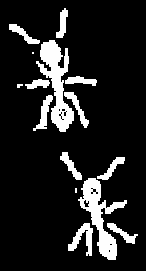
Collective decision









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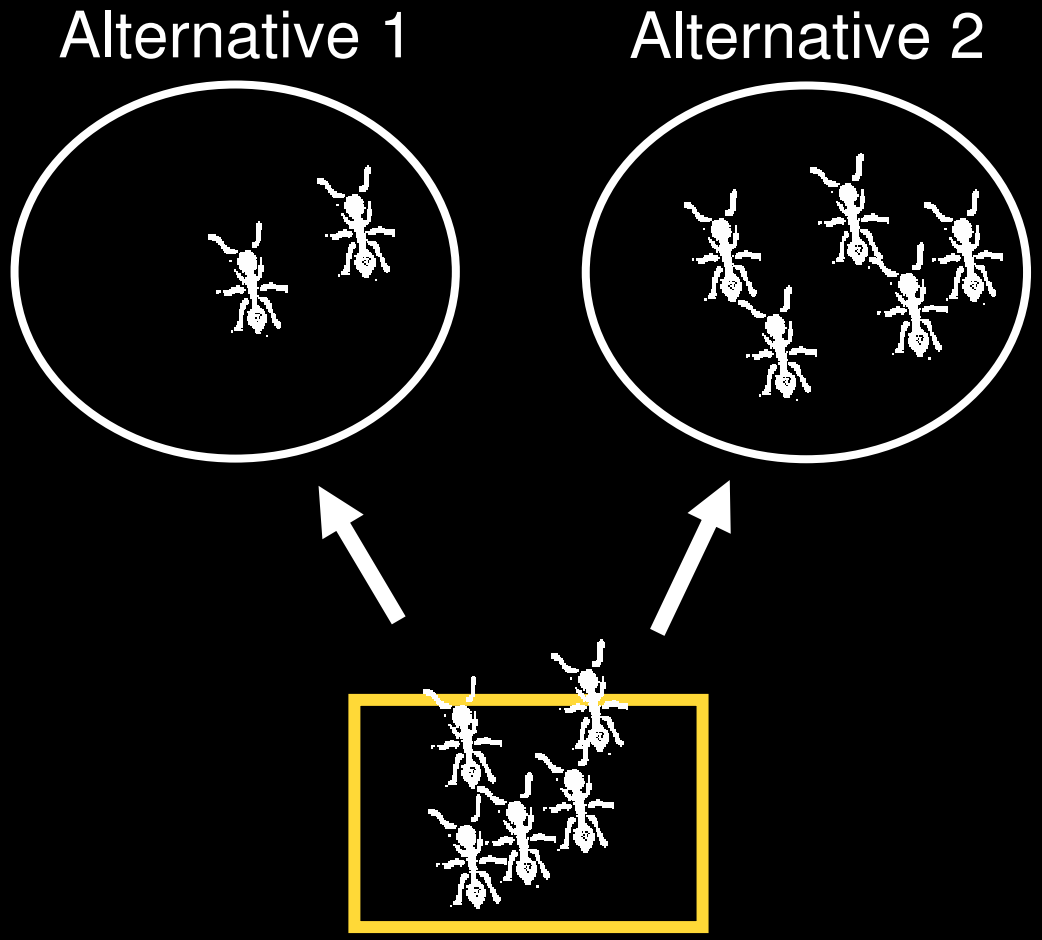
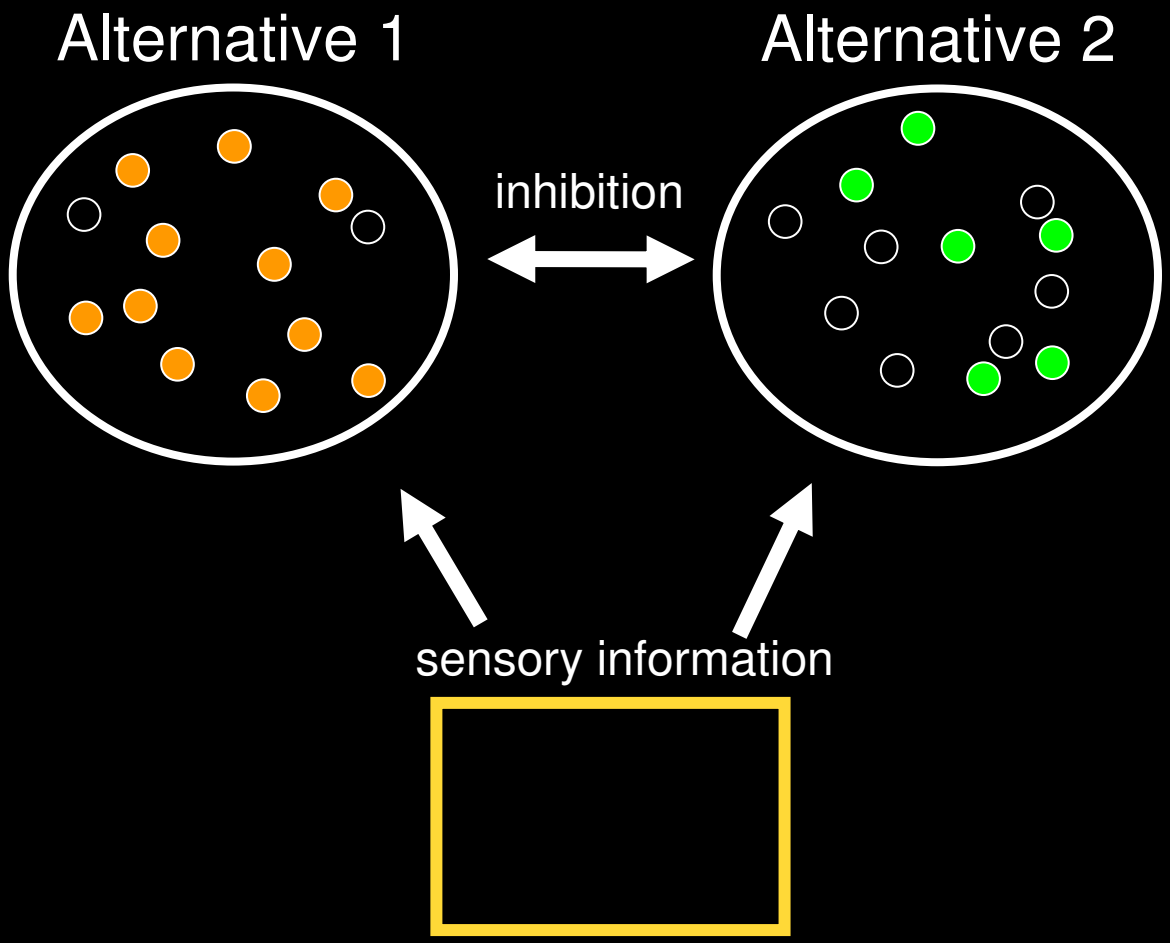
Collective decision



