Collective sensing and intelligence in animal groups

ANDREW BERDAHL

SANTA FE INSTITUTE








Galton and the wisdom of crowds

450 *NATURE* [MARCH 7, 1907

VOX POPULI.

ELSEVIER
Update
TRENDS in Ecology and Evolution Vol.19 No.9 September 2004
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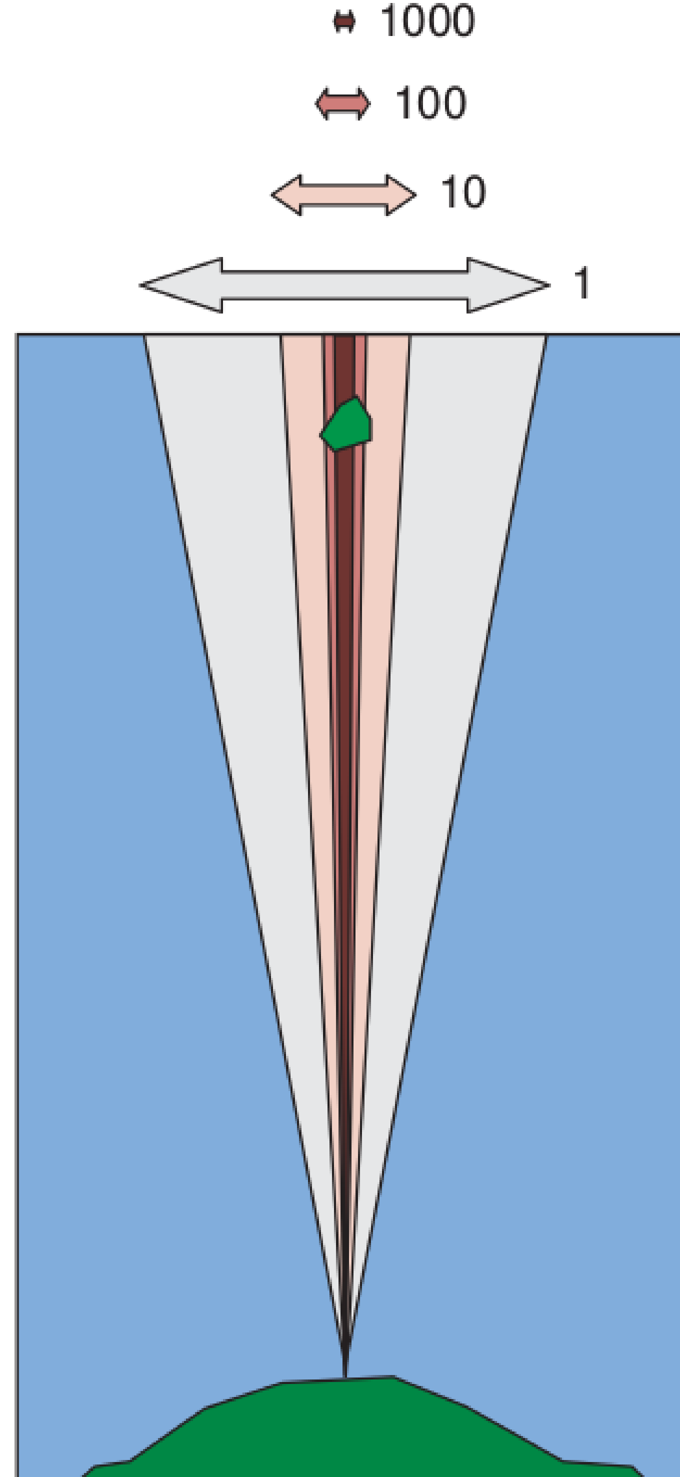
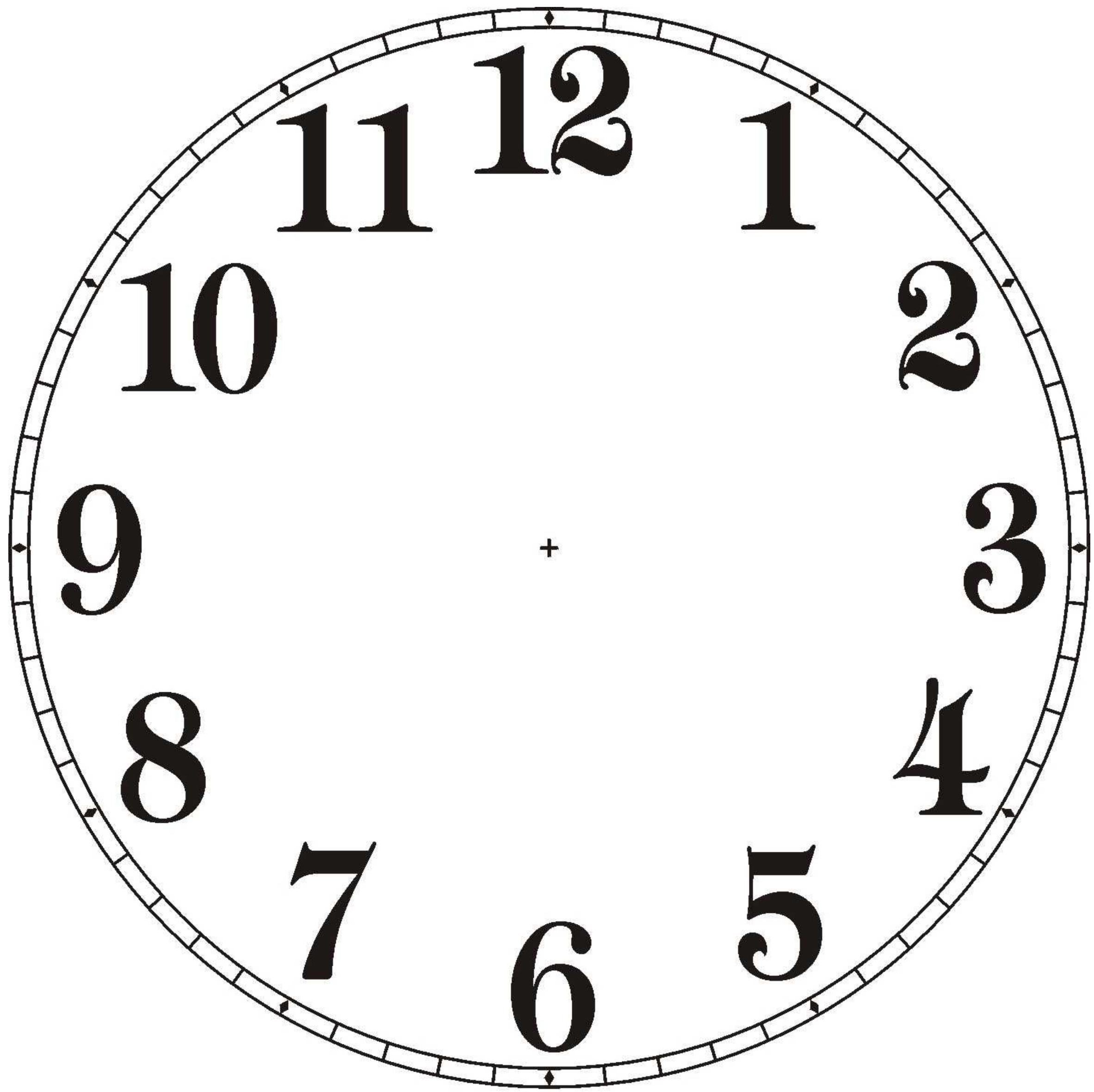
Research Focus

Many wrongs: the advantage of group navigation

Andrew M. Simons

Department of Biology, College of Natural Sciences, Carleton University, 1125 Colonel By Drive, Ottawa, ON, Canada K1S 5B6




12
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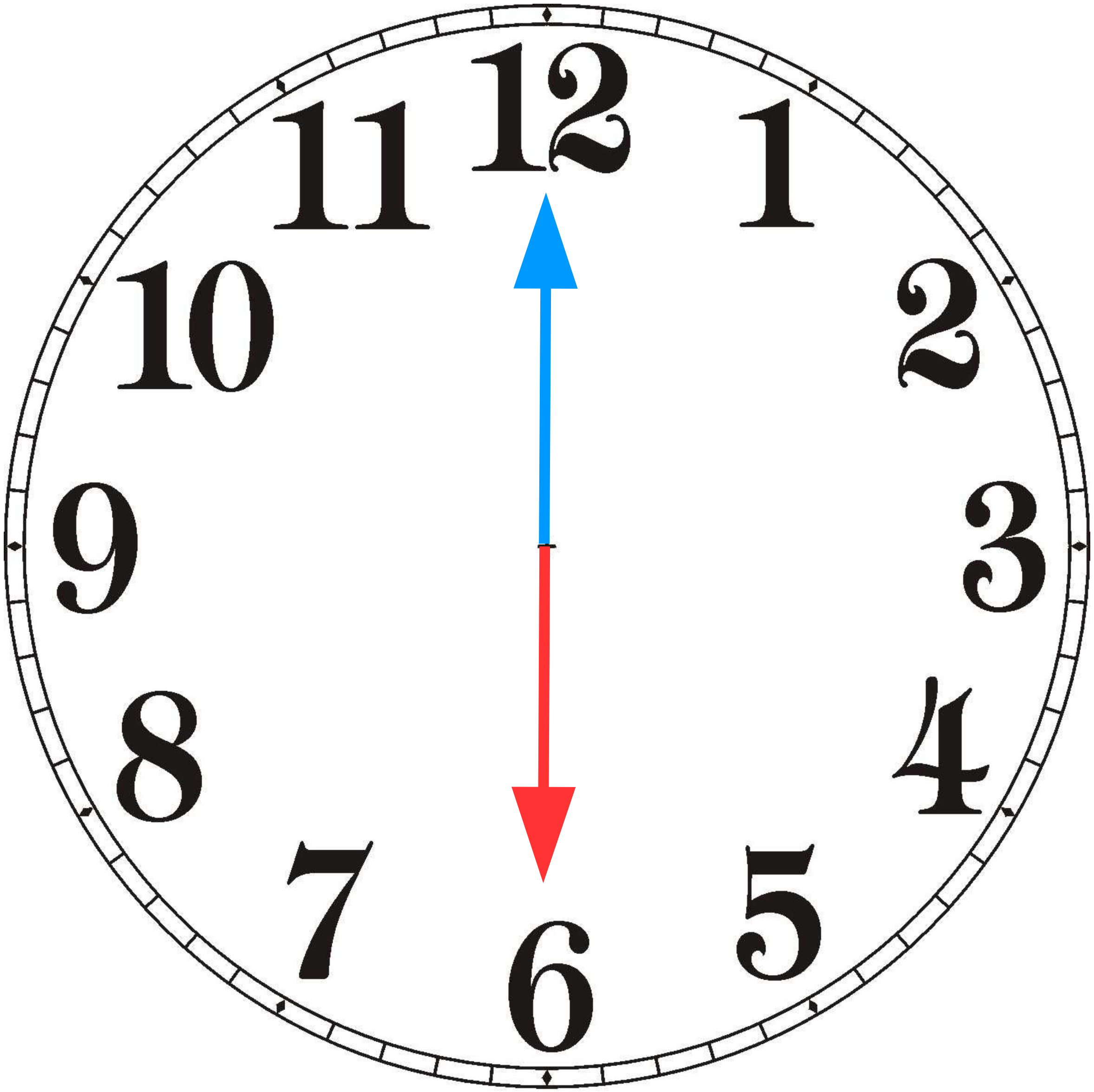
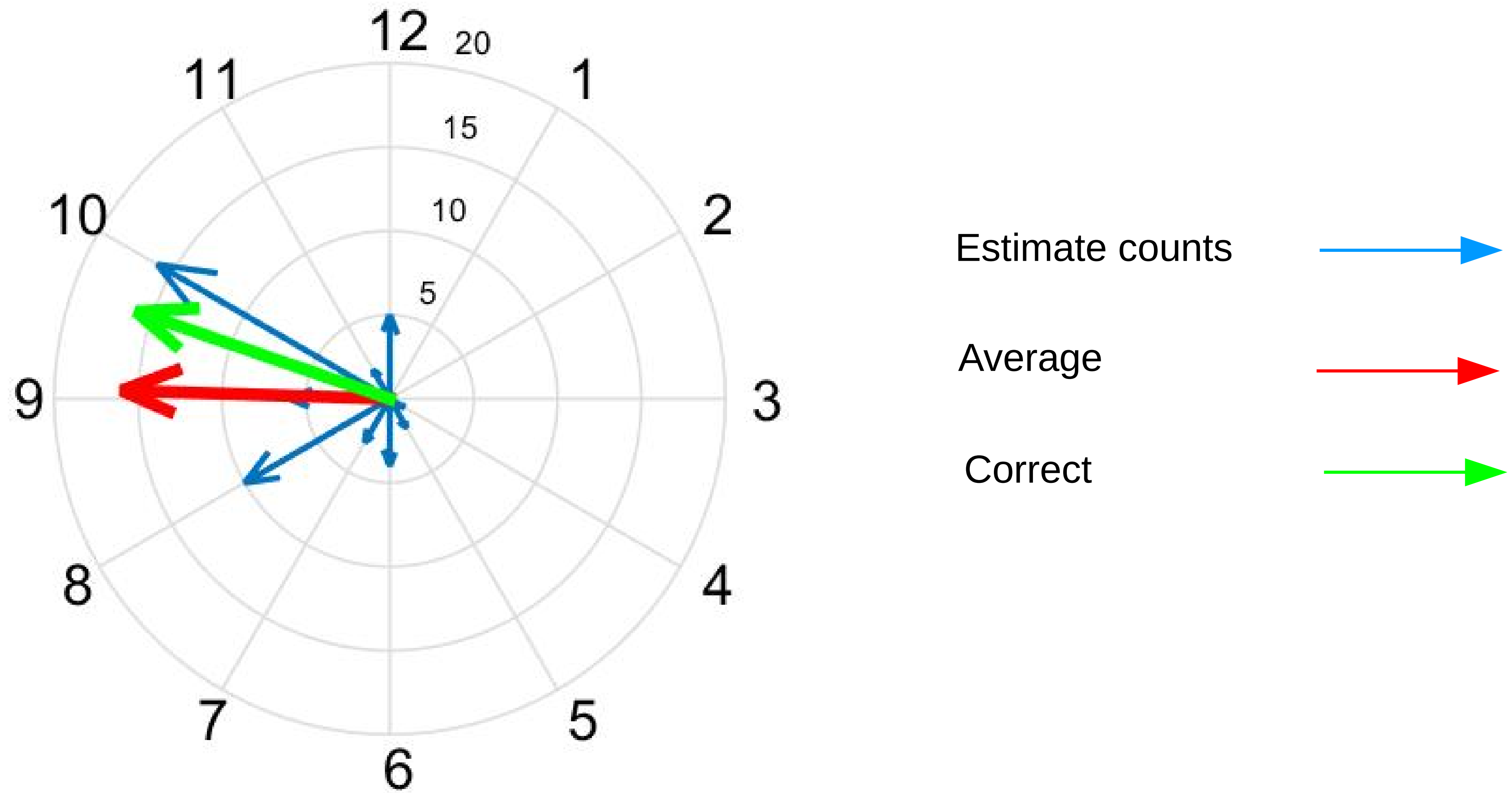
Front of room

