

Are decisions continuous or binary?

Readings for today

- Sridhar, V. H., Li, L., Gorbonos, D., Nagy, M., Schell, B. R., Sorochkin, T., ... & Couzin, I. D. (2021). The geometry of decision-making in individuals and collectives. *Proceedings of the National Academy of Sciences*, 118(50), e2102157118.

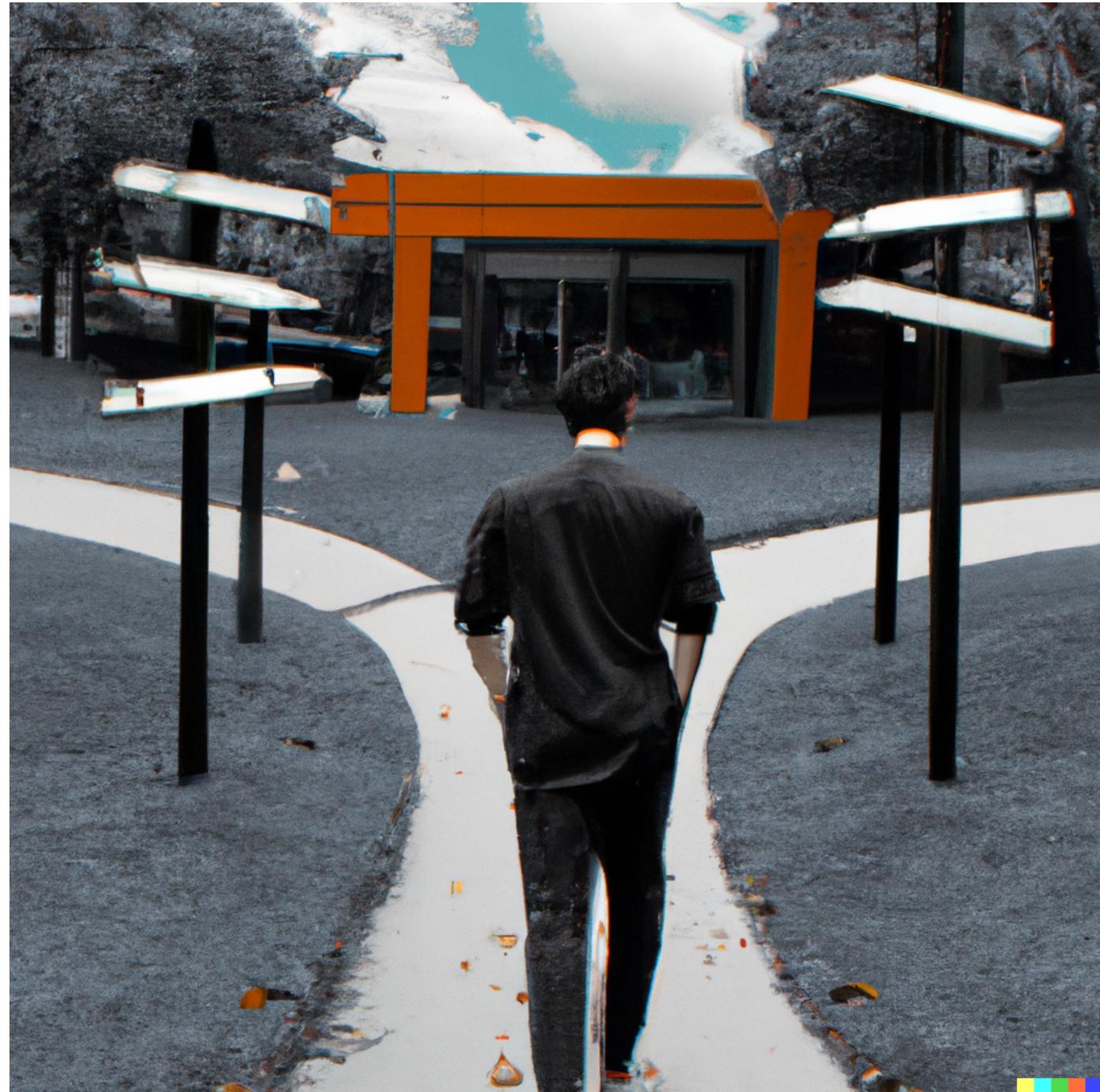
Topics

- Discrete vs. continuous decisions
- Continuous actions as discrete decisions

Discrete vs. Continuous Decisions

How many choices do you really have?

