Collective Cognition Via Embodied Approximate Bayesian Computation

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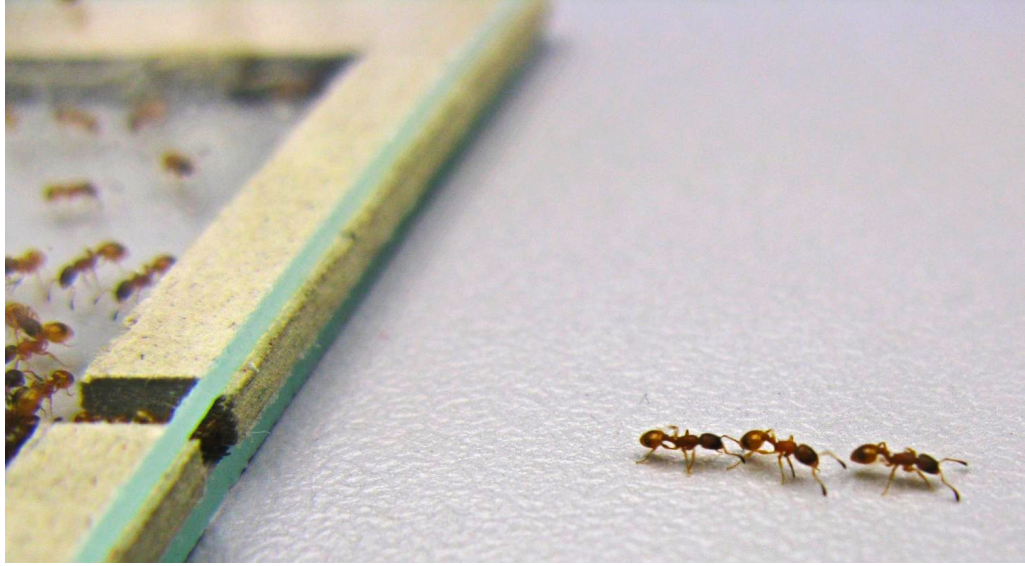
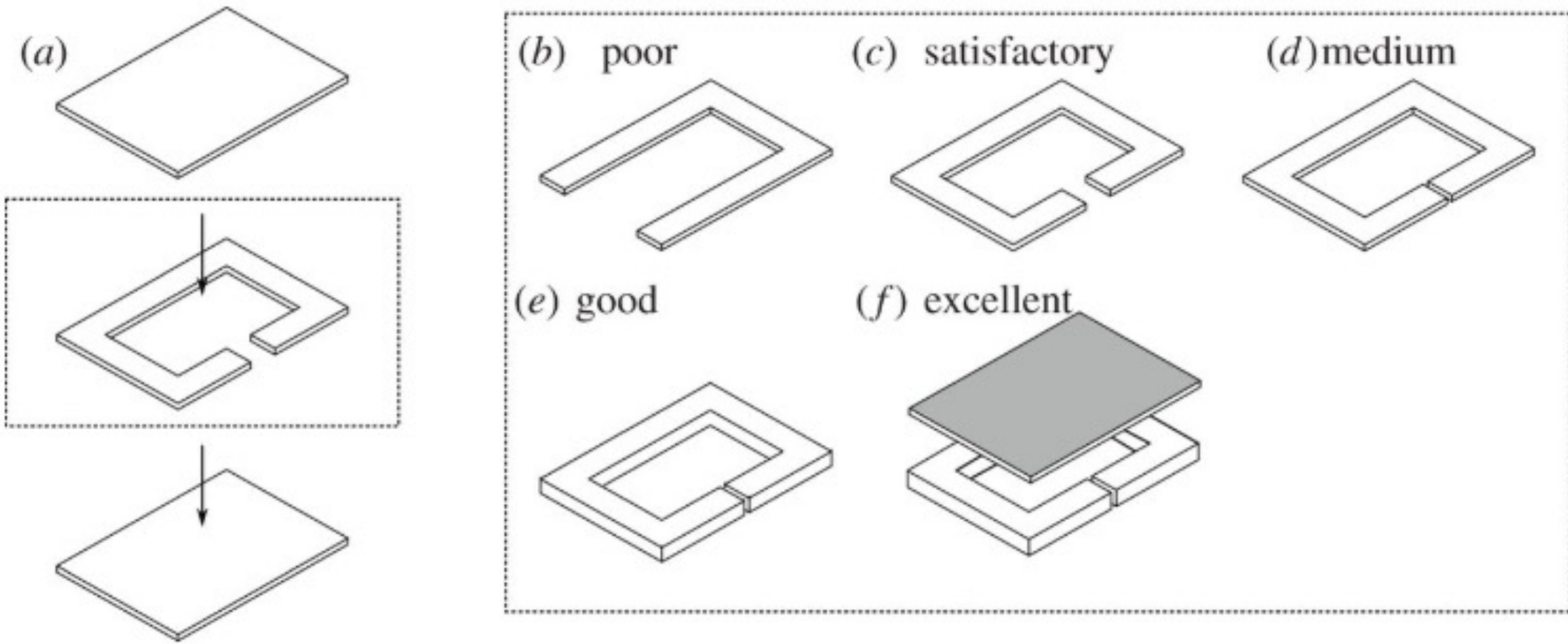
Self-organized distributed cognition → reliant on embodiment