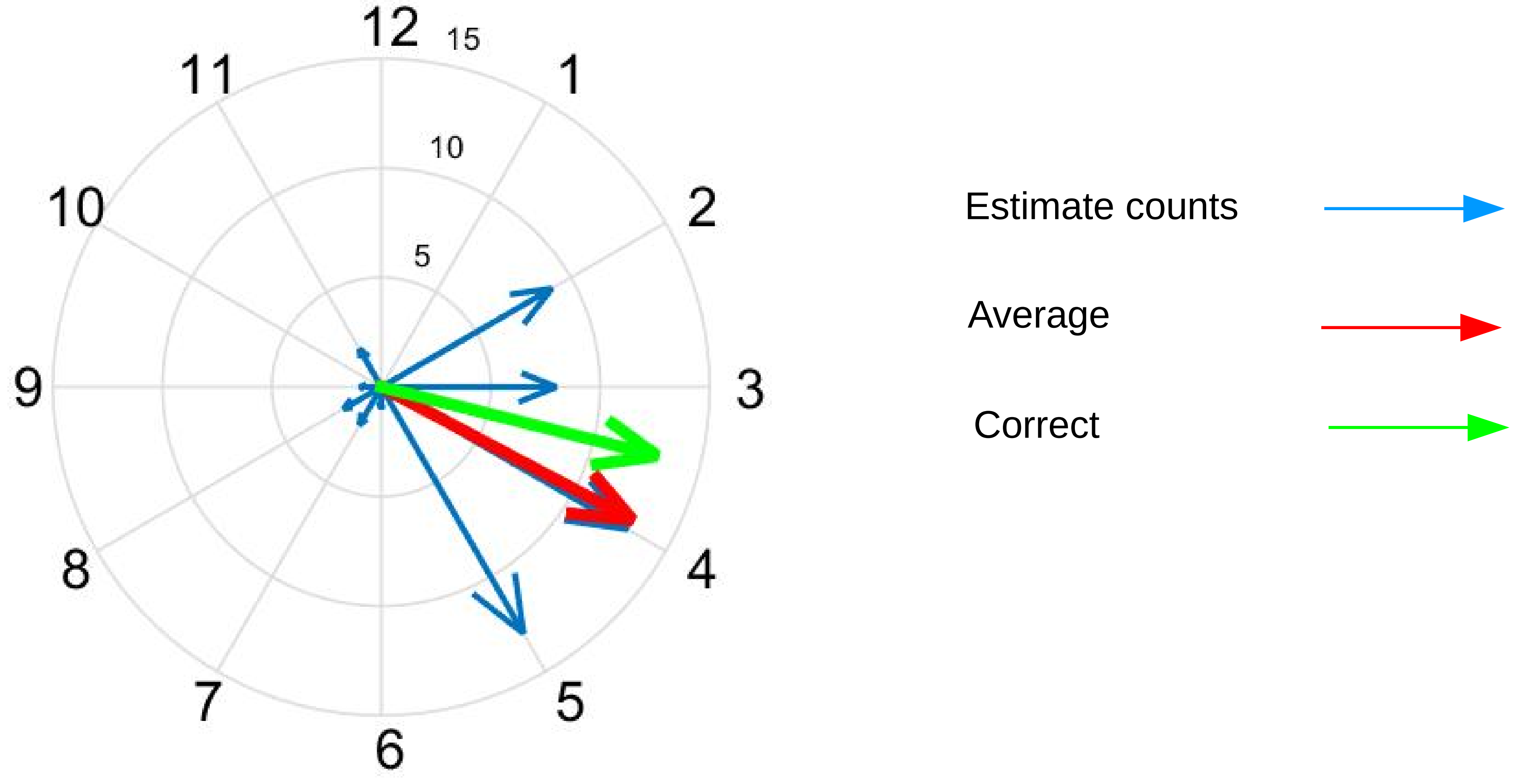


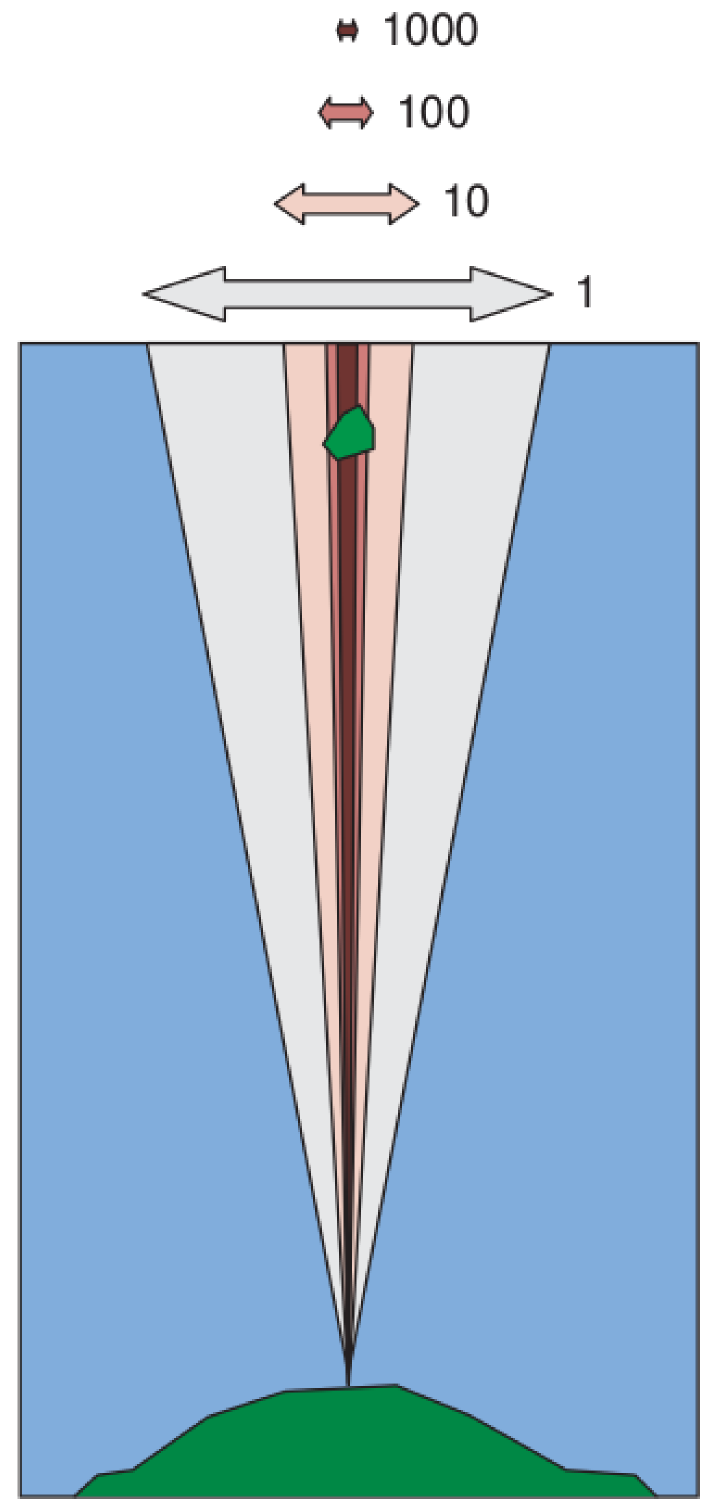
Back of room

direction to Albuquerque



direction to London





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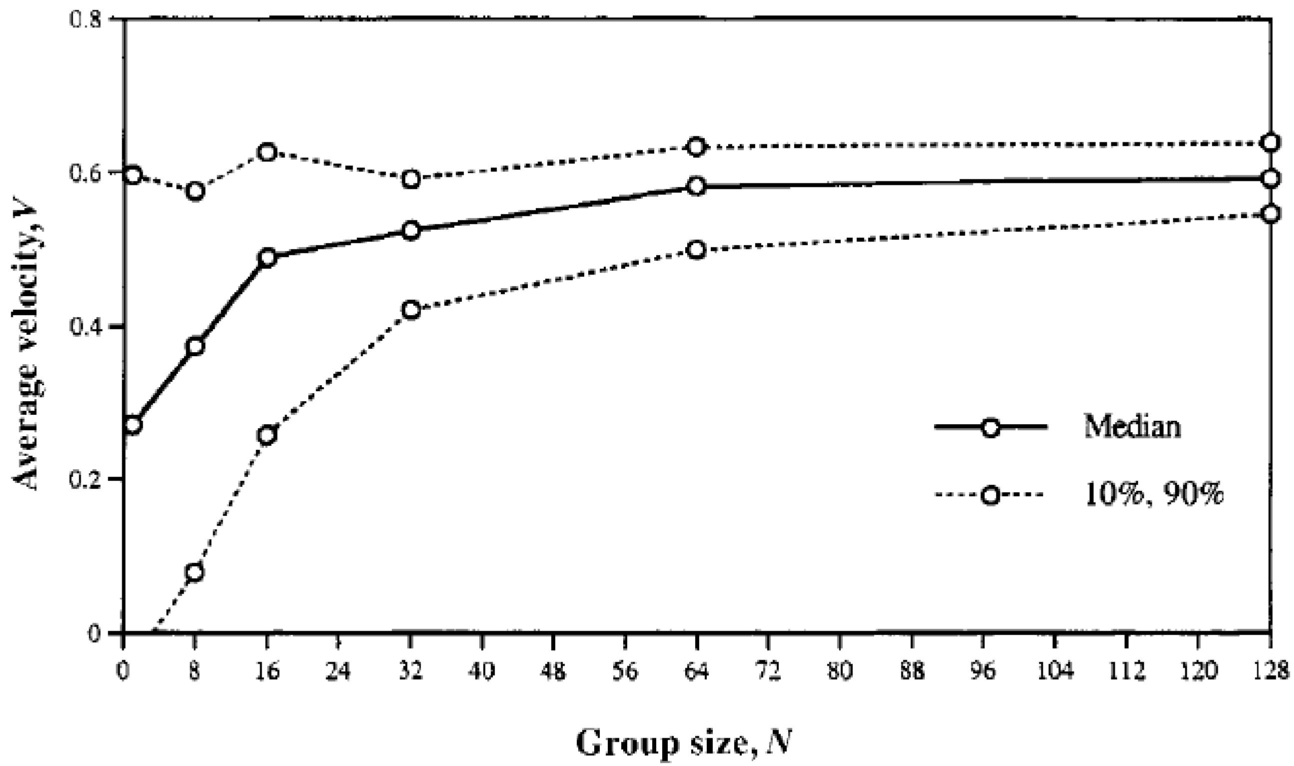

Evolutionary Ecology 1998, **12**, 503–522

Schooling as a strategy for taxis in a noisy environment

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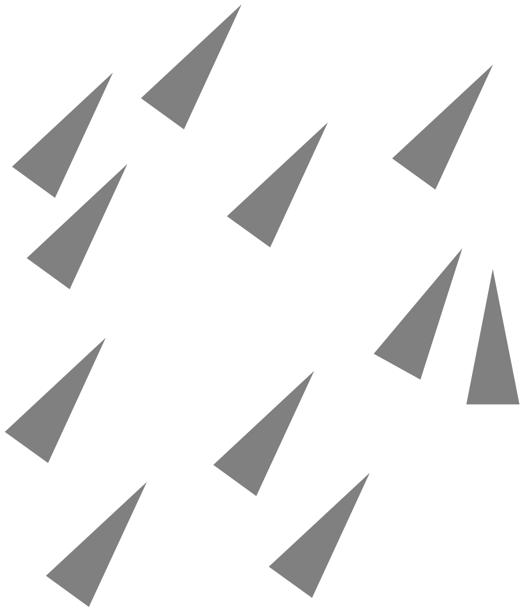
Department of Mathematics, University of British Columbia, Vancouver, B.C. V6T 1Y4, Canada

schooling model (zonal)



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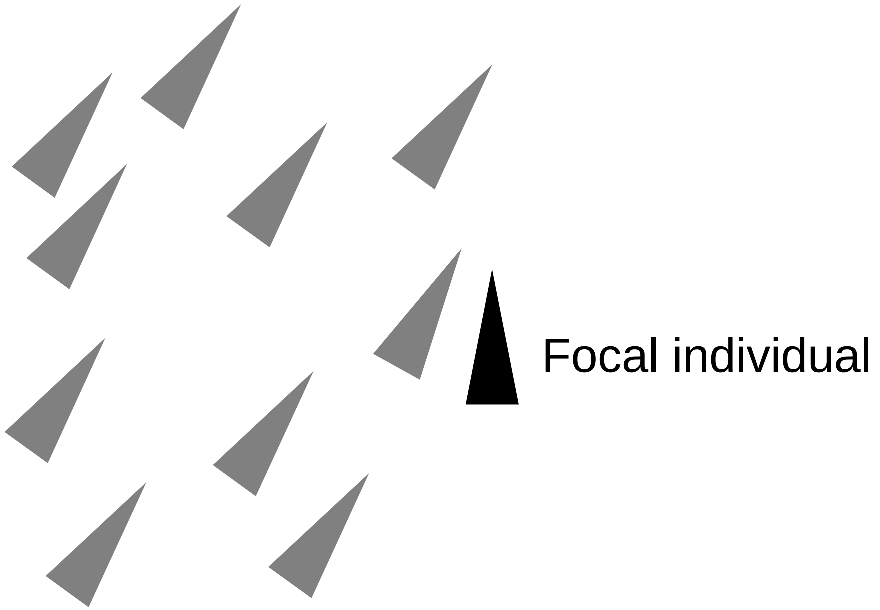

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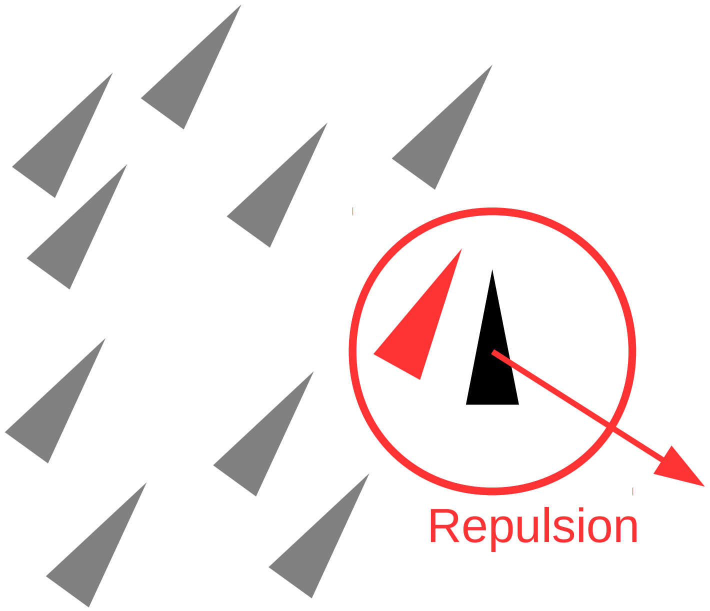

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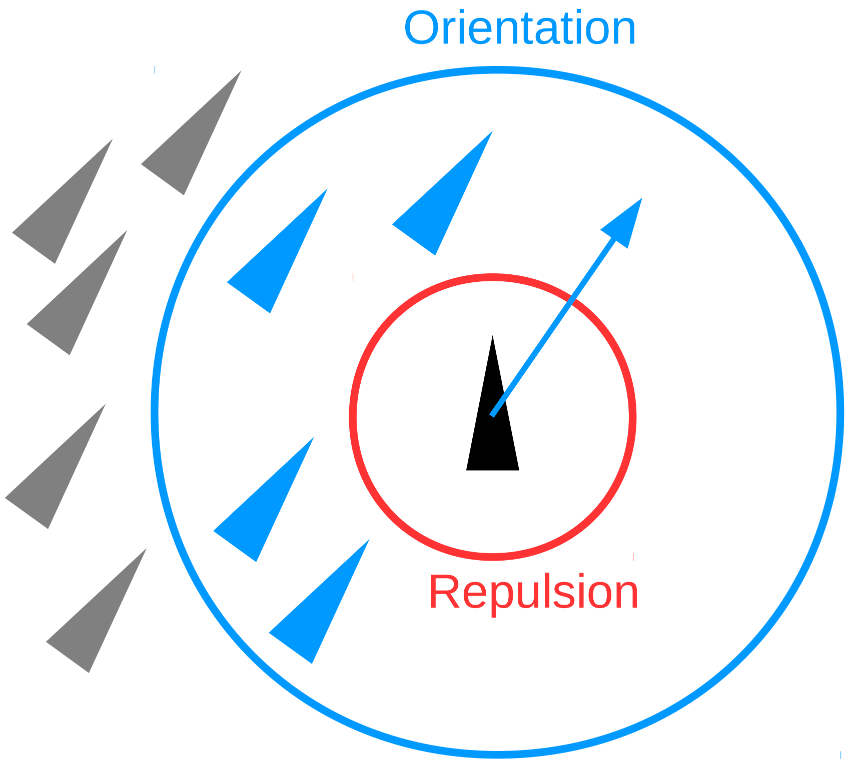