Discrete decisions



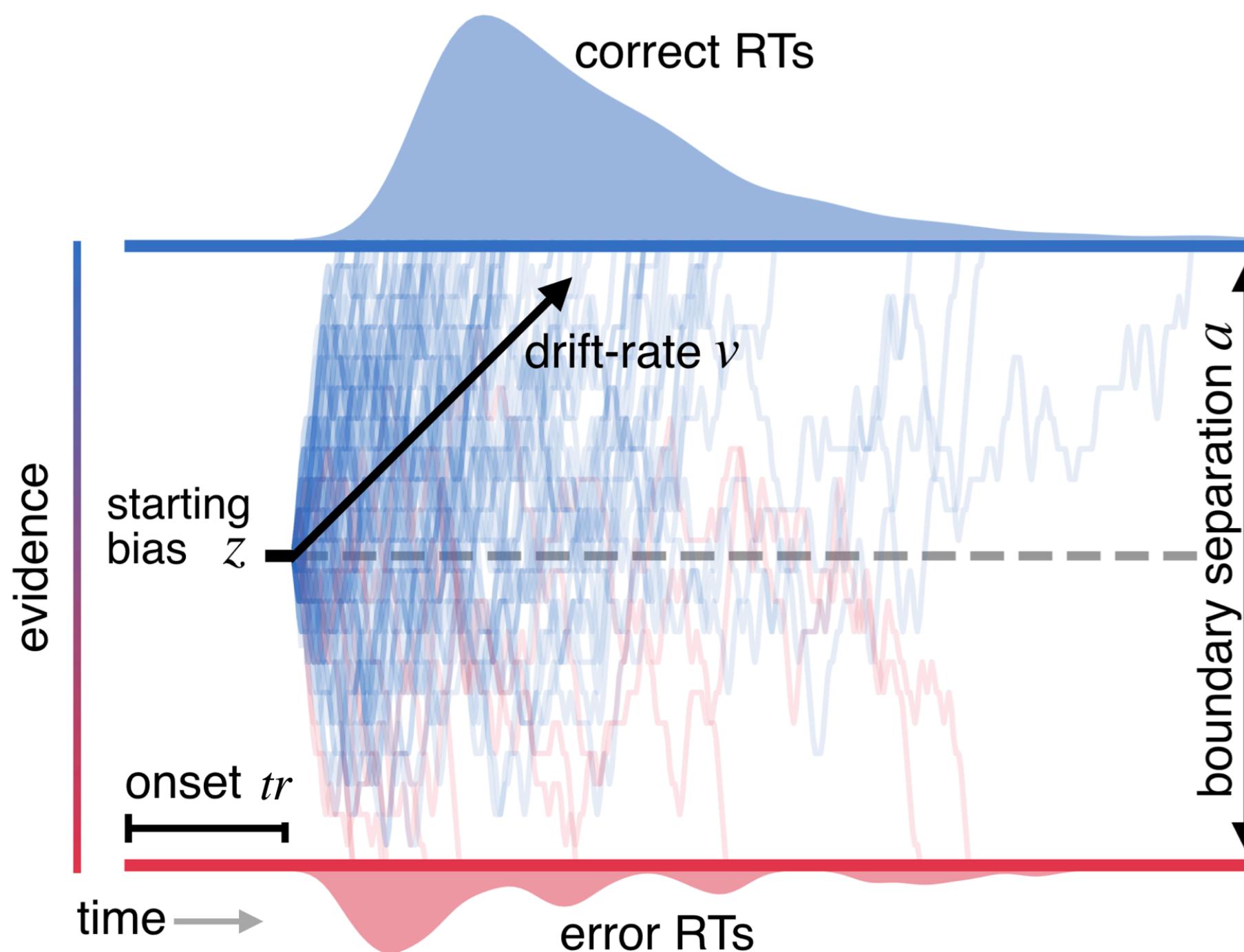
Continuous decisions



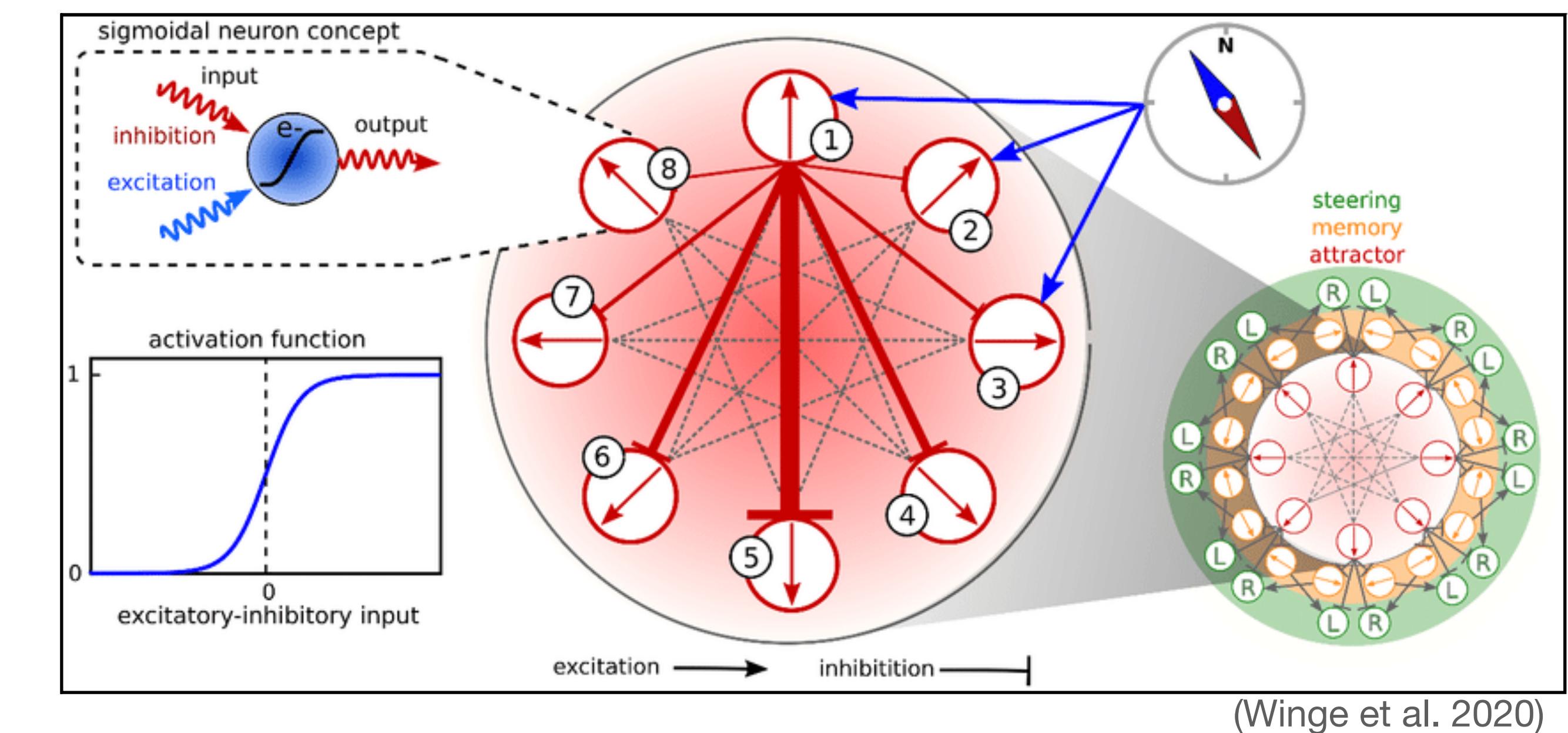
<https://tenor.com/view/davecam-driving-game-gif-14779379>

How many choices do you really have?

Discrete decisions



Continuous decisions



How many choices do you really have?

	Discrete	Continuous
Nature of Decision Variables	Can only take on a finite number of distinct values. These values are often whole numbers.	Can take on any value within a specified range, often lying within a continuous interval.
Decision Space	Isolated points or groups of independent actions (digital).	Infinite number of points or potential actions (analogue).
Complexity	Scales exponentially with size of the decision problem (e.g., number of actions, value estimates).	Complexity does not scale with size of problem thanks to calculus-based approaches.
Solution Approaches	SPRT-style models, dynamic programming (RL), decision trees.	Calculus-based optimization, linear programming, gradient methods.
Examples	Selecting a YouTube channel, choosing a mode of transportation, buying produce.	Choosing how much water to pour, steering while driving,

Continuous actions as discrete decisions

Insect navigation: a continuous problem?