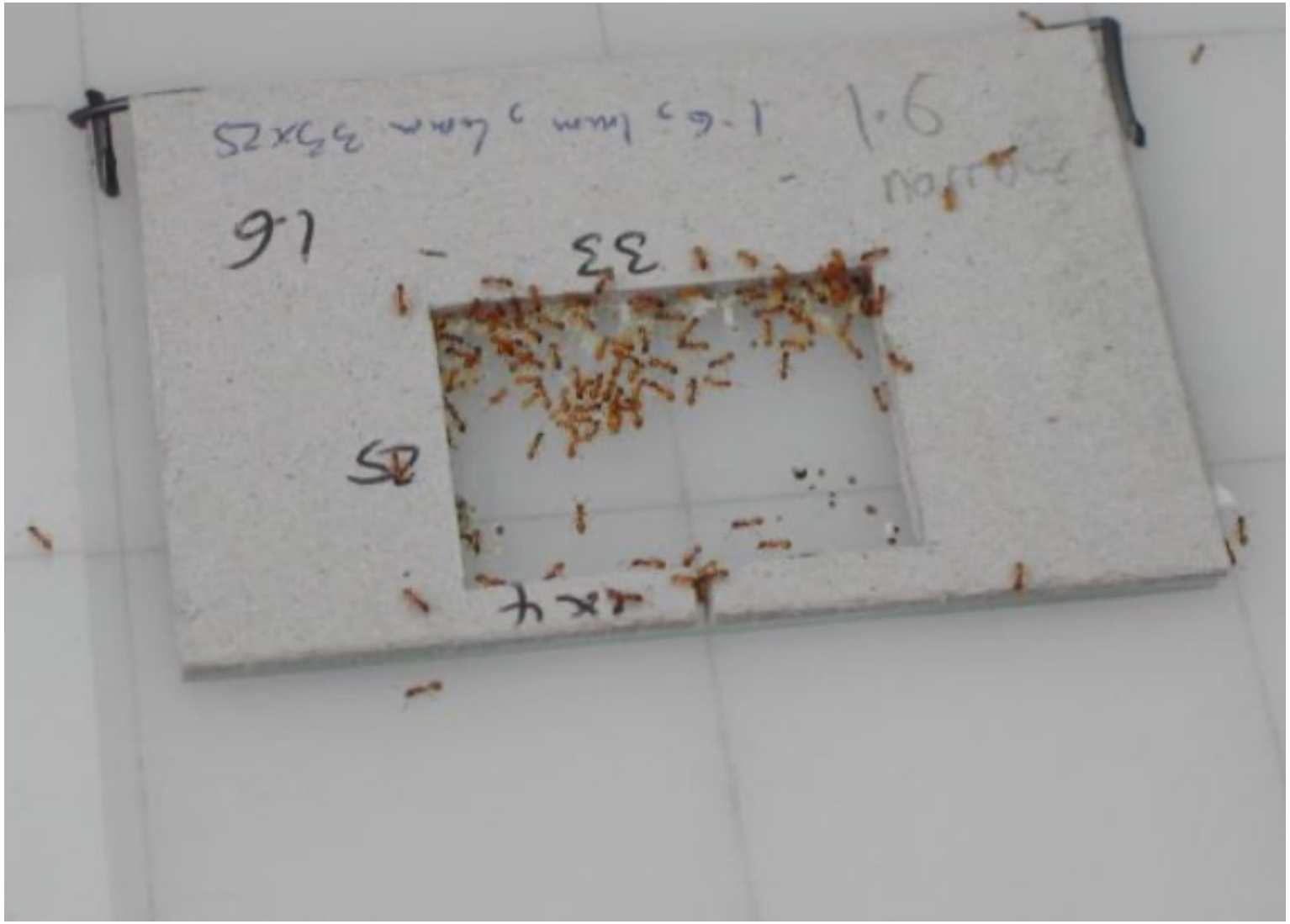
- ‘Swarm’ systems like ant, honeybee colonies are recognised as being very effective at making collective decisions, e.g. about where to live
- The field of swarm robotics is inspired by this kind of biology – decentralised, scalable, robust
  → valuable for move of robots into the real world
- Embodiment is particularly important for collective cognition