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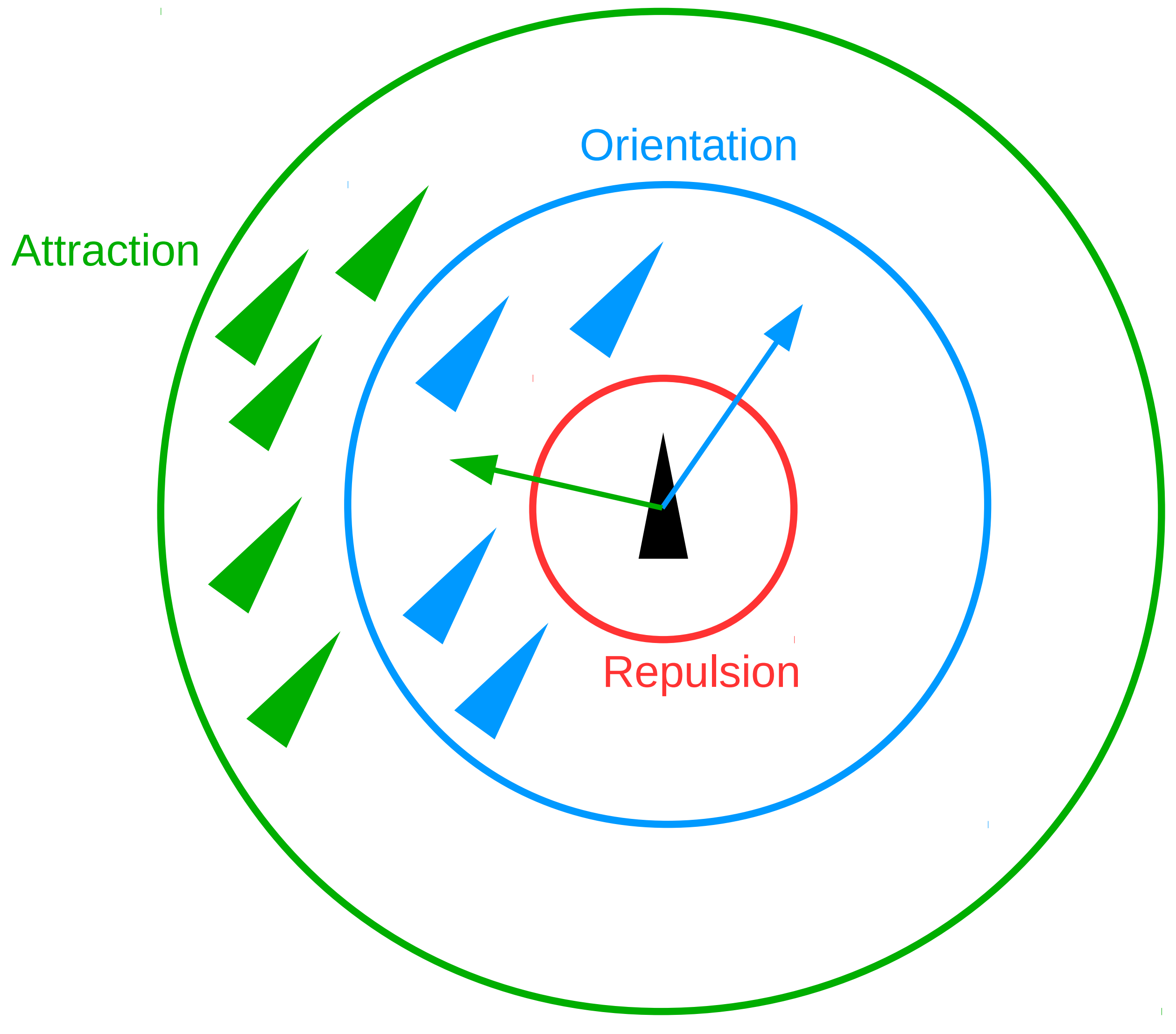
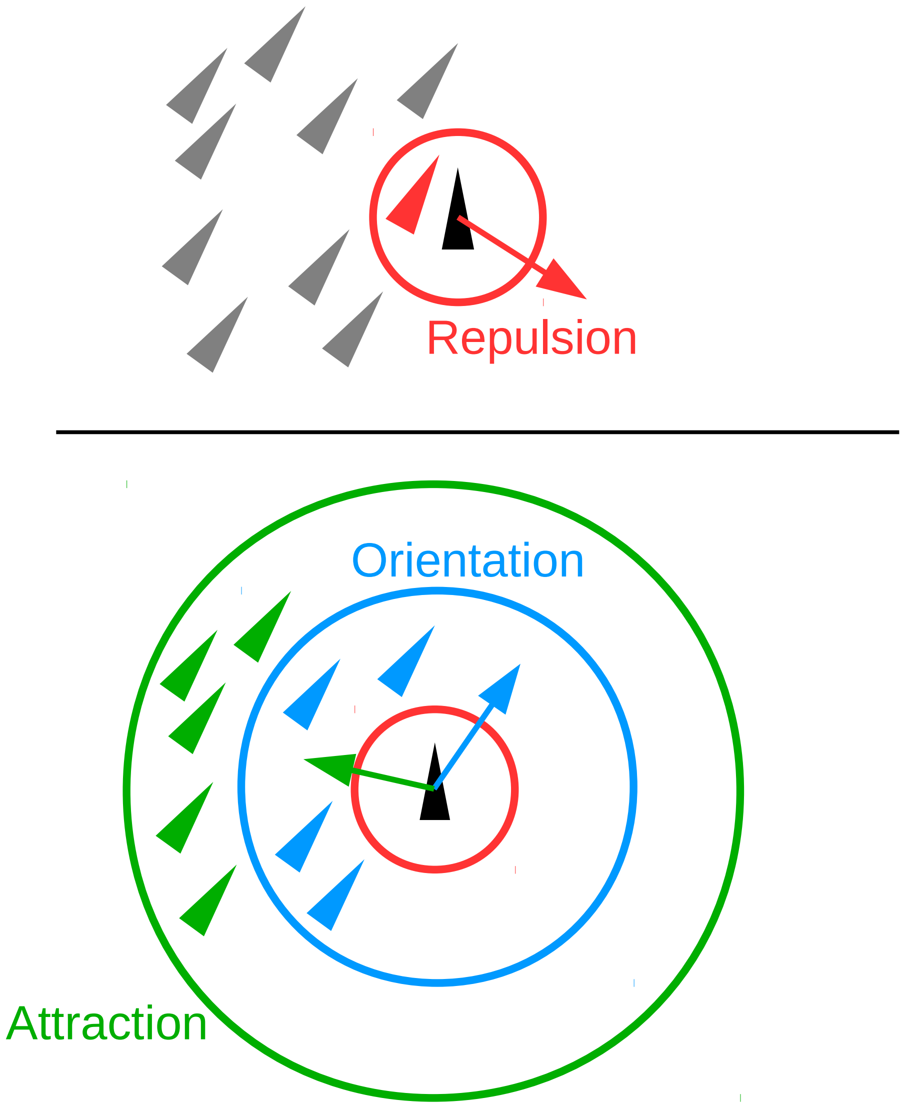


pseudo code



loop over individuals

if(others in repulsion zone)

move away

elseif(others in attraction and orientation zones)

attract and orient

end %if

end %loop

collective intelligence: enhancement vs emergent

Enhancement

Individuals make error-prone estimates.

Pooling of information improves individual's noisy estimate.

“Many-wrongs”

collective intelligence: enhancement vs emergent

Enhancement

Individuals make error-prone estimates.

Pooling of information improves individual's noisy estimate.

“Many-wrongs”

Emergent

No individual-level estimate or strategy.

Awareness emerges at group-level.

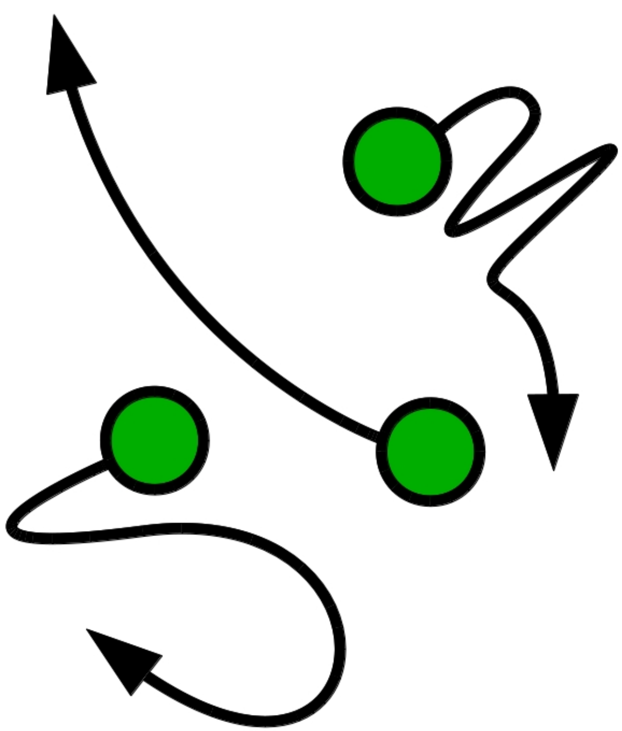
Can group-level search emerge without any individual-level taxis?

Colin
Torney

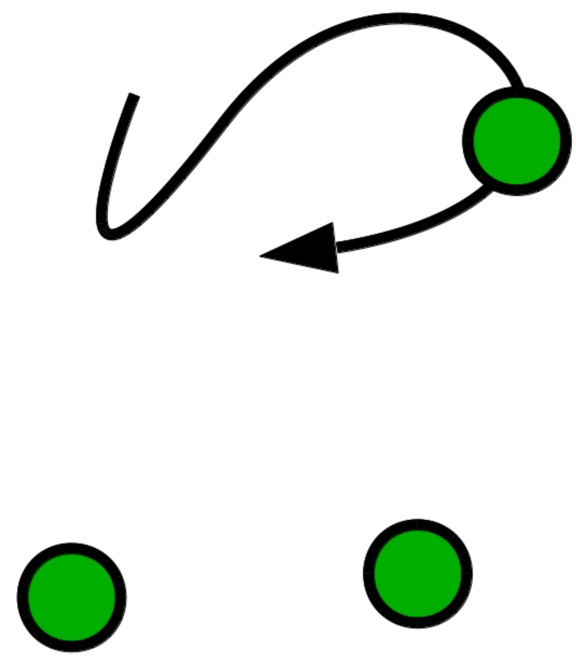
Iain
Couzin

model

Agents perform random walk...

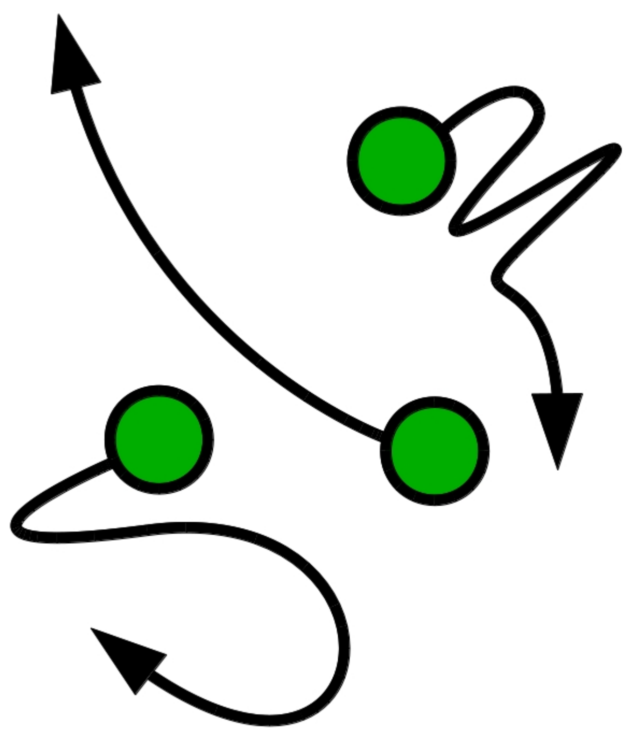


...with bias towards signals.



model

Agents perform random walk...



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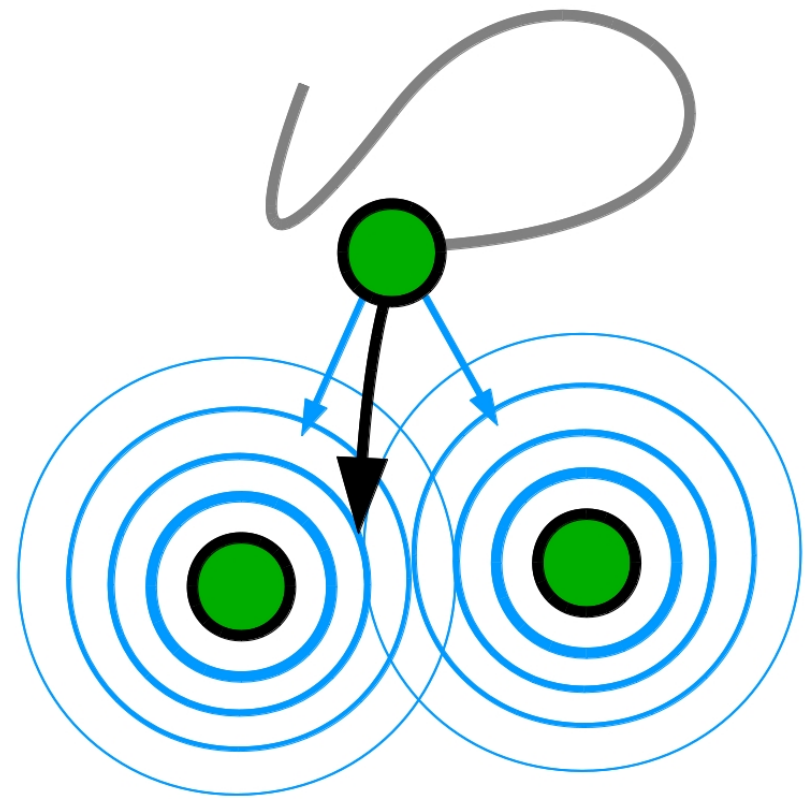
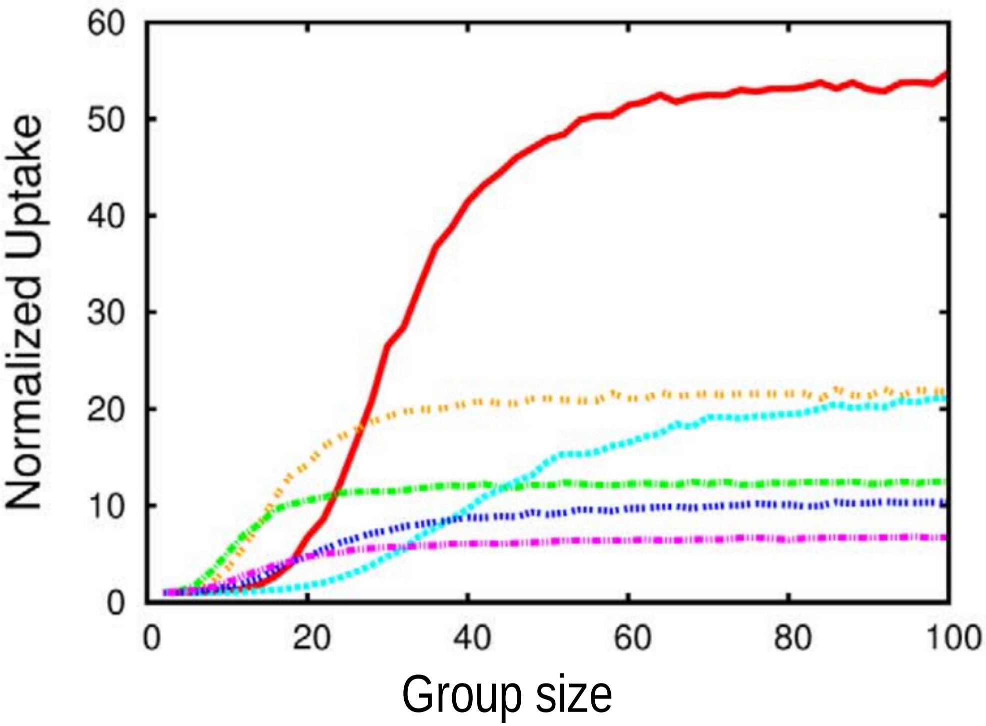
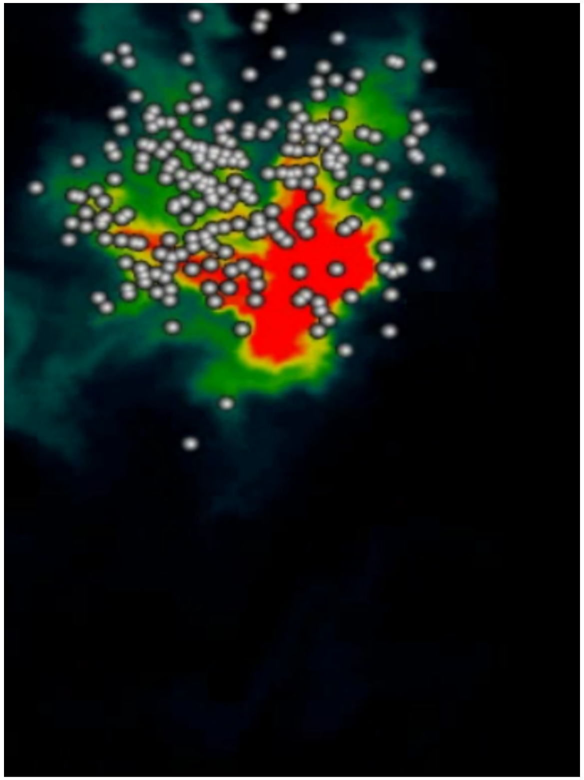