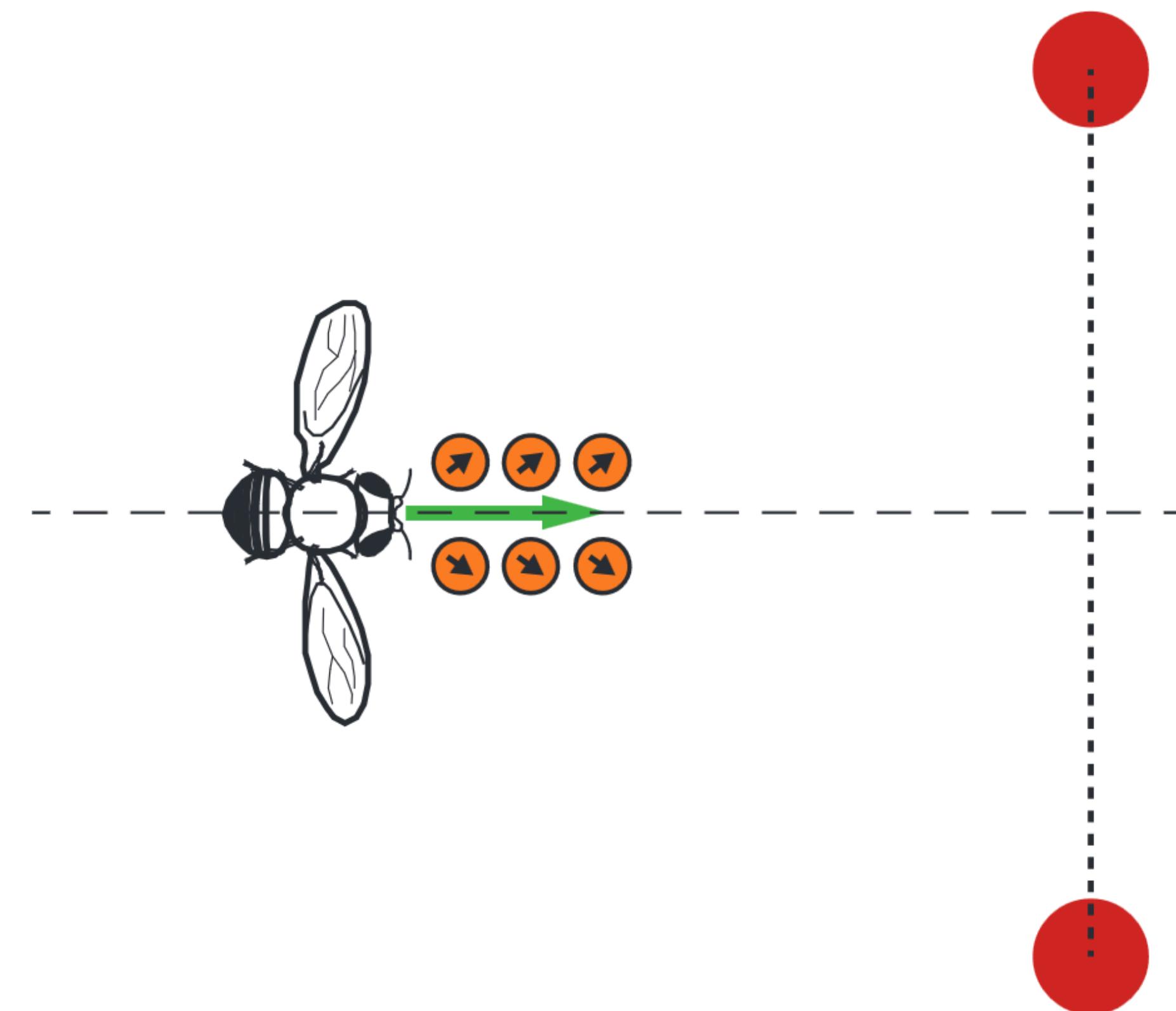
Drosophila



https://en.wikipedia.org/wiki/Drosophila_melanogaster

Xi En Cheng et al (2015),
PLoS ONE,
DOI : 10.1371/journal.pone.0129657

The navigation problem



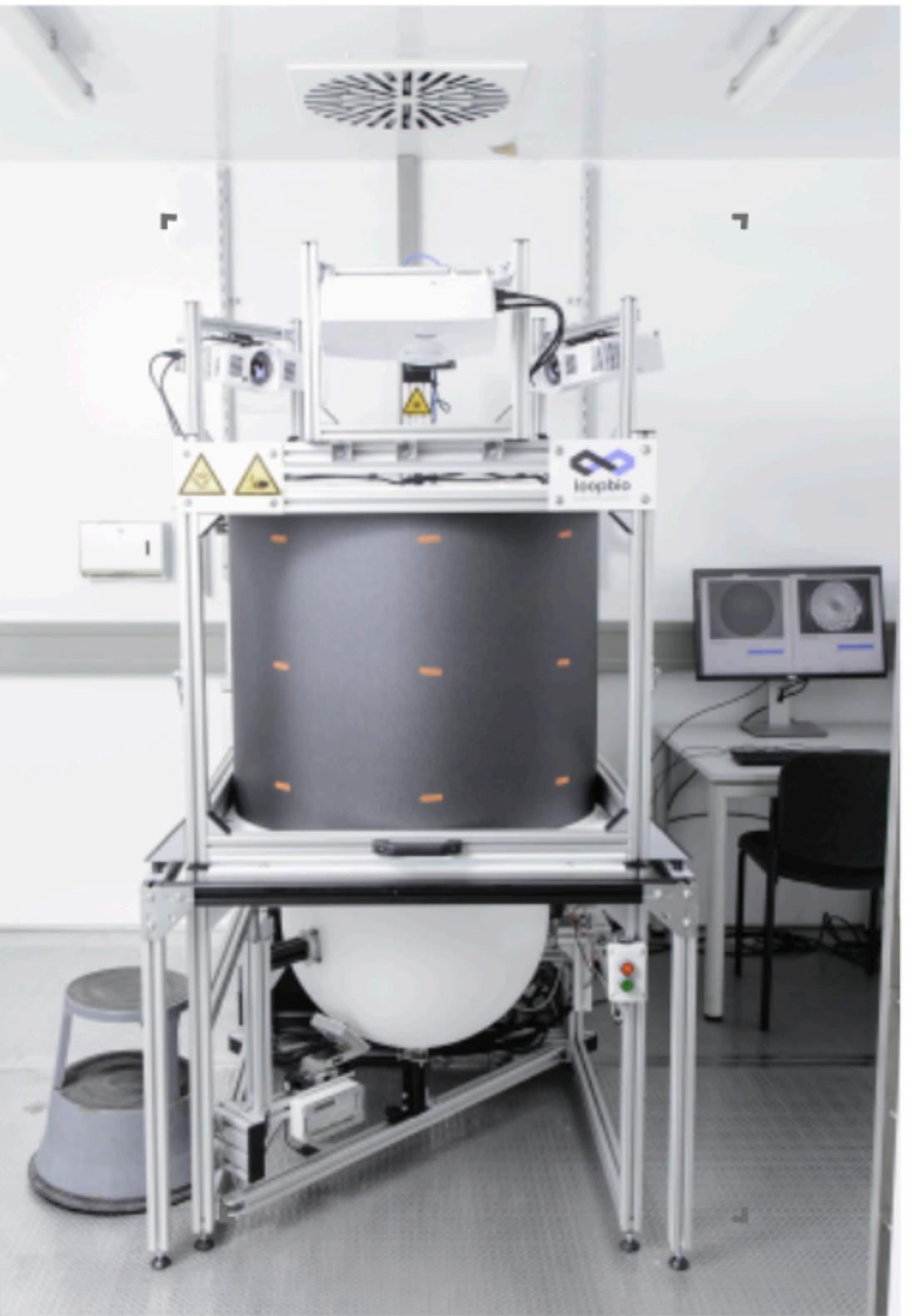
When approaching two targets, the fly must make a choice to approach only one.

