

COSMOS

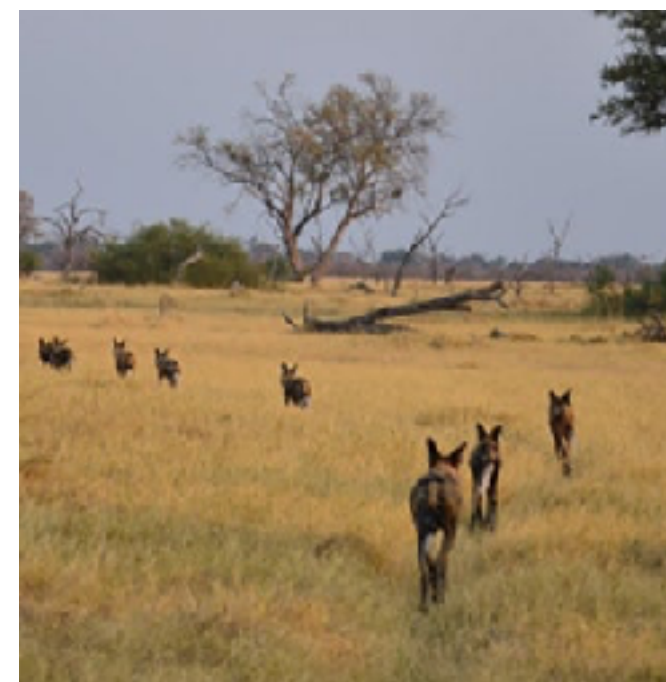
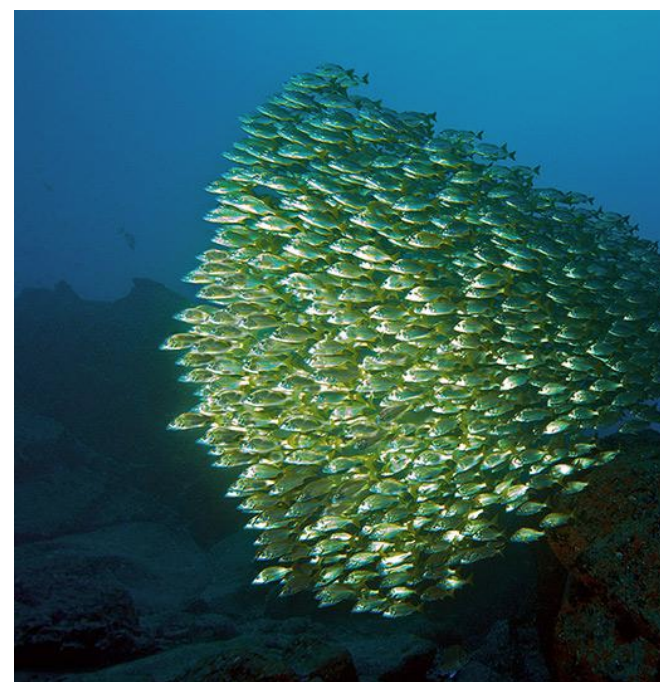
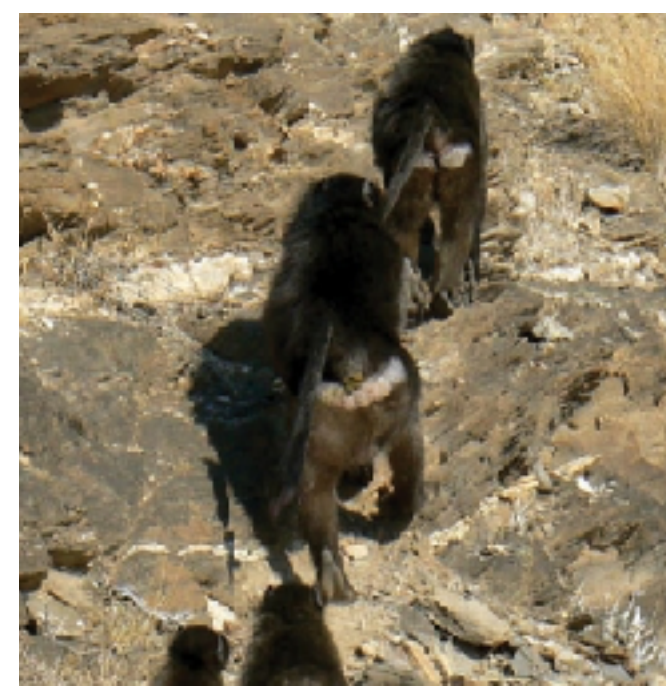
Tutorial 1: Social Learning Tasks

Wataru Toyokawa & Charley Wu
September 29th

Goals of Tutorial 1

- Real world examples of social learning (SL)
- Introduction to the multi-armed bandit task
- Ontology of SL problems
 - Environmental structure
 - Social structure
 - Cognitive complexity
- Interactive demonstration

Collective decision making in an uncertain world



Height (1-100): 48 Width (1-100): 30 Thickness (1-100): 90

Shape: Shape 3 Colour: Orange

SHOW

OTHER PLAYERS' SCORES

Player 1:	482
CLICK HERE TO COPY	
Player 2:	500
CLICK HERE TO COPY	
Player 3:	593
CLICK HERE TO COPY	
Player 4:	545
CLICK HERE TO COPY	
Player 5:	555
CLICK HERE TO COPY	

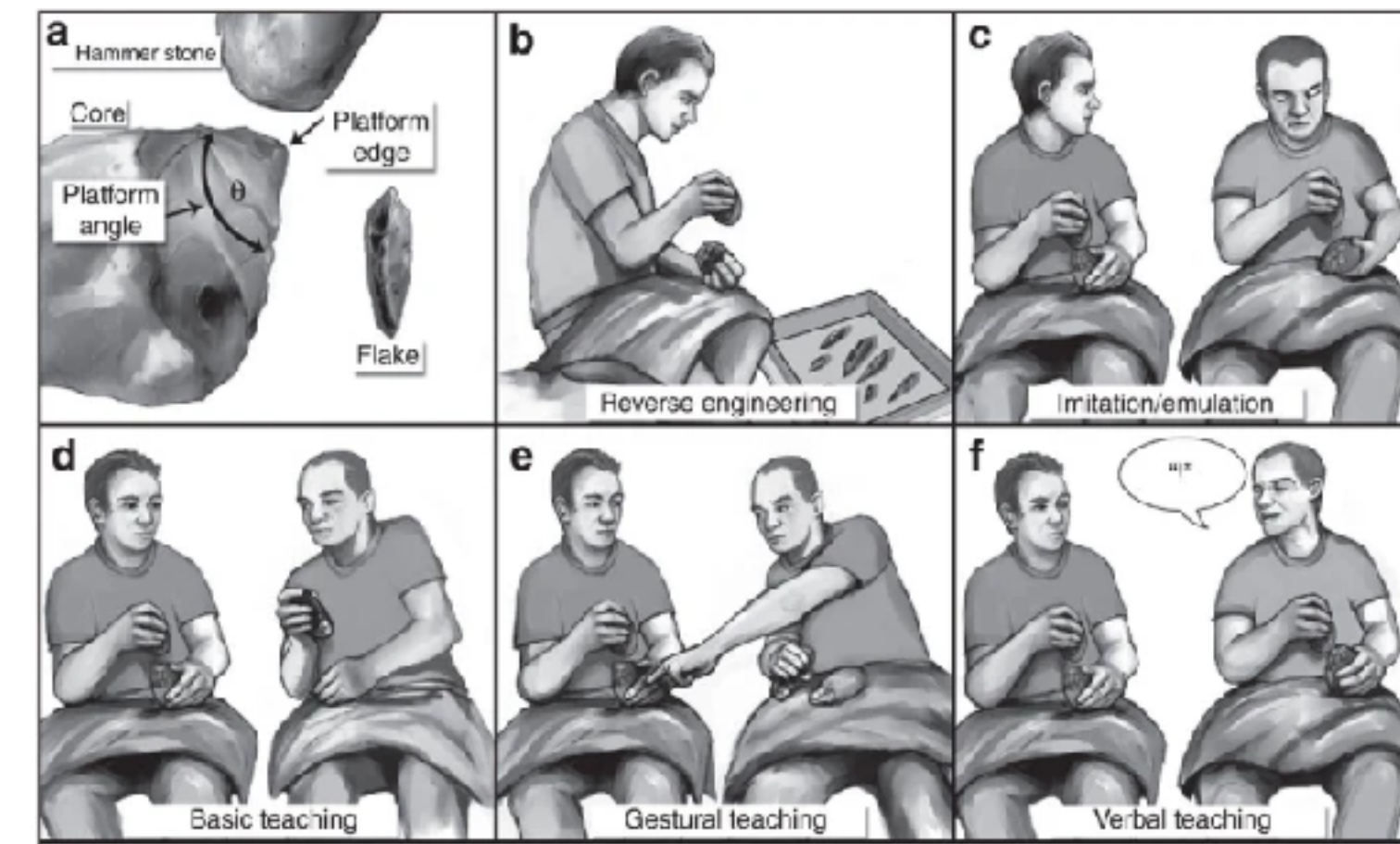
You may now change the values above as before, clicking SHOW to see your arrowhead and HUNT to see how it does.

Alternatively, you can click one of the buttons on the left to copy the design of another player. If you do this, your current design will be replaced with their design.

Season: 1 Hunts Left: 29 Group Rank: 6th

Calories (/1000): 368 Previous calories: 368 Season Score: 368

HUNT NEXT HUNT

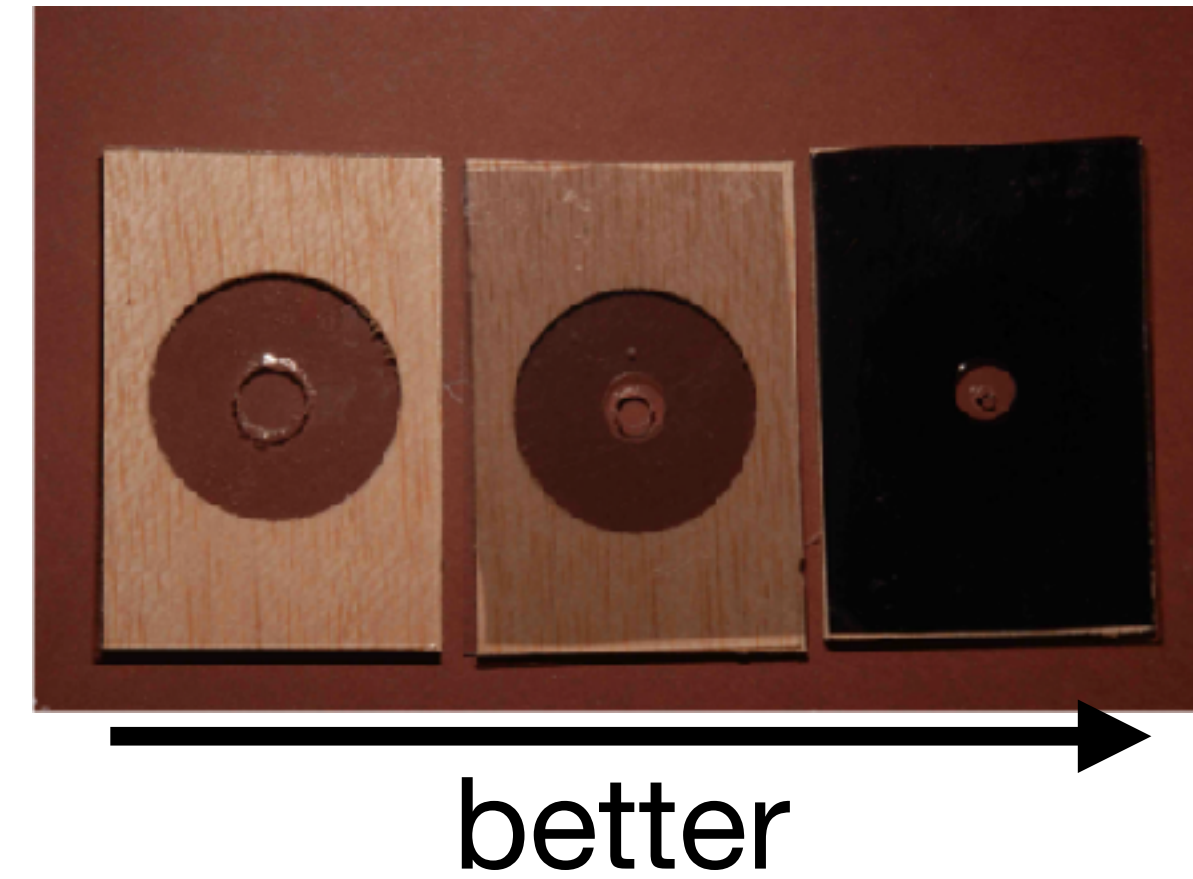


Social learning as collective decision-making

House hunting ants



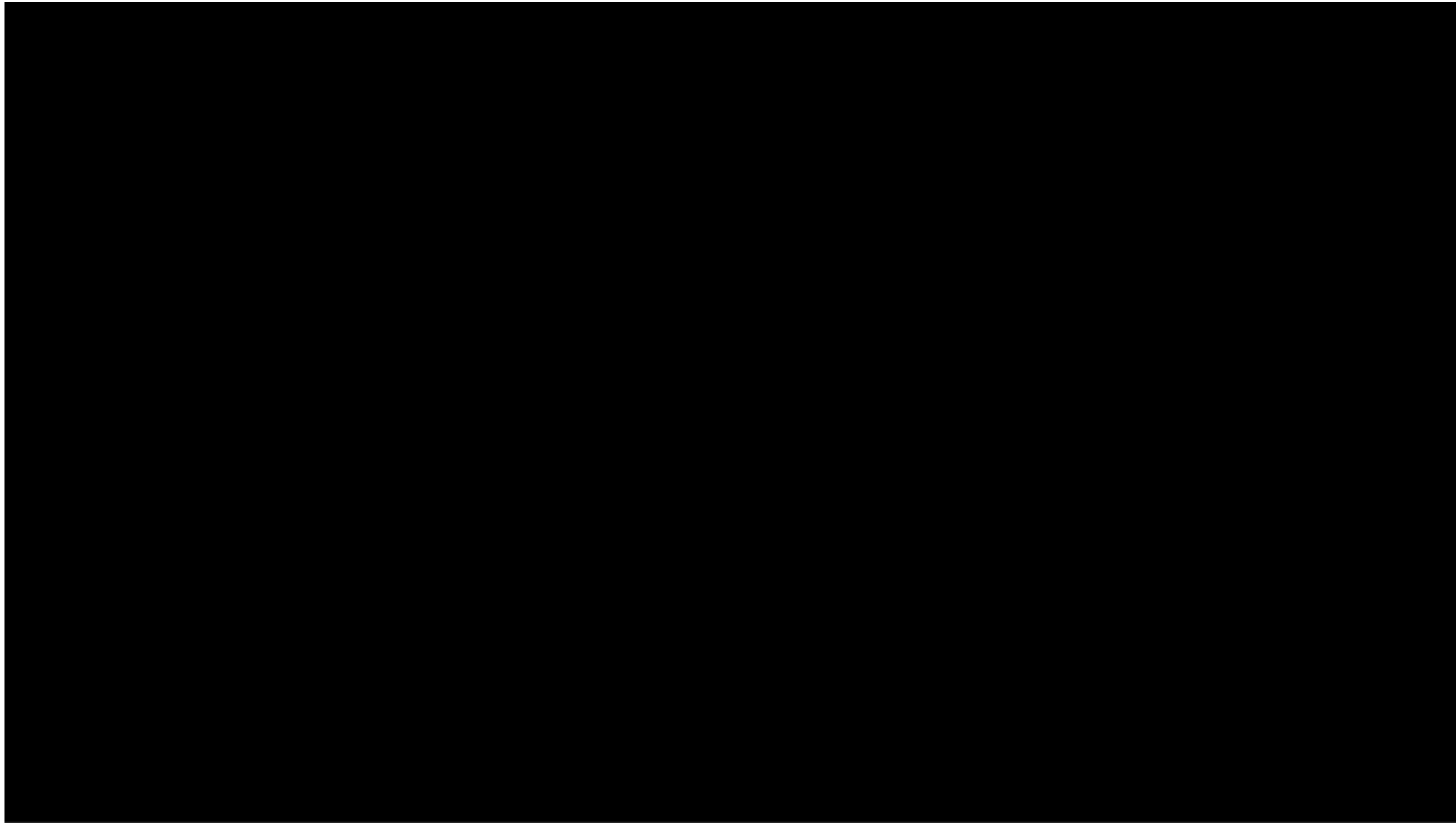
Colonies & individuals have the same preference



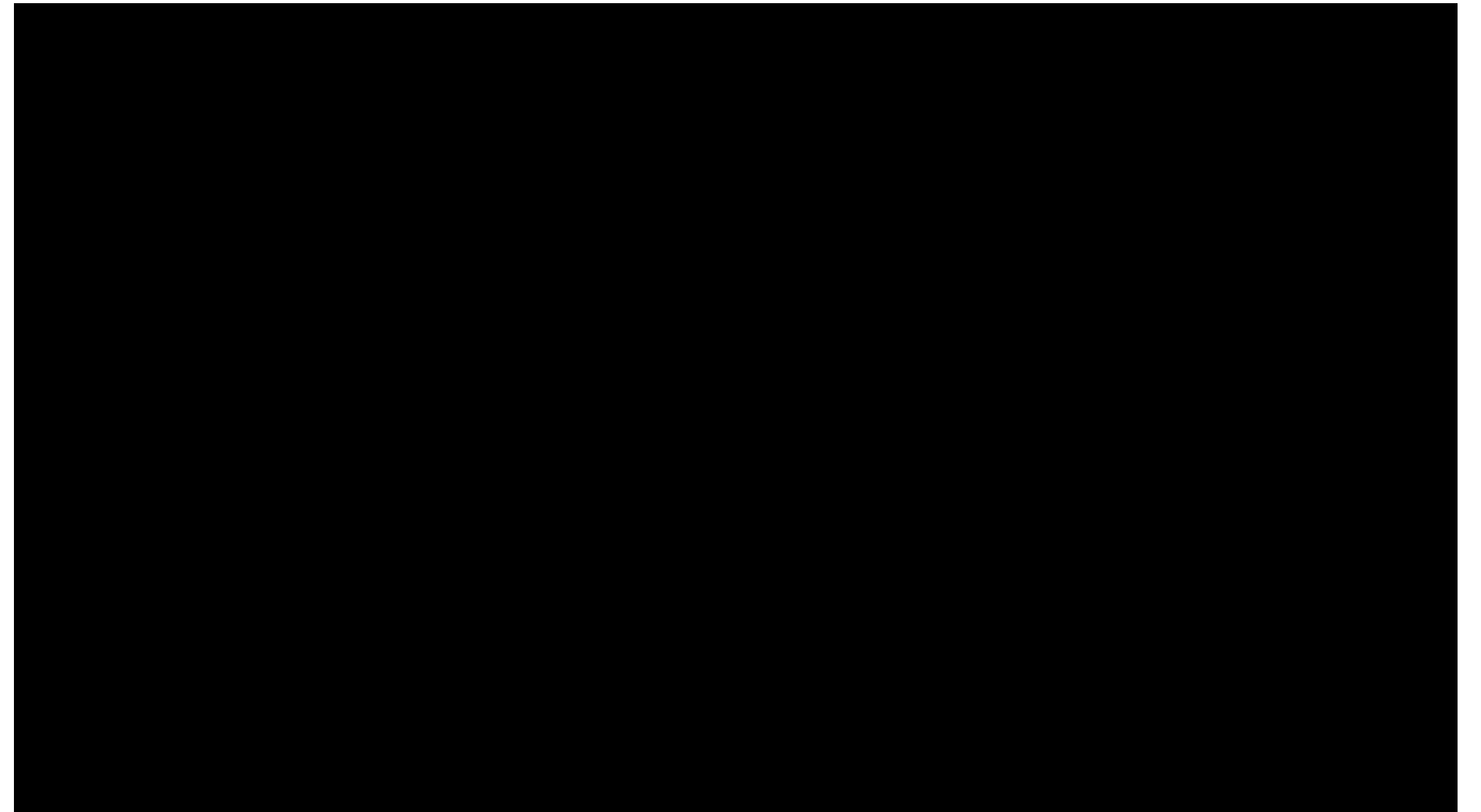
Sasaki, T., Granovskiy, B., Mann, R. P., Sumpter, D. J., & Pratt, S. C. (2013). Ant colonies outperform individuals when a sensory discrimination task is difficult but not when it is easy. *Proceedings of the National Academy of Sciences*, 110(34), 13769-13773.



Two behavioural options

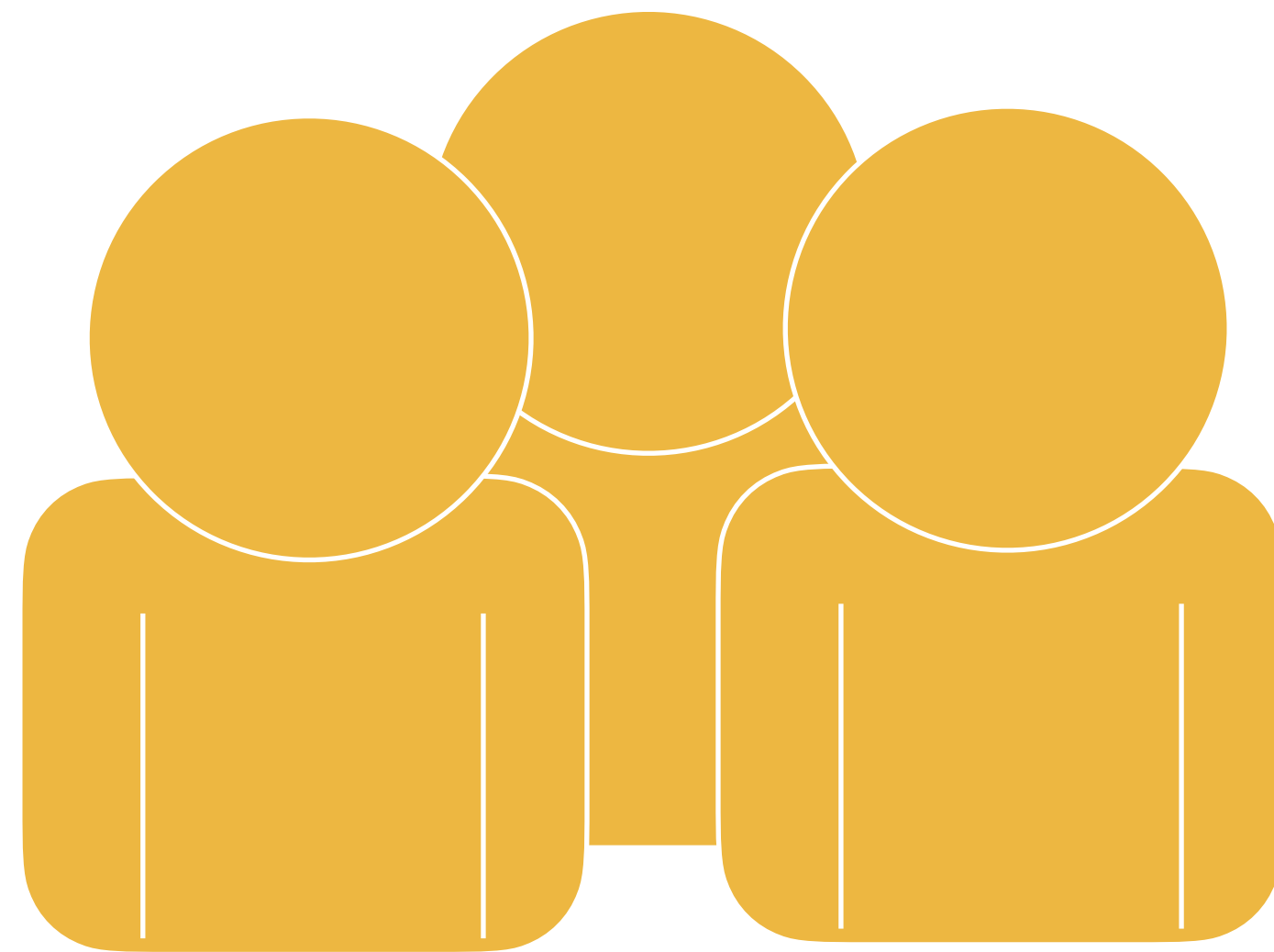
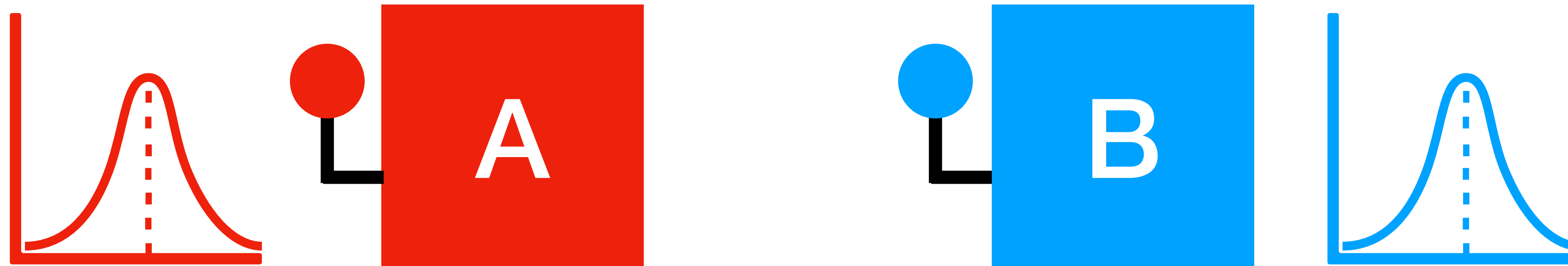