model: results

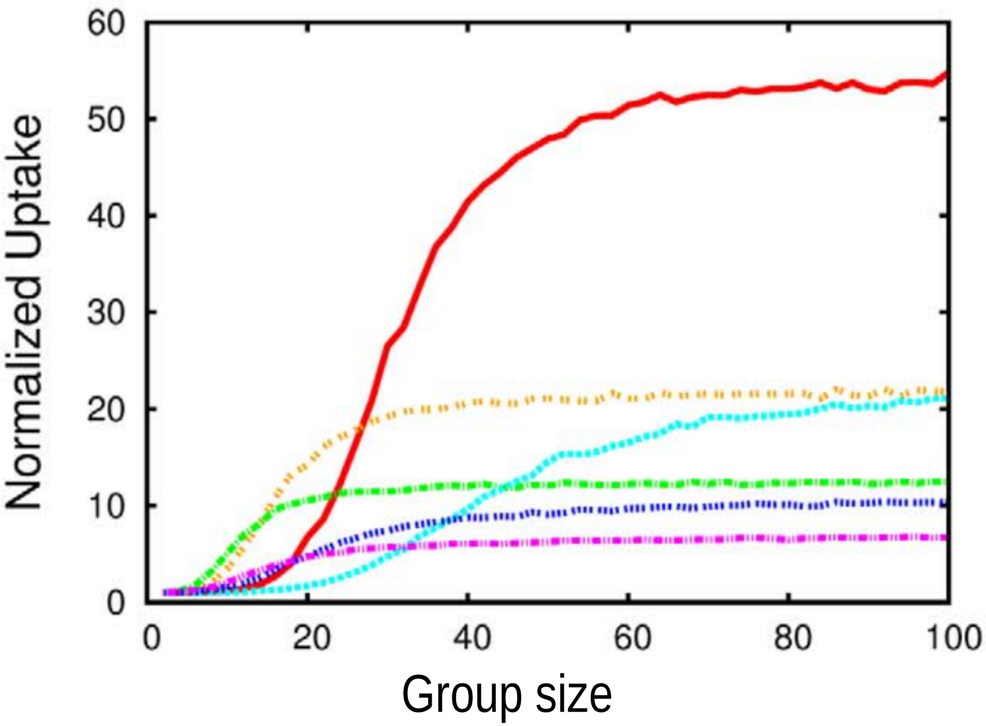


GPU CUDA simulation



Torney, Berdahl & Couzin (2011) *PLoS Computational Biology*

model: results



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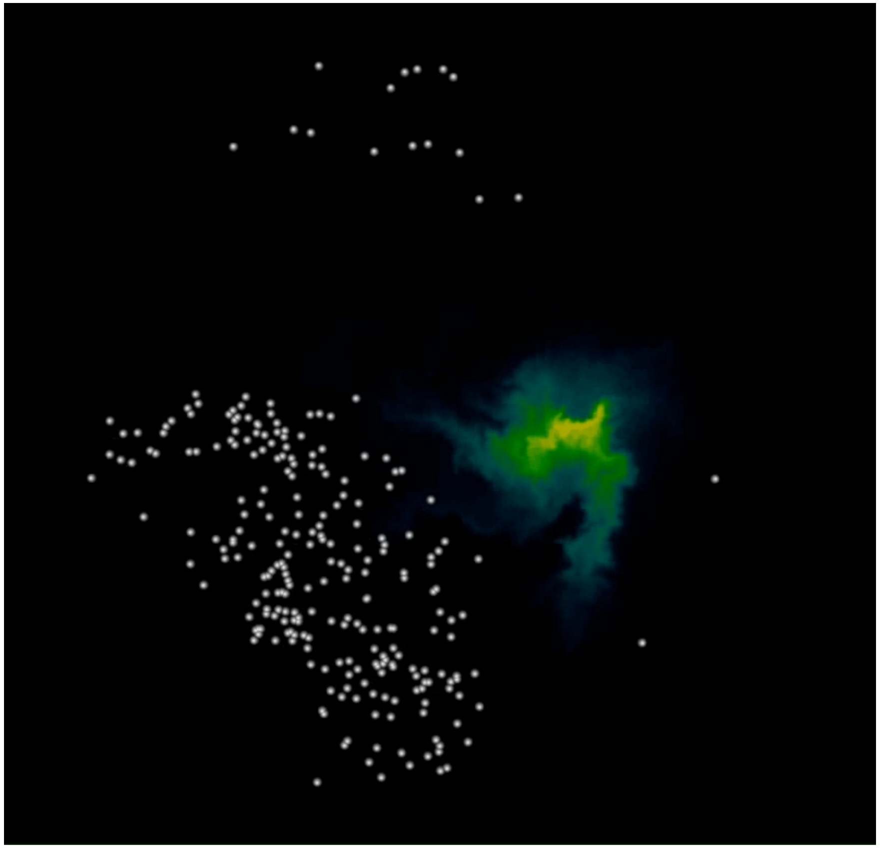
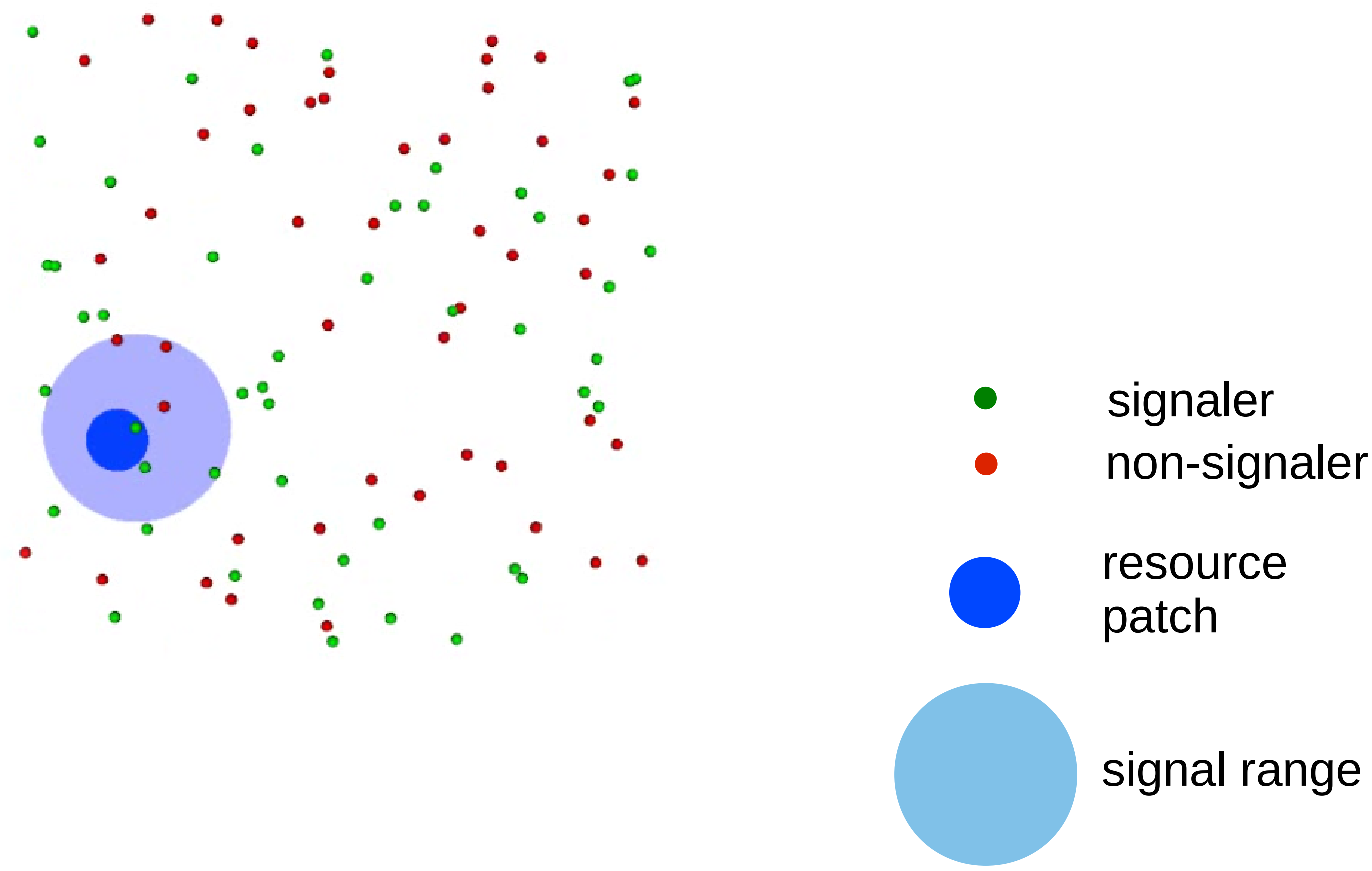


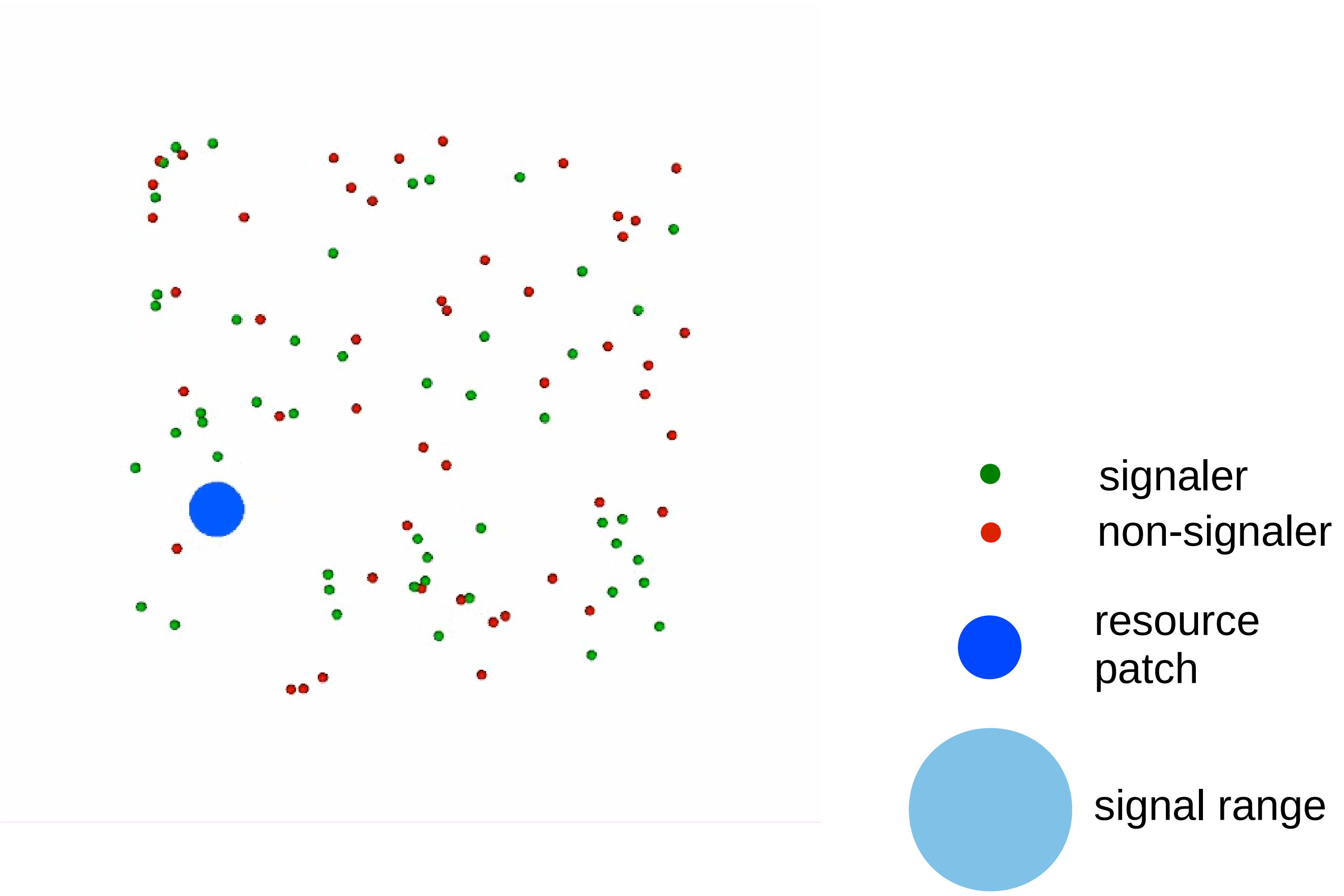
Torney, Berdahl & Couzin (2011) *PLoS Computational Biology*

reduced model



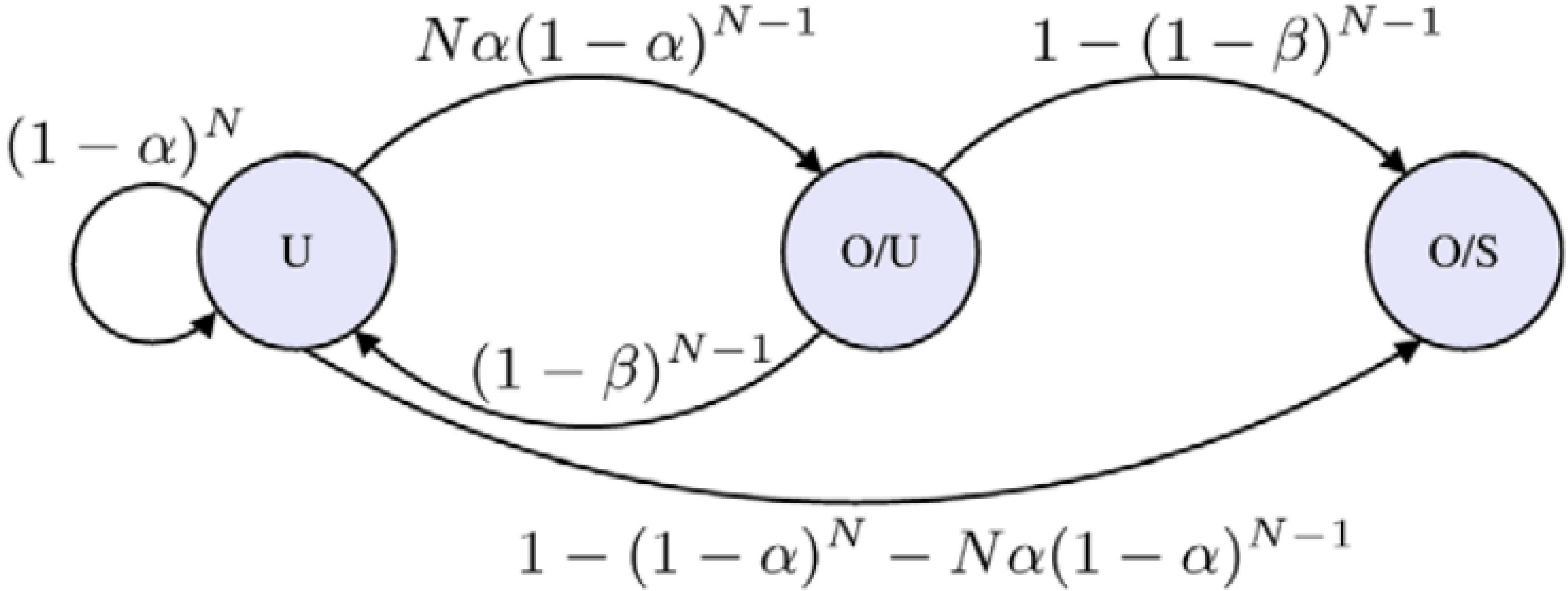
Torney, Berdahl & Couzin (2011) *PLoS Computational Biology*

reduced model



Torney, Berdahl & Couzin (2011) *PLoS Computational Biology*

markov model

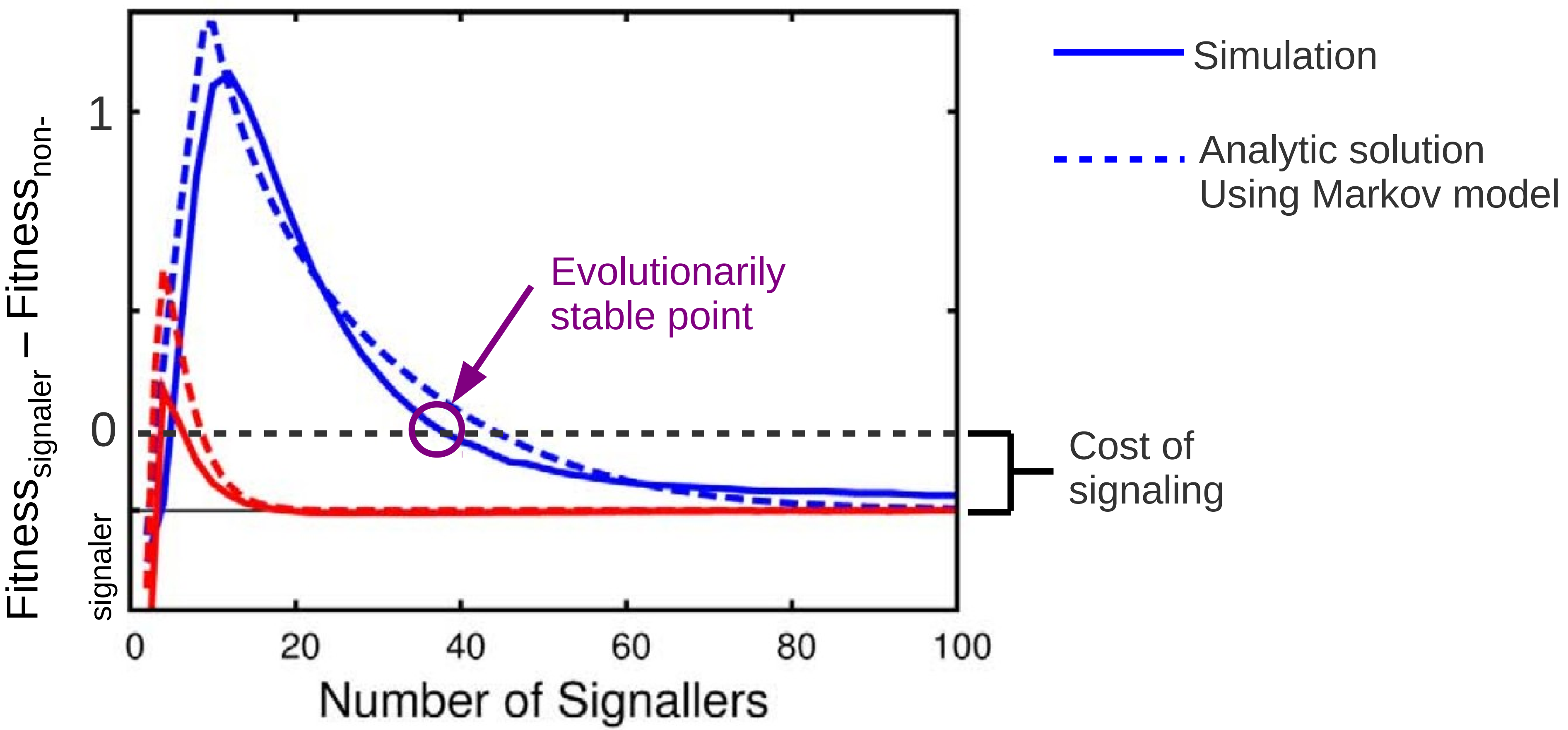


Unoccupied

Occupied
Unstable

Occupied
Stable

co-operation evolves



Torney, Berdahl & Couzin (2011) *PLoS Computational Biology*

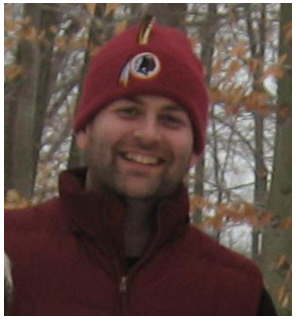
Can group-level search emerge without any individual-level taxis?