Two options for doing this:

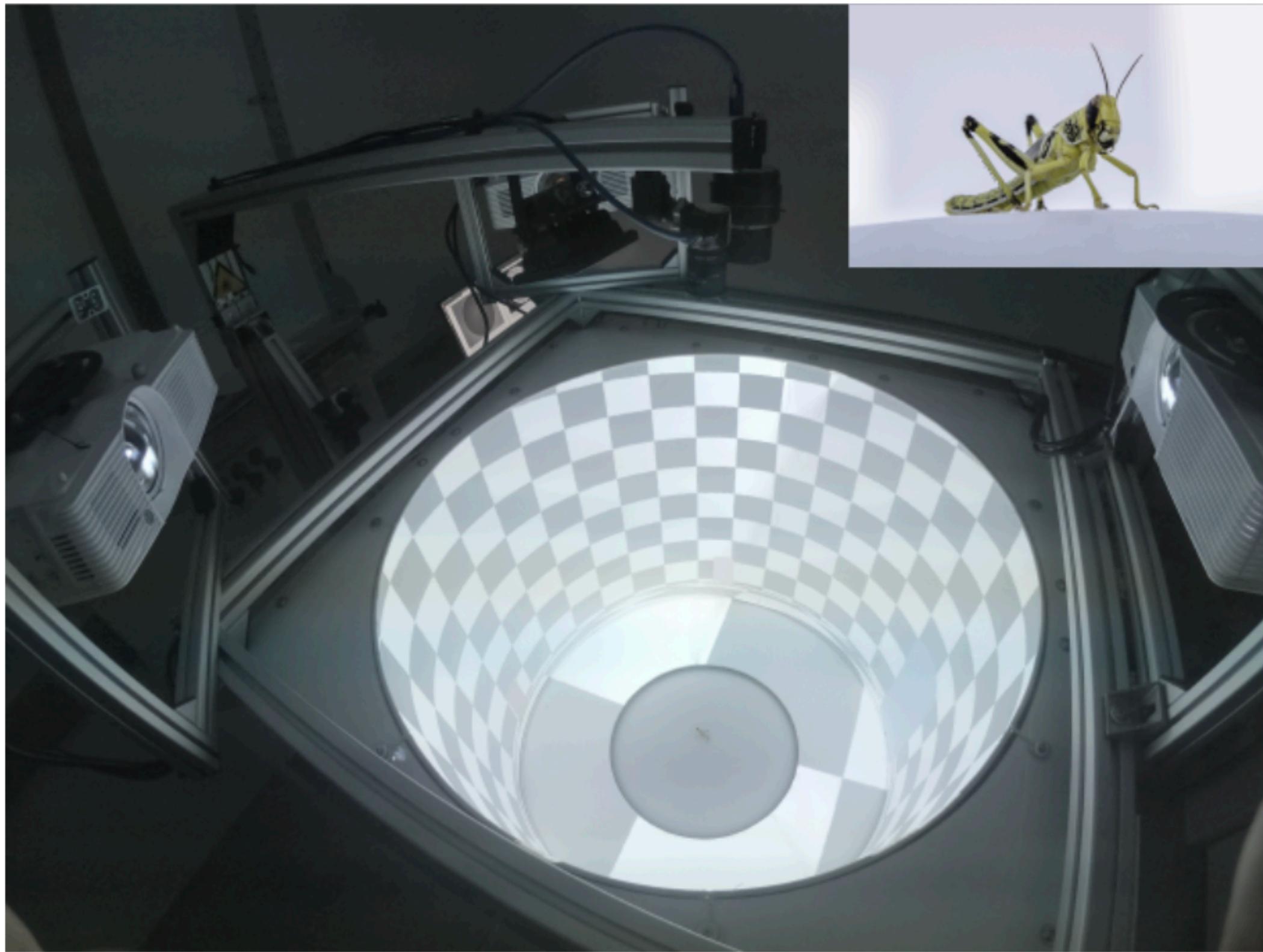
- Continuous vector averaging
- Discrete state shifts

