When push comes to shove: communicating with a small vocabulary

Statistical Mechanics Day

Weizmann Institute

25.6.2012

Foraging by the desert runner ant

Lone foragers

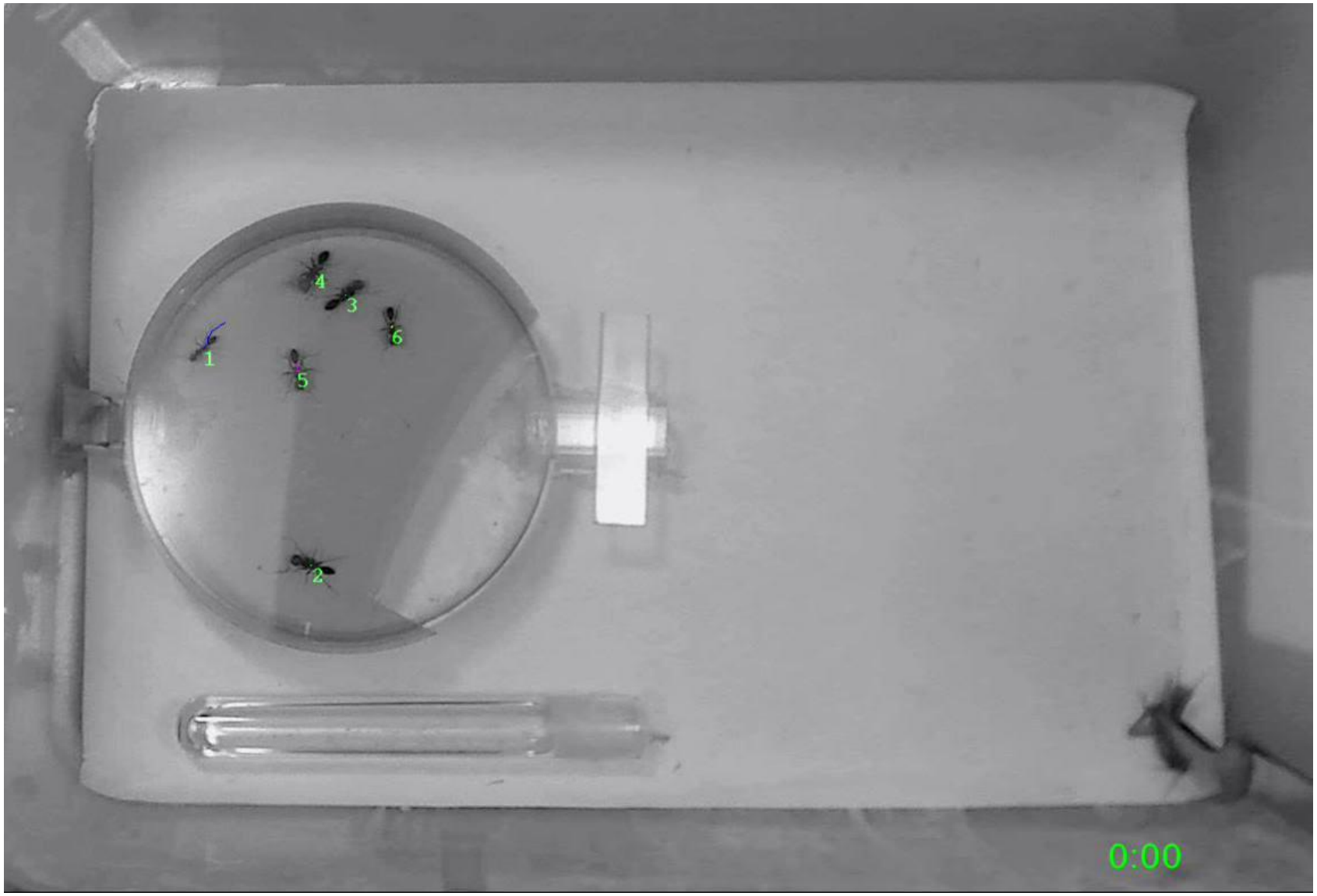
- Insectivorous

- Homing behavior “vector integration” – no chemical trails.

➔ Not much reason to recruit

Rudimentary recruitment to short distances (Amor et. al 2010).