Social learning (scrounging)



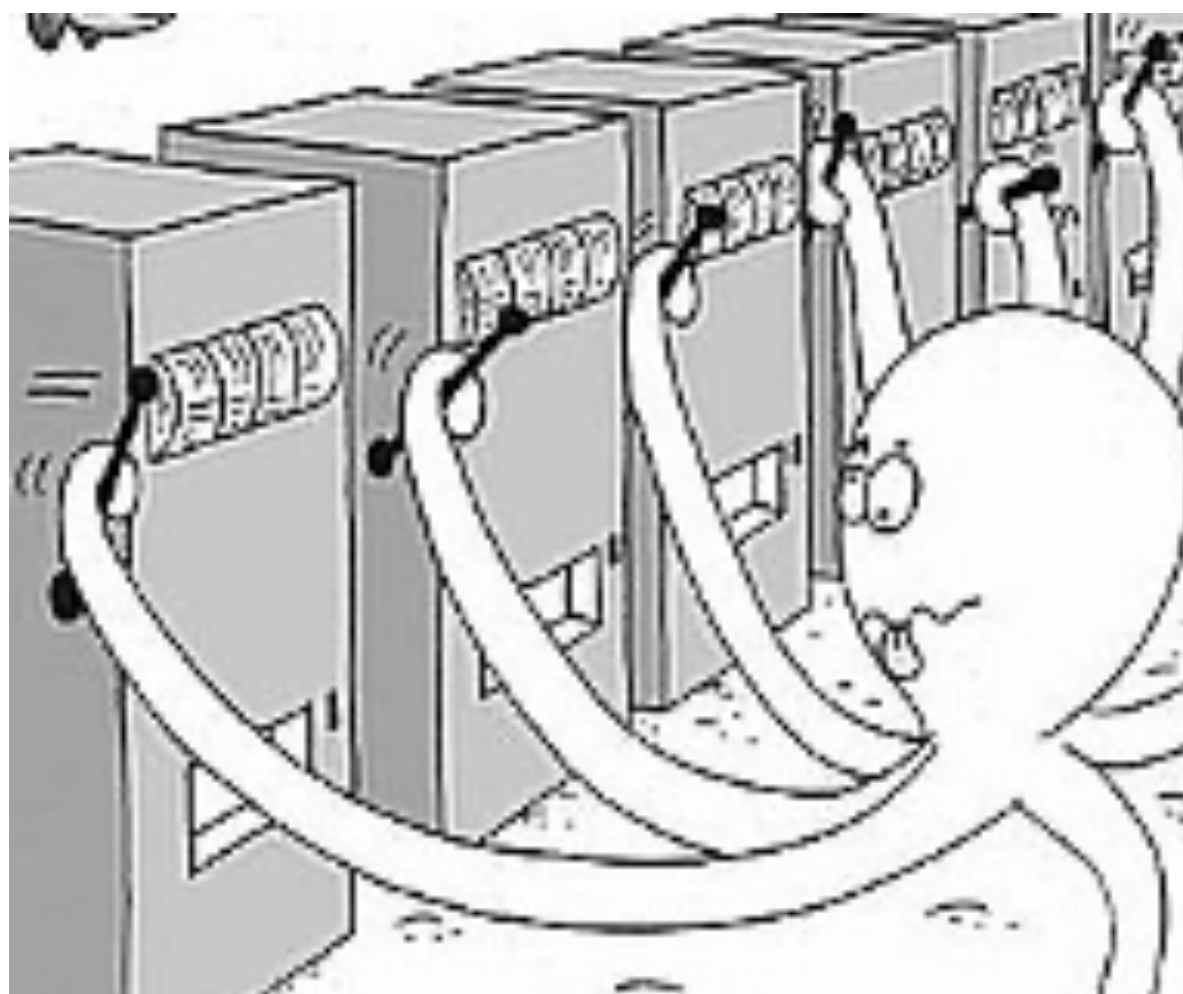
Aplin, L. M., Farine, D. R., Morand-Ferron, J., Cockburn, A., Thornton, A., & Sheldon, B. C. (2015). Experimentally induced innovations lead to persistent culture via conformity in wild birds. *Nature*, 518(7540), 538-541.

Multi-armed bandit



Multi-armed bandit problem

A simple model of the experience-based decision-making situations

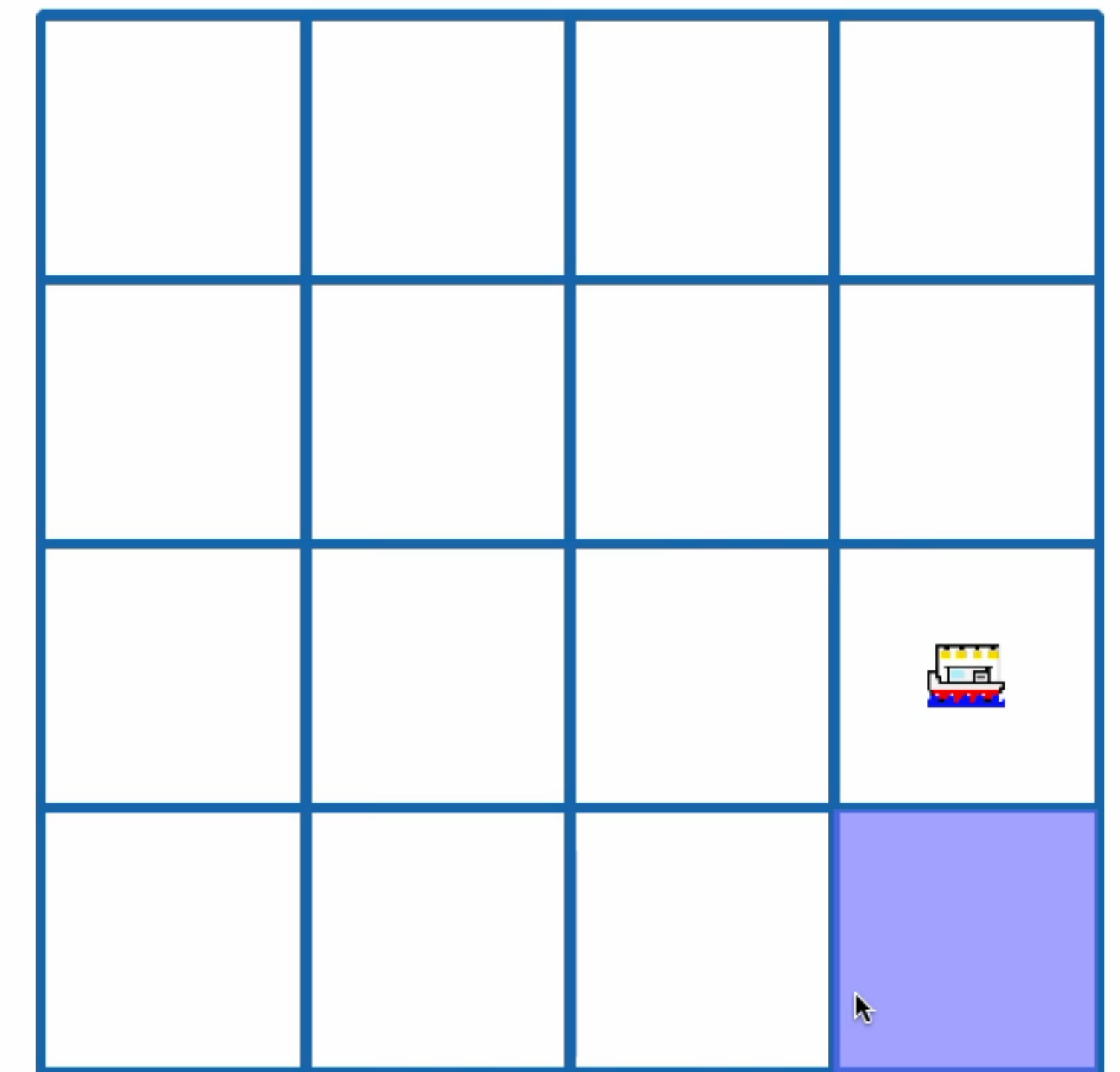


Key features:

- Reward is unknown until the option is actually chosen
- The goal is to maximise your payoff, by sequentially playing one of the options at each time within a limited time horizon
- Exploration-Exploitation tradeoff arises

Fishing game

A fishing zone divided into 16 areas (that is, behavioural options). You want to maximize the total catch through trial and error!

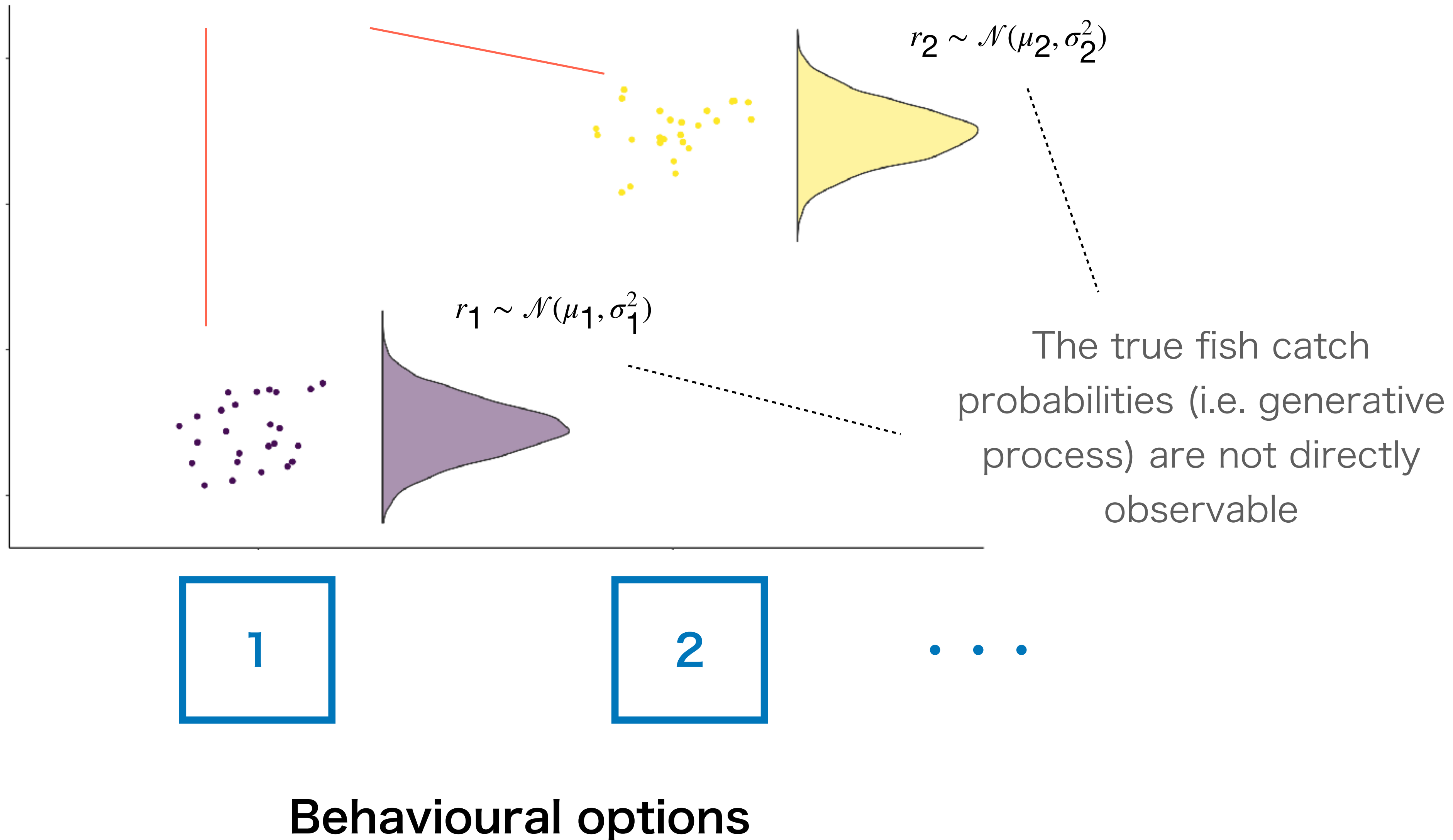


Remaining clicks: 10



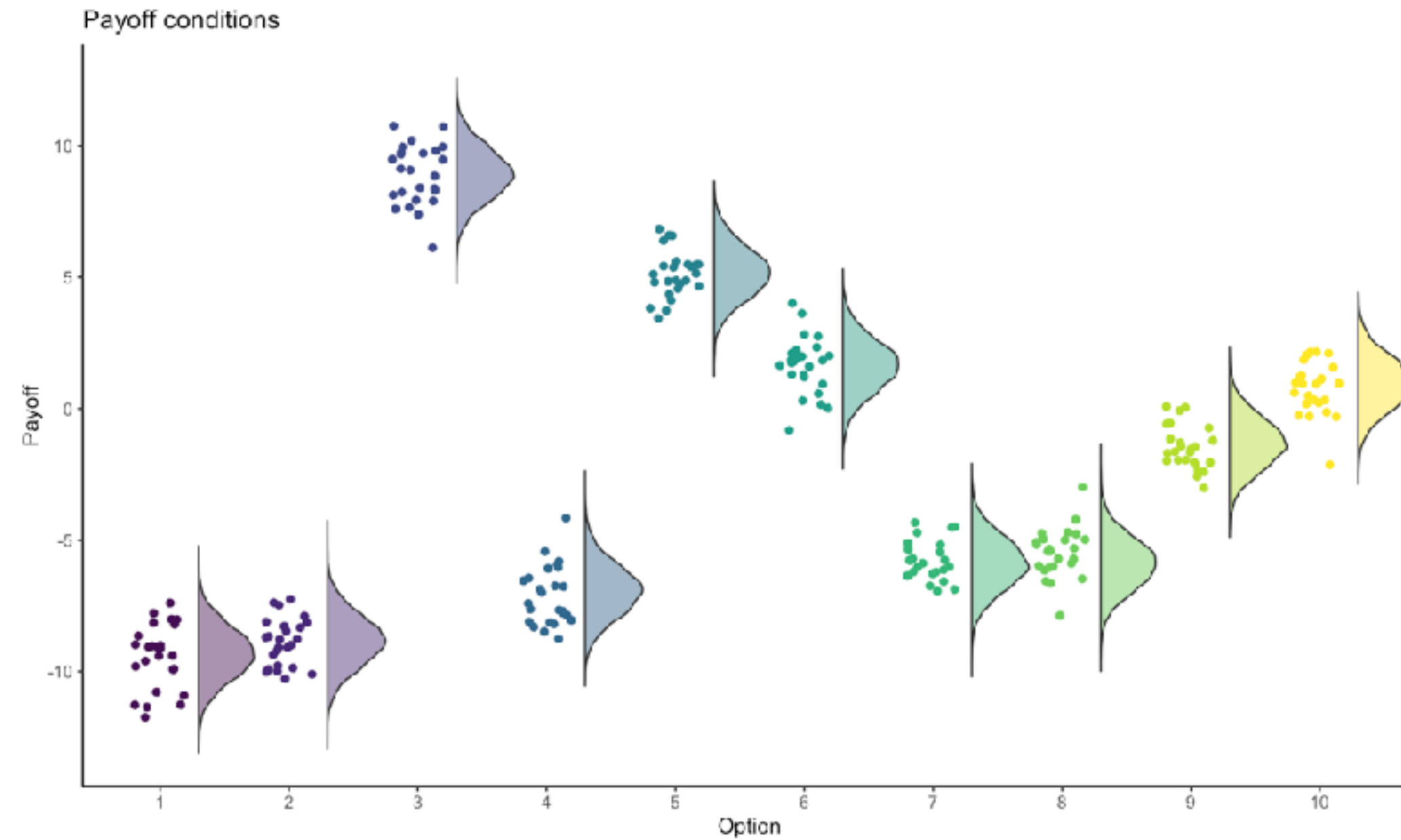
Amount of fish
(Payoff)

Realised payoffs that
individual fishers observe

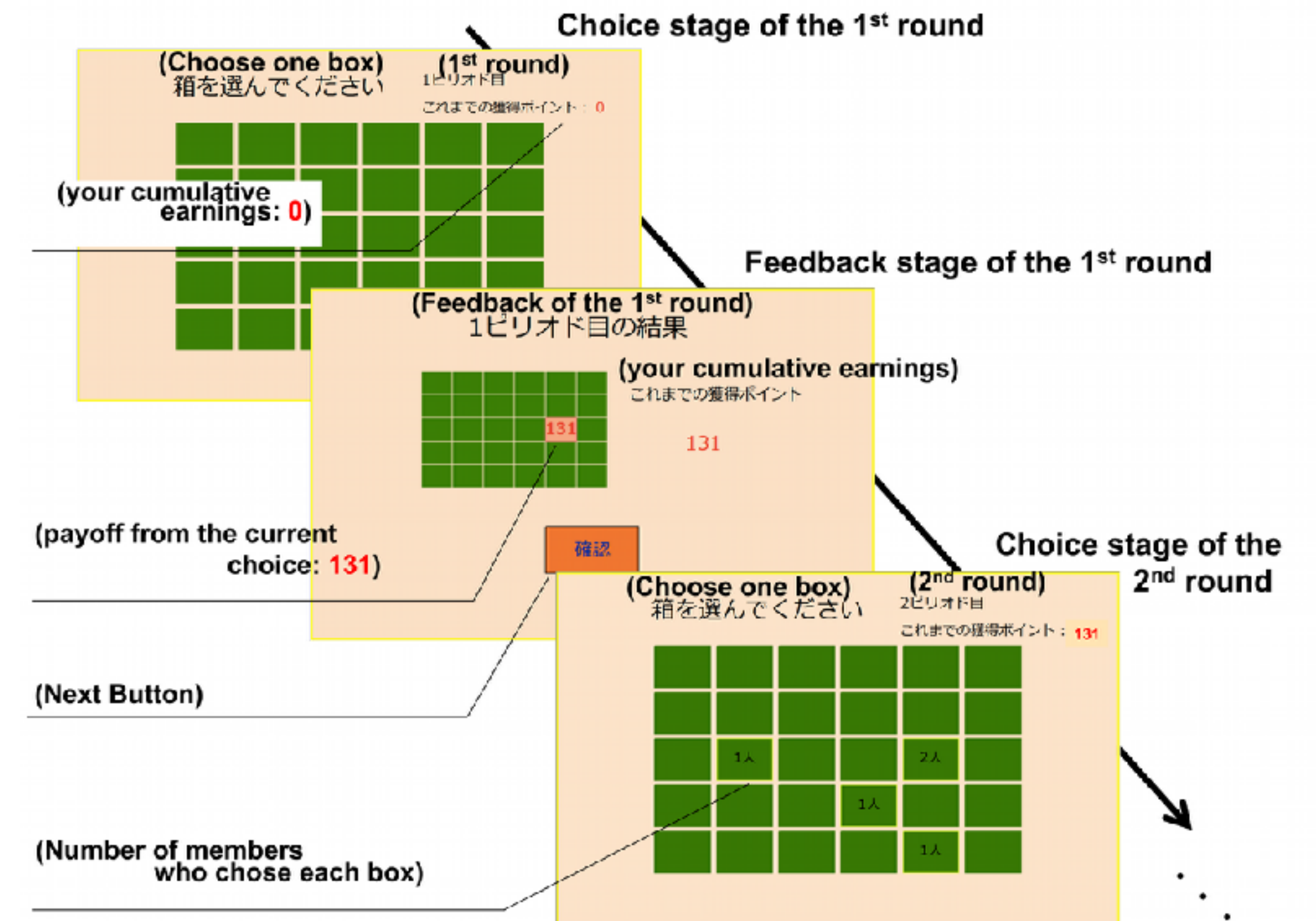


Scaling up

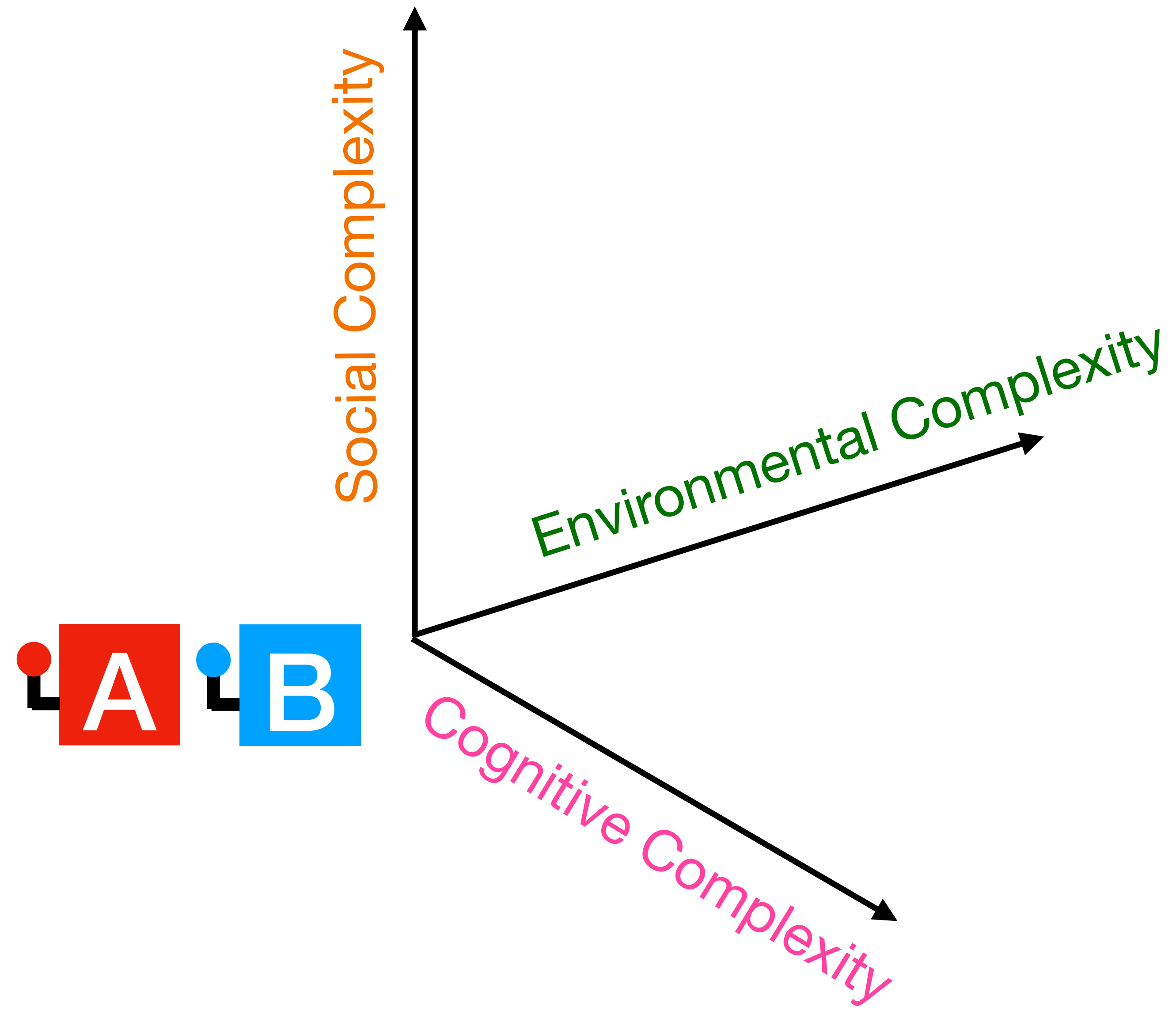
10-armed bandit



30-armed bandit (Toyokawa et al. 2014)