Insect virtual reality

A
Front global view



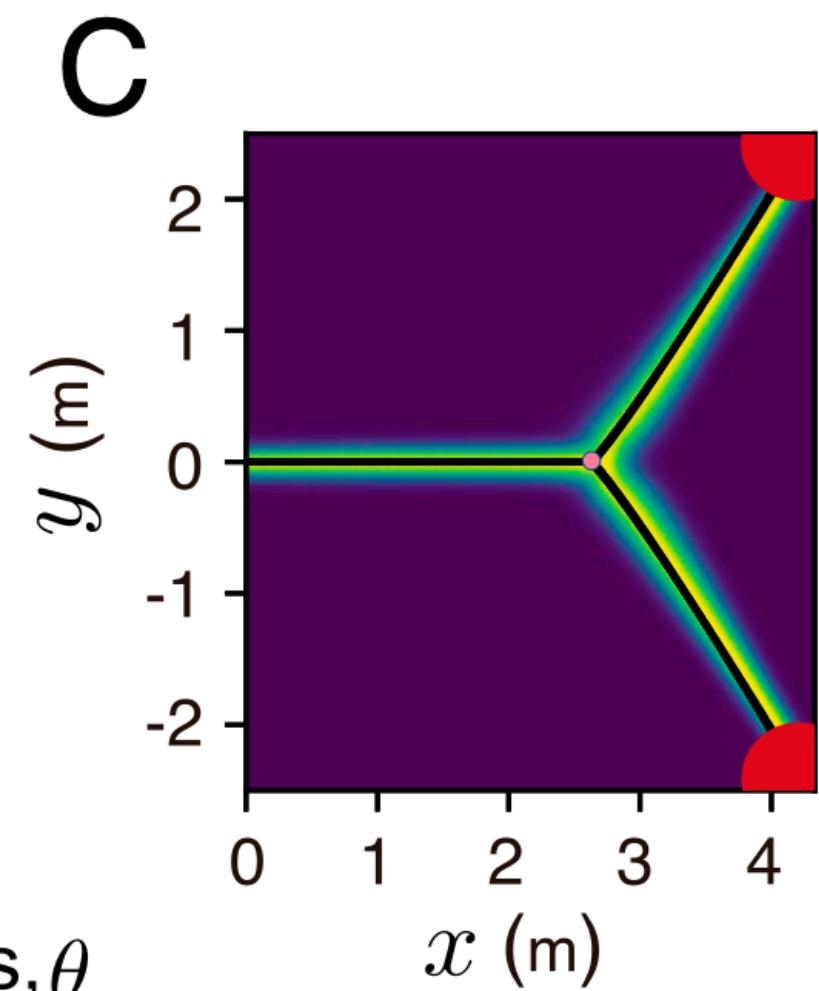
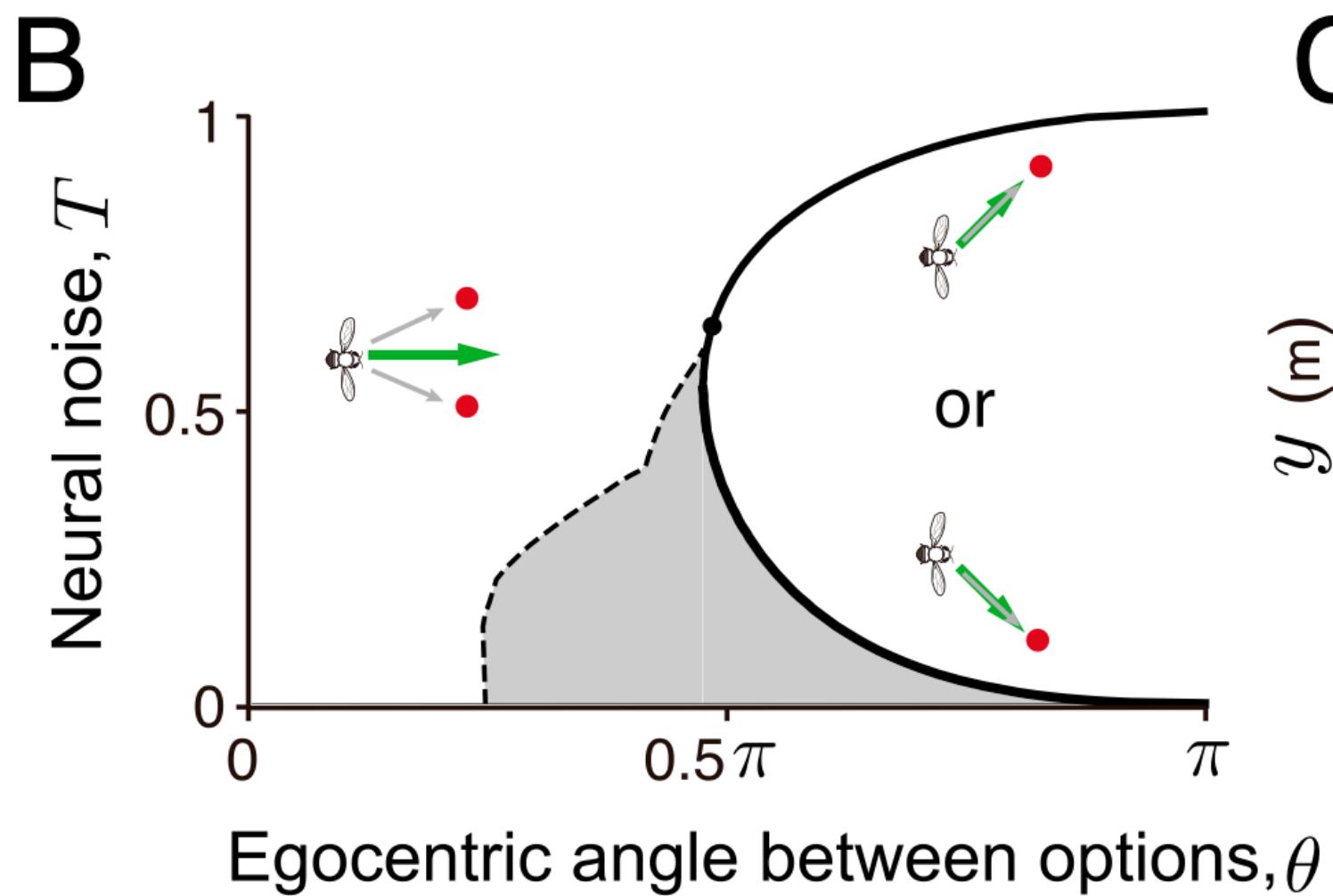
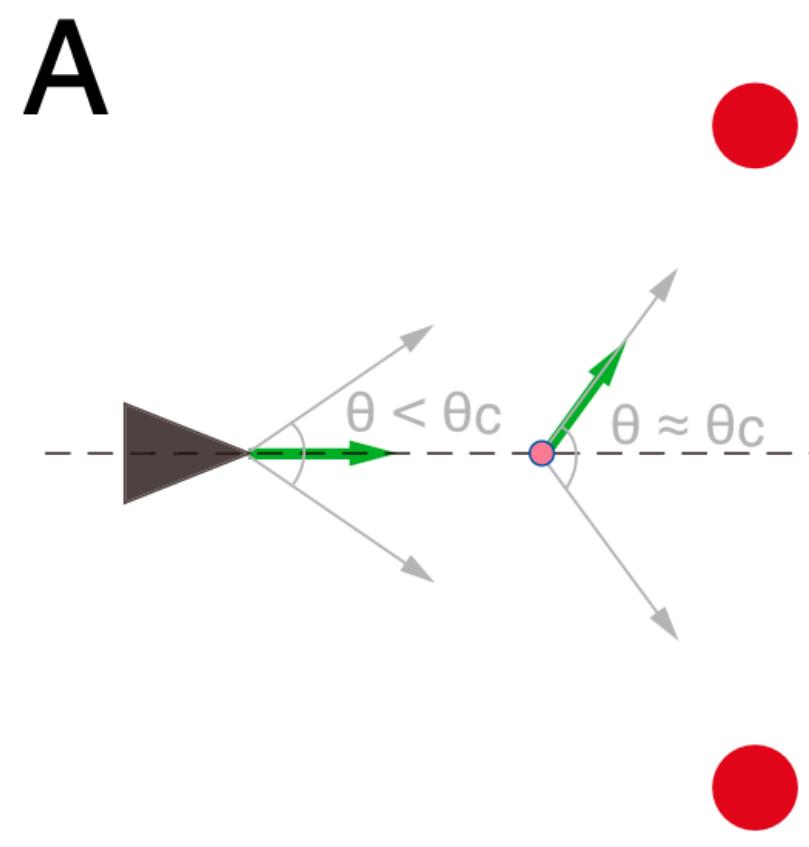
B
Top view