The collective task



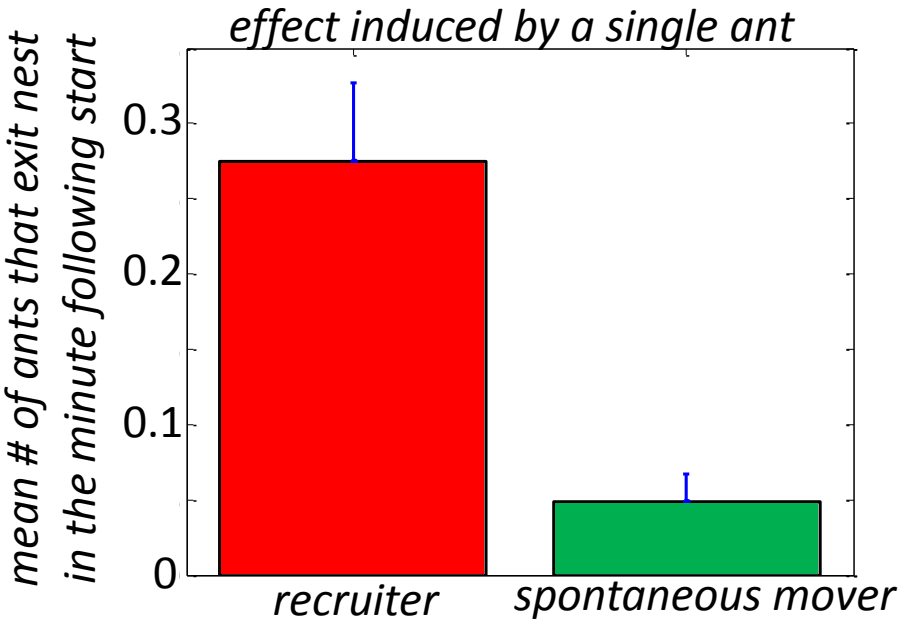
Two types of exits

1. Before cricket is found:

   Induced by an ant that started to move spontaneously.

2. After cricket is found:

   Induced by a recruiter ant.



This can easily be accomplished using a decent vocabulary.

Do the desert ants have a decent vocabulary?

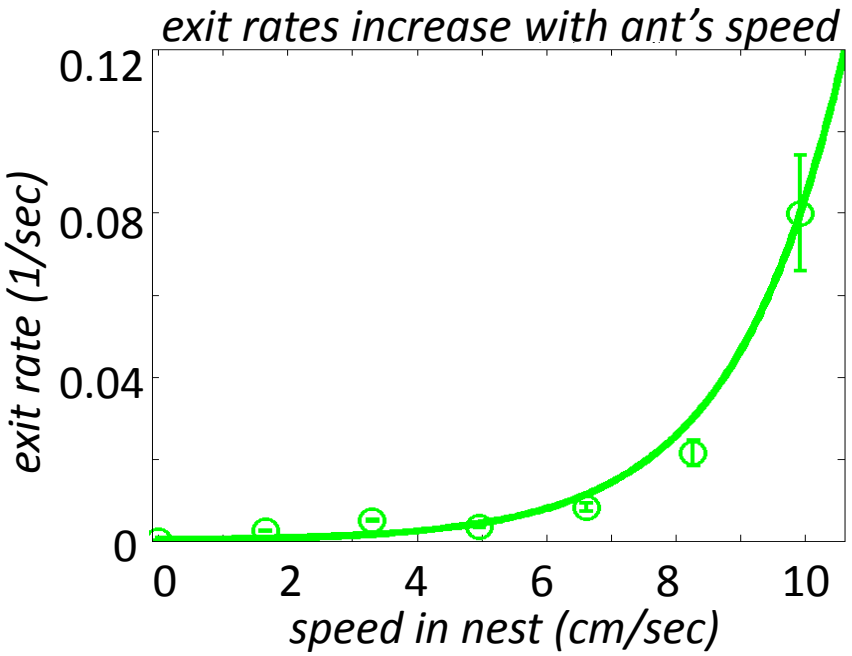
Take a closer look at the ants' exit and interaction behavior.

Exit by speed

What made the first ant exit?

What made the recruited ants exit?