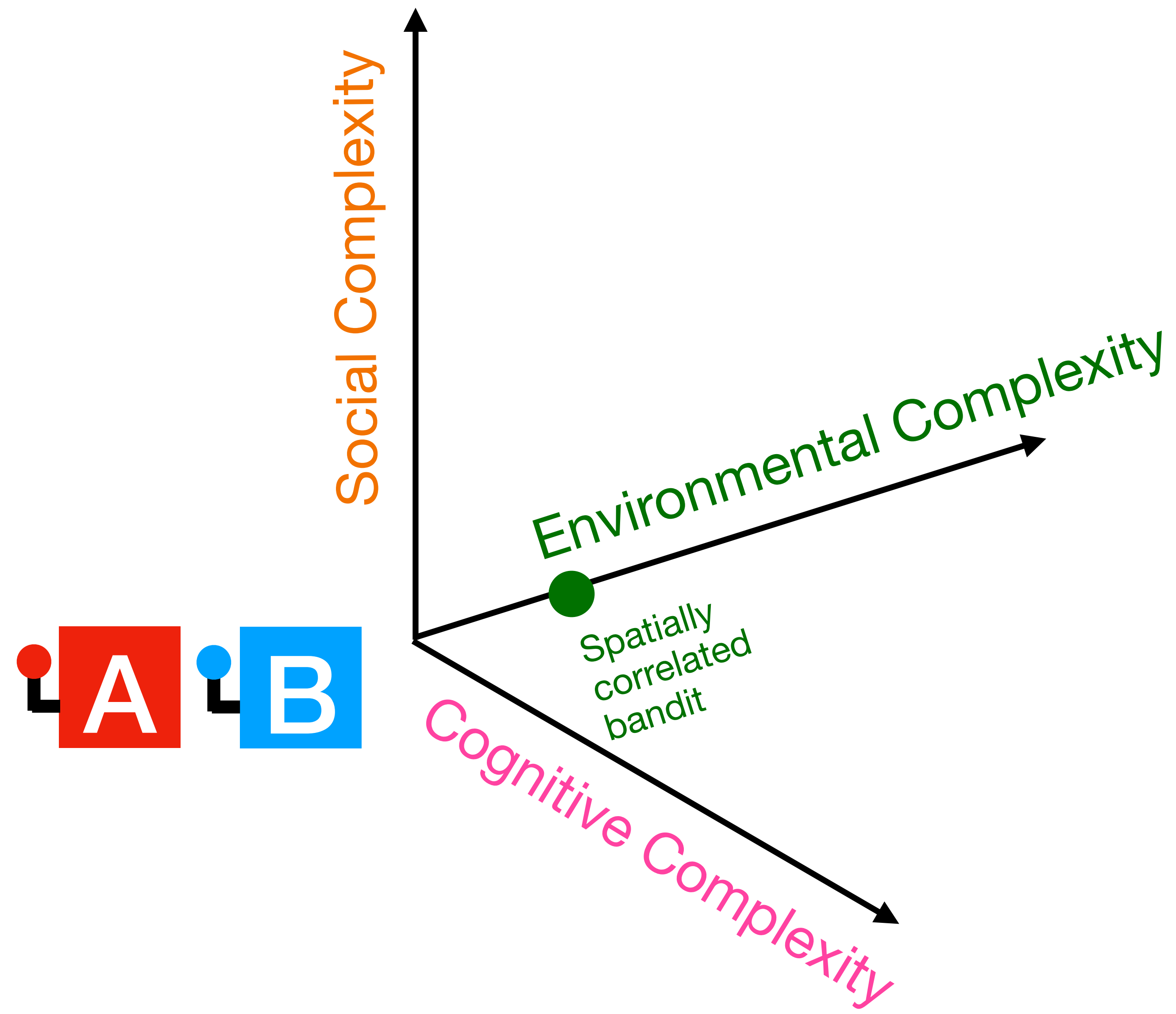


Ontology of social learning problems



- Environmental complexity
 - Reward structure
 - Temporal dynamics
- Social complexity
 - Network structures
 - Incentives
- Cognitive complexity
 - imitation vs. emulation (ToM)
 - Pedagogy vs. observational learning

Environmental Complexity



Spatial structure of environments

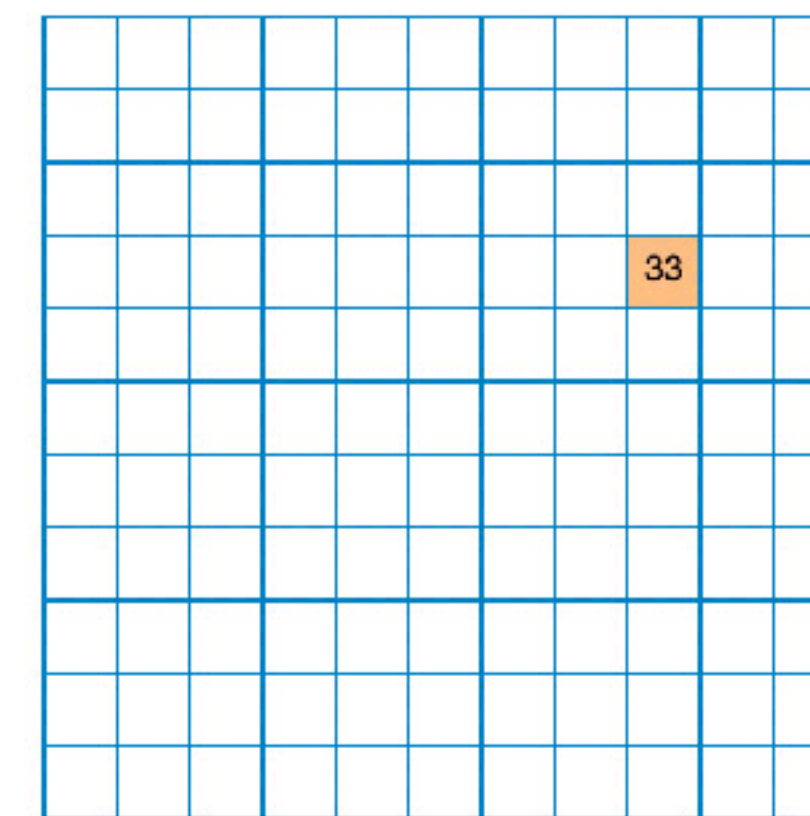
Crop yields



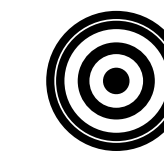
38	38	37	41	38	35	39	5	35	41	54
39	19	18	29	46	33	32	55	35	37	57
27	19	21	21	47	46	19	72	38	42	40
22	23	20	18	44	35	36	53	27	45	47
23	14	15	24	35	55	51	53	46	38	63
19	17	12	25	38	74	77	71	46	65	63
20	19	21	23	6	57	60	63	56	60	68
19	19	14	28	31	33	47	56	66	70	61
16	19	19	22	28	31	54	66	74	74	65
21	11	31	30	21	43	50	66	70	72	57
27	21	27	31	45	45	66	56	53	60	42



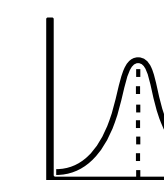
Spatially correlated bandit



click tiles on the grid



maximize reward



each tile has normally distributed rewards



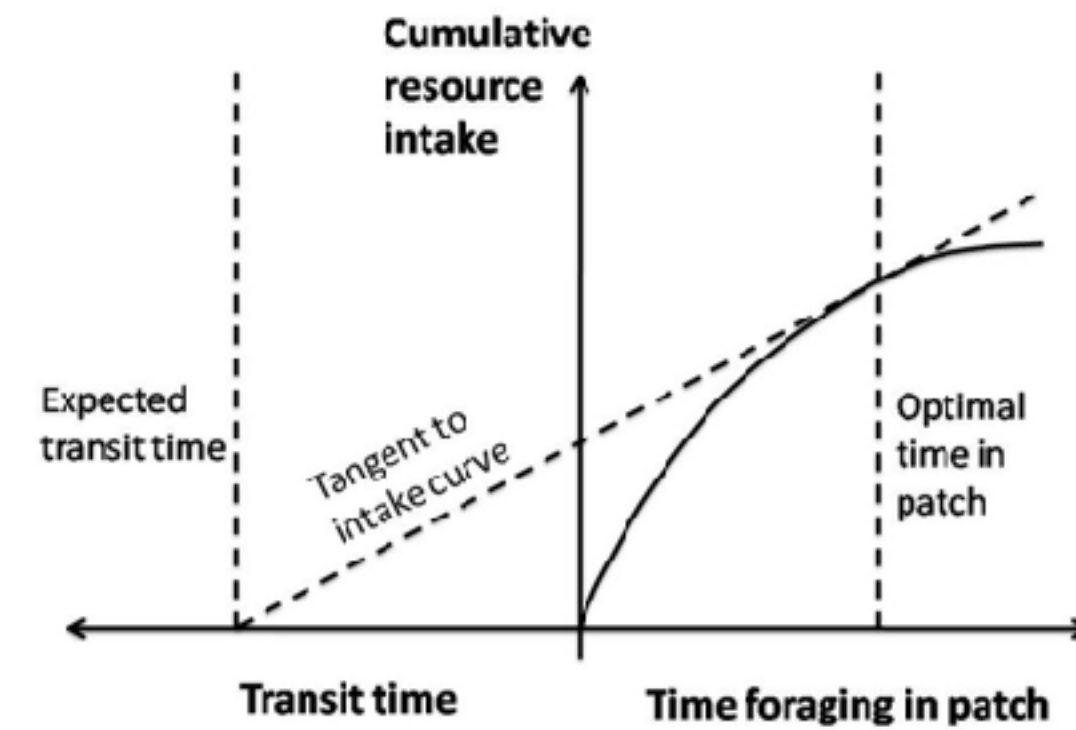
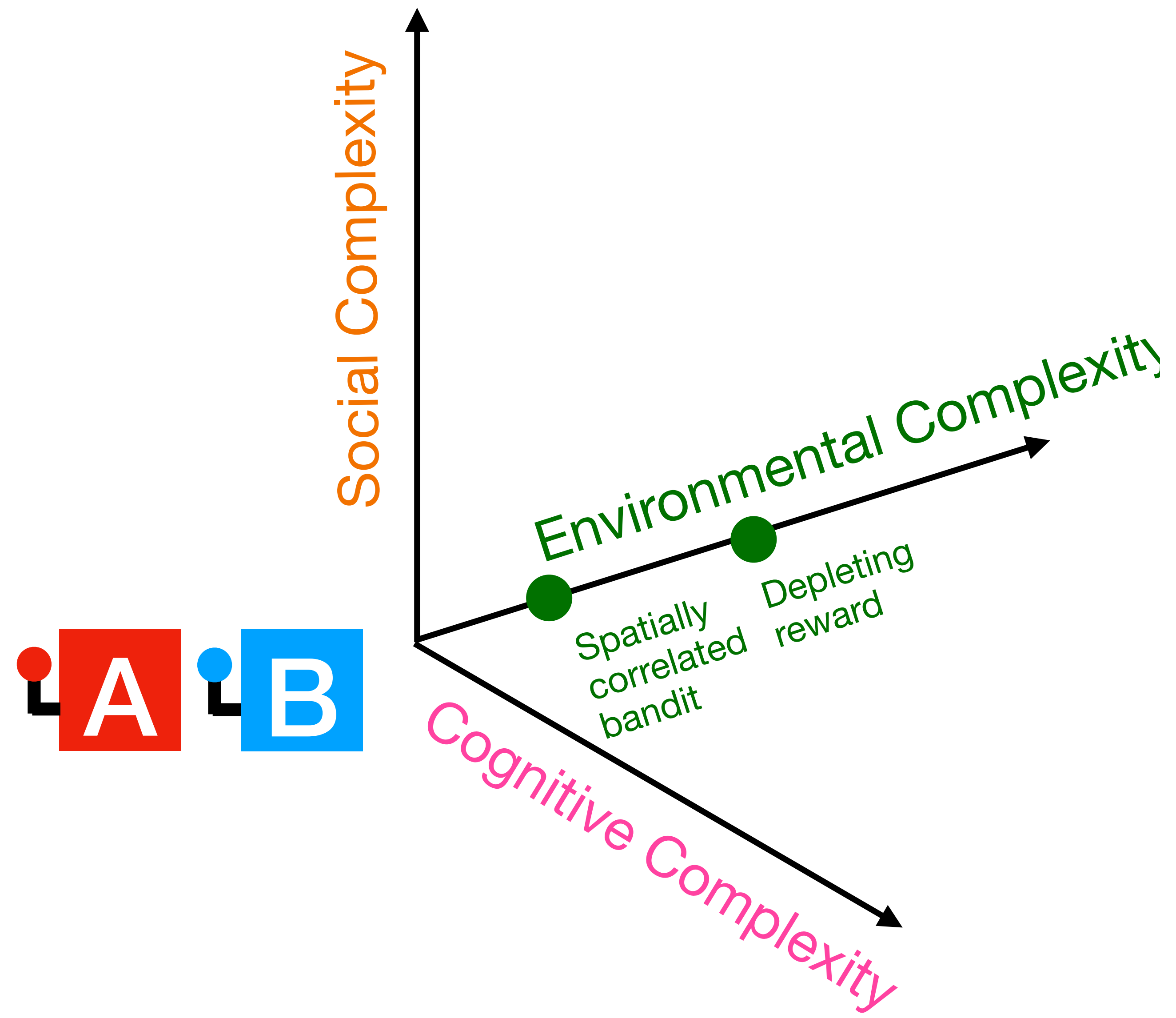
nearby tiles have similar rewards



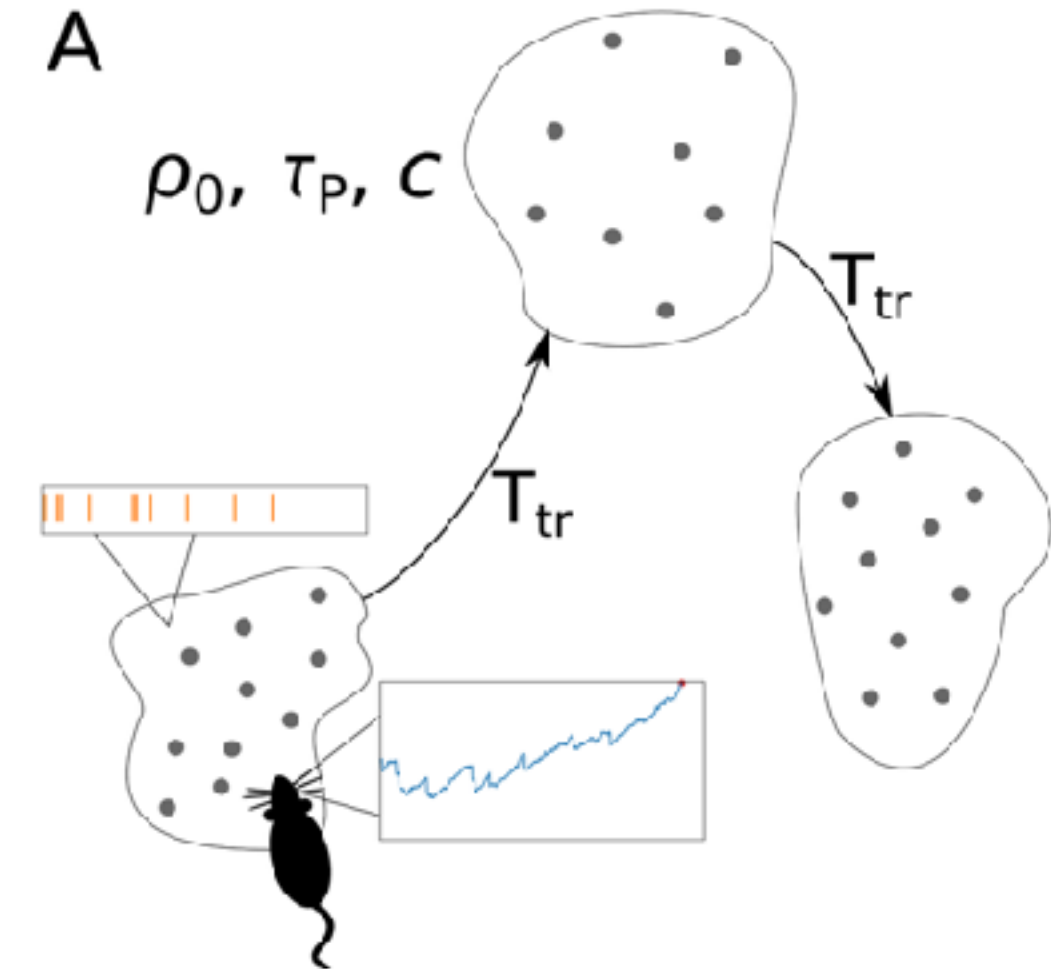
limited search horizon

Wu, C. M., Schulz, E., Speekenbrink, M., Nelson, J. D., & Meder, B. (2018). Generalization guides human exploration in vast decision spaces. *Nature human behaviour*, 2(12), 915-924.

Environmental Complexity

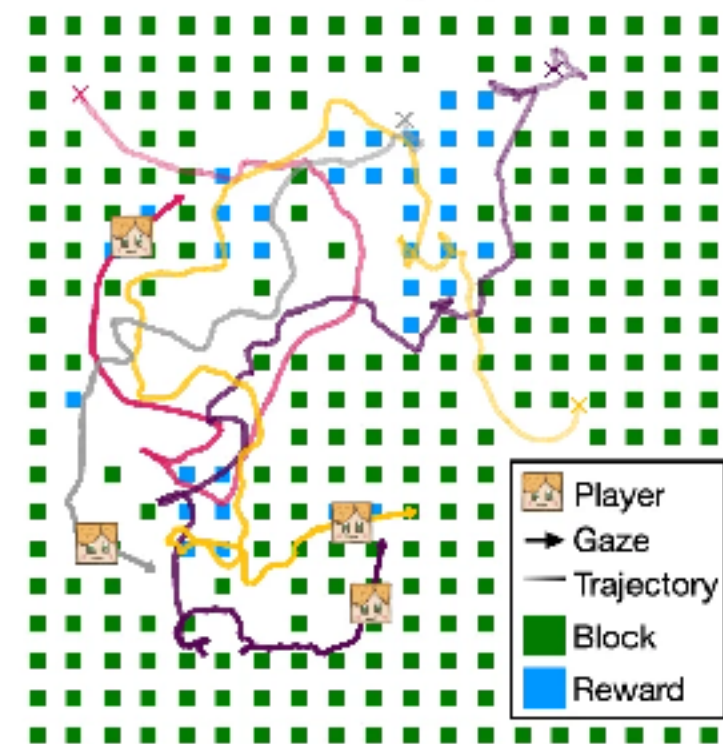


Charnov, E. L. 1976. Optimal foraging: the marginal value theorem. *Theoretical Population Biology* 9:129–136



Davidson JD, El Hady A (2019) Foraging as an evidence accumulation process. *PLoS Comput Biol* 15(7): e1007060. <https://doi.org/10.1371/journal.pcbi.1007060>

a Collective foraging task

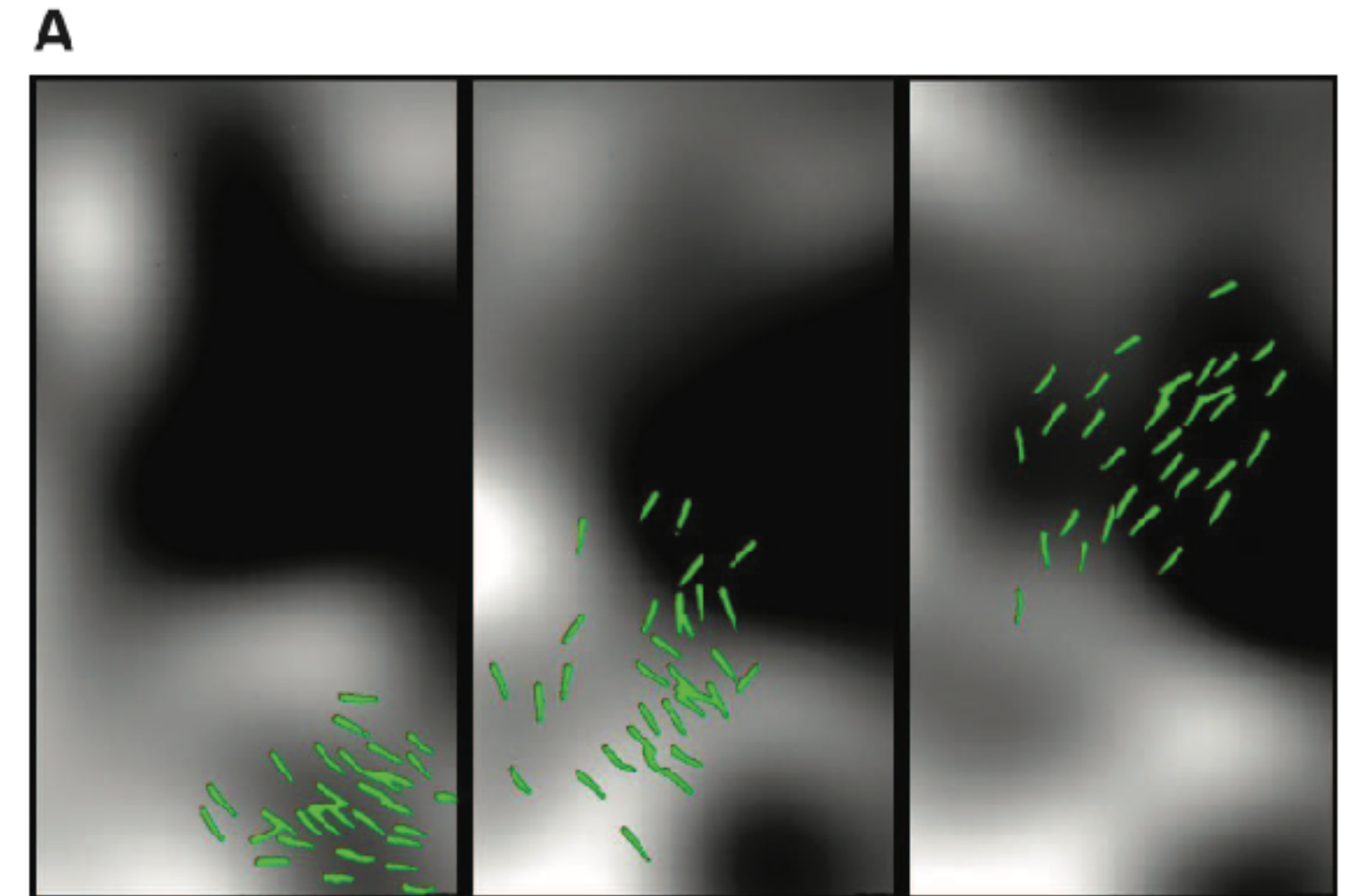
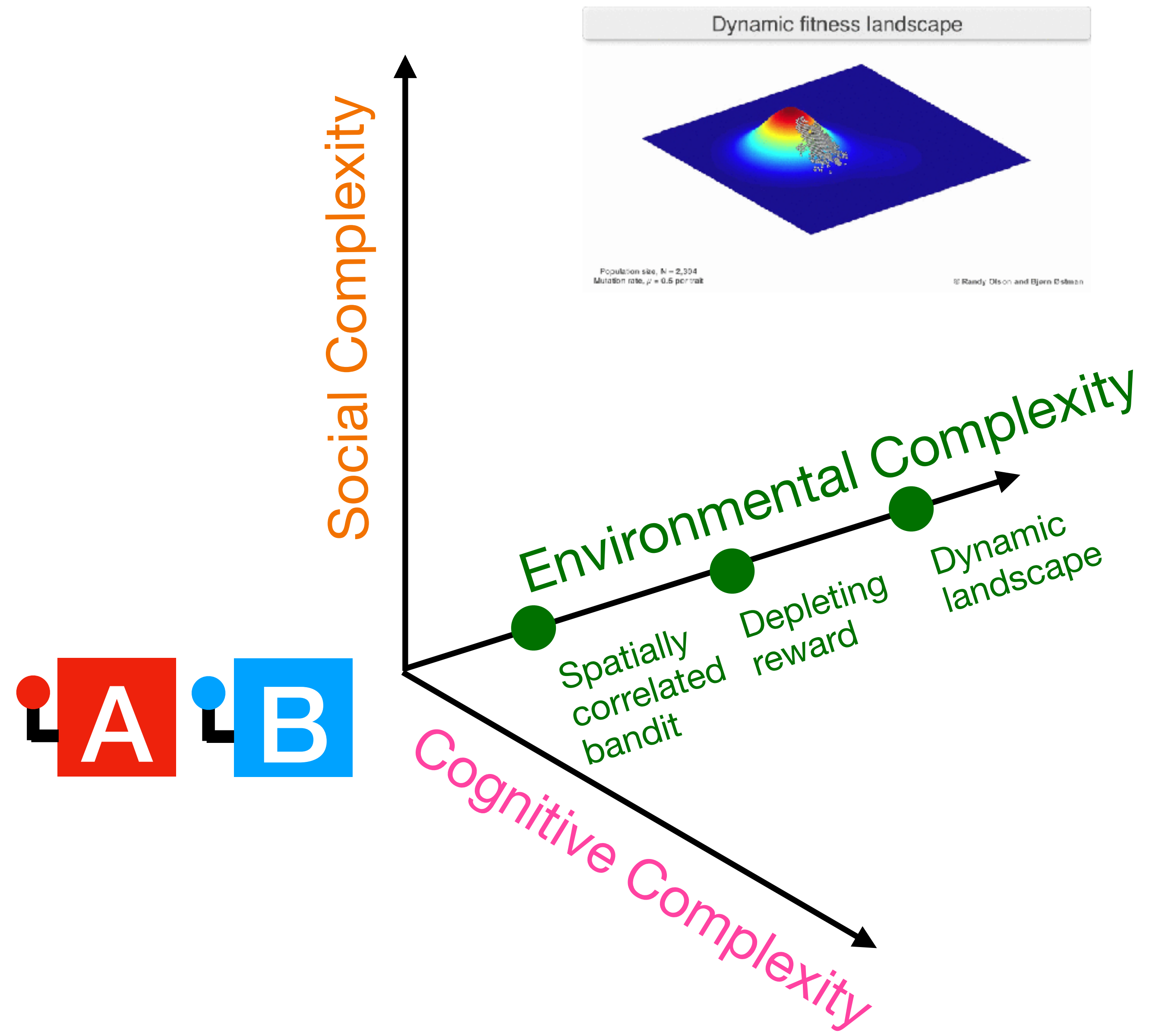


b Screenshot from perspective

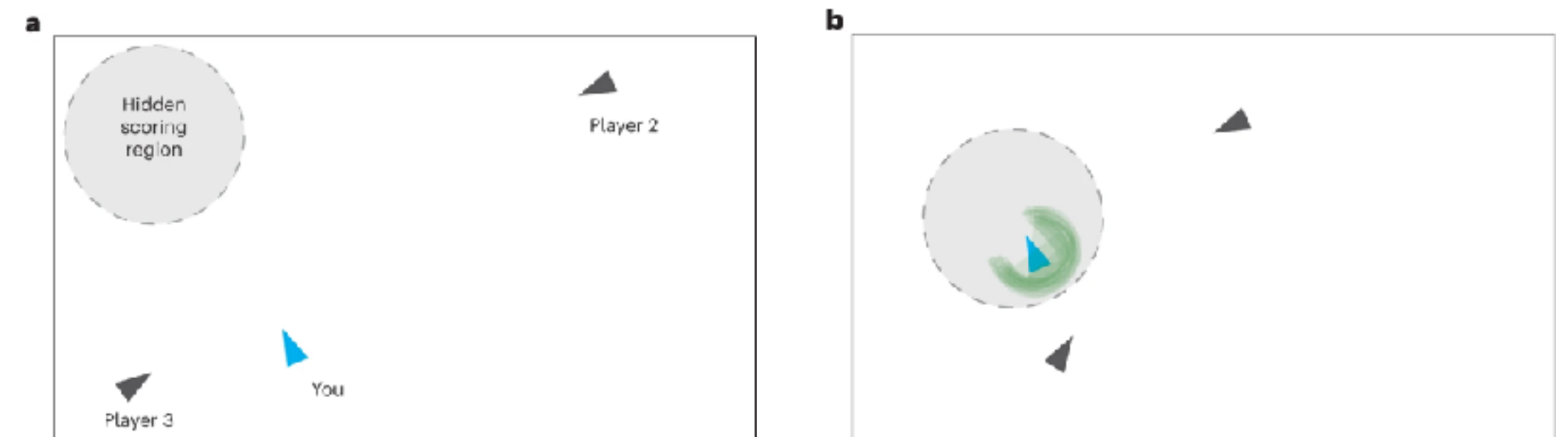


Wu, C.M., Deffner, D., Kahl, B. *et al.* Adaptive mechanisms of social and asocial learning in immersive collective foraging. *Nat Commun* 16, 3539 (2025). <https://doi.org/10.1038/s41467-025-58365-6>