The two choice problem

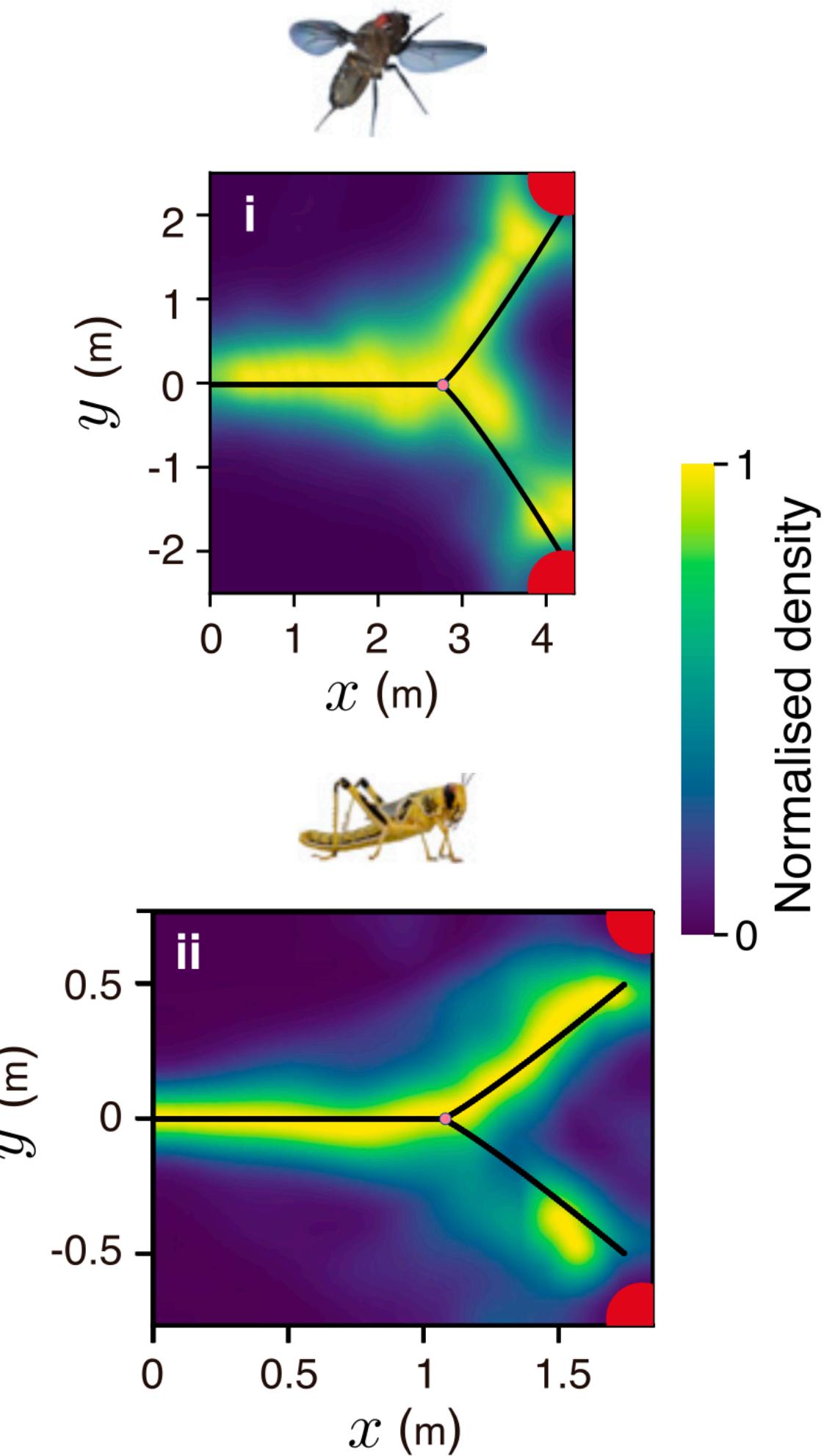
Model

→ velocity vector
→ directions to available targets



Insects move in the average angle to each targets, θ , until a critical angular threshold