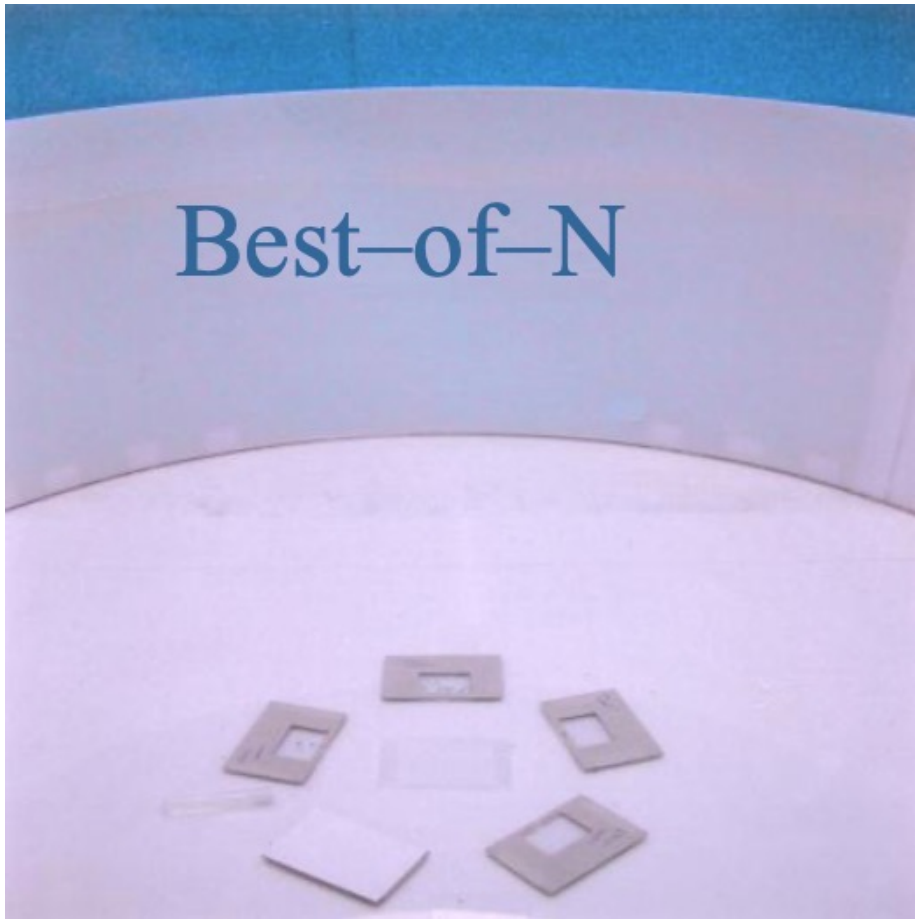
House-hunting rock ants

- Some social insects do not build their nest from scratch but look for pre-formed cavities
- Rock ant colonies (*Temnothorax albipennis)* have consistent preferences
- Options can be easily manipulated in the lab: they are a model system for studying collective decision-making