Collective sensing emerges through co-operative signaling.

Even at a cost co-operative signaling is maintained by evolution in stochastic environments.

How do real animal groups sense complex environments?

How do real animal groups sense complex environments?



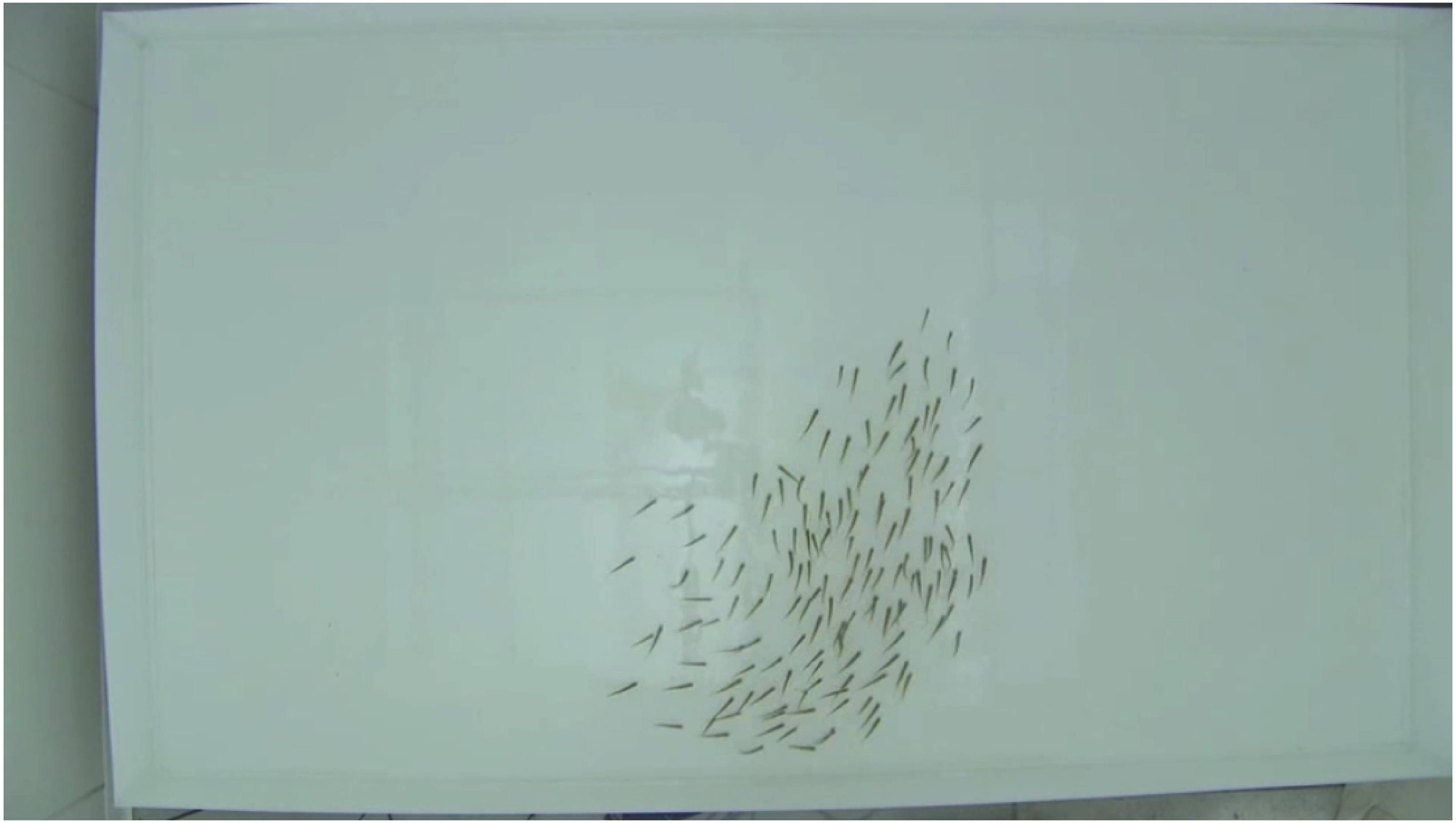
Colin
Torney

Christos
Ioannou

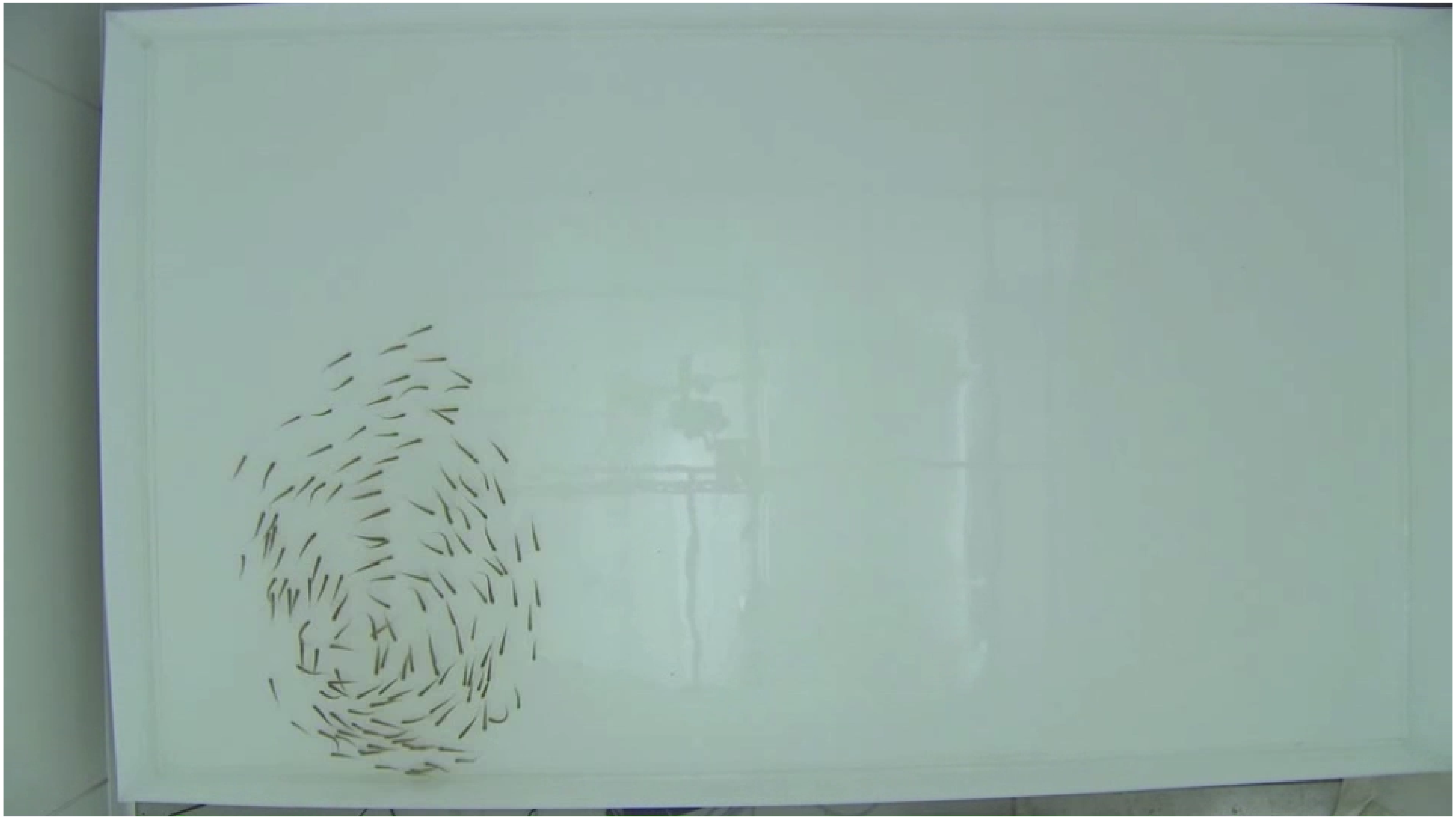
Jolyon
Faria

Iain
Couzin

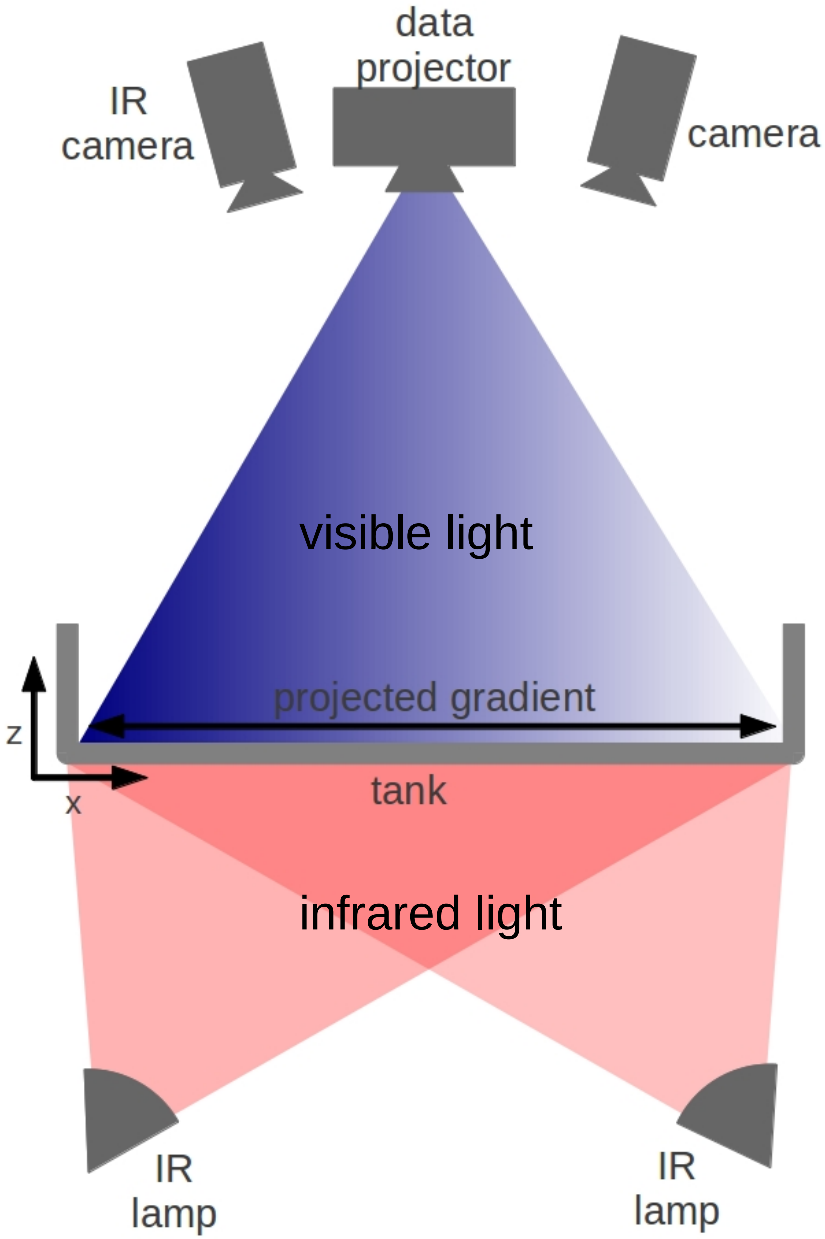
system: fish schools

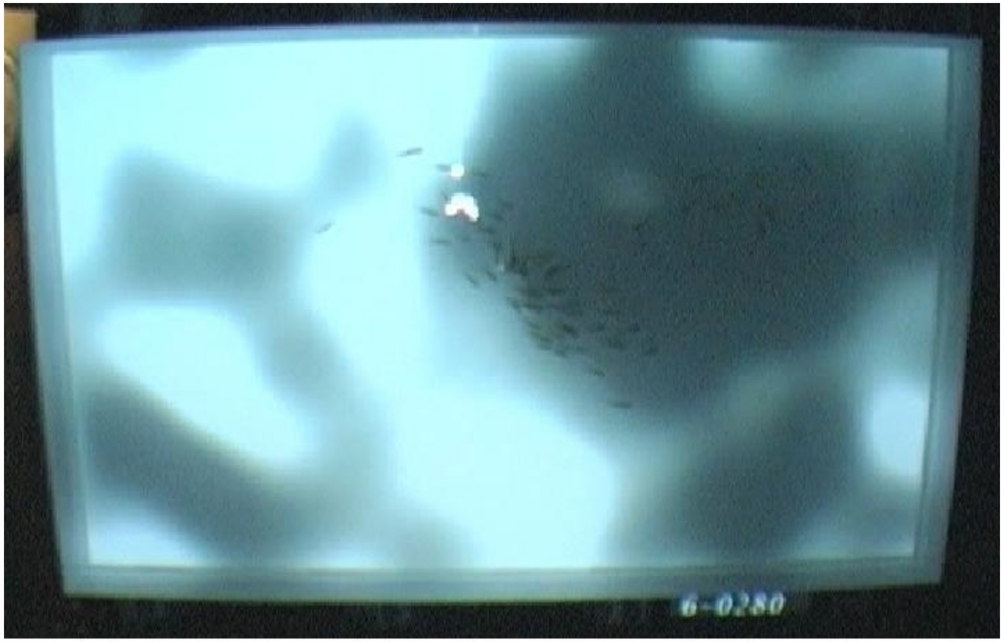