Environmental Complexity

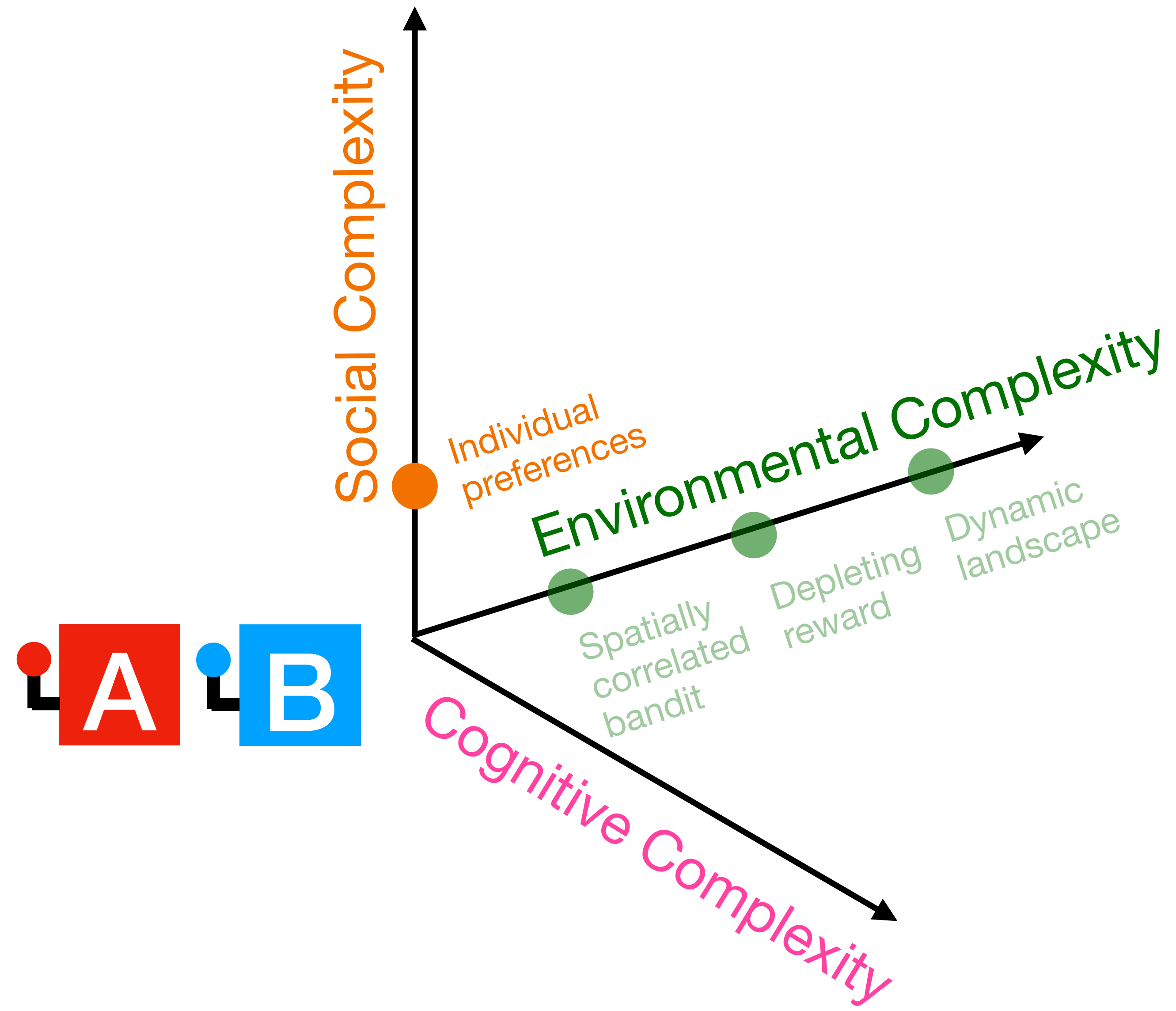


Andrew Berdahl *et al.*, Emergent Sensing of Complex Environments by Mobile Animal Groups. *Science*. **339**,574-576(2013). DOI:[10.1126/science.1225883](https://doi.org/10.1126/science.1225883)



Hawkins, R.D., Berdahl, A.M., Pentland, A.' *et al.* Flexible social inference facilitates targeted social learning when rewards are not observable. *Nat Hum Behav* **7**, 1767–1776 (2023). <https://doi.org/10.1038/s41562-023-01682-x>

Social Complexity



Socially correlated bandit task



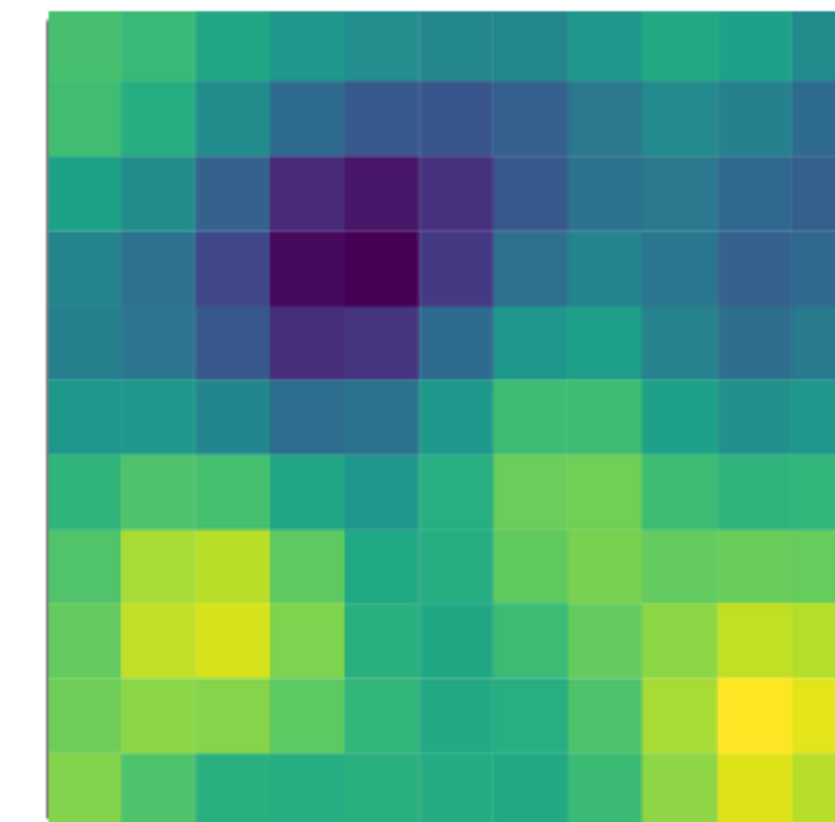
Gather as much salt as possible within 14 clicks



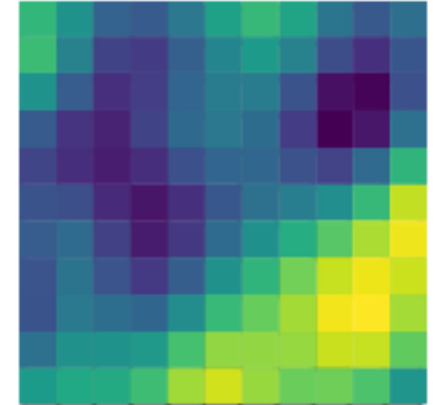
Salt concentration is correlated spatially...



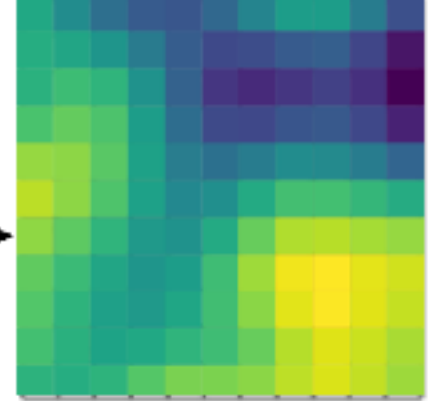
.... as well as socially



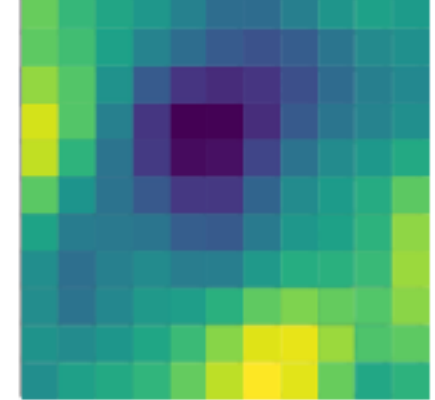
Scientist 2



Scientist 3



Scientist 4



Social Complexity

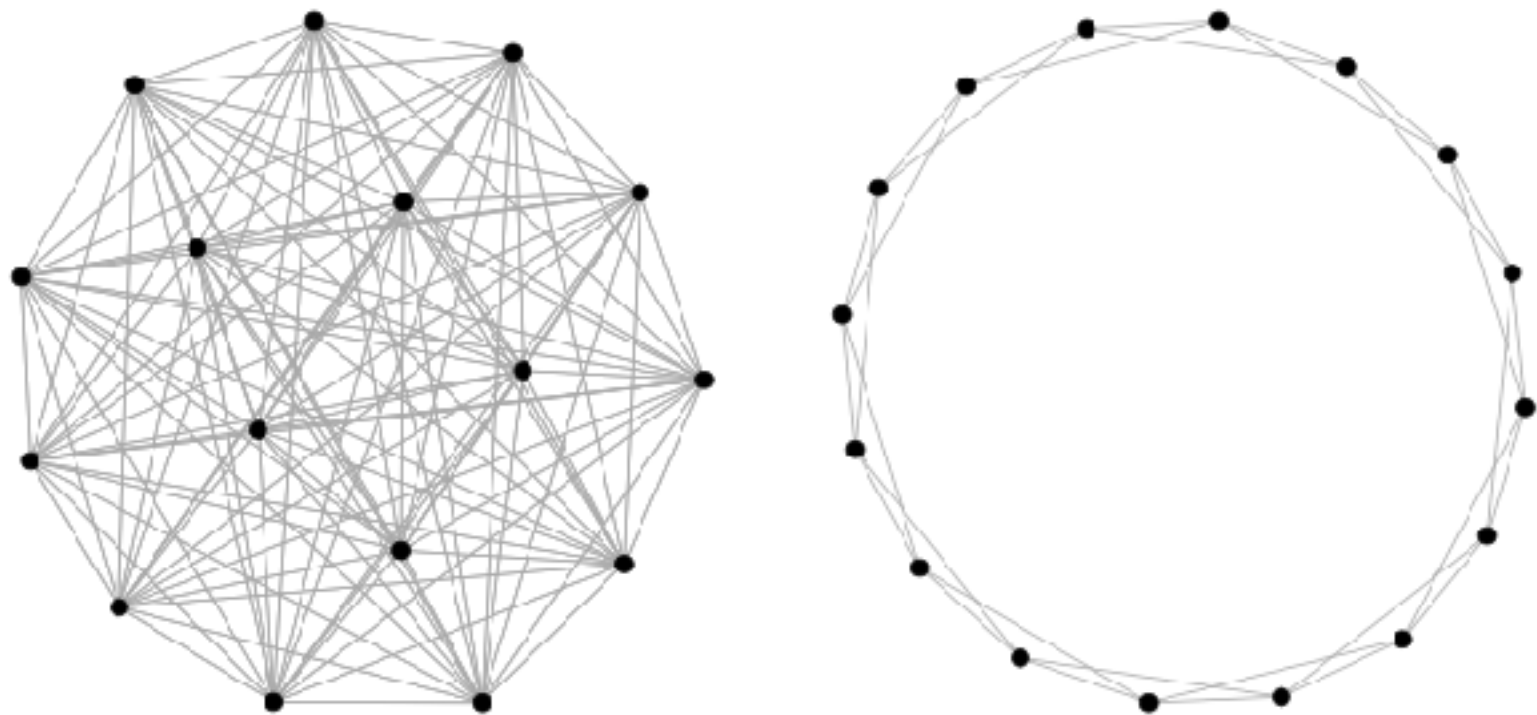
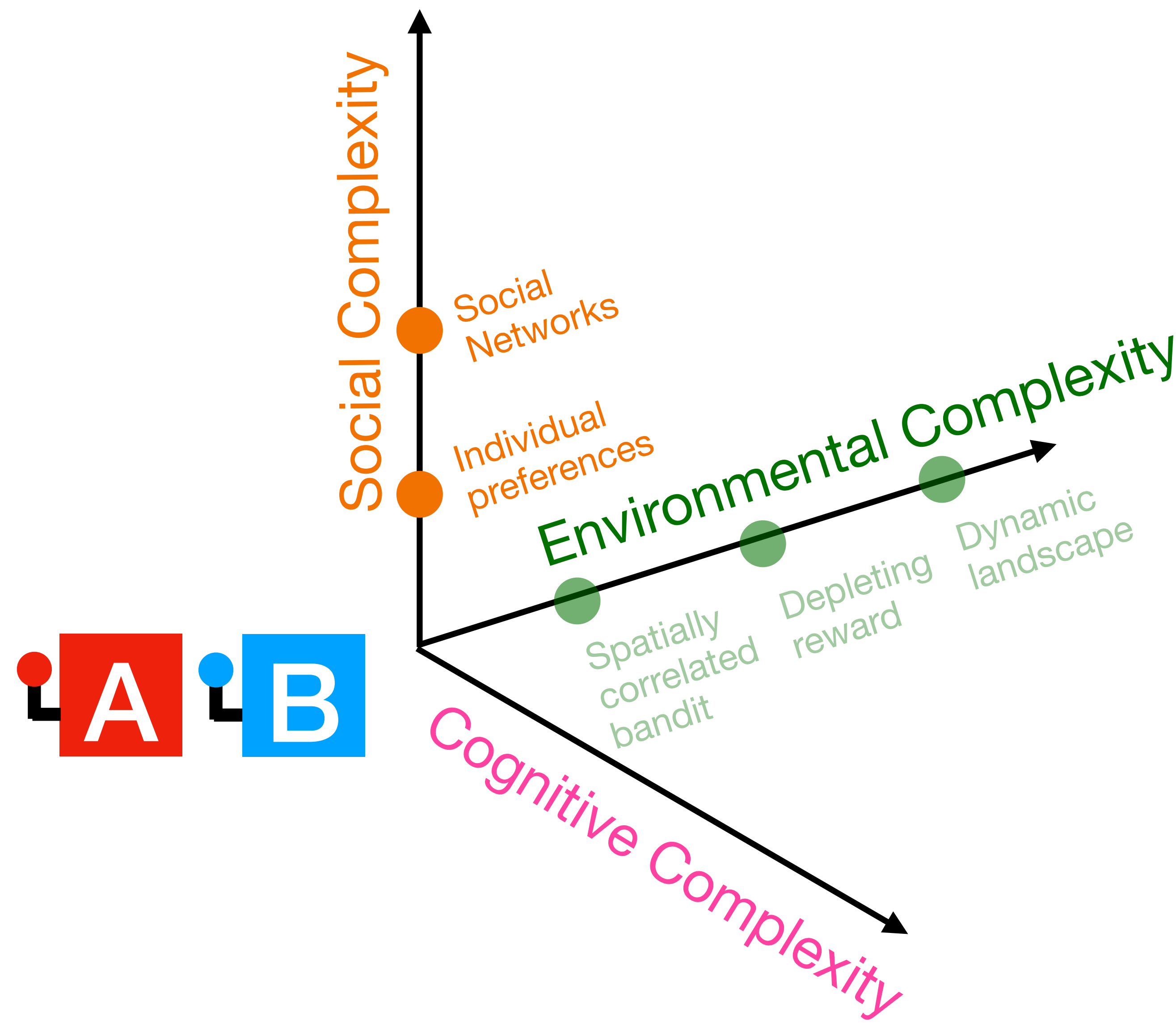
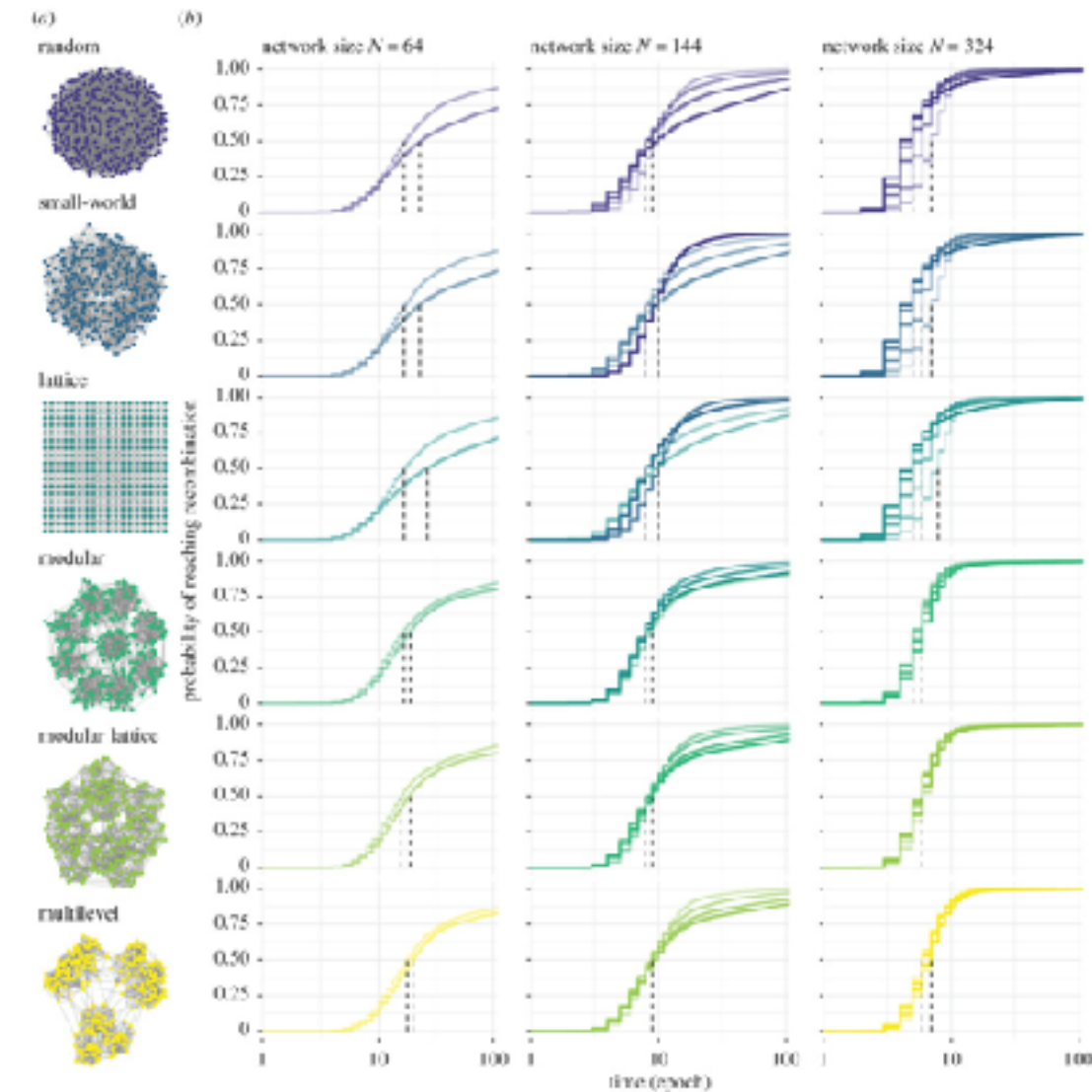
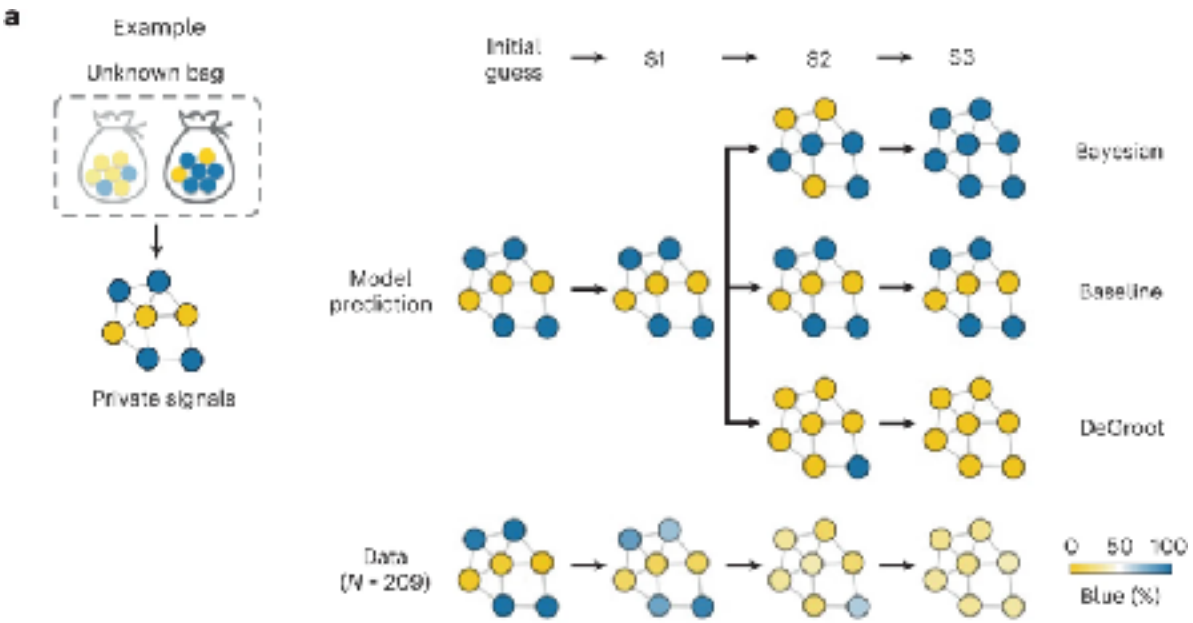


Figure 2: Examples of a fully connected (left) and locally connected lattice (right) networks.