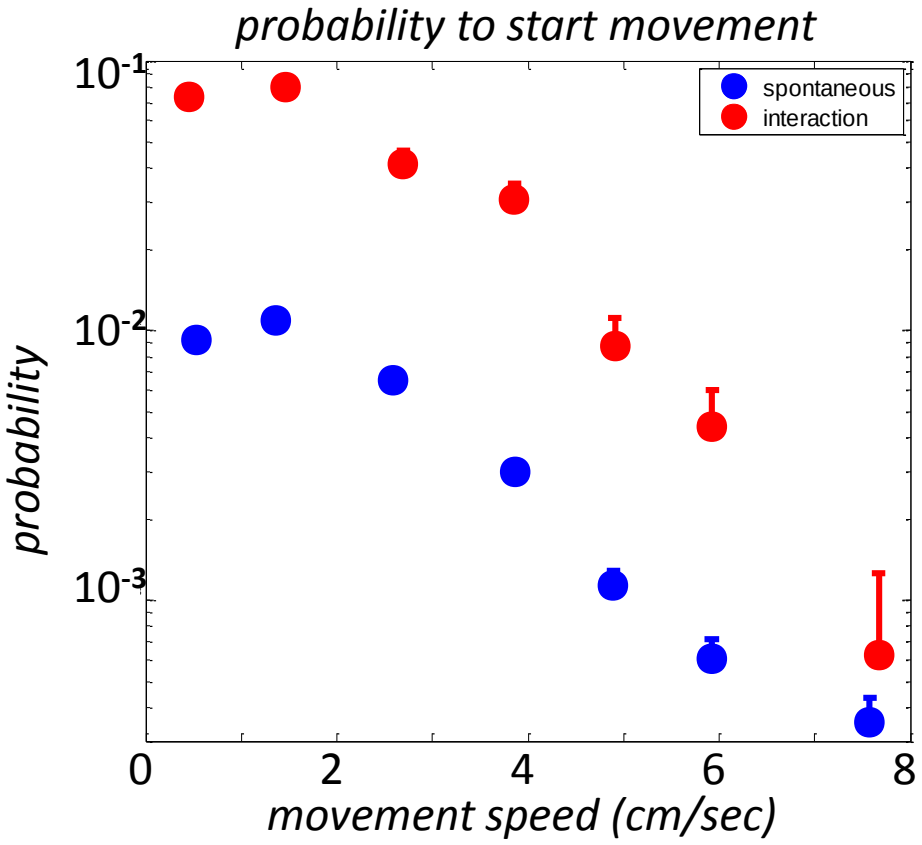
We can predict an exit before it happens:



Speed is a good readout for estimating an ant's state.

To exit an ant must accelerate. **What makes her accelerate?**

Example: accelerating from zero



On average:

Spontaneous events: once every 2.5 minutes per ant.

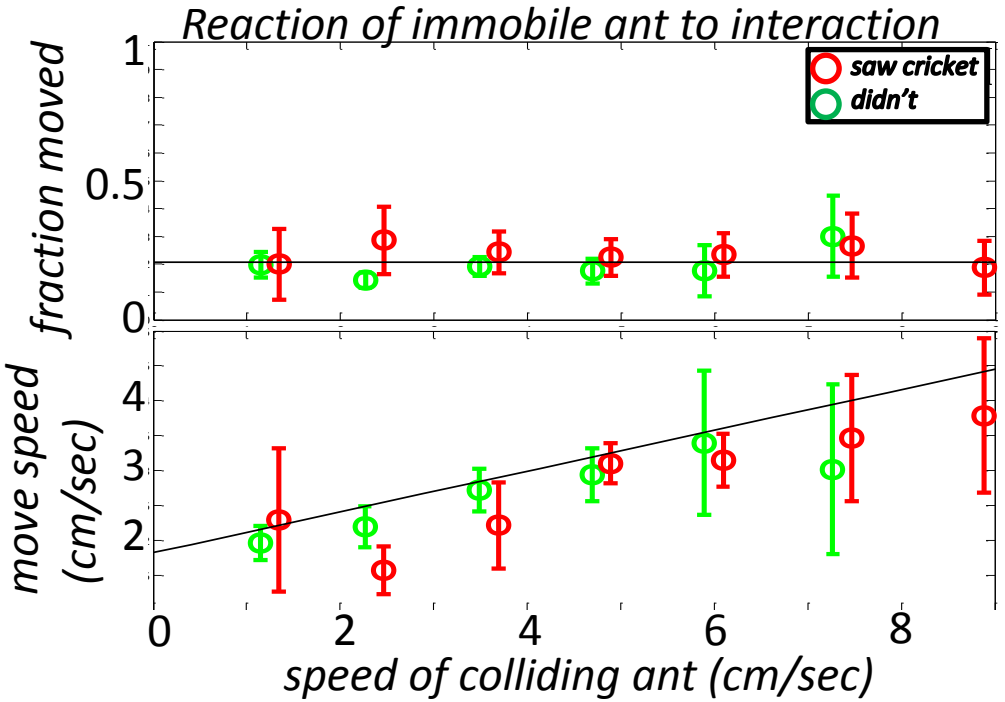
Interactions: 4-5 interaction to start moving.