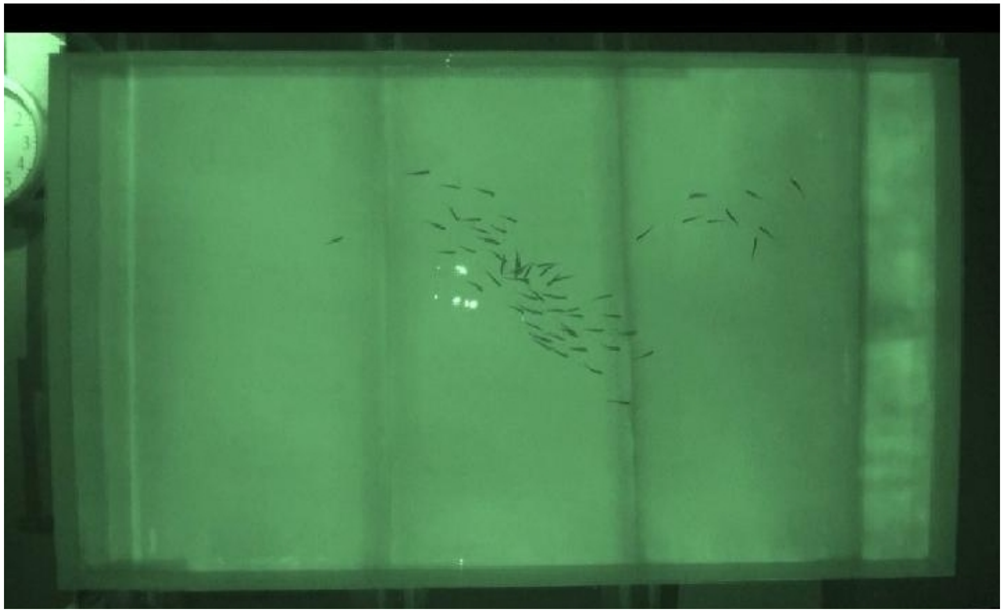
system: fish schools



experimental set-up

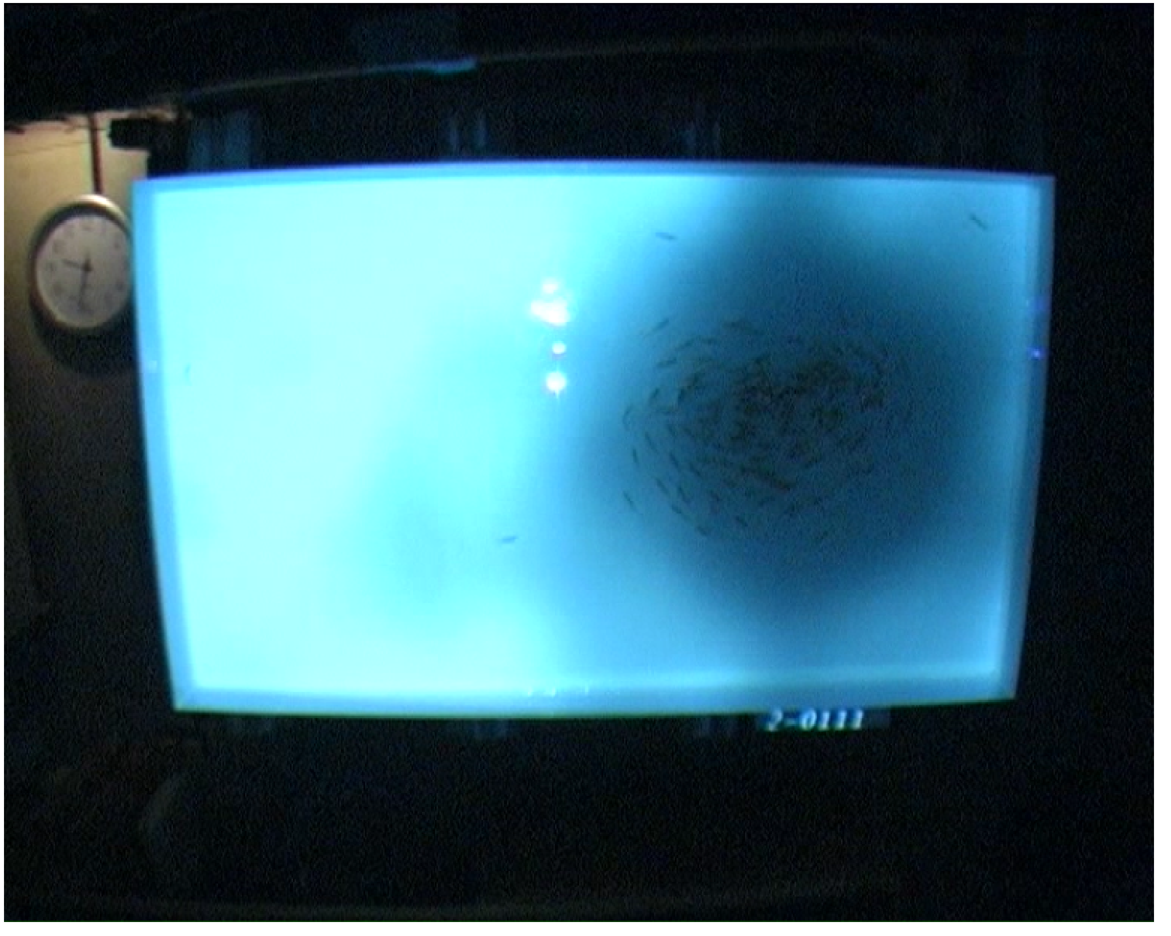




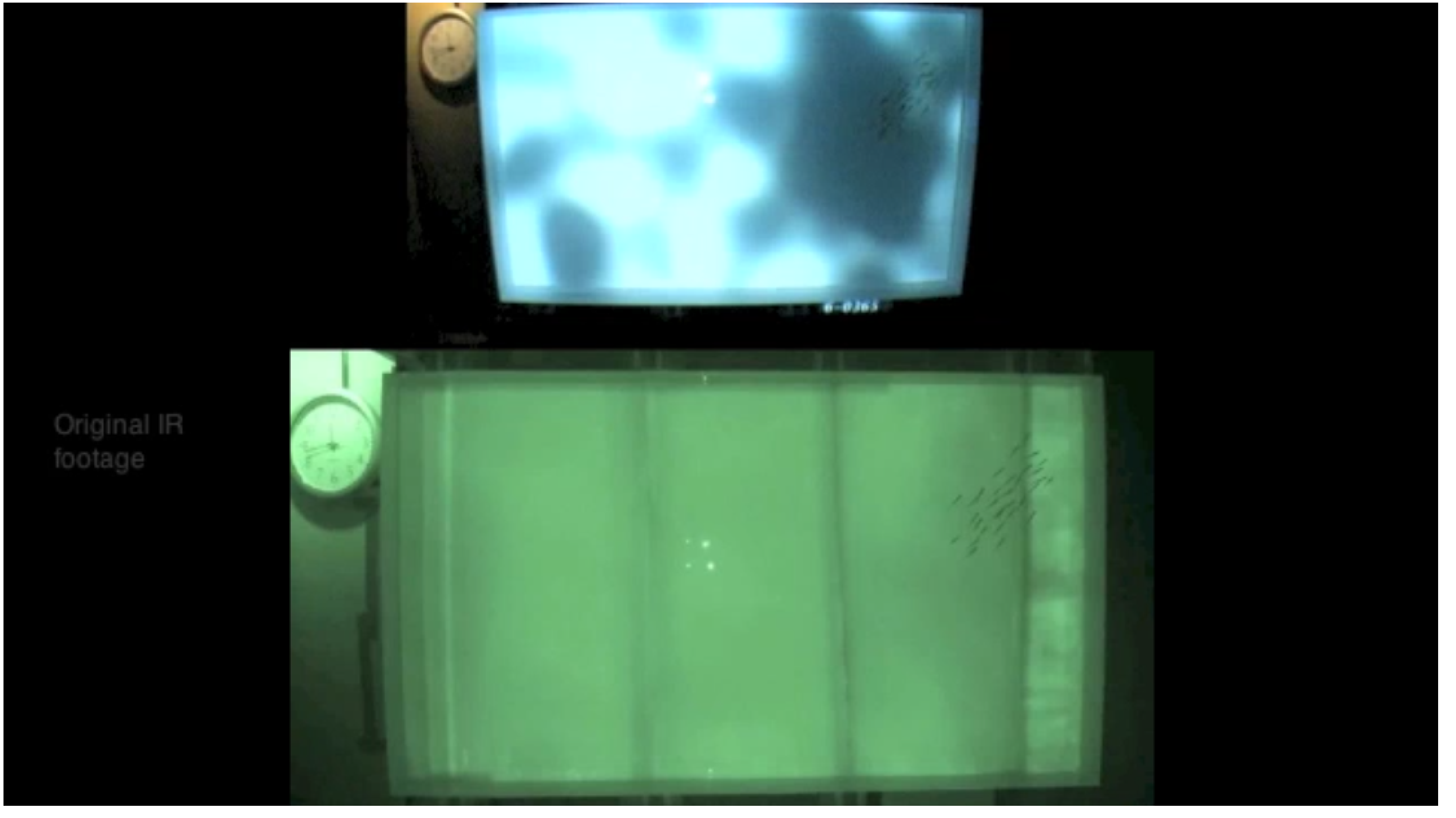


experimental trial

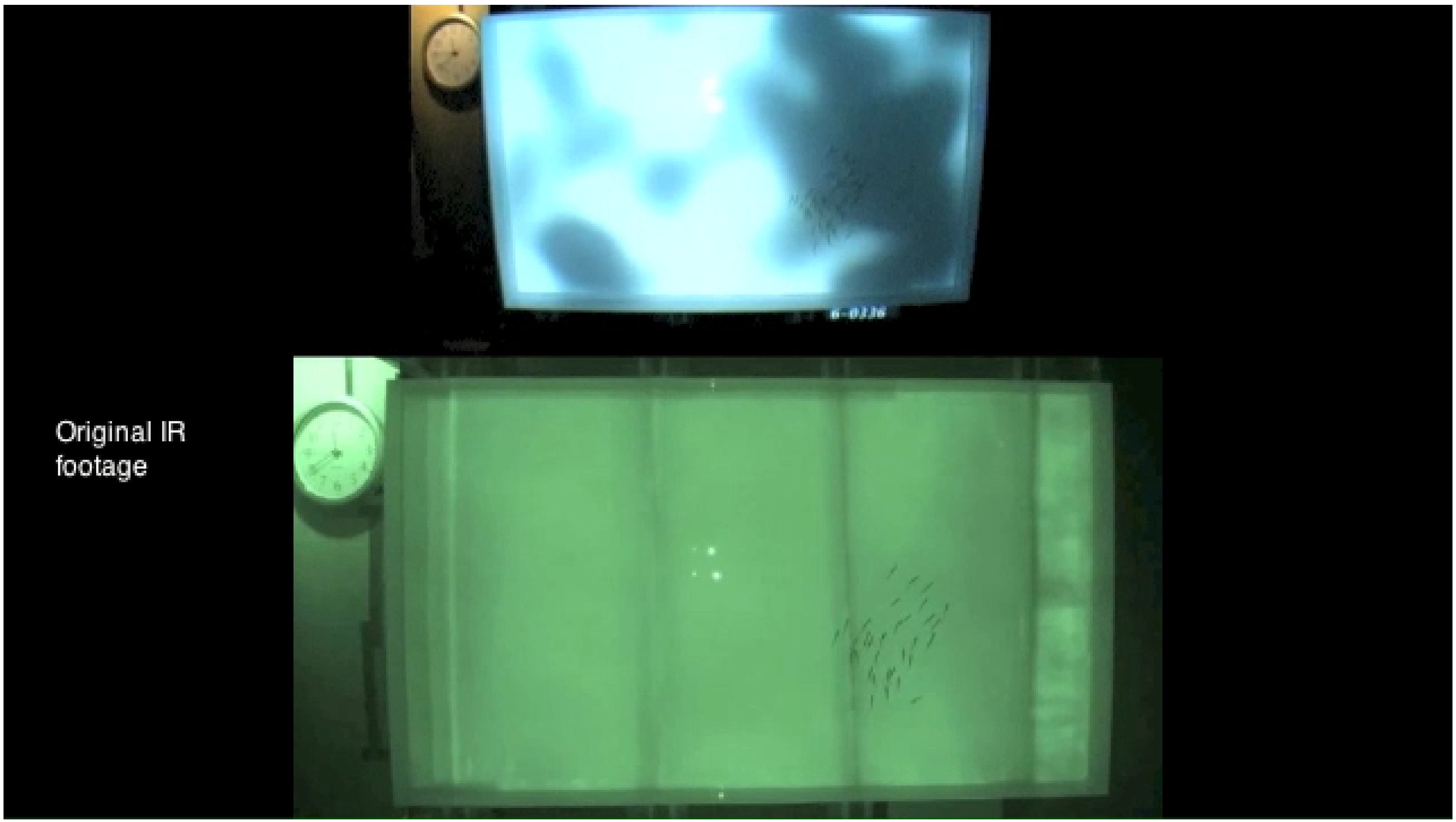
experimental trial



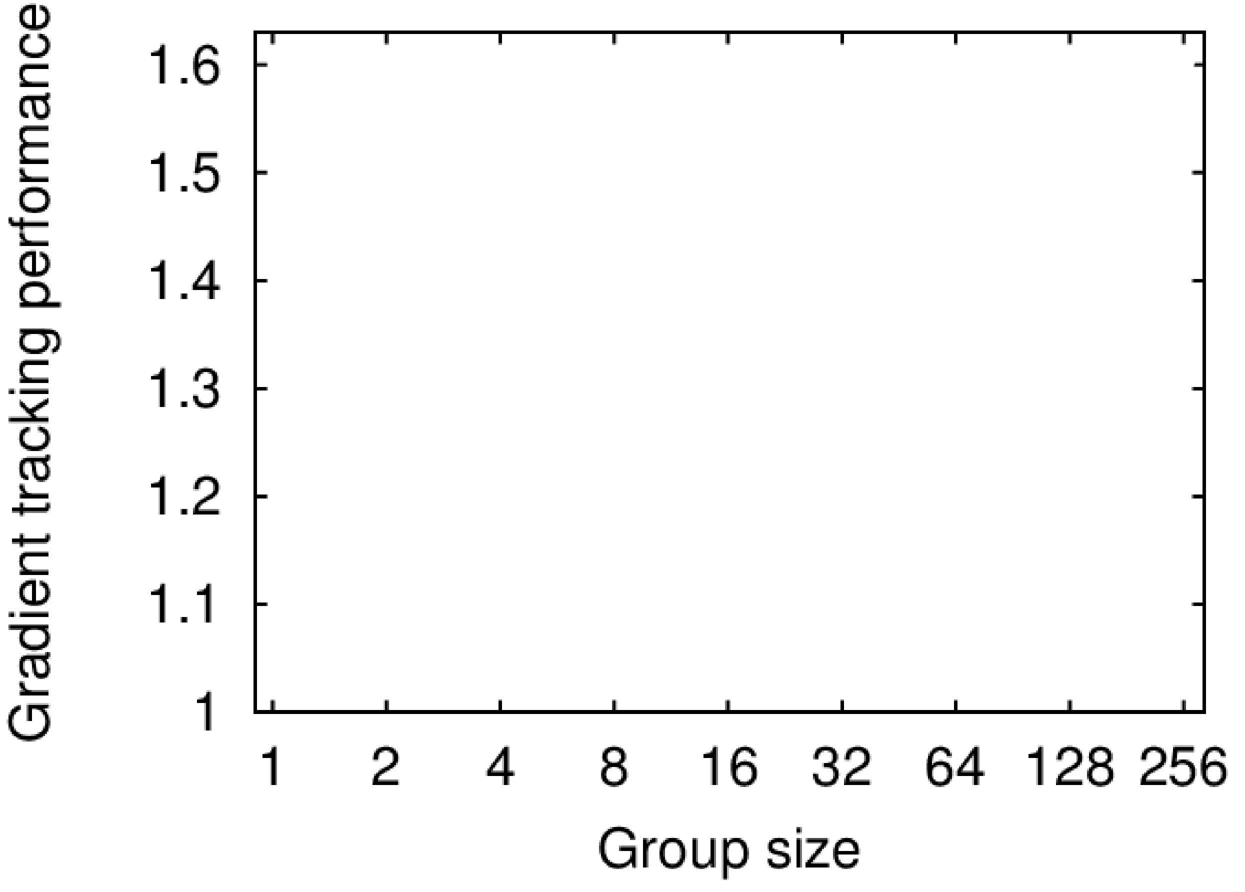
automated infrared tracking



automated infrared tracking

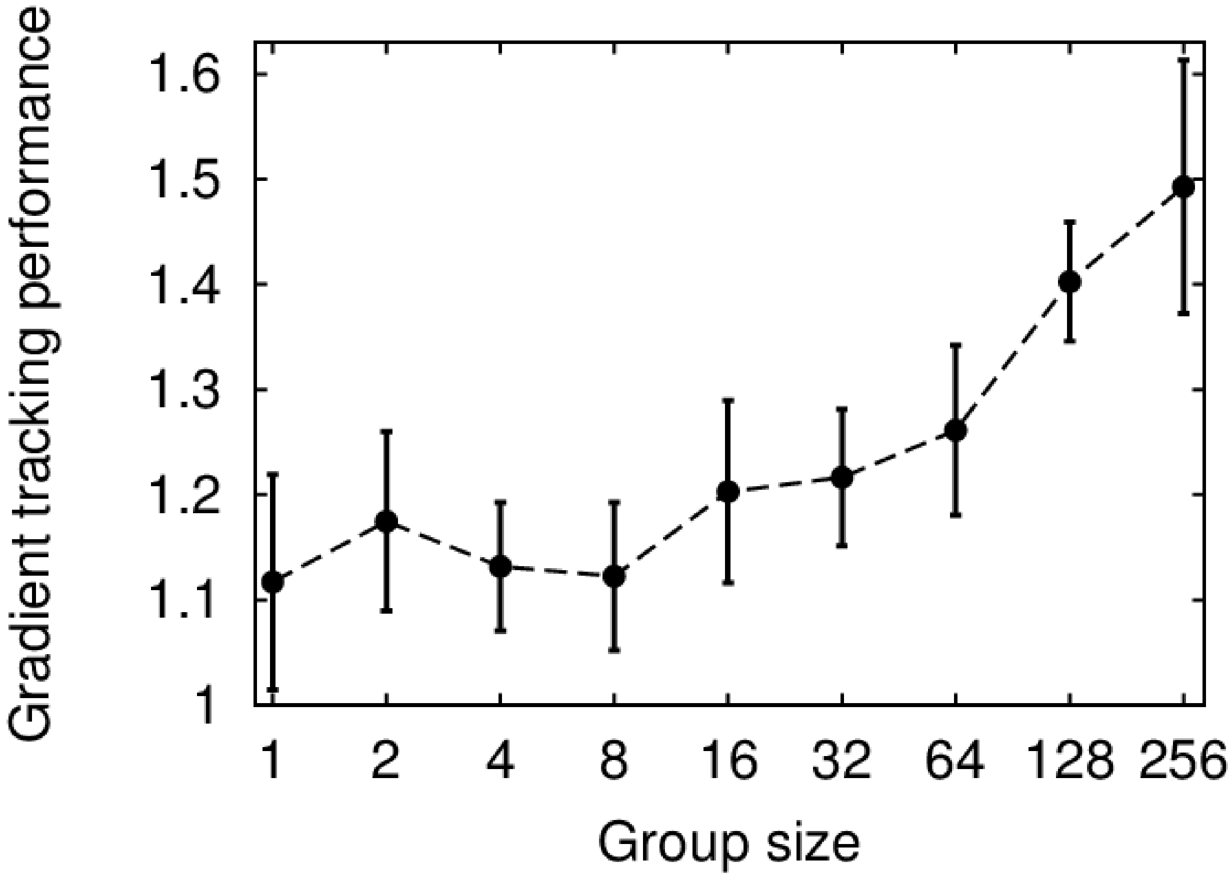


experimental results



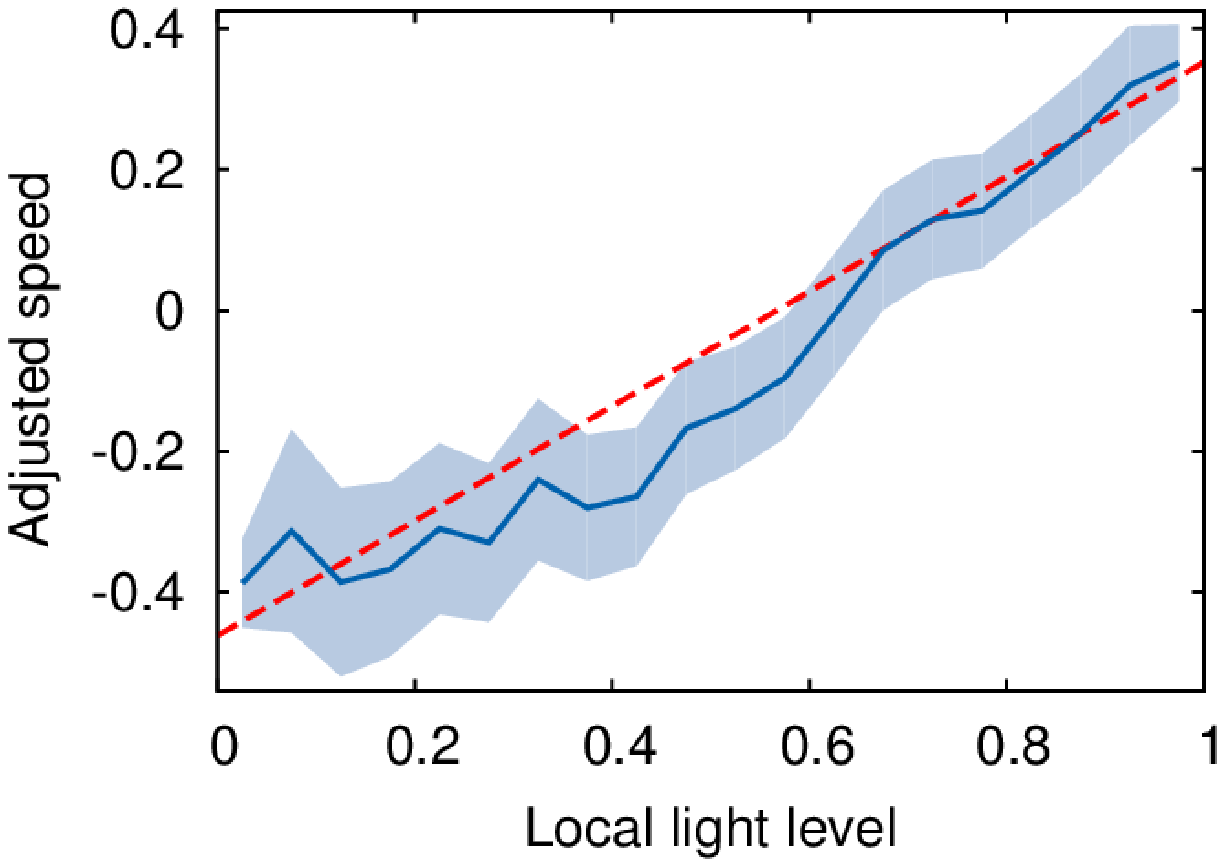
Berdahl *et al*. (2013) *Science*

experimental results: performance vs group size