is reached, θ_C . The decision is made to go to the target with the smallest angle.

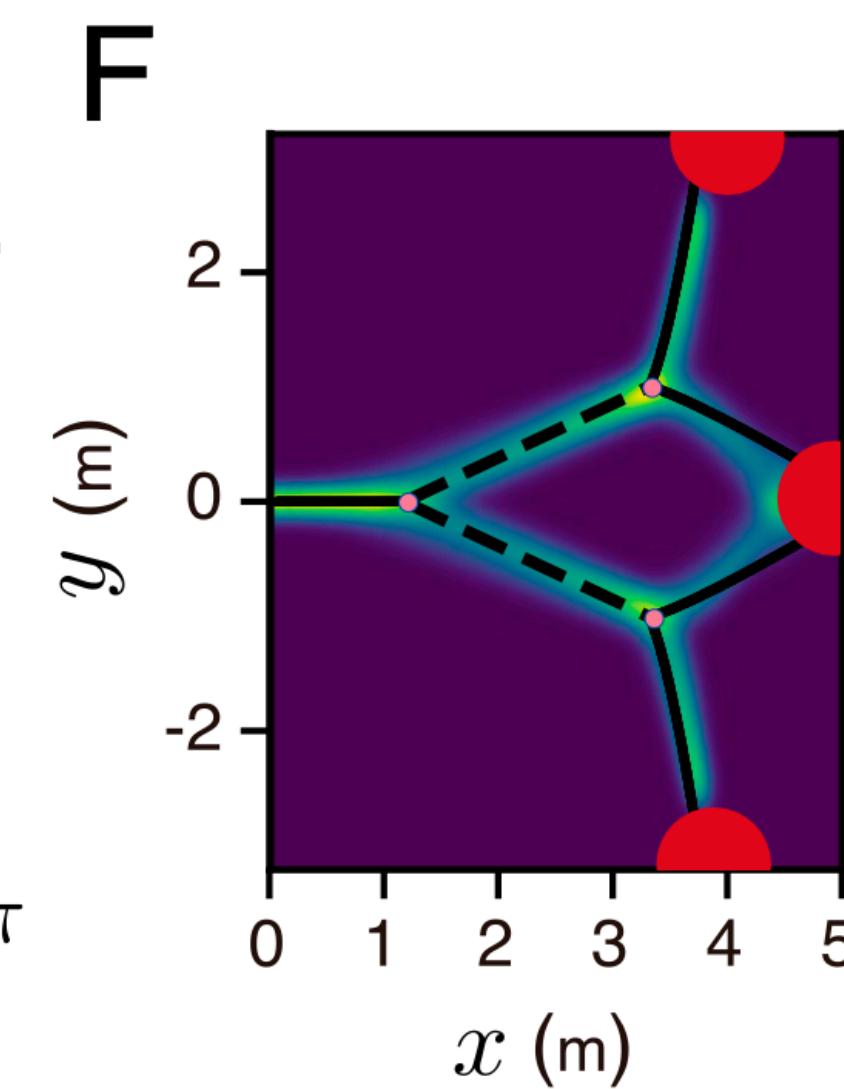
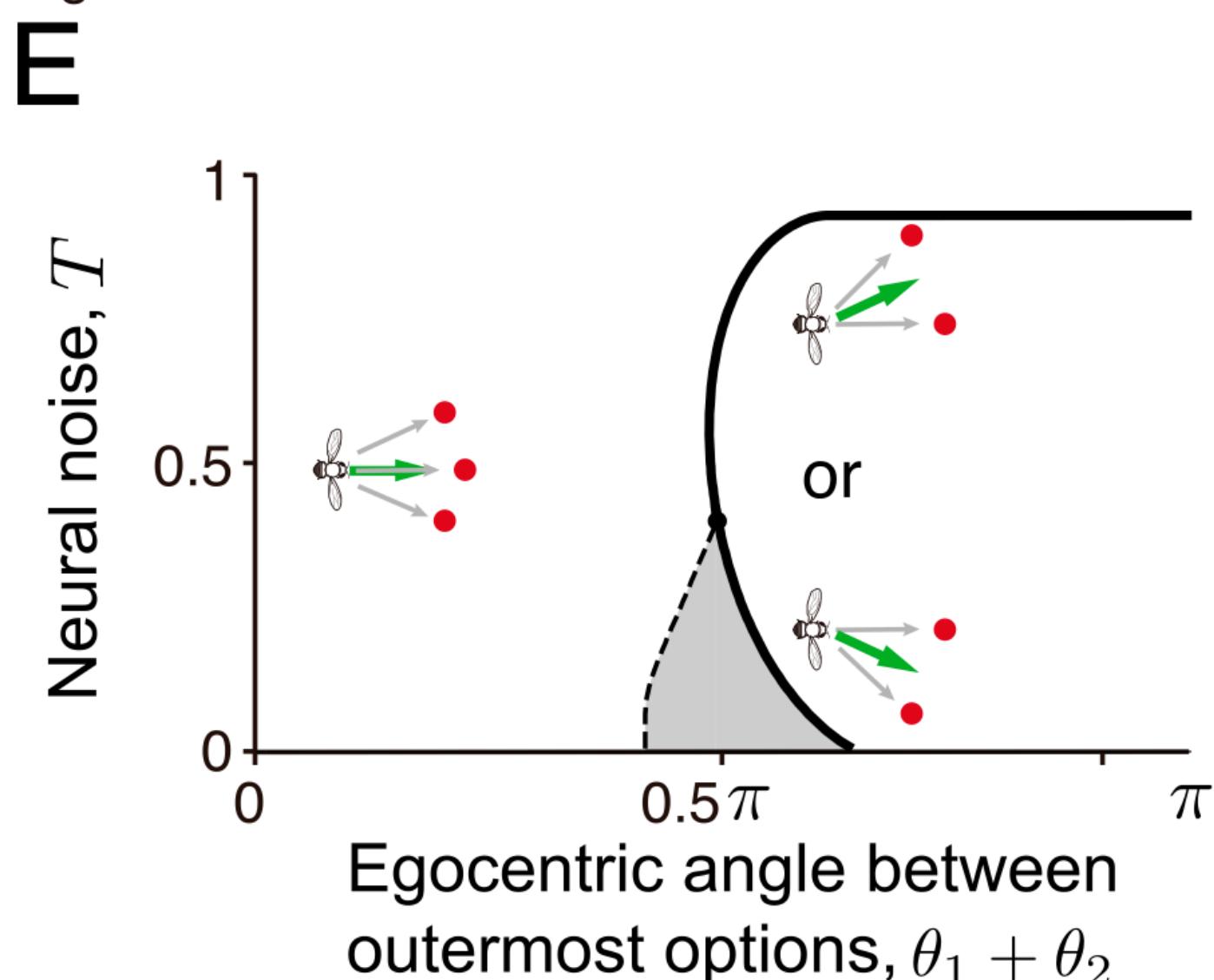
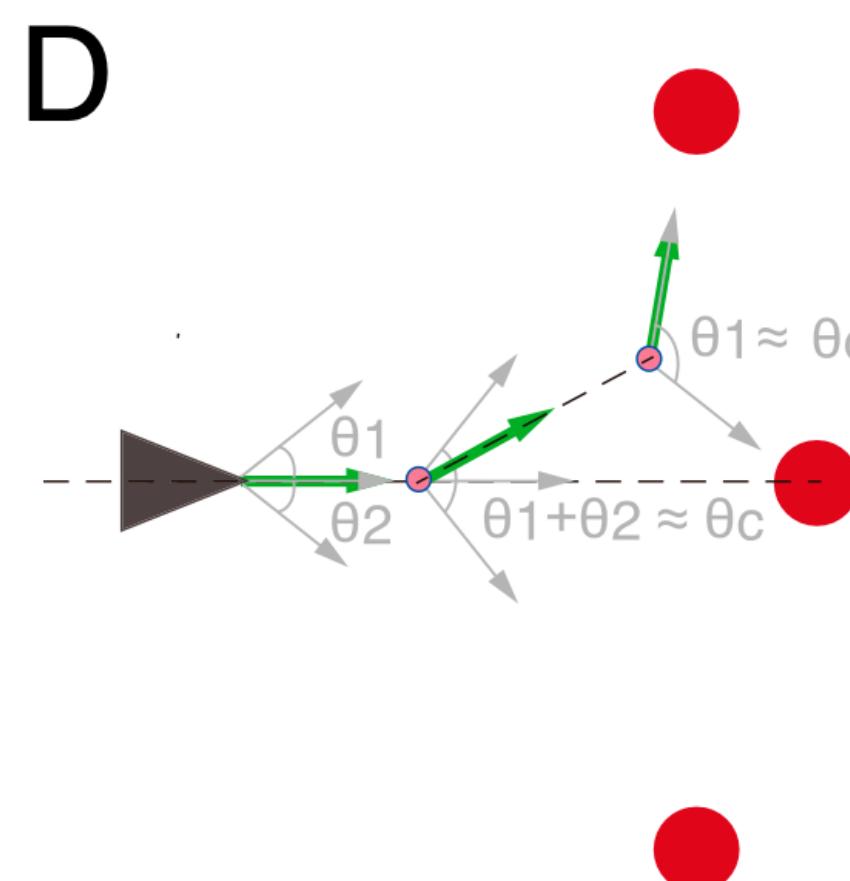
Data