➔Interactions have a strong effect on speed.

What information is transferred in the interactions?

What information is passed in the interactions?

Look at two ants carrying very different information:
One has seen the cricket, the other didn't.
How would interacting with them affect the speed change of an immobile ant?



The only effect is that of the speed of the other ant.
This is very consistent with what we visually see: the ants mostly bump into each other.

How many words can be encoded in the speed?

A question of noise….and bumping to communicate is noisy.

Ants don't always say what they meant to say:

- Moving from place to place is equivalent to saying something.
- Ants have a probability (~1/20) to spontaneously start moving fast (appearing to others as a recruiter).

Even when they do they are not too well heard:

- Speed changes – are quite noisy:
  Up to our measurement noise, capacity of information channel >0.12 bits…
- Out of those ants that exit after meeting with recruiter only 1/3 do so following a single interaction. Indicates upper bound for capacity of only ~0.5 bits.

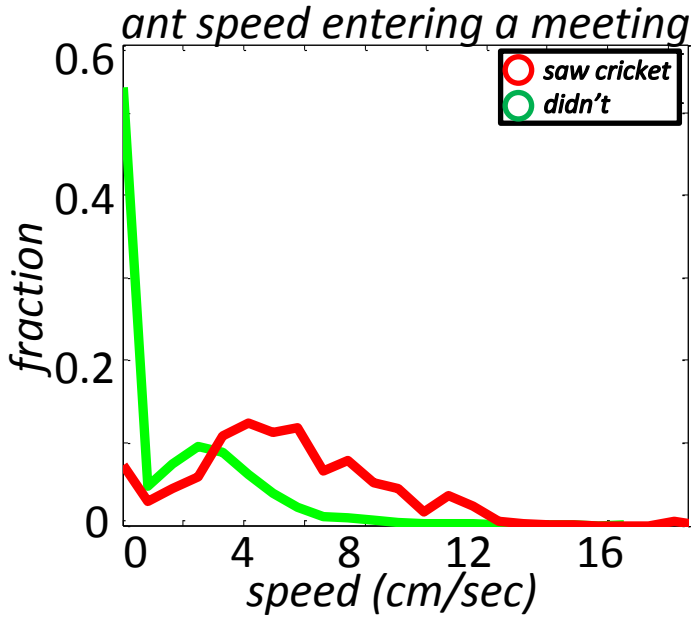
Not even two clear words!

Desert ants dedicate a small vocabulary to this task!

“was that a push or a shove?” a problem of noise control

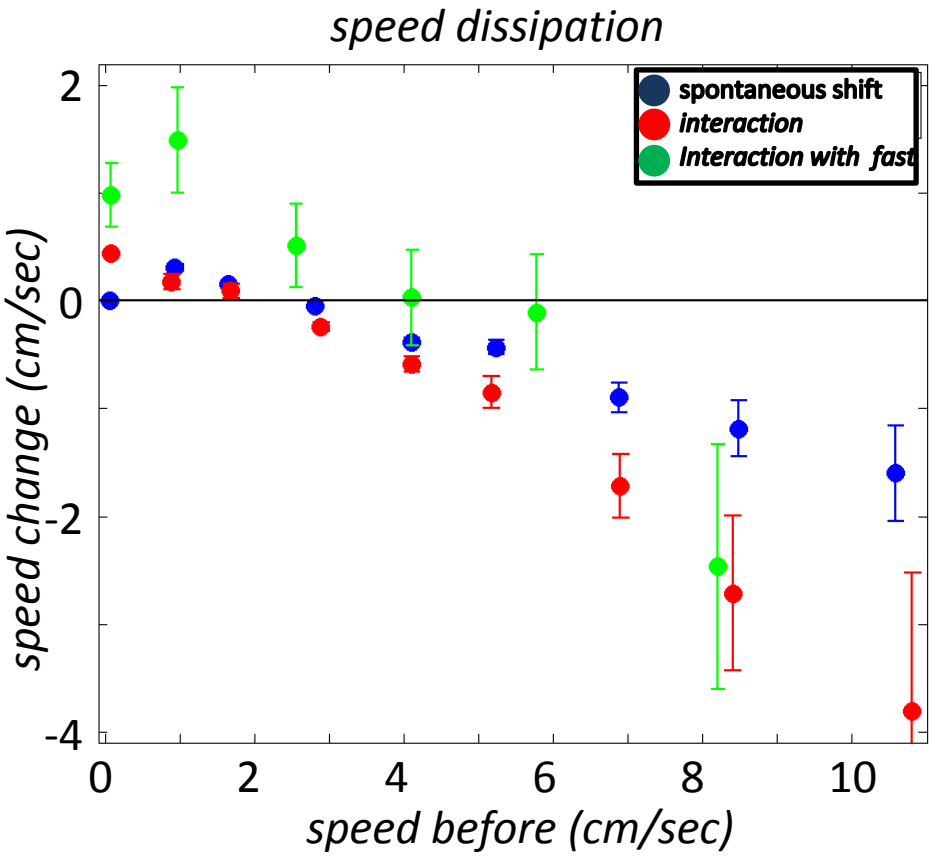
So how can an ant differentiate a random bump from a recruiting attempt?
…we just saw that she can’t! It is the group that differentiates between the two:

Ants behave differently and react to messages differently depending on whether they already saw the cricket.



Recruiters have been exposed to information an hold on to it – remaining always fast, their speed - not affected by interactions.

Ants that didn't see cricket: speed and response to interactions



DISSIPATION

Speed spontaneously dissipates.

Speed dissipates even more upon interactions, except:

Speed goes up when interacting with fast ants.

Reminiscent of "dissipative gas".

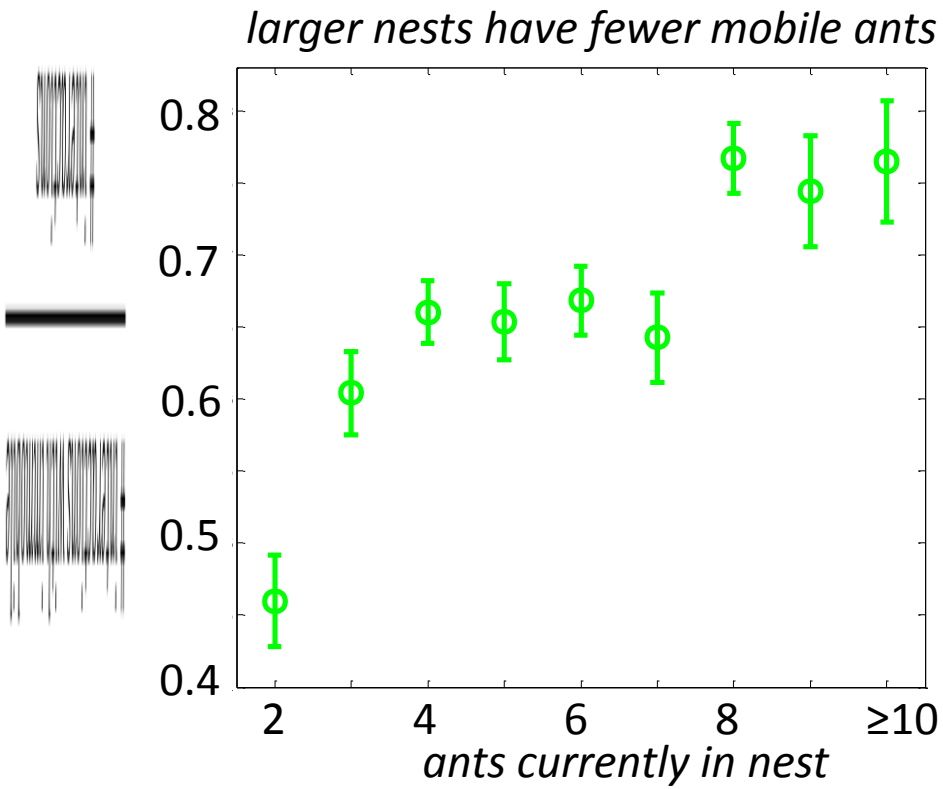
FIXED POINTS

Without recruiters: fixed point at 2 cm/sec (even a fast ant will quickly dissipate). Controls spontaneous exits…

With recruiter: an option to raise the fixed point to around 6 cm/sec closer to exit threshold. Allows for recruitment….