Berdahl *et al.* (2013) *Science*

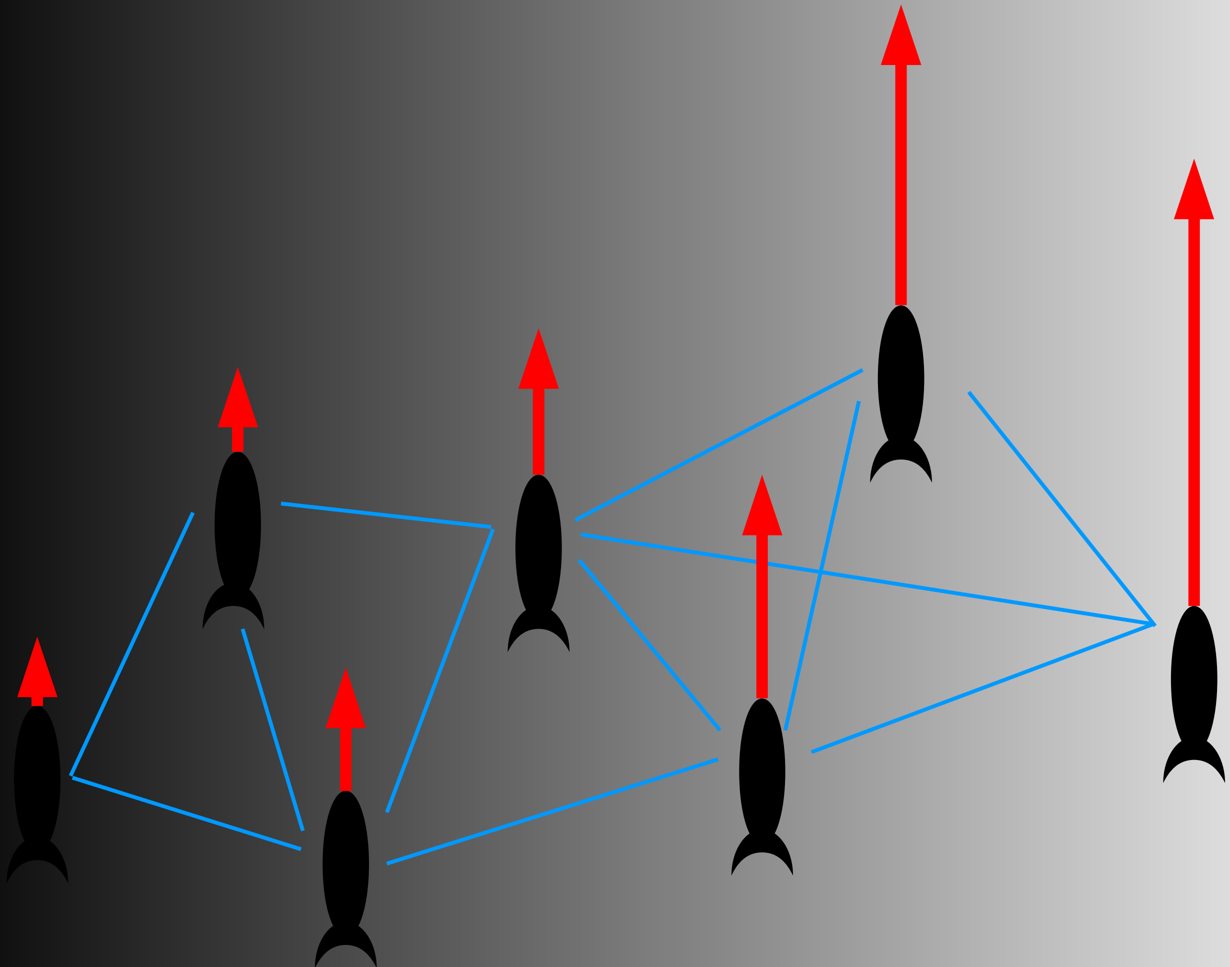
experimental results: swim speed vs light



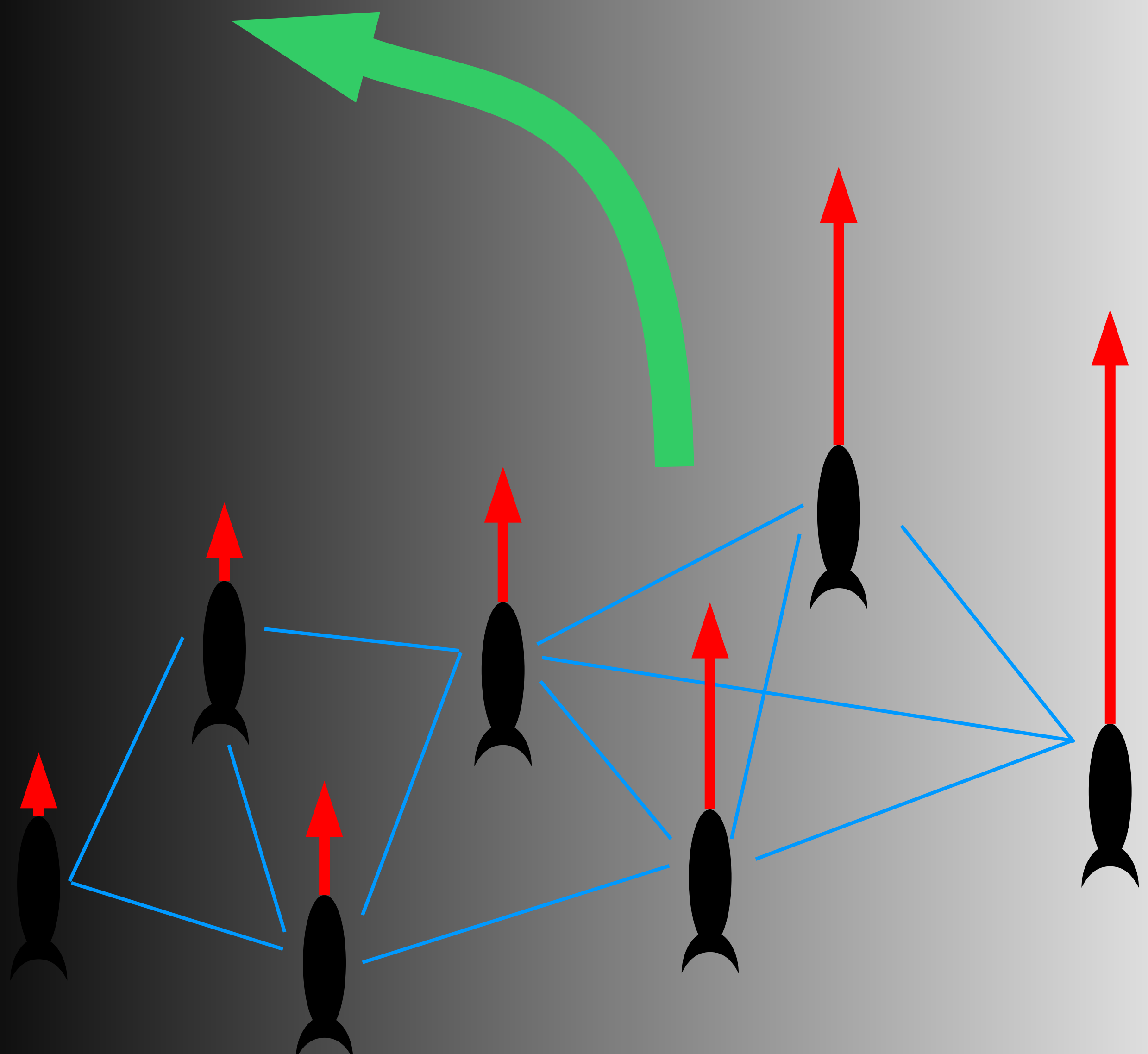
Berdahl *et al.* (2013) *Science*

Can kinesis lead to emergent taxis?

kinesis + social interactions =



kinesis + social interactions =
emergent taxis



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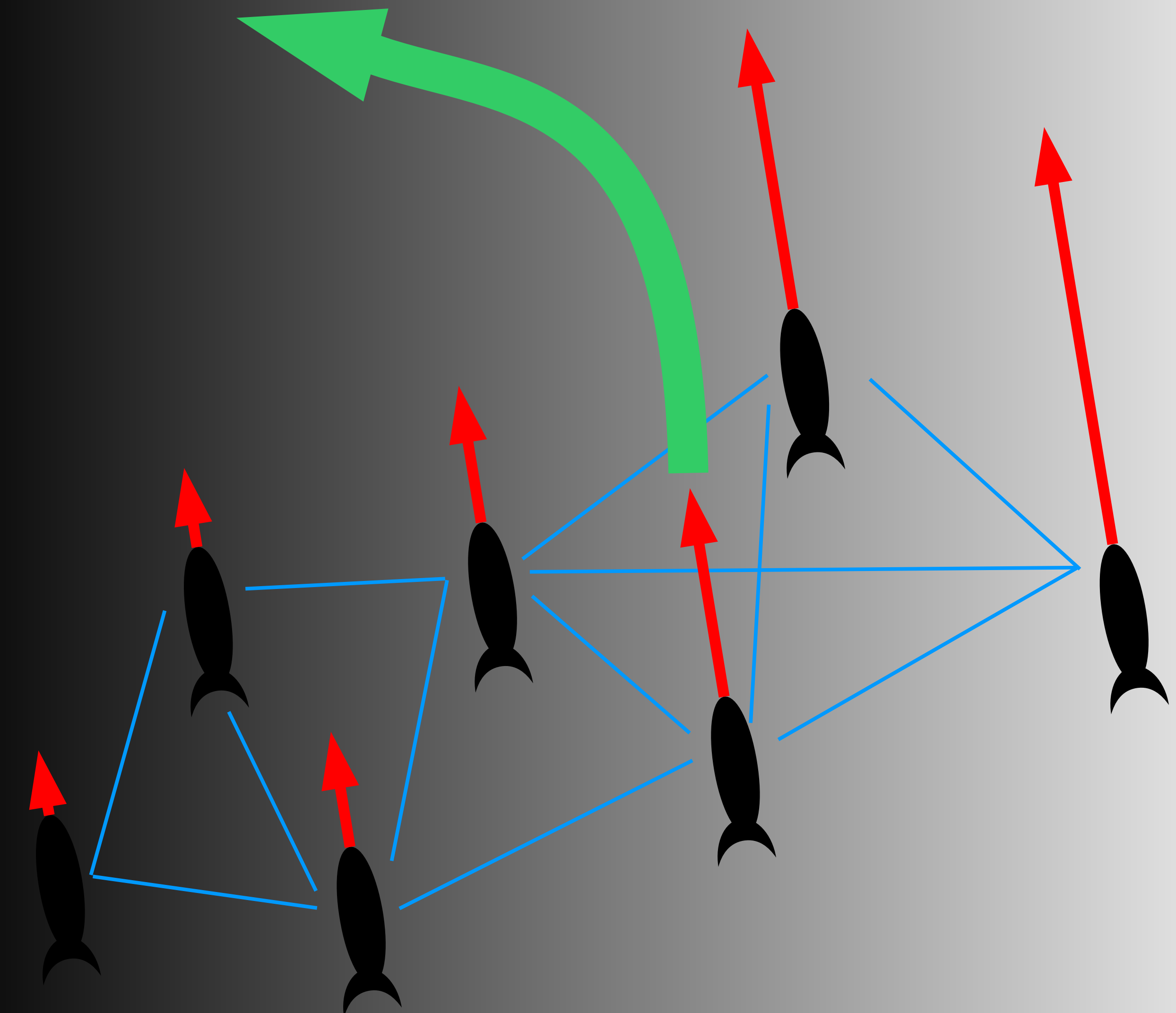
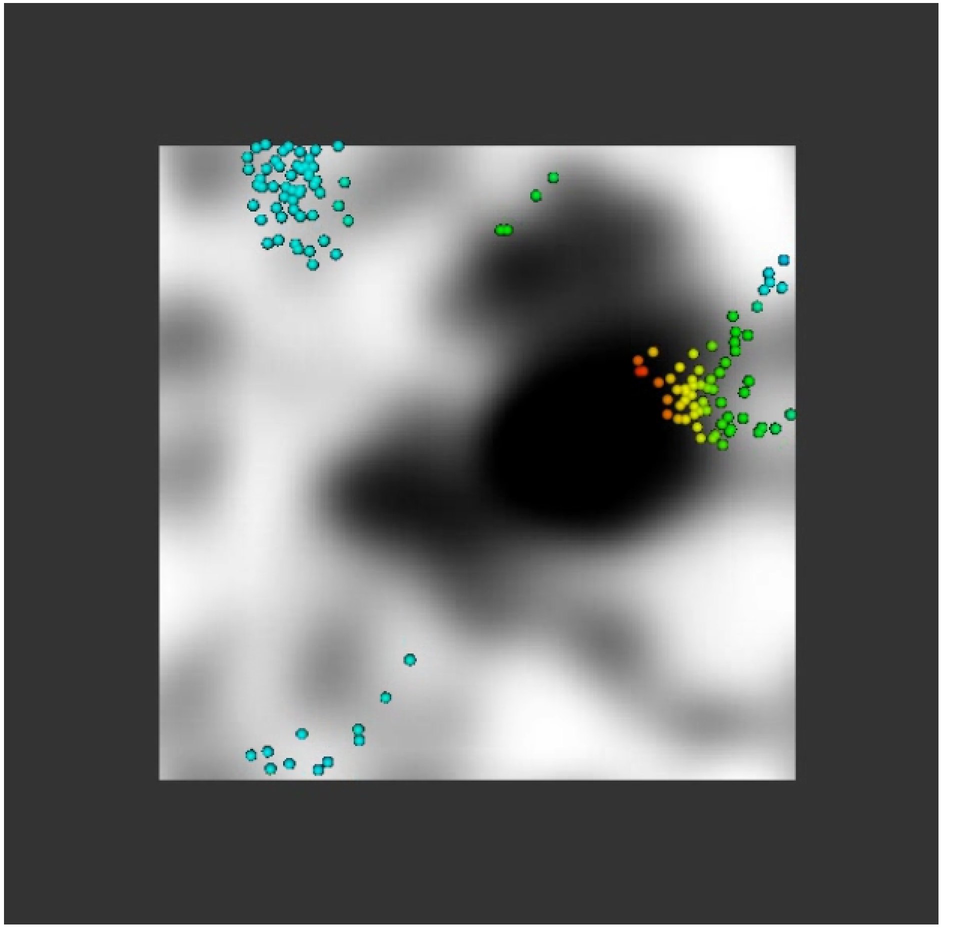
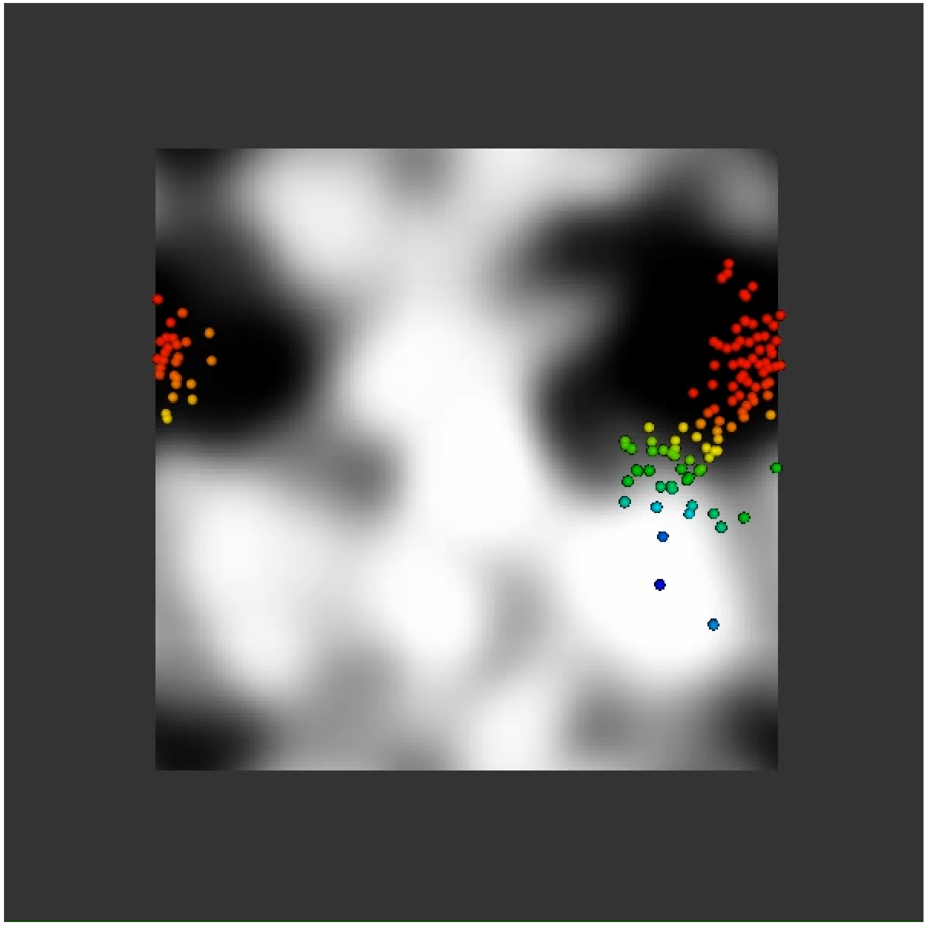