(a)
(b) poor
(c) satisfactory
(d) medium
(e) good
(f) excellent



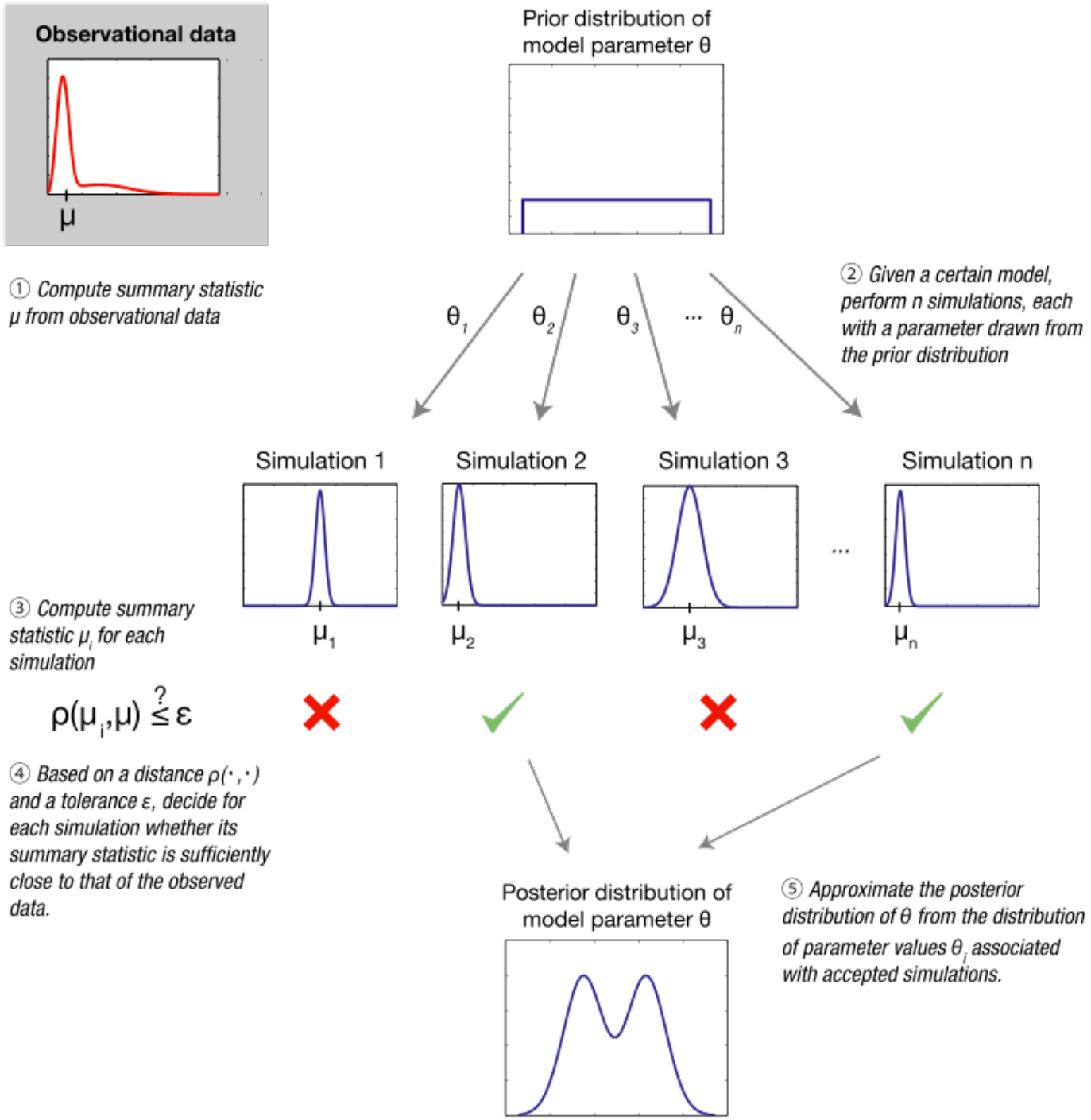

Best–of–N

Making Bayes Feasible Via Distributed Embodiment

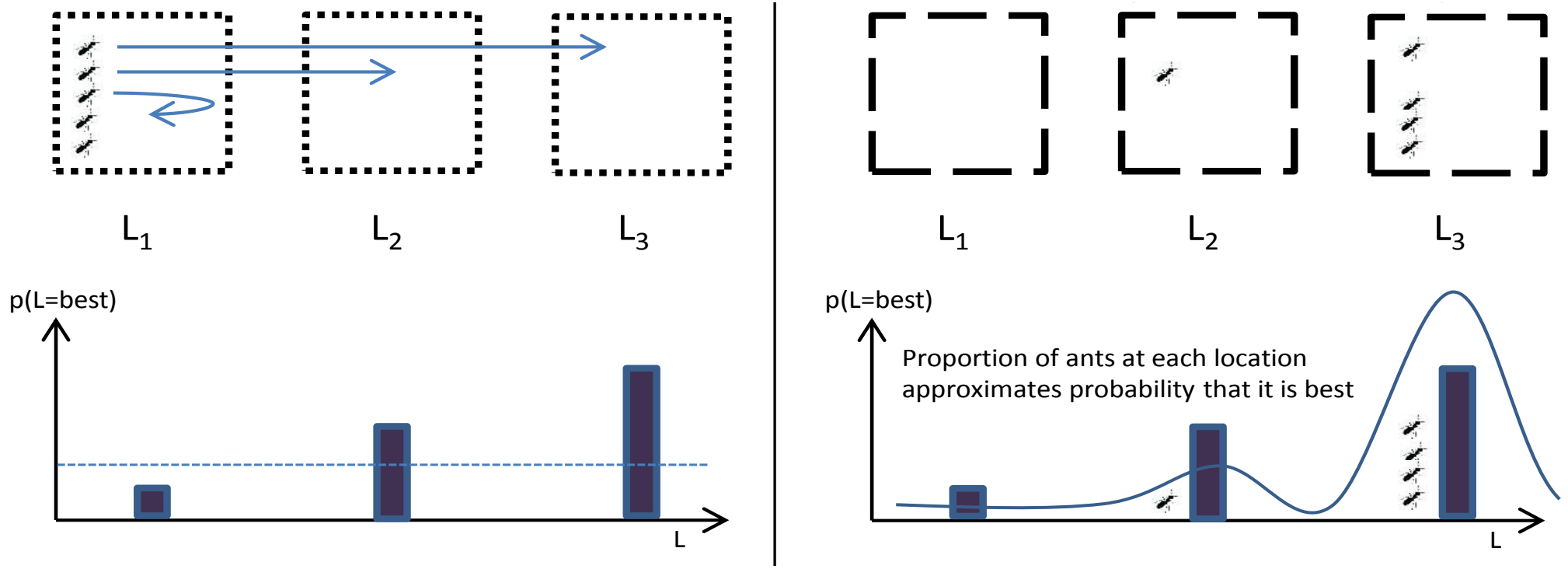
- For an individual (ant) the ‘full’ solution to the nest choice problem could be to carefully inspect each option and ‘compute’ the probability that each one is best using Bayes’ rule
- Too much time, energy, brain power, communication
- Instead, each ant’s decision to reject, or ultimately accept, an option, can be seen as a accept/reject parameter draw in approximate Bayesian computation (ABC)

Approximate Bayesian computation

Sunnåker et al. 2013



Collective posterior estimation



- Multiple ants rejecting/accepting = ABC?

Conclusions

- Superorganisms like ants flourish because of embodied collective information processing capabilities – distributed embodiment
- A Bayesian framework can be employed to describe and explain what the ants are doing in informational terms (ABC, also MCMC/particle filtering/shared memory)
- Our model suggests how collective cognition can emerge via collective probability estimation, achieved through spatial approximate Bayesian computation (SABC)

Hunt, E. R., Franks, N. R., & Baddeley, R. J. (2020, July). The Bayesian Superorganism: collective probability estimation in swarm systems. In *Artificial Life Conference Proceedings* (pp. 315-323).

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