1. **Information collection**
2. **Recruitment**
3. **Activation threshold:**

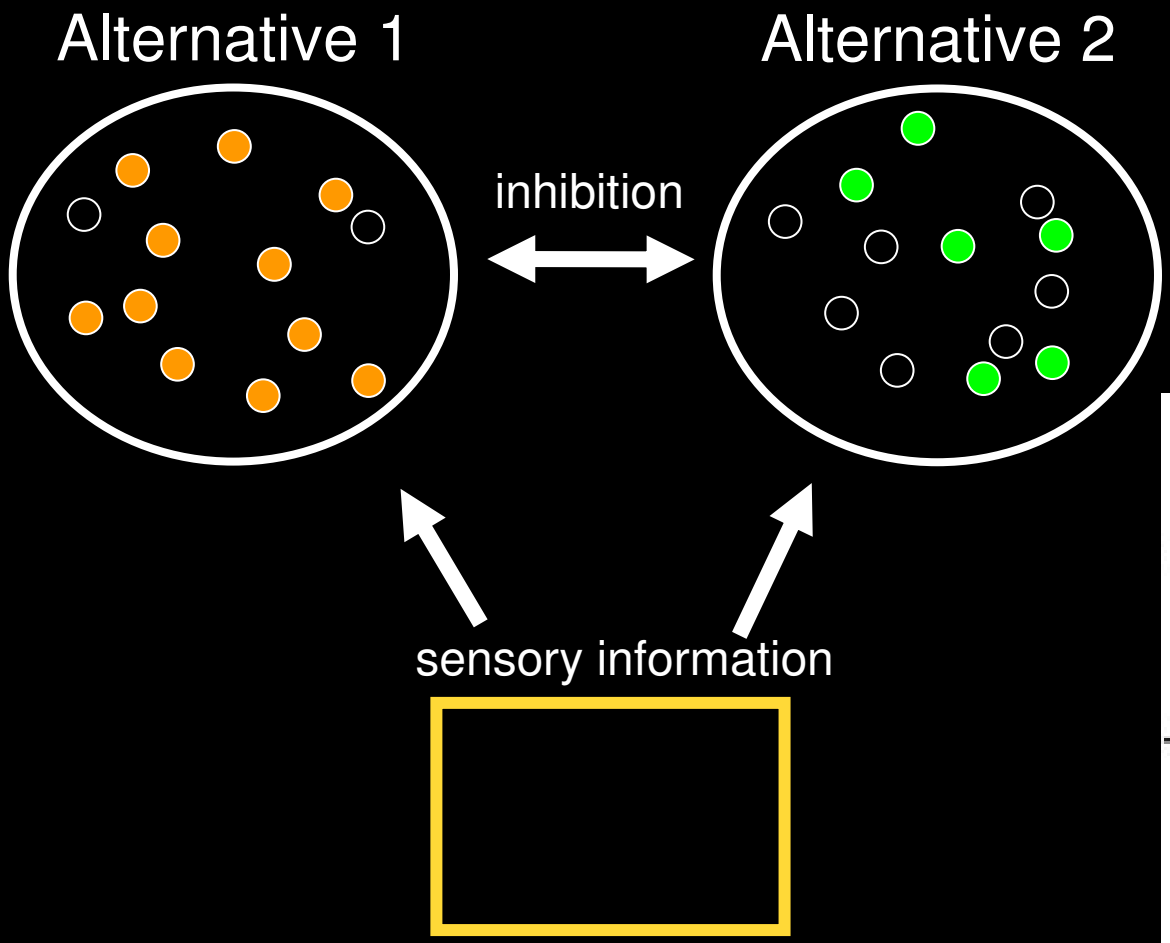
decision

Decision-making in the brain

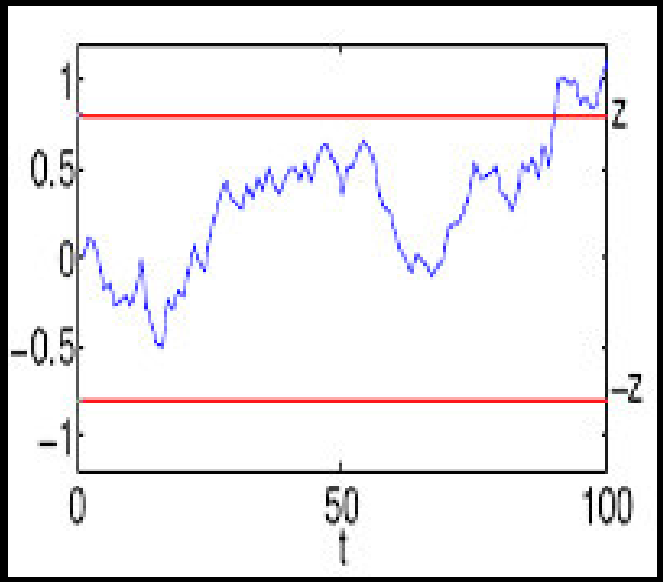


1. **Information collection**
2. **Recruitment**
3. **Activation threshold: decision**

Decision-making in the brain



1. **Information collection**
2. **Recruitment**
3. **Activation threshold**



Collective decisions

Ant colonies

- populations of ants committed to each site

Brain

- populations of neurons committed to each alternative

- as information is collected, active population committed to ‘correct’ alternative increases
- decision is made when active population exceeds a threshold
- threshold → speed & accuracy of decision

Research areas

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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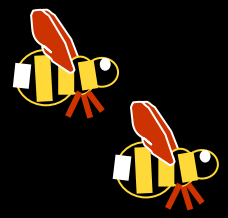
Communication systems in social insects

- 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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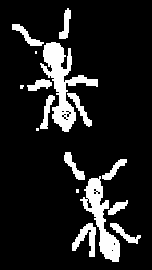

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