Barkoczi, D., Analytis, P. P., & Wu, C. M. (2016). Collective search on rugged landscapes: A cross-environmental analysis. In *Proceedings of the Annual Meeting of the Cognitive Science Society* (Vol. 38).

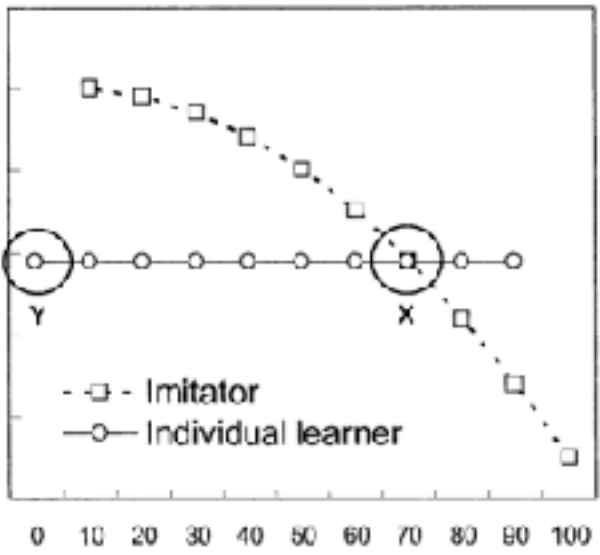
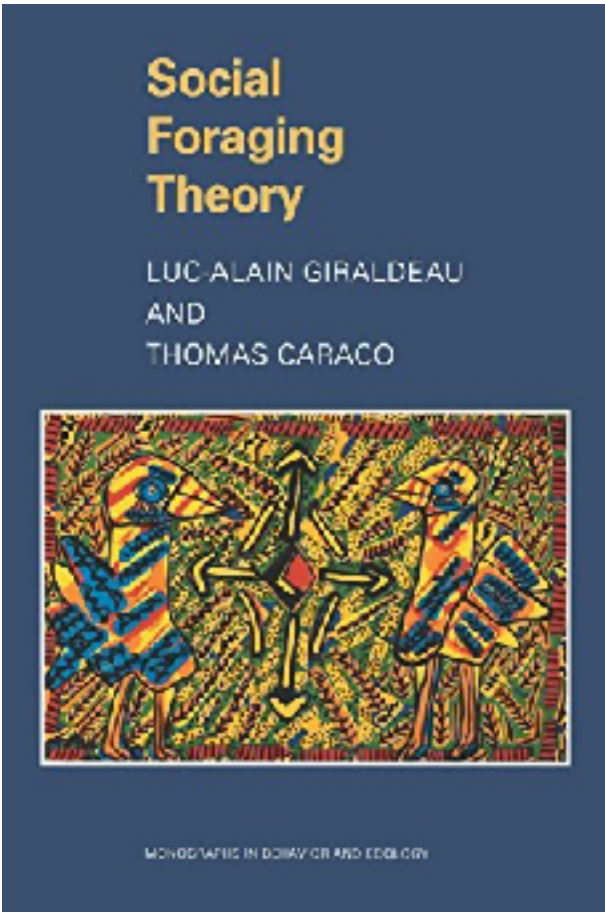


Cantor, M., Chimento, M., Smeele, S. Q., He, P., Papageorgiou, D., Aplin, L. M., & Farine, D. R. (2021). Social network architecture and the tempo of cumulative cultural evolution. *Proceedings of the Royal Society B*, 288(1946), 20203107.

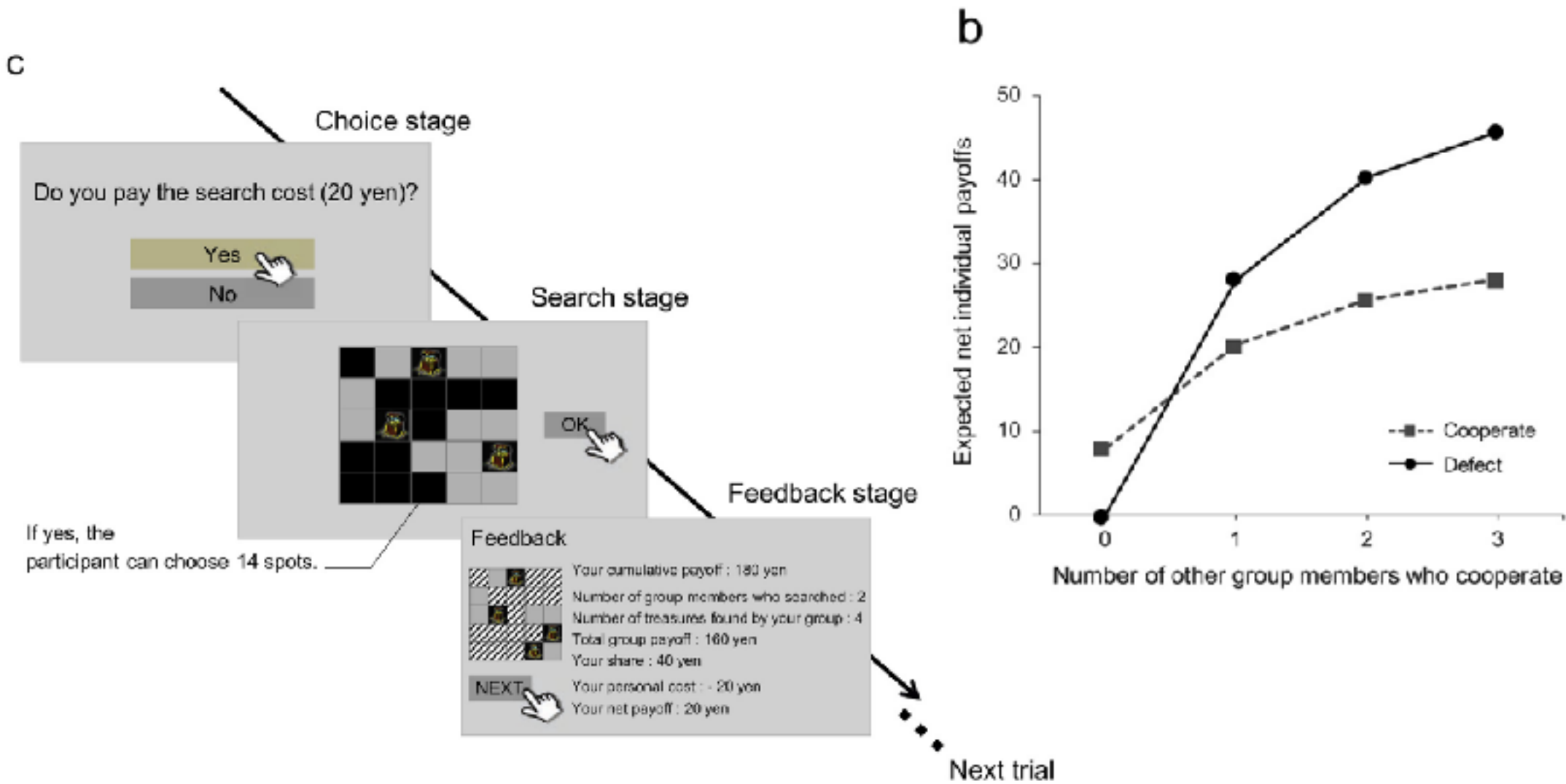
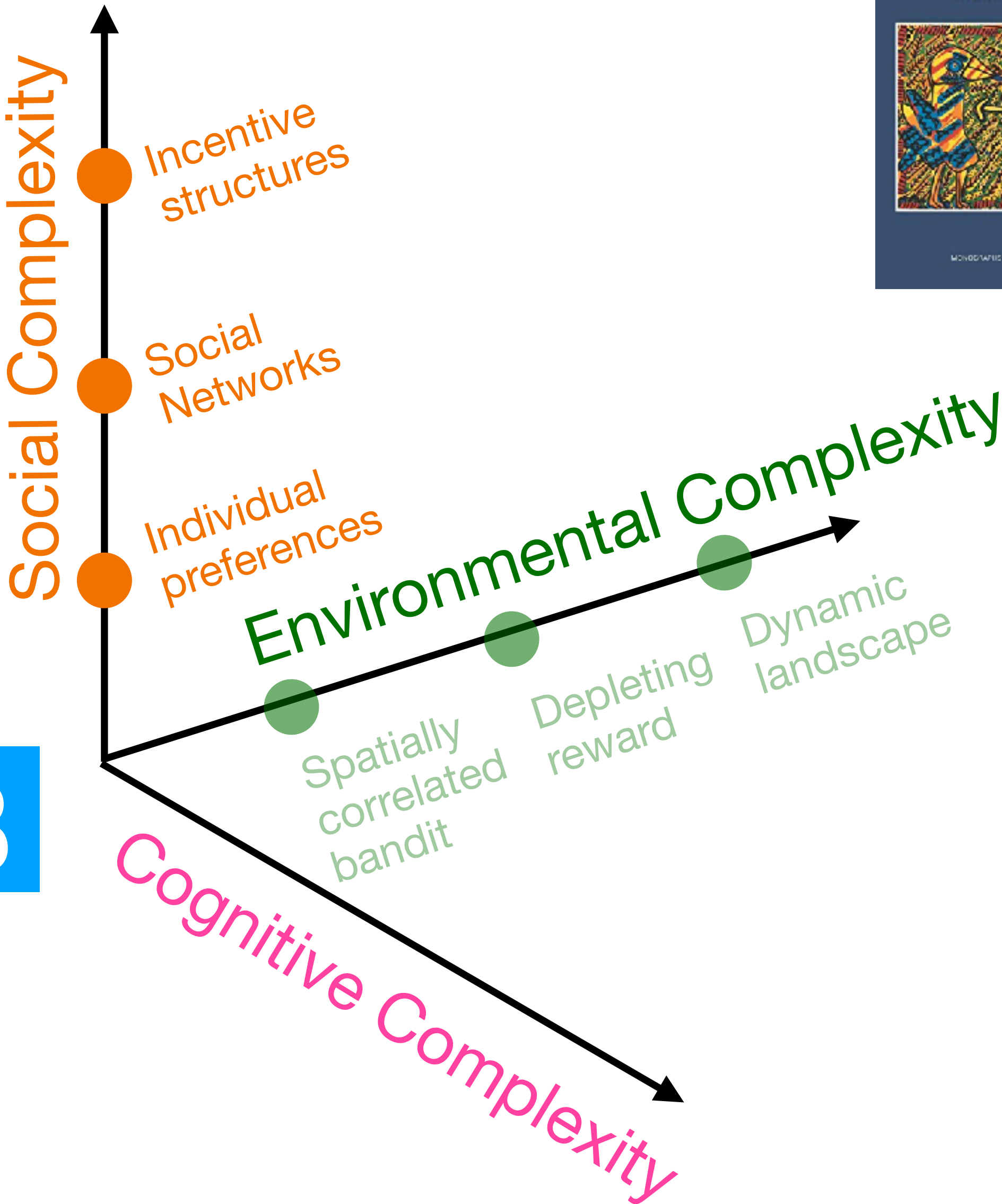


Jiang, Y., Mi, Q. & Zhu, L. Neurocomputational mechanism of real-time distributed learning on social networks. *Nat Neurosci* 26, 506–516 (2023). <https://doi.org/10.1038/s41593-023-01258-y>

Social Complexity

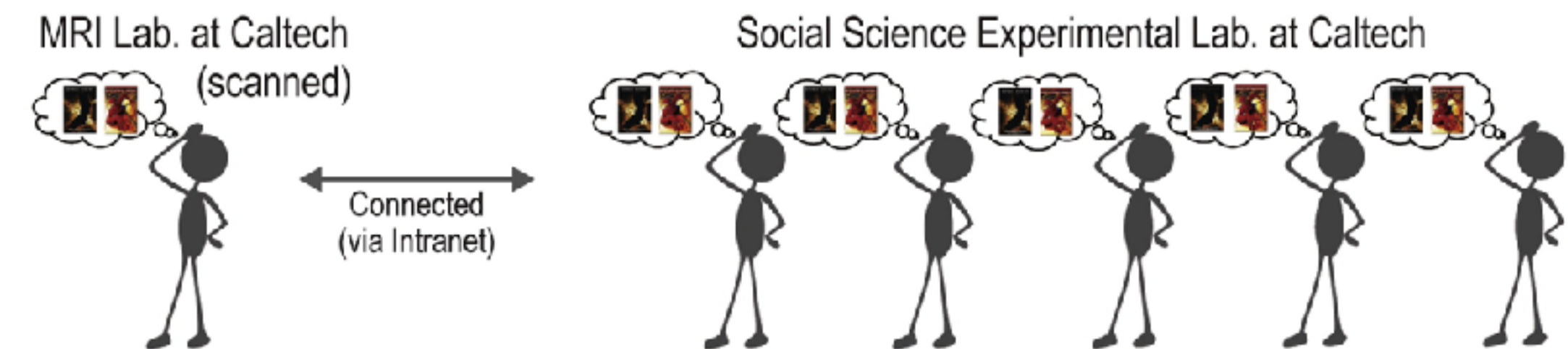
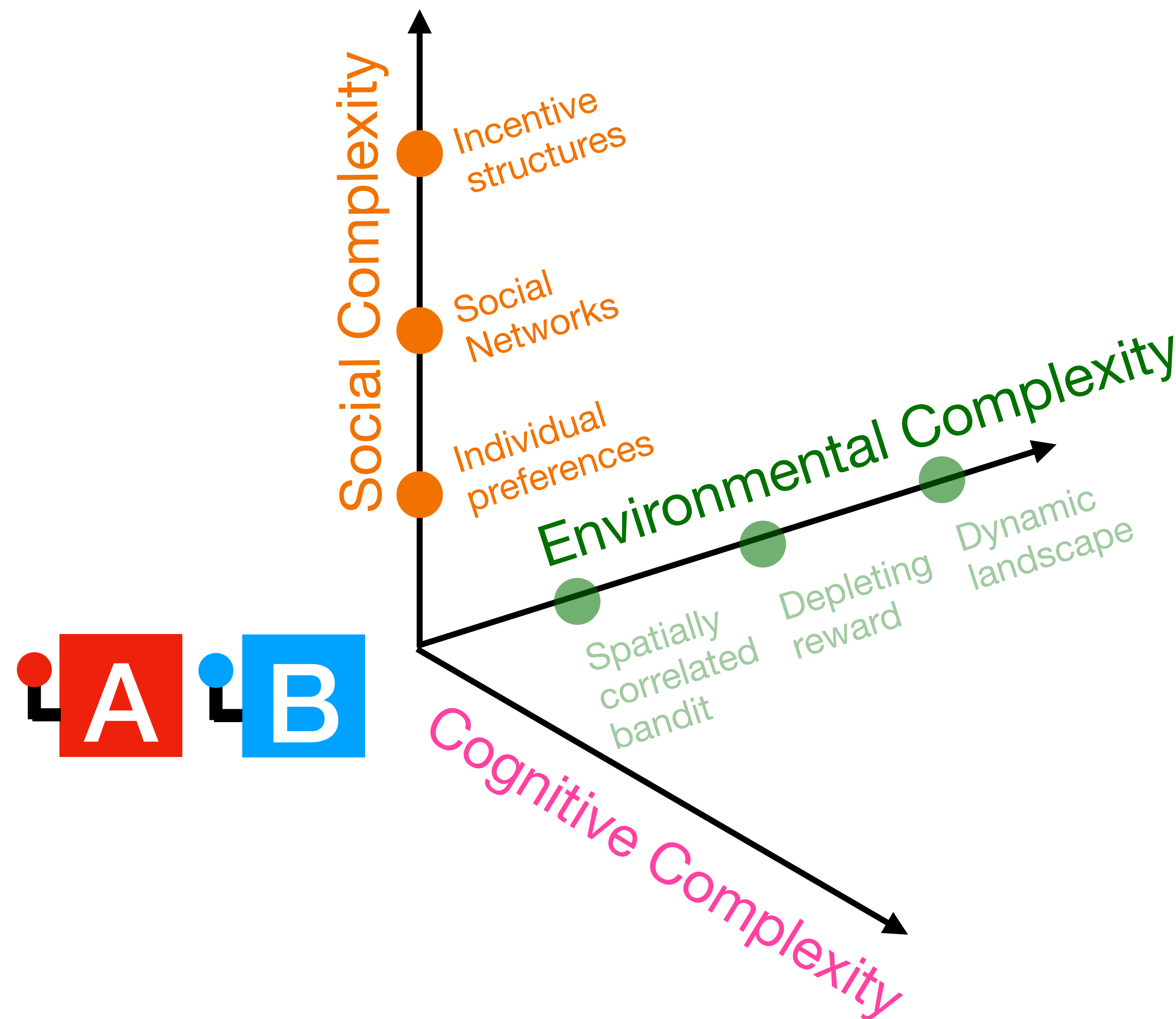


Keynan, O., Ridley, A. R., & Lotem, A. (2015). Social foraging strategies and acquisition of novel foraging skills in cooperatively breeding Arabian babblers. *Behavioral Ecology*, 26(1), 207-214.

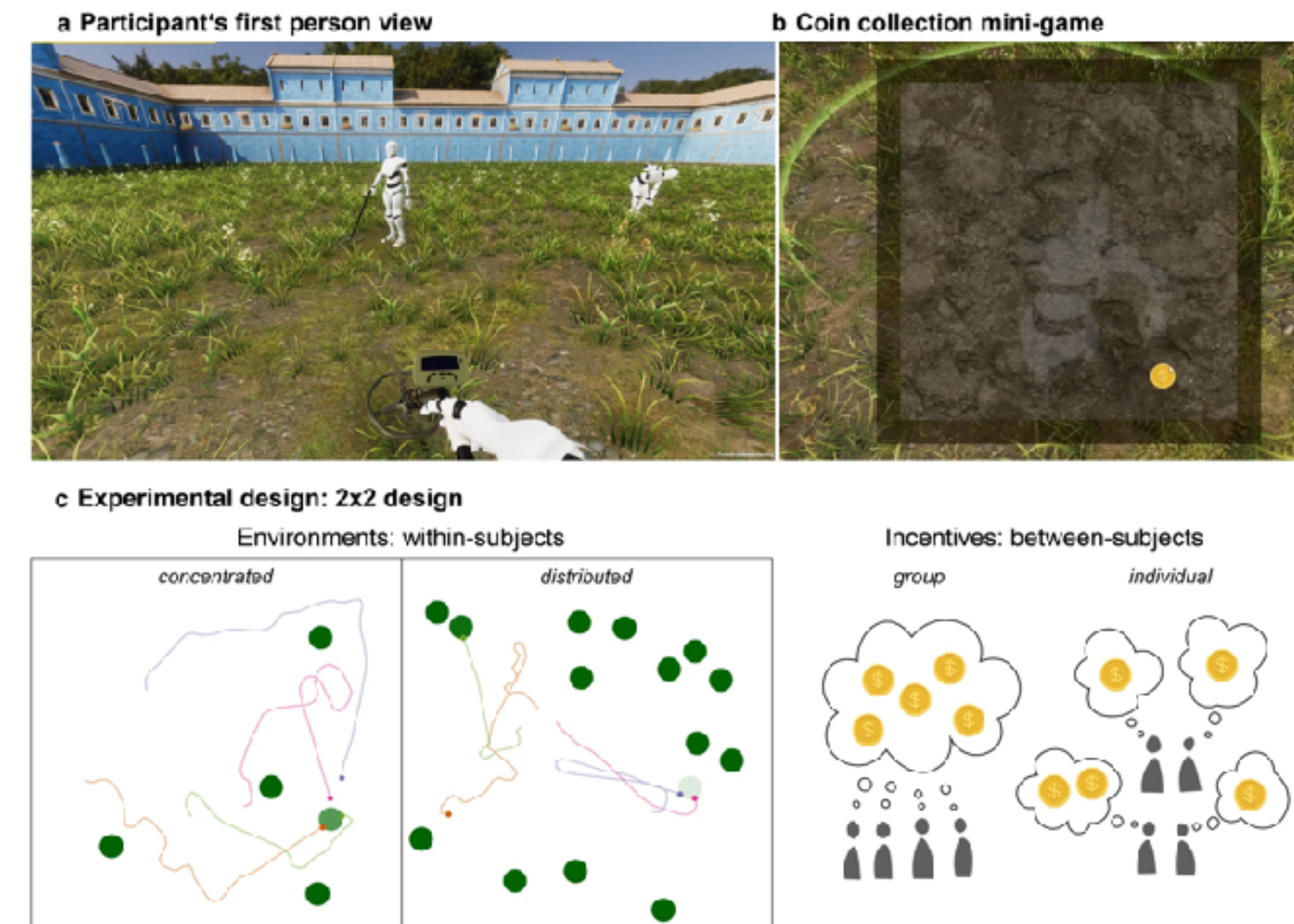


Kim, H. R., Toyokawa, W., & Kameda, T. (2019). How do we decide when (not) to free-ride? Risk tolerance predicts behavioral plasticity in cooperation. *Evolution and Human Behavior*, 40(1), 55-64.

Social Complexity

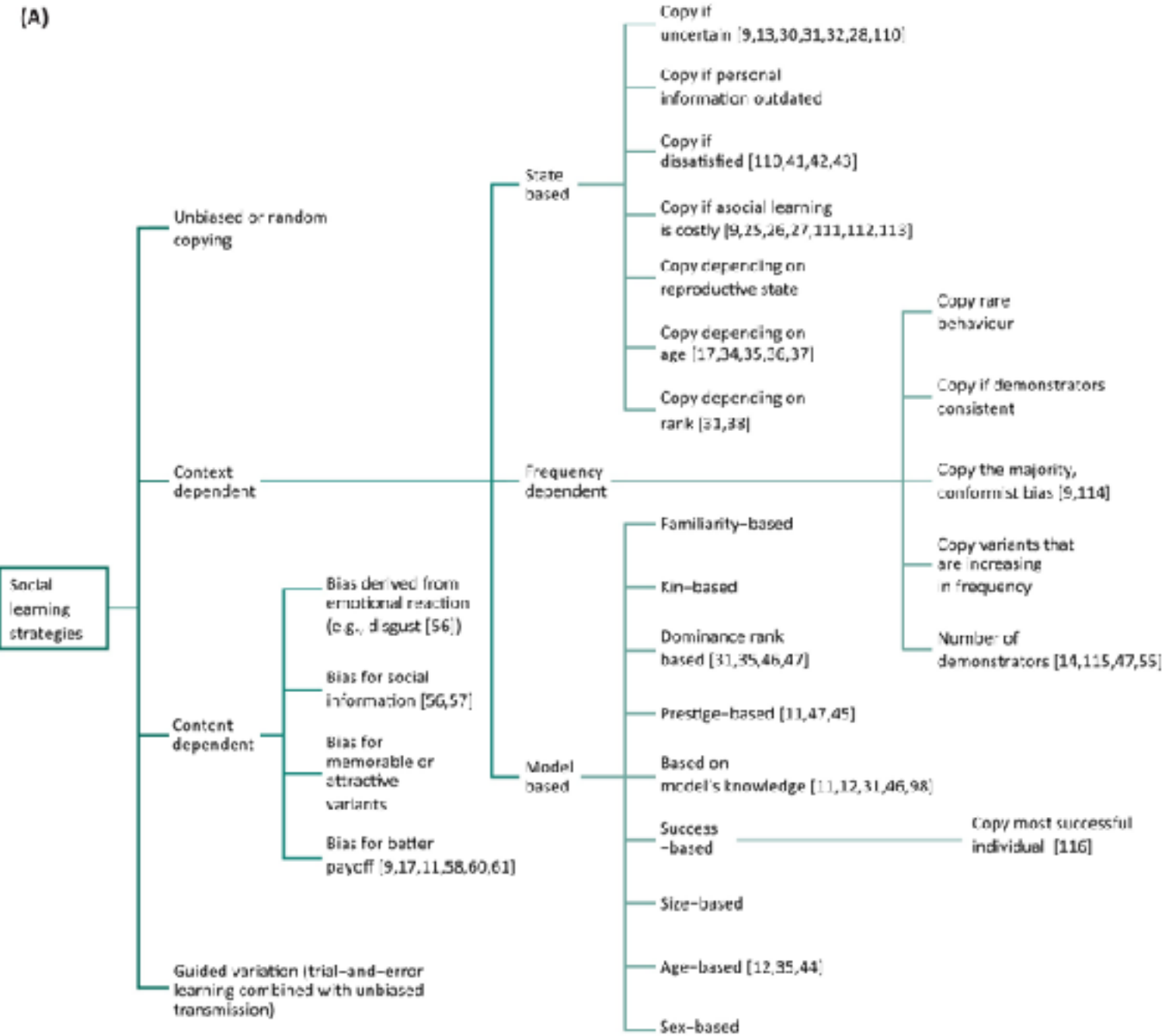
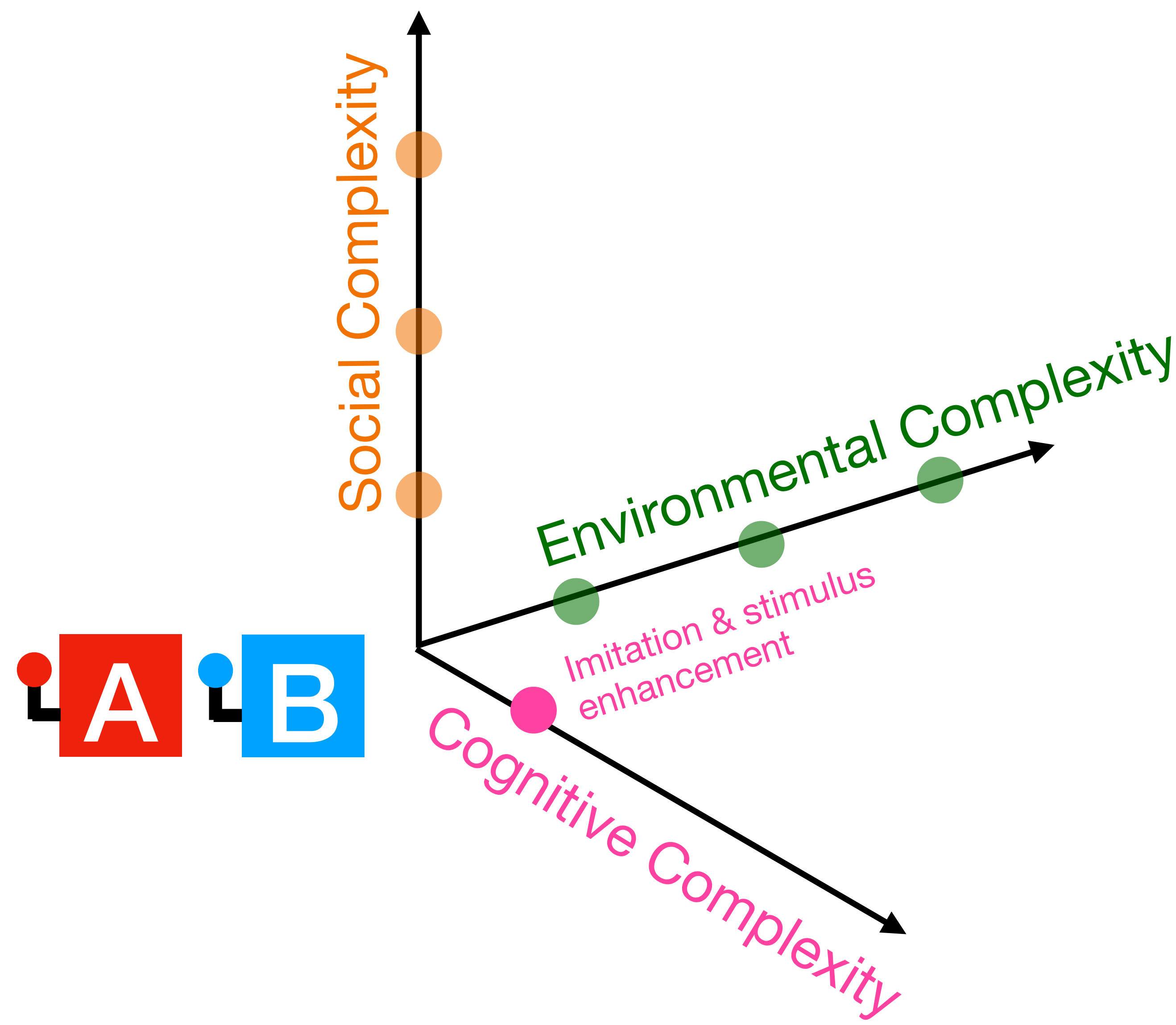