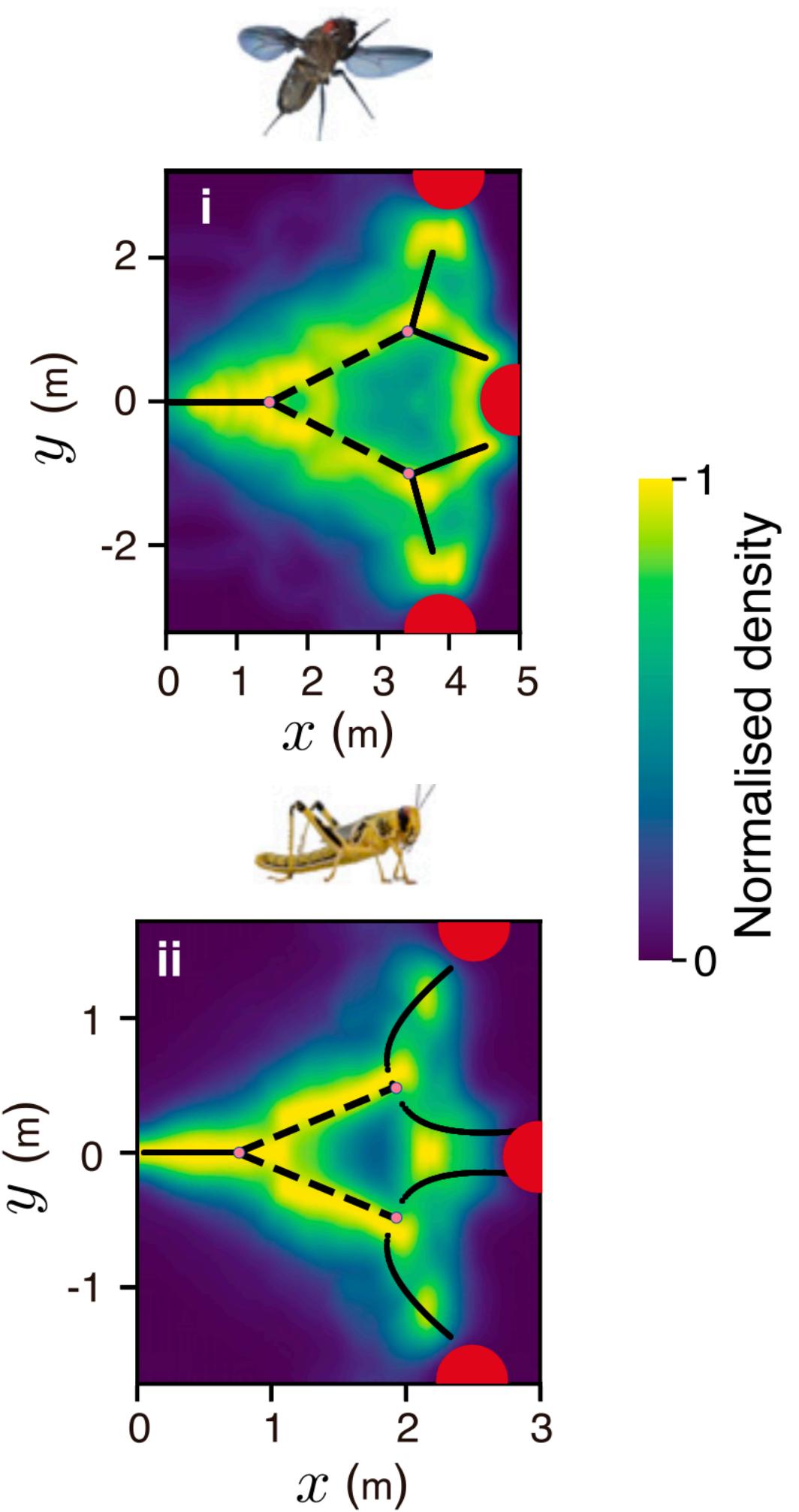
The three choice problem

Model

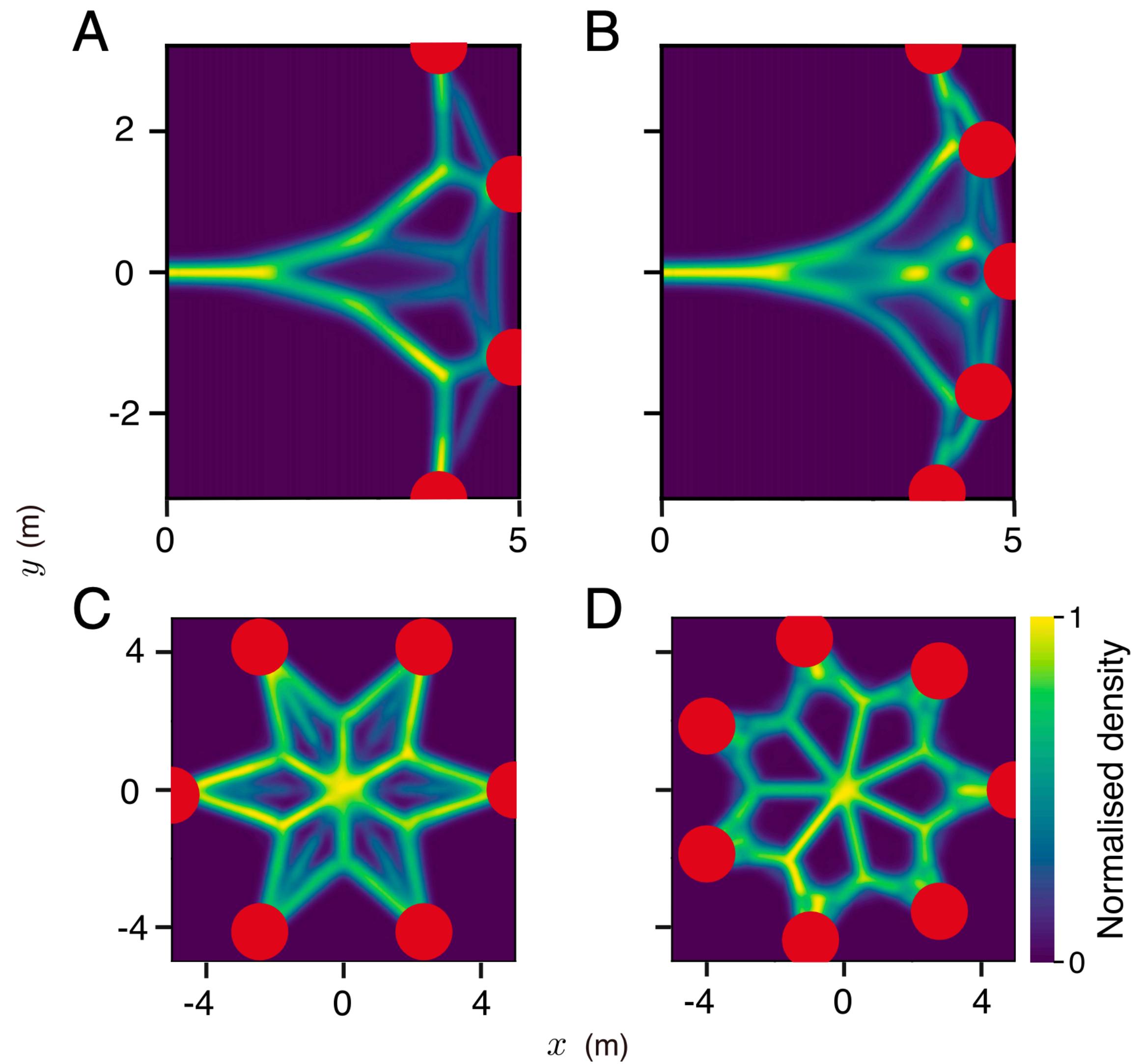
→ velocity vector
→ directions to available targets



Data



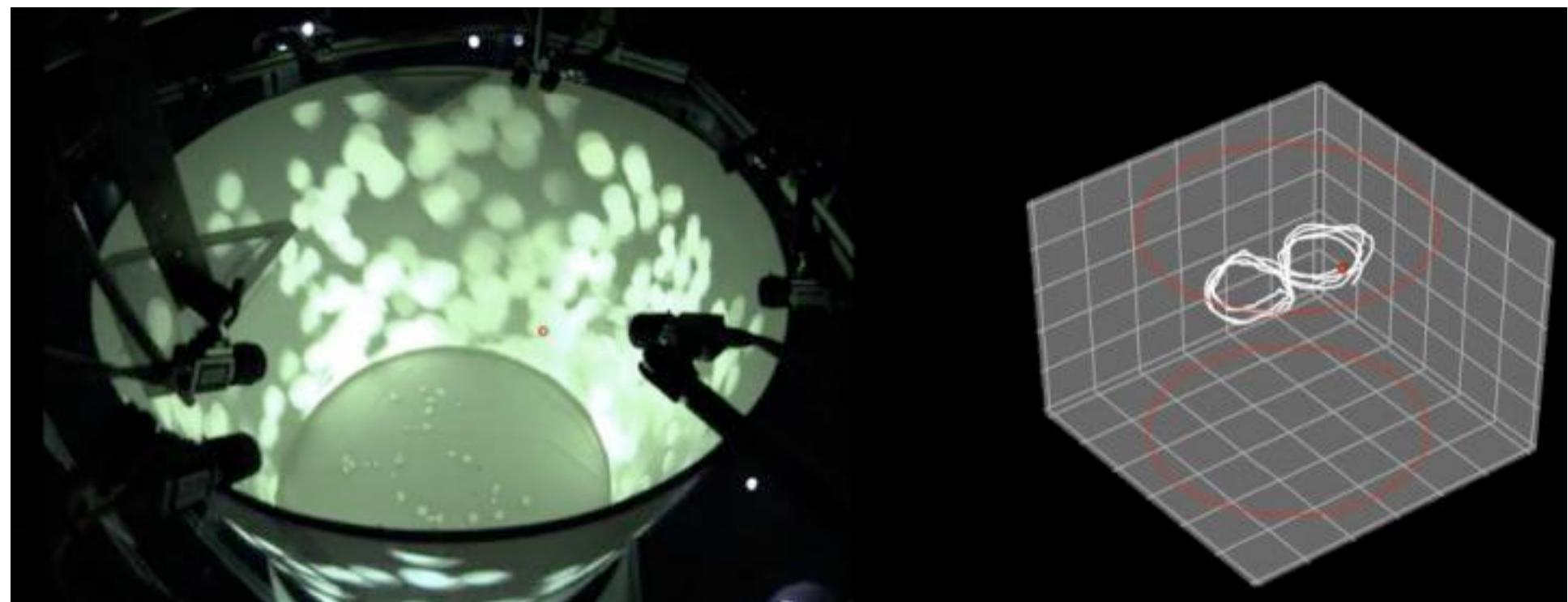