schooling simulation with speed modulation



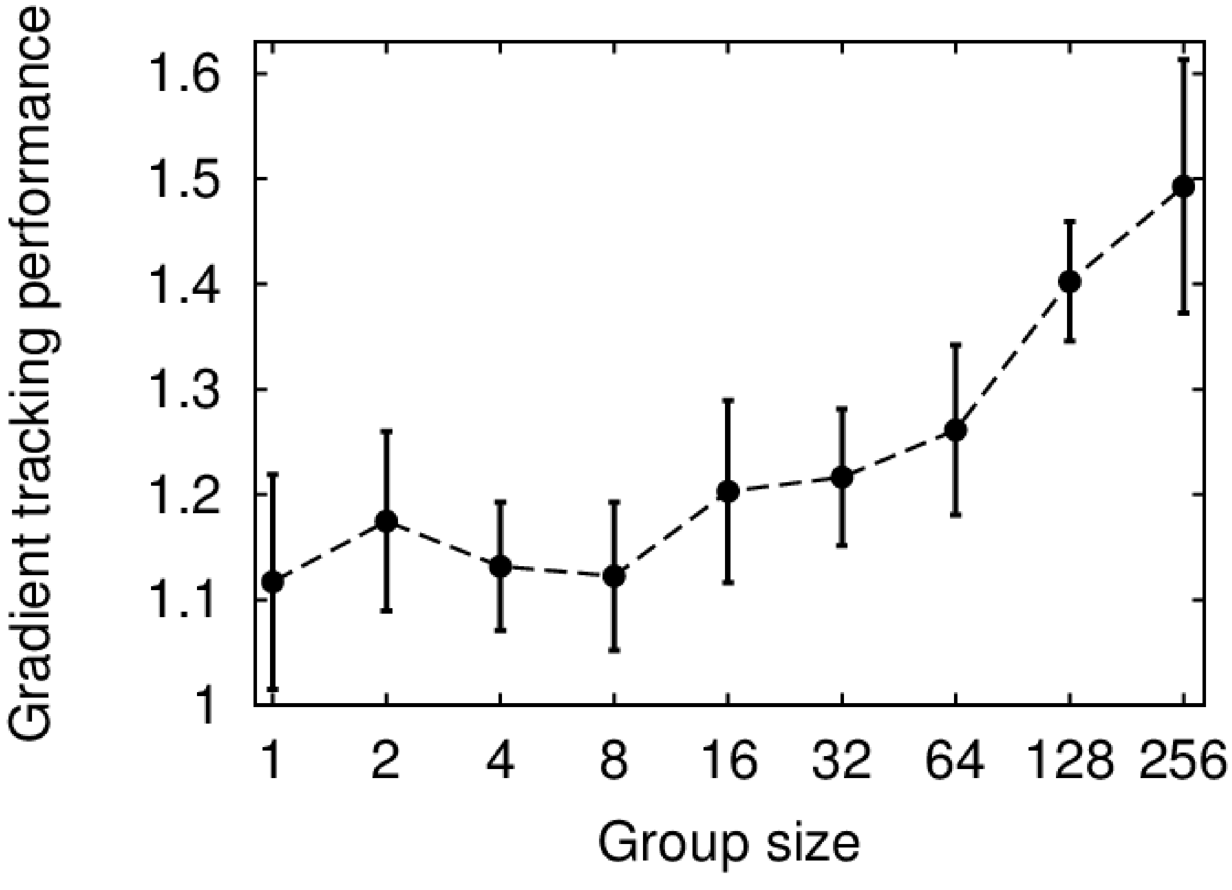
GPU CUDA simulation

schooling simulation with speed modulation



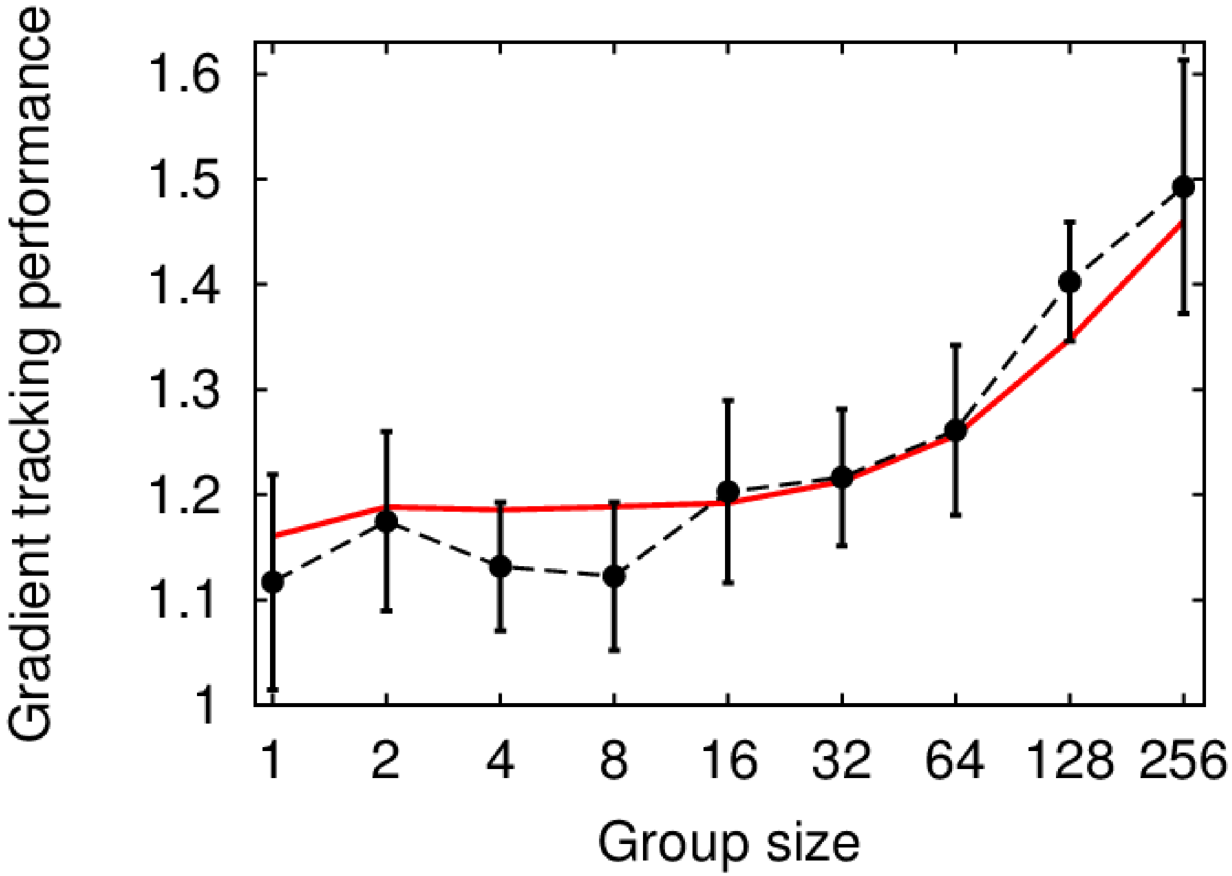
GPU CUDA simulation

experimental results



Berdahl *et al*. (2013) *Science*

simulation results

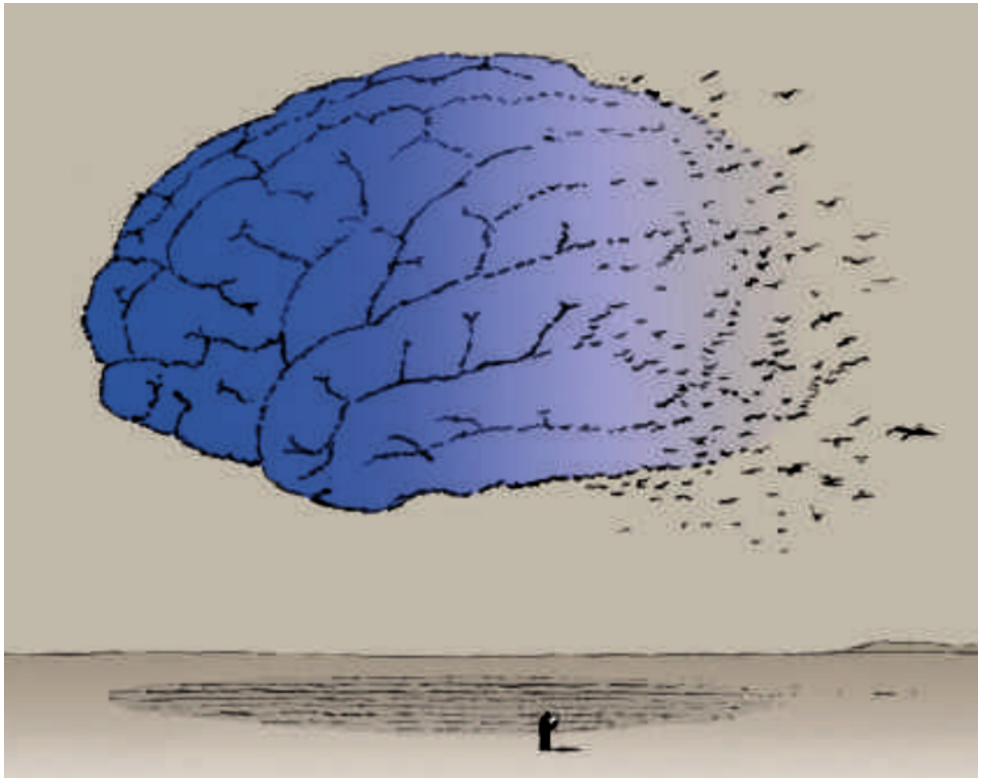


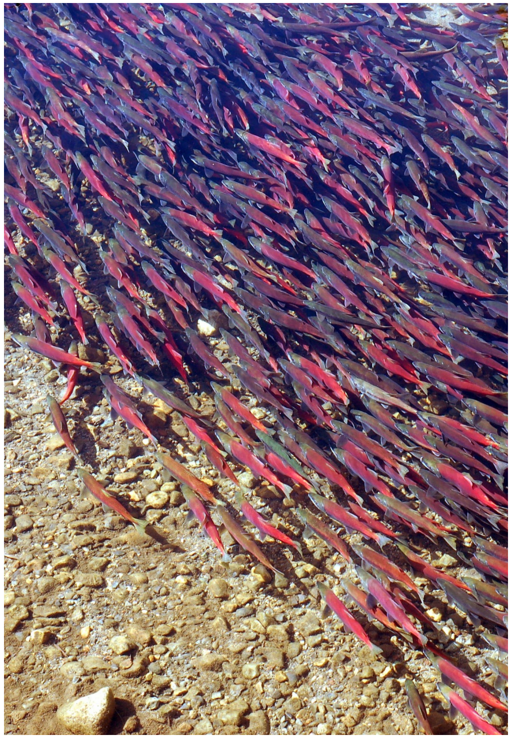
Berdahl *et al*. (2013) *Science*

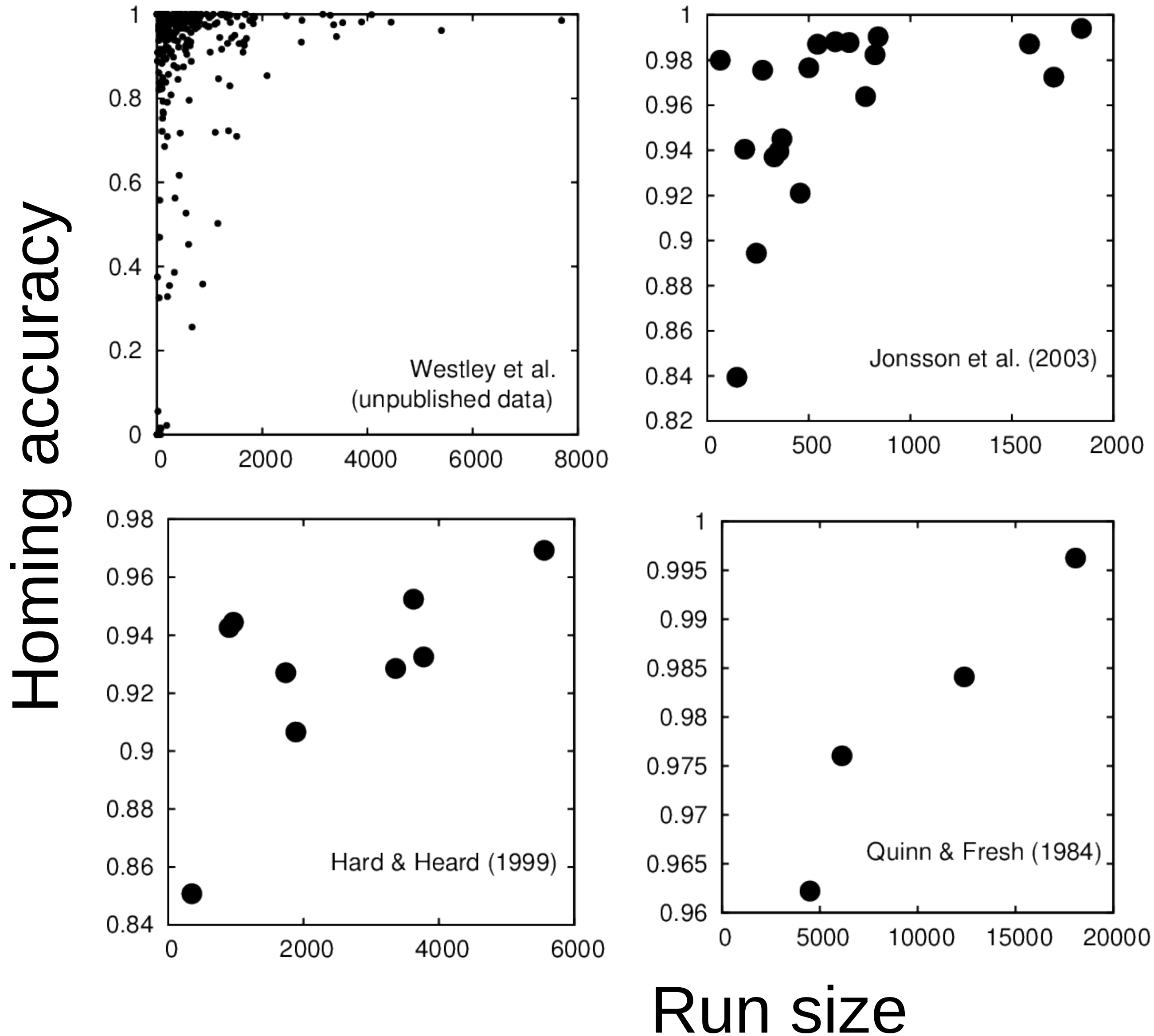
How do real animal groups sense complex environments?

Group acts as:
- a sensory array
- a distributed computer

Awareness only emerges at group-level.







Berdahl *et al*. (2014) *Fish & Fisheries*

take home:
collective intelligence

The “wisdom of crowds” in people is...

take home:
collective intelligence

The “wisdom of crowds” in people is...

Group-level sensing/navigation/intelligence

- can emerge without any individual-level taxis
- is resistant to evolutionary invasion by defectors, even when costly
- is used by real animal groups

take home:
agent based models

“Don't”s	“Do”s
Model extremely specific systems	
Make quantitative predictions	

take home:
agent based models

“Don't”s

Model extremely specific systems

Make quantitative predictions

“Do”s

Build intuition about general effects (establish proofs-of-principle)

Explore qualitative patterns

Andrew Berdahl

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