Suzuki S, Adachi R, Dunne S, Bossaerts P, O'Doherty JP. Neural mechanisms underlying human consensus decision-making. *Neuron*. 2015 Apr 22;86(2):591-602. doi: 10.1016/j.neuron.2015.03.019.

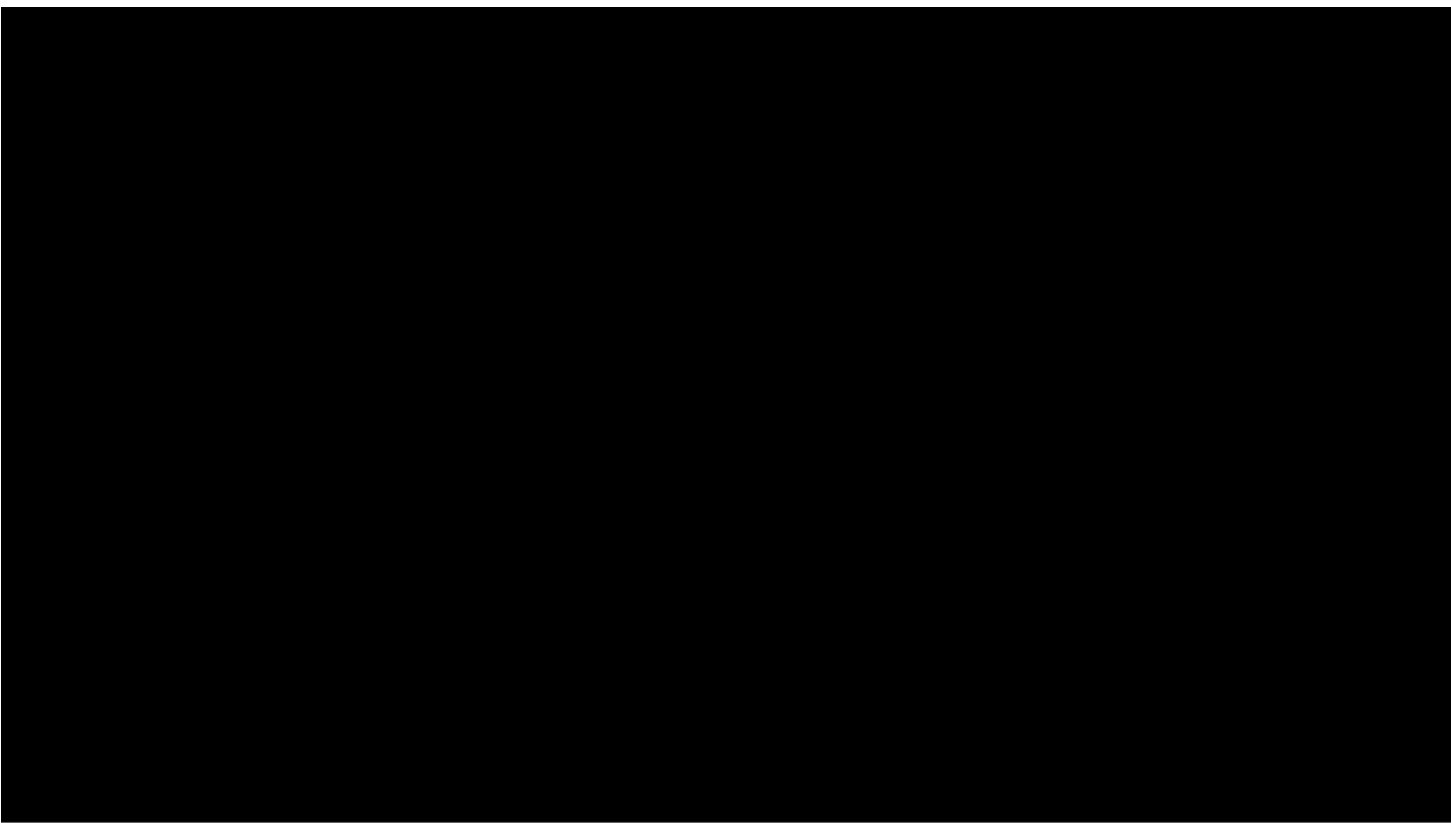


Deffner, D., Mezey, D., Kahl, B. *et al.* Collective incentives reduce over-exploitation of social information in unconstrained human groups. *Nat Commun* **15**, 2683 (2024). <https://doi.org/10.1038/s41467-024-47010-3>

Cognitive Complexity

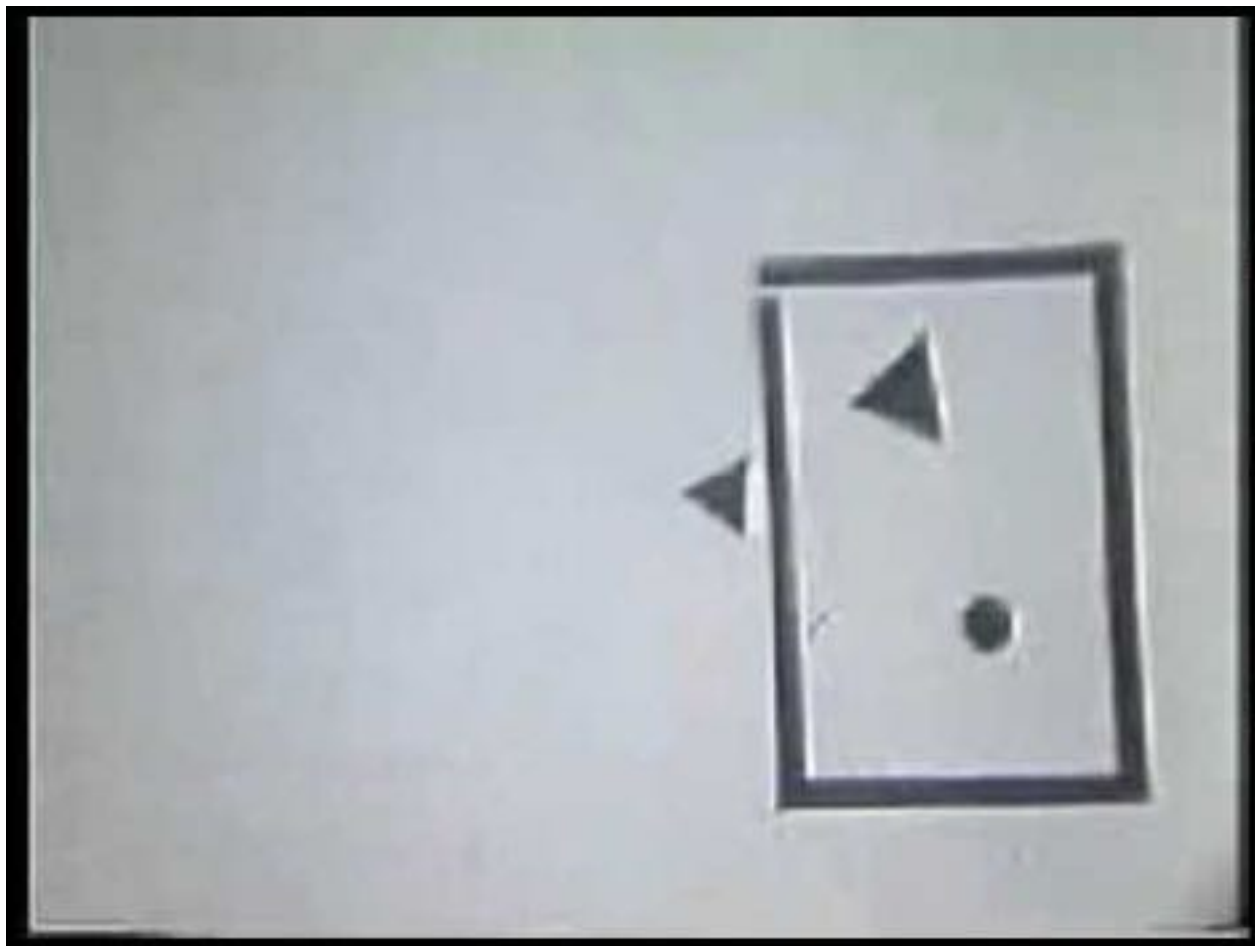
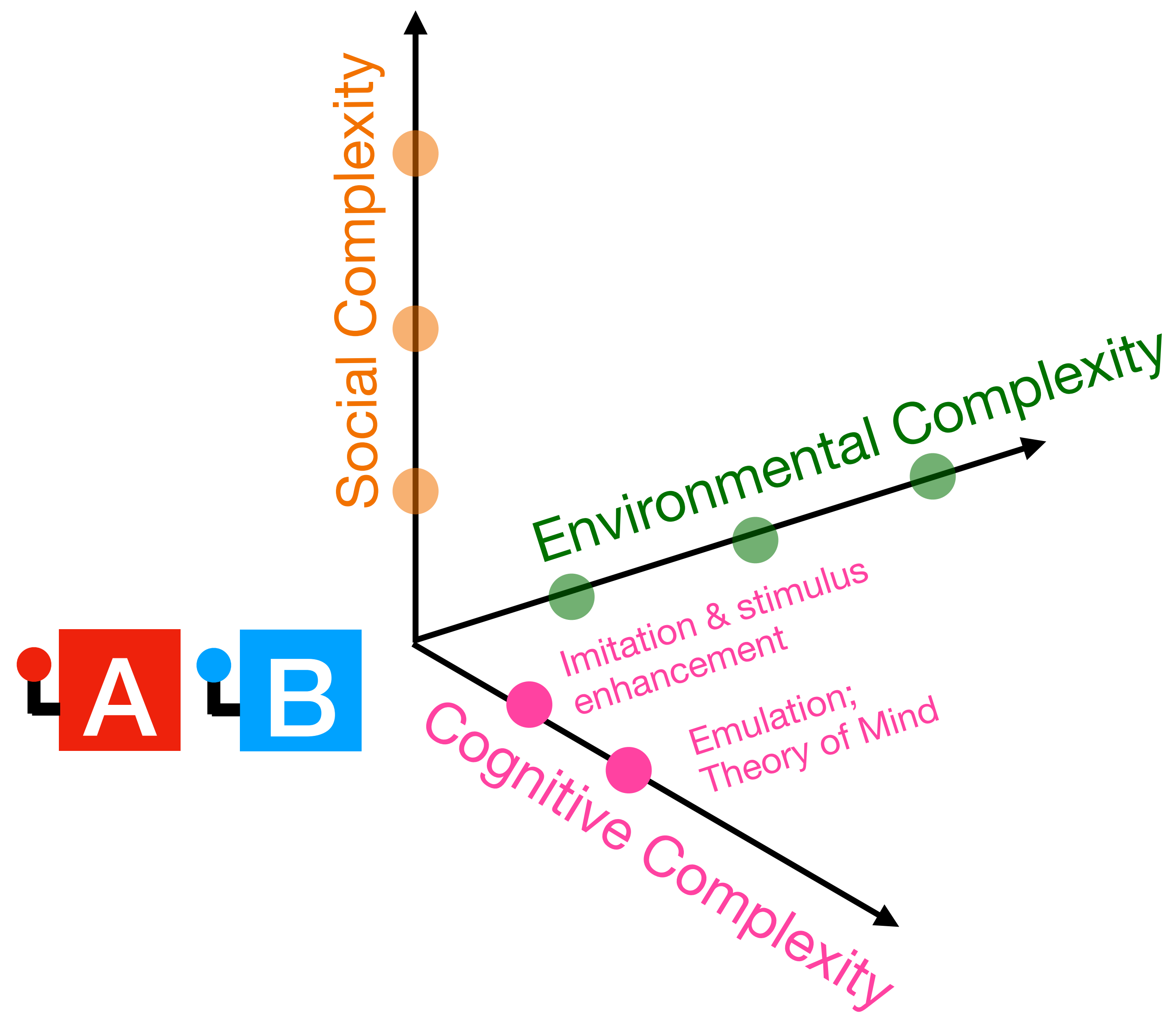


Kendal RL, Boogert NJ, Rendell L, Laland KN, Webster M, Jones PL. Social Learning Strategies: Bridge-Building between Fields. Trends Cogn Sci. 2018 Jul;22(7):651-665. doi: 10.1016/j.tics.2018.04.003.

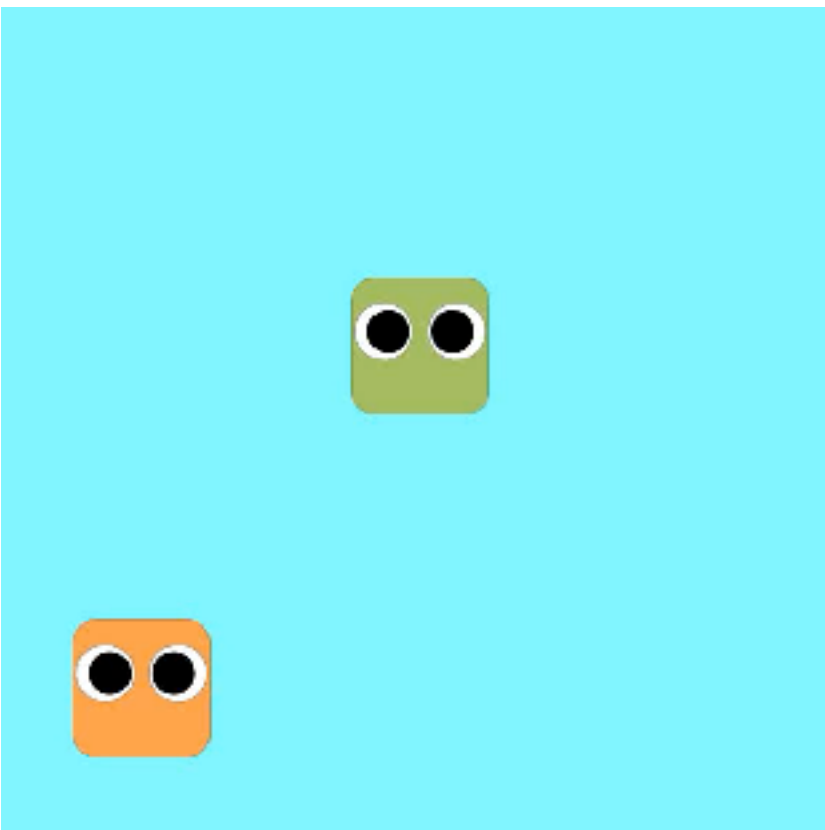


Aplin, L. M., Farine, D. R., Morand-Ferron, J., Cockburn, A., Thornton, A., & Sheldon, B. C. (2015). Experimentally induced innovations lead to persistent culture via conformity in wild birds. Nature, 518(7540), 538-541.

Cognitive Complexity

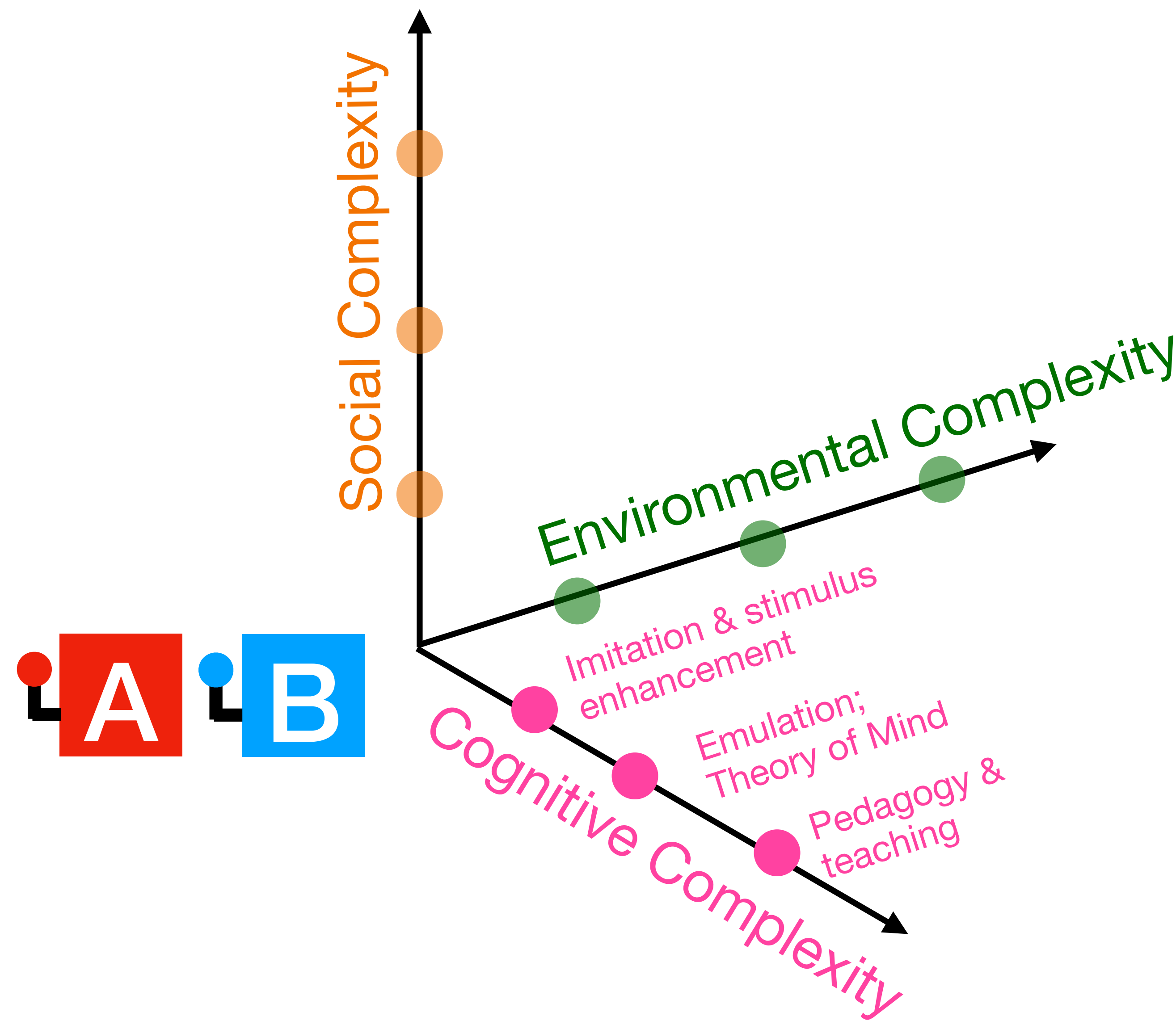


Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *The American Journal of Psychology*, 57, 243–259.

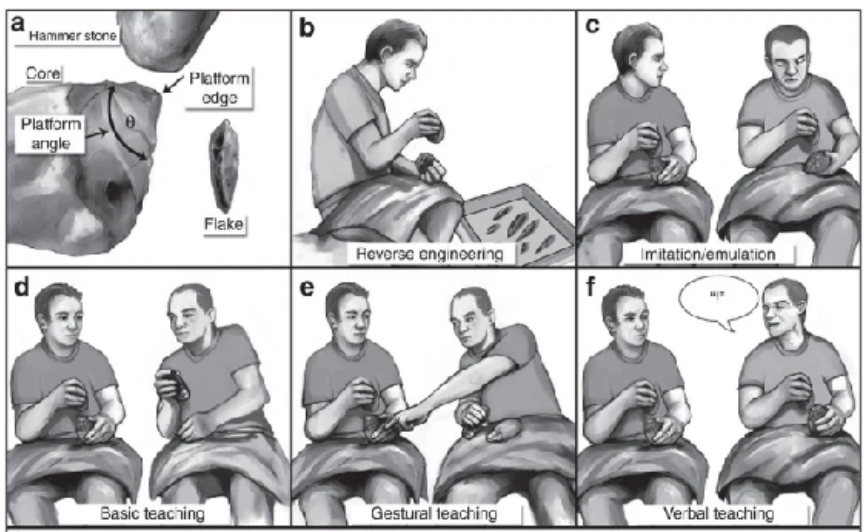


Kanakogi, Y., Miyazaki, M., Takahashi, H. *et al.* (2022) Third-party punishment by preverbal infants. *Nat Hum Behav* 6, 1234–1242.