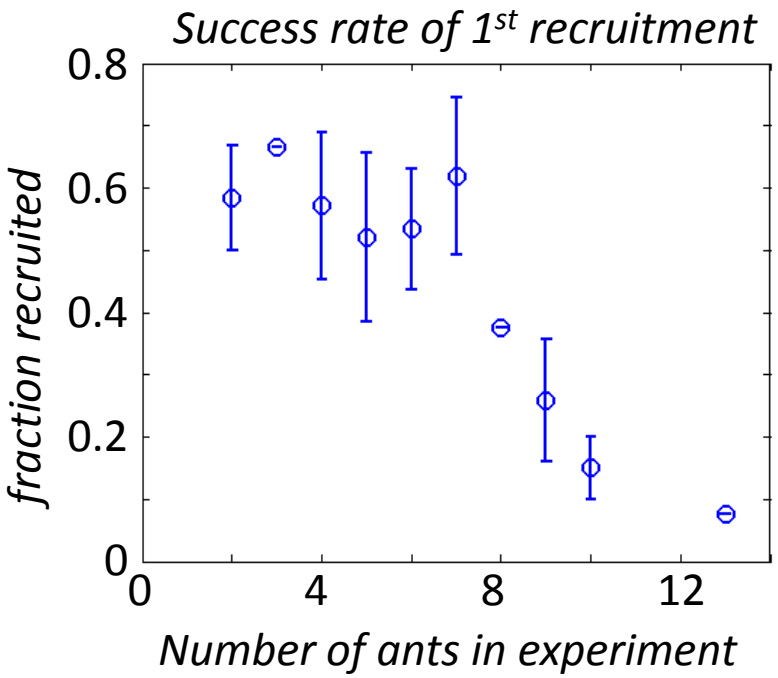
Moving to the colony level

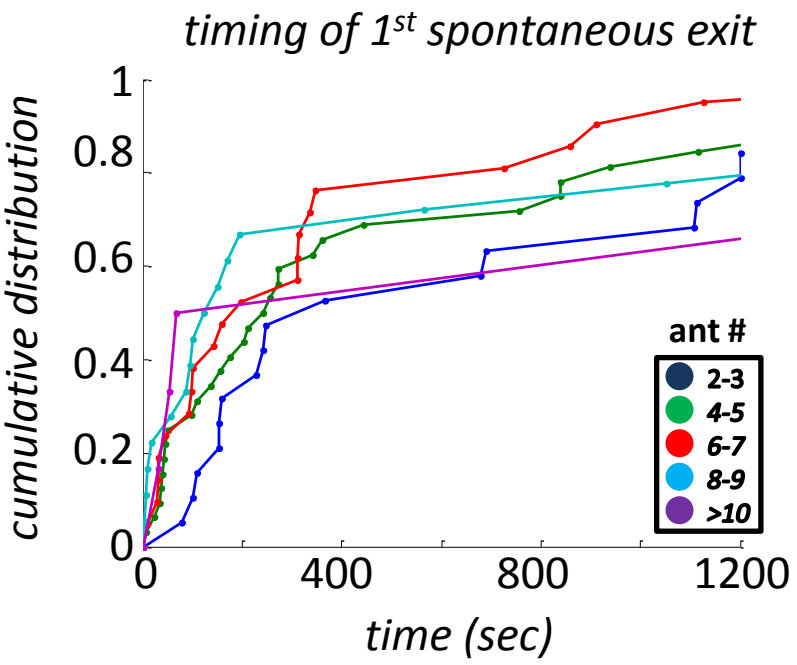
To bridge the scales we make connections between
group size and interaction statistics.



In larger (denser) nests more interaction are with the slow (here, standing) ants.
Larger nests can be expected to be more dissipative.

Colony level consequences of dissipation





Dissipation becomes more and more pronounced in groups larger than ~7 ants.
This is clearly visible in both spontaneous exit and recruitment statistics.

Summary

- Ants “combat” noisy communication by changing the way they distribute and react to messages in a history dependent manner.

1. **Conviction**: Ants who saw the cricket
   – spread the word and are unaffected by different “opinions”.

2. **Dissipation:** Ants without a first account knowledge of cricket
   – spread the word but only for a very limited time.

This dissipative signaling results
in a somewhat inefficient recruitment process.

Thank you

Our Lab:
Yuri Burnishev
Tal Eliav
Ehud Fonio
Efrat Greenwald
Yael Heyman
Nitzan Razin
Oded Shor

Jean-Pierre Eckmann (University of Geneve)

The Clore Foundation.
ISF FIRST grant.