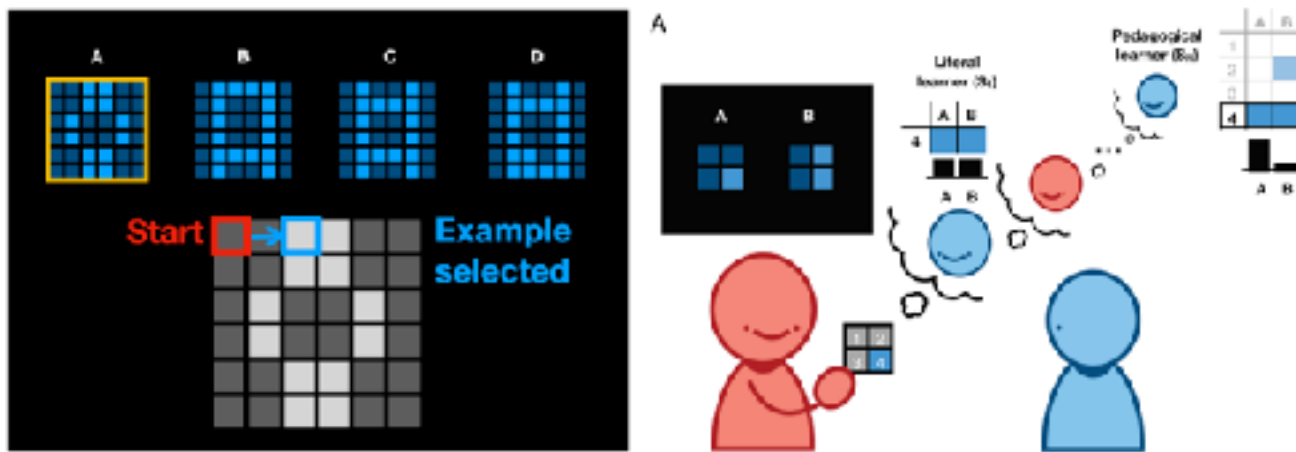
Cognitive Complexity



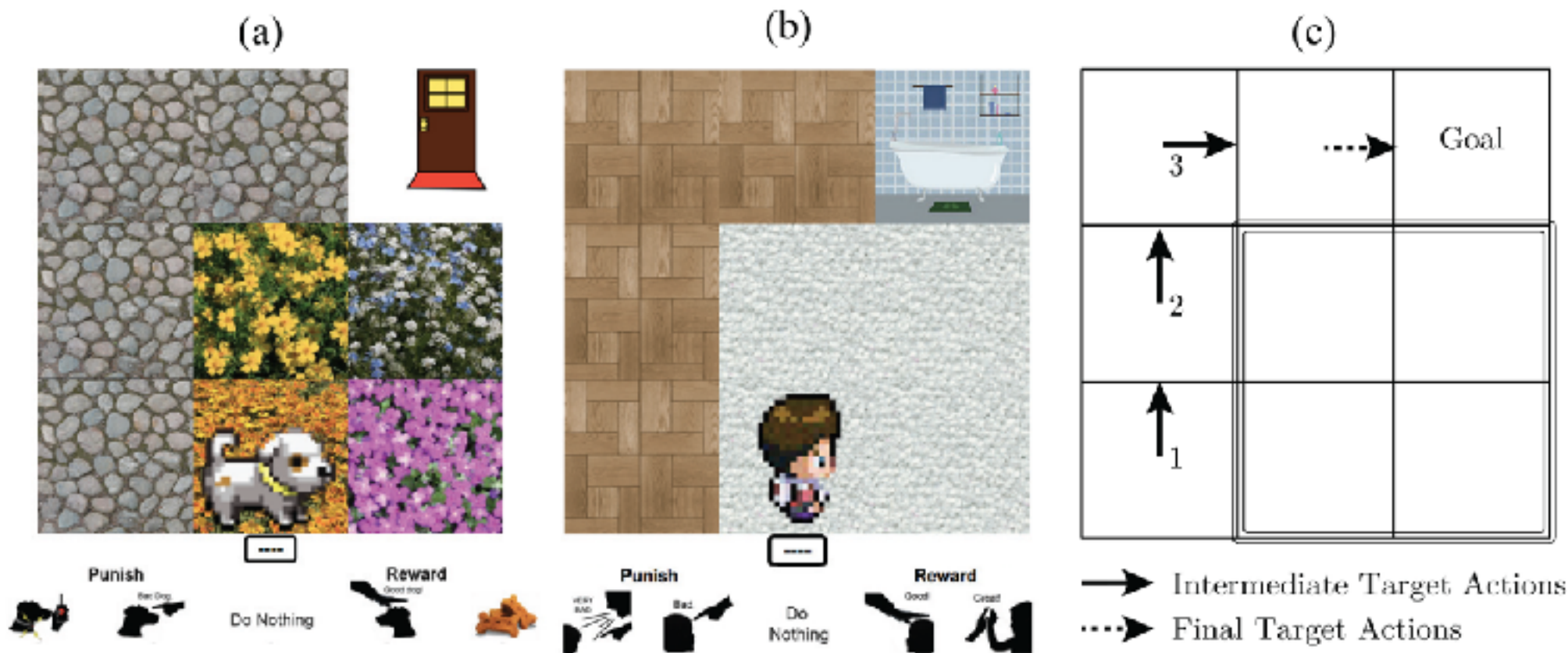
Chandra, K., Li, T. M., Tenenbaum, J., & Ragan-Kelley, J. (2023, July). Acting as inverse inverse planning. In *Acm siggraph 2023 conference proceedings* (pp. 1-12).



Morgan et al. (2015) Experimental evidence for the co-evolution of hominin tool-making teaching and language. *Nat Commun* 6, 6029.

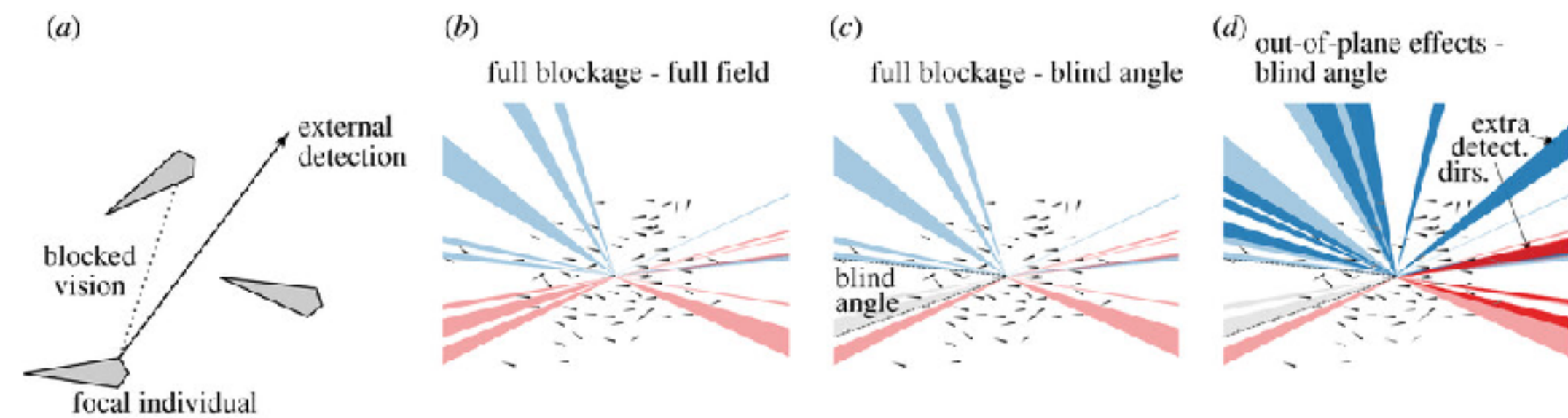
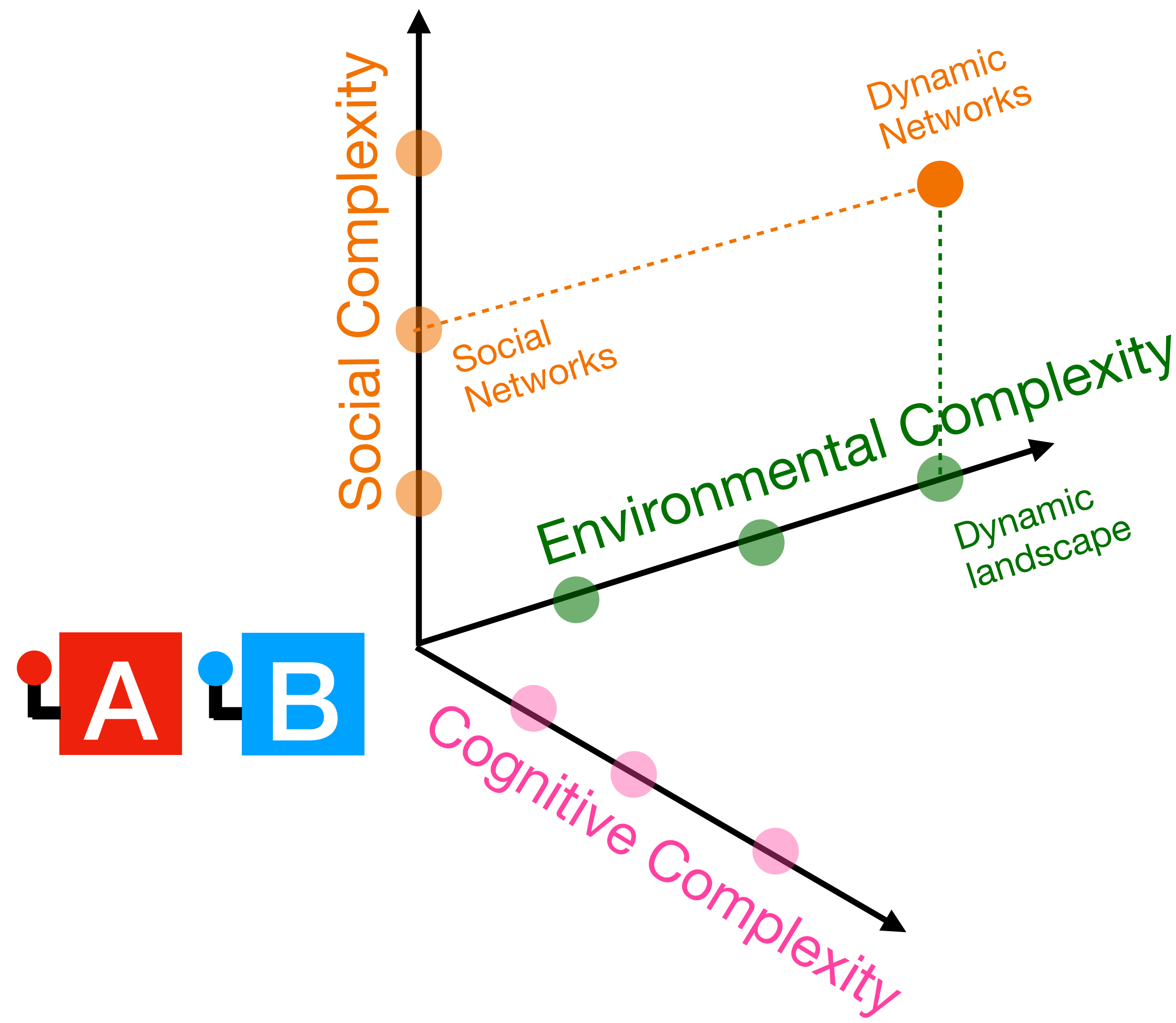


Vélez et al. (2023) Mentalizing regions and anterior cingulate cortex represent learners' beliefs during teaching. <https://doi.org/10.31234/osf.io/5un89>

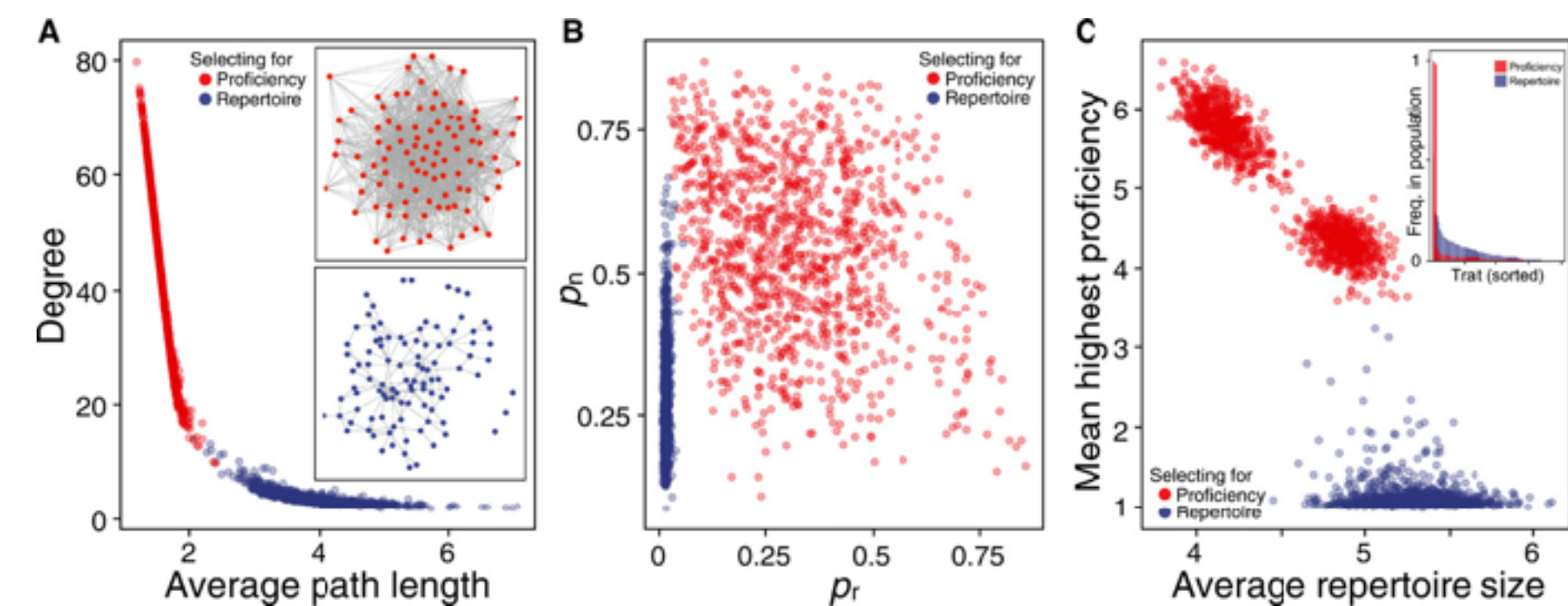


Ho, ... Austerweil (2019). People teach with rewards and punishments as communication, not reinforcements. *Journal of Experimental Psychology: General*, 148(3), 520–549.

Environmental × Social

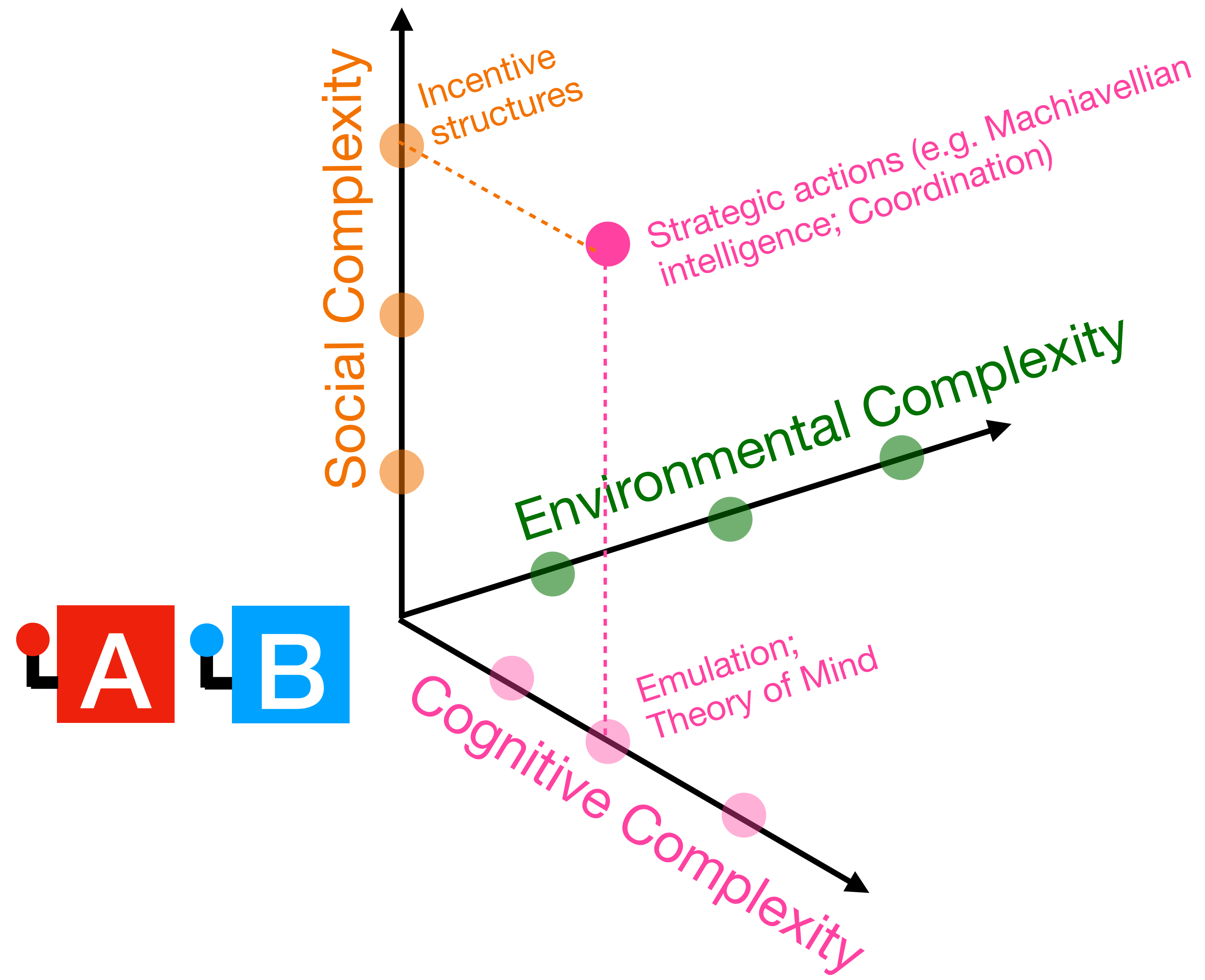


Davidson Jacob D., Sosna Matthew M. G., Twomey Colin R., Sridhar Vivek H., Leblanc Simon P. and Couzin Iain D. 2021 Collective detection based on visual information in animal groups *J. R. Soc. Interface*. **18**20210142



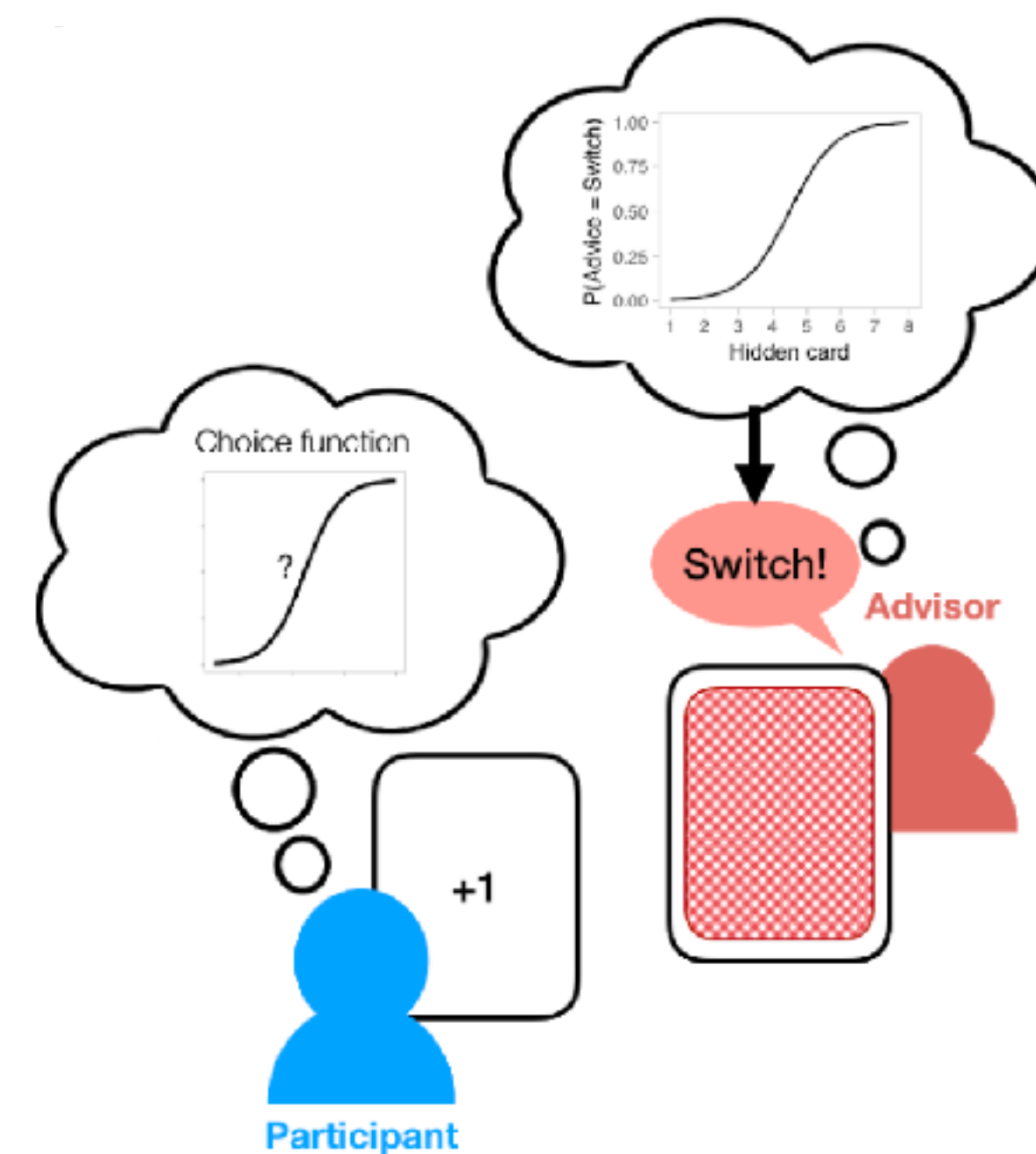
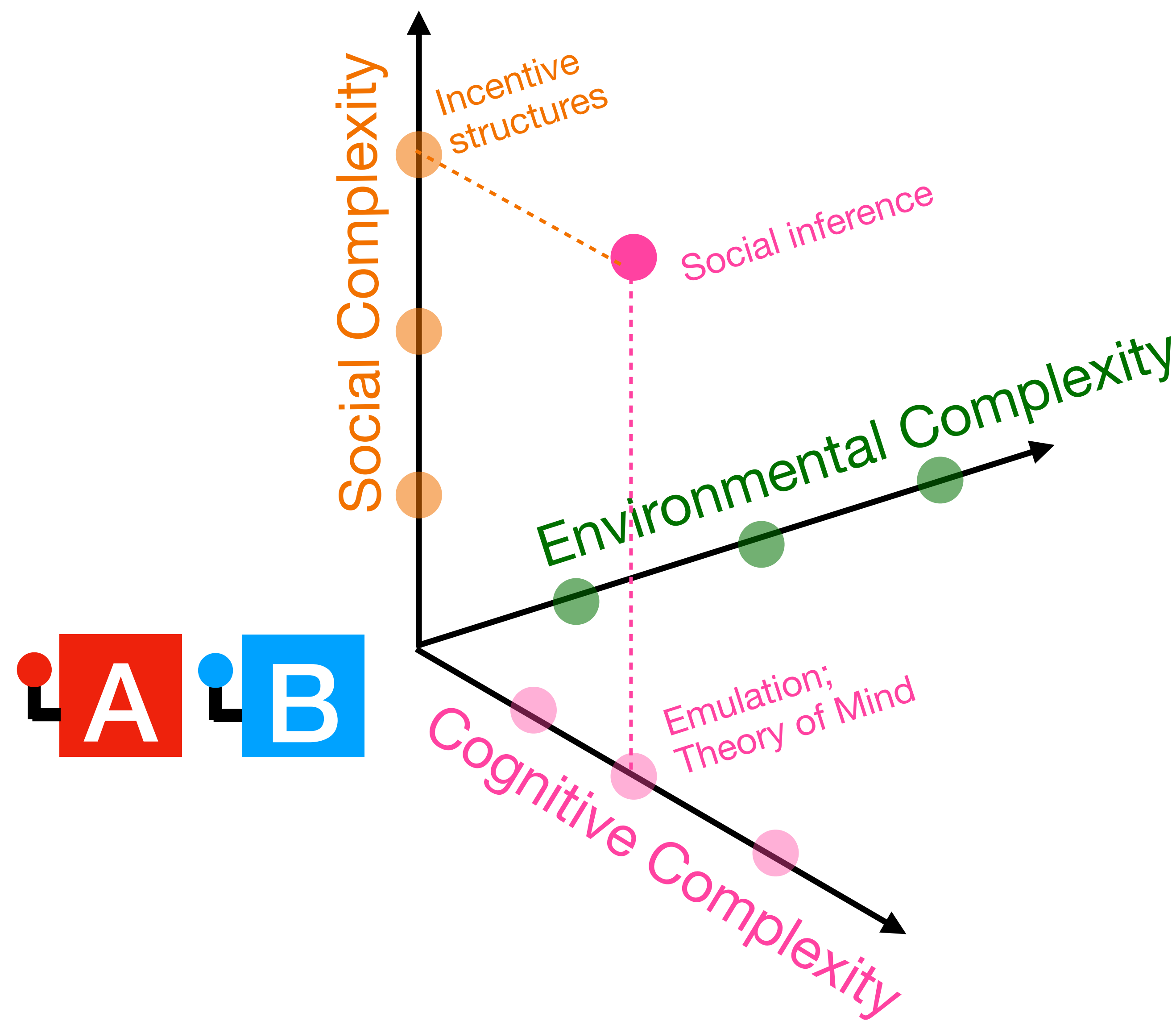
Marco Smolla, Erol Akçay, Cultural selection shapes network structure. *Sci. Adv.* **5**, eaaw0609 (2019). DOI: [10.1126/sciadv.aaw0609](https://doi.org/10.1126/sciadv.aaw0609)

Cognitive × Social

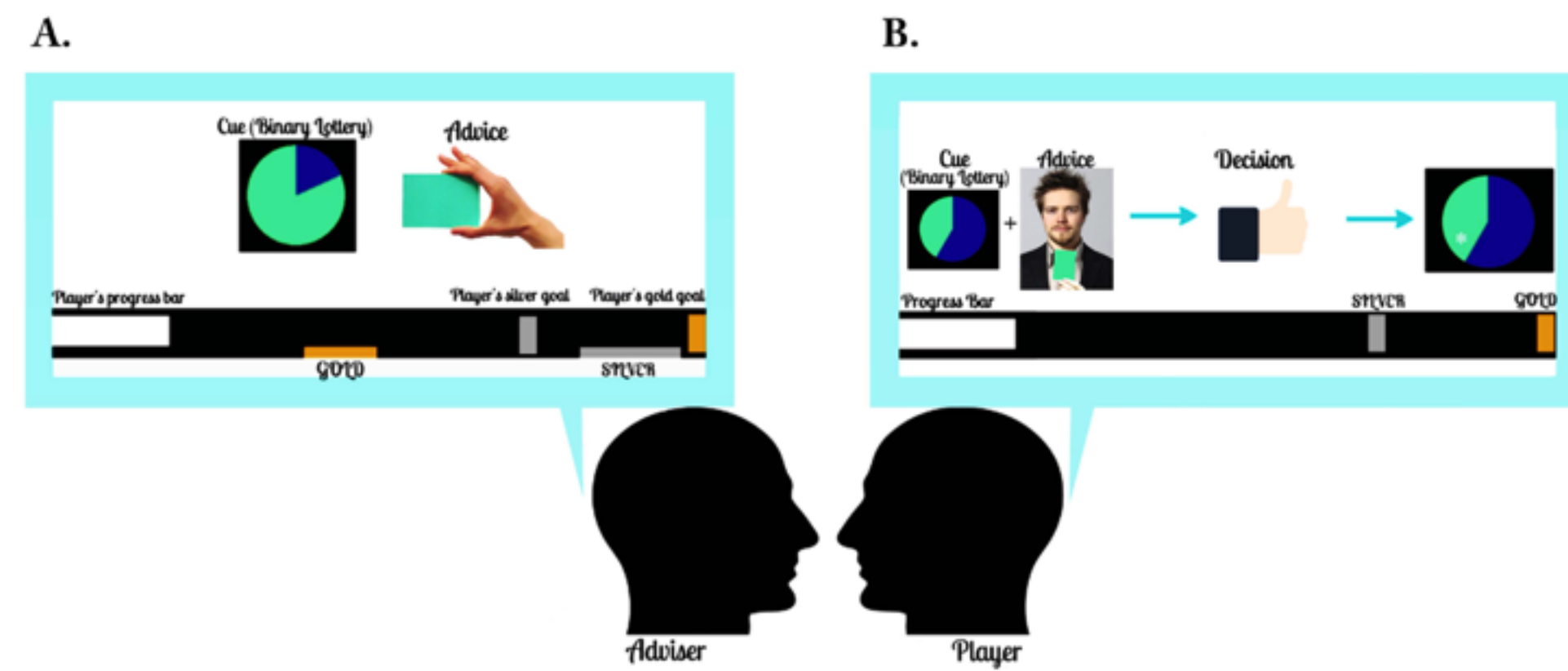


Whiten, A., & Byrne, R. W. (1988). Tactical deception in primates. *Behavioral and brain sciences*, 11(2), 233-244.

Cognitive × Social

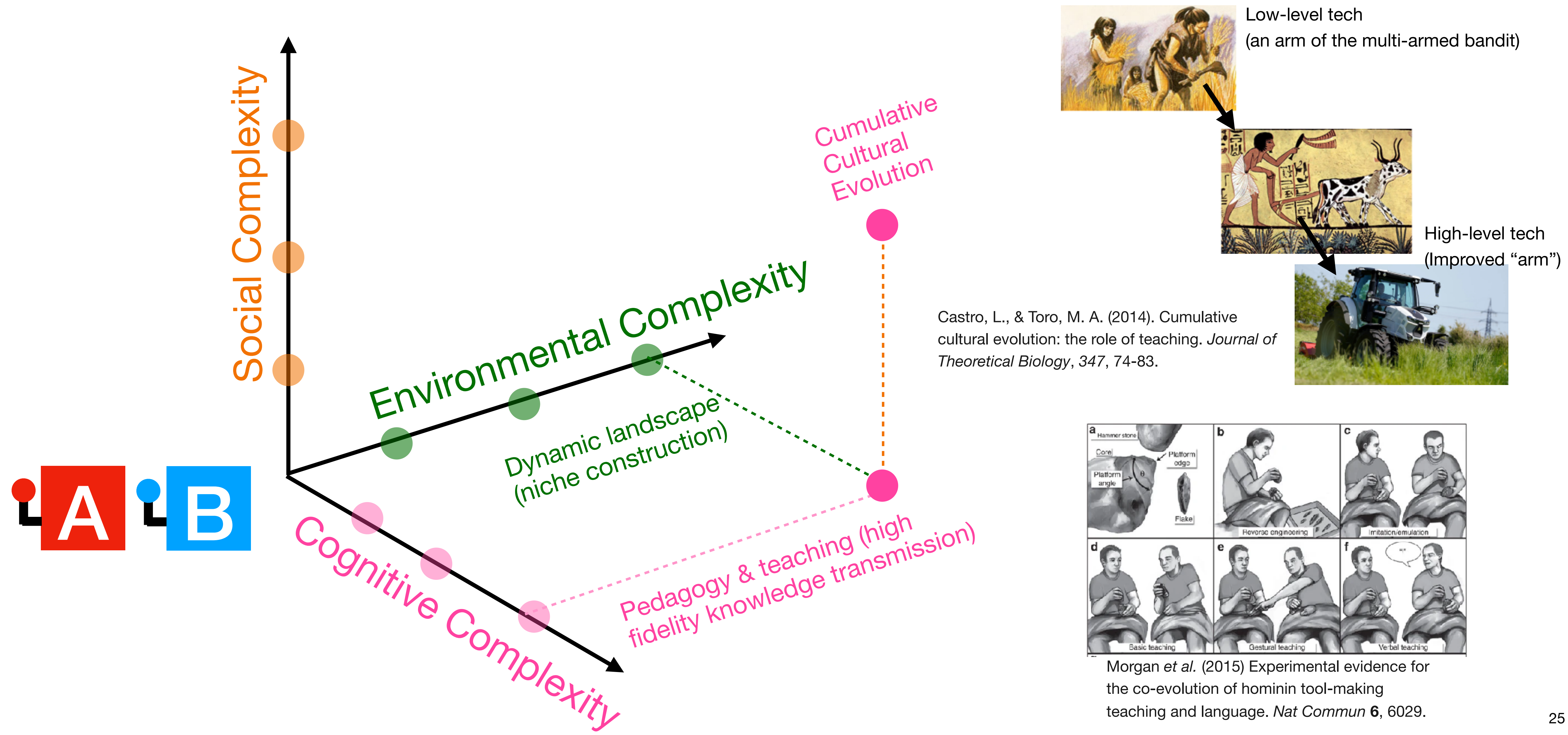


Vélez, N., & Gweon, H. (2019). Integrating incomplete information with imperfect advice. *Topics in cognitive science*, 11(2), 299-315.

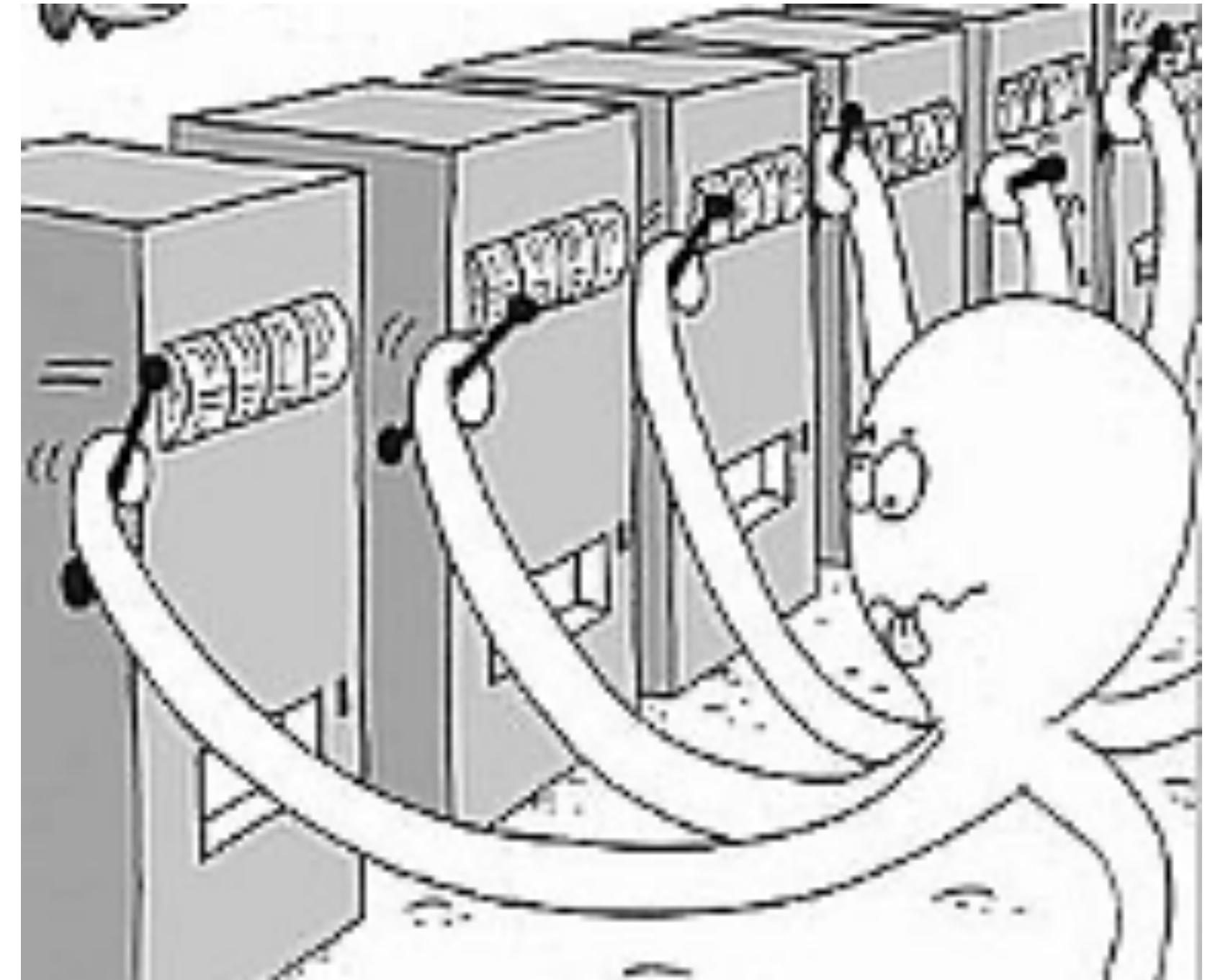
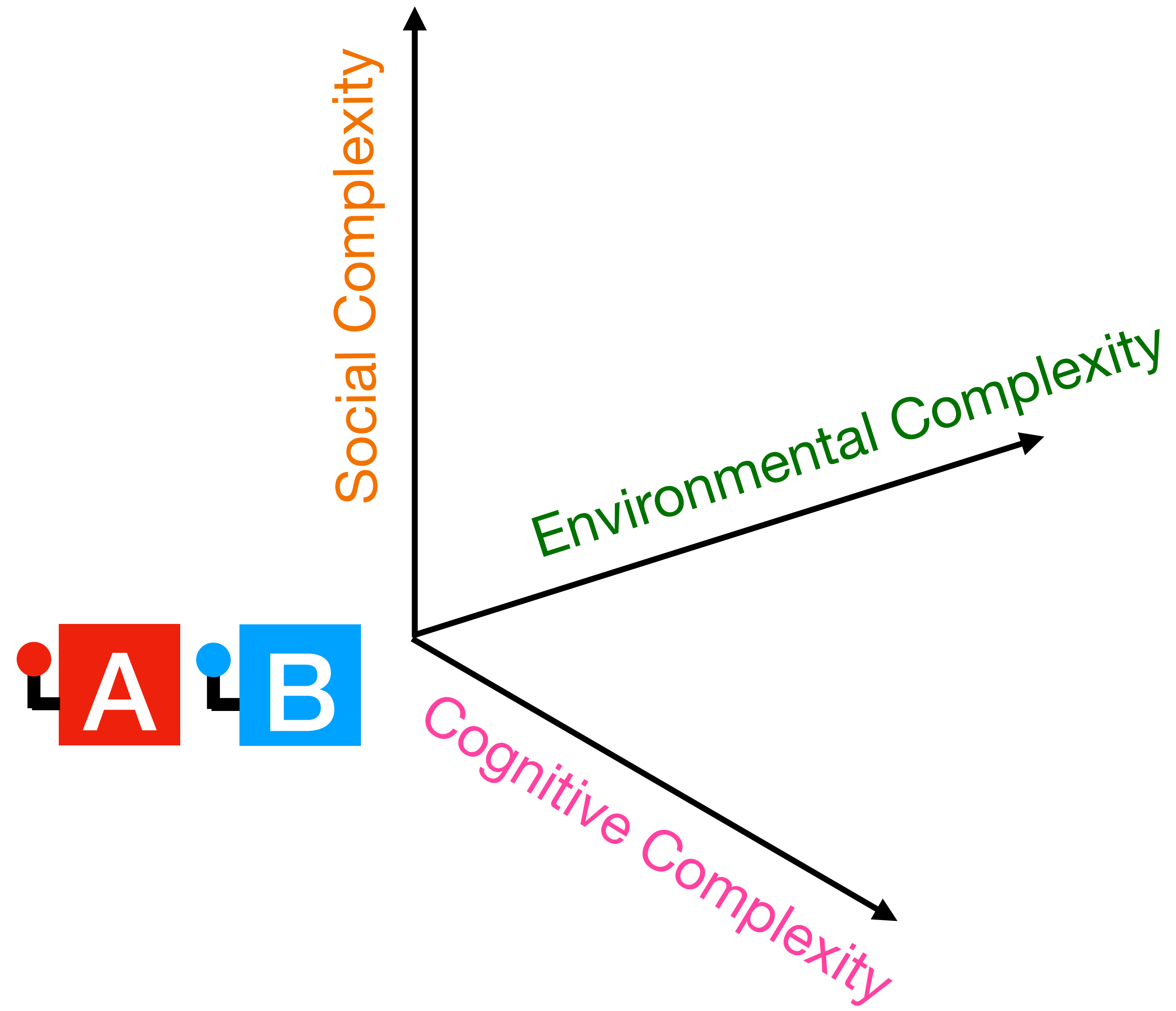


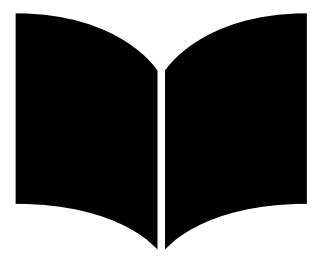
Diaconescu et al. (2014). Inferring on the intentions of others by hierarchical Bayesian learning. *PLoS Comput Biol.* 4;10(9):e1003810

Environmental × Social × Cognitive



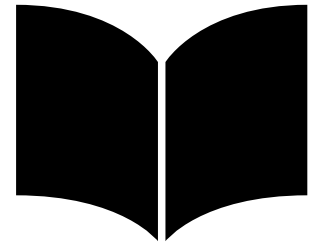
Multi-Armed Bandit Problem





Live demonstration Fishing game!

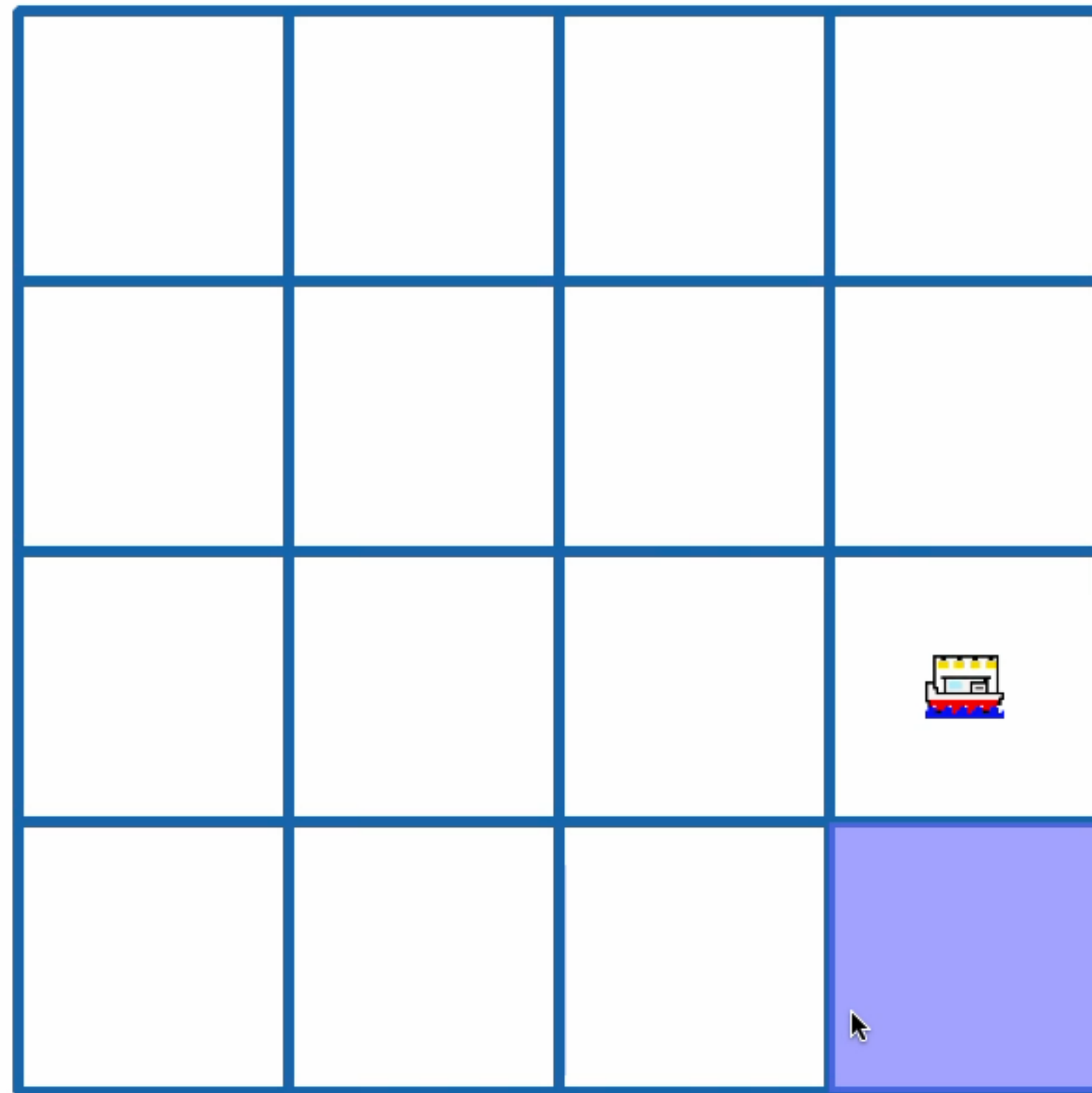




Notebook

<https://cosmos-konstanz.github.io/notebooks/tutorial-1-n-armed-task.html#live-demonstrations>

(1) Individual learning task

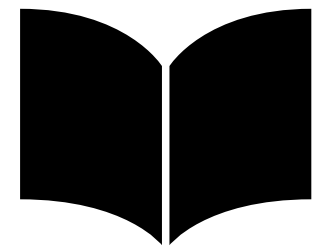


Remaining clicks: 10

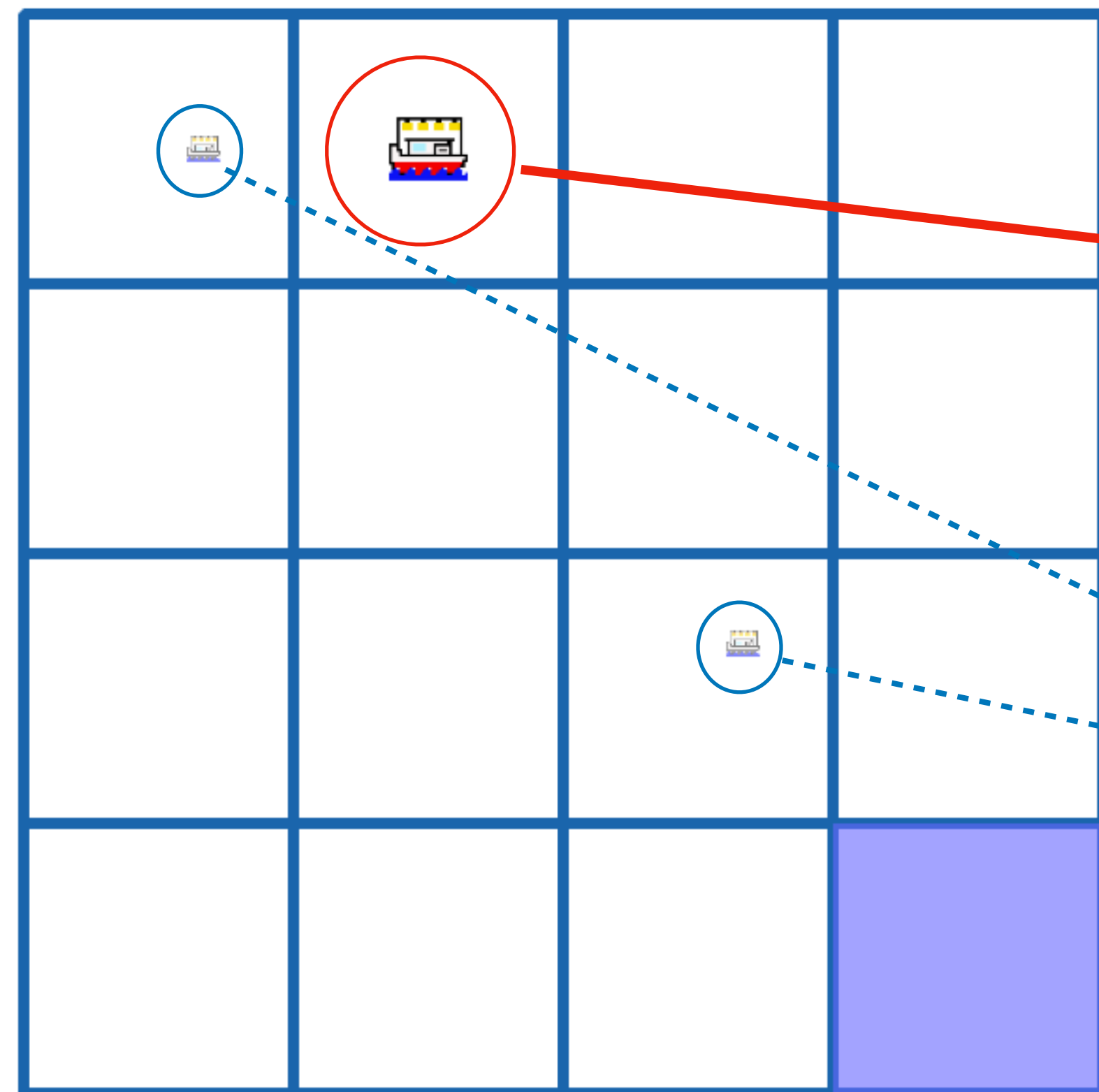


Q:

How would you learn which options provide the best rewards and how you navigate the explore-exploit dilemma?



(2) Social learning task (no competition)

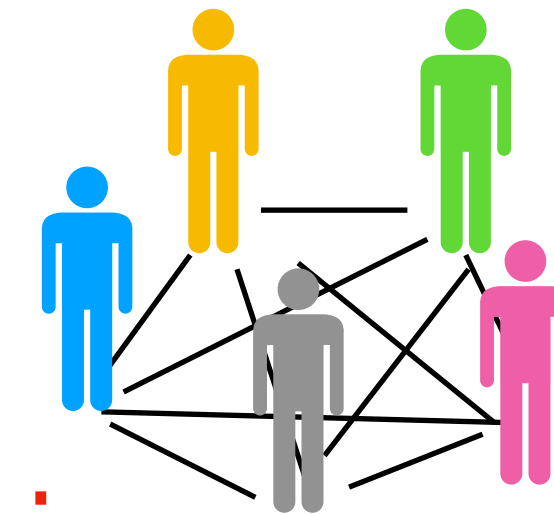


Your ship

Other players' ship

You will be able to observe the actions of other players, but not see the rewards they earn.

Remaining clicks: 9



Q:

When do you think social learning will outperform individual learning, and when would it fail?

Tutorial structure

- ~~1. Introduction to social learning tasks~~
2. Models of individual and social learning
3. Modeling social cognition using memo
4. Model comparison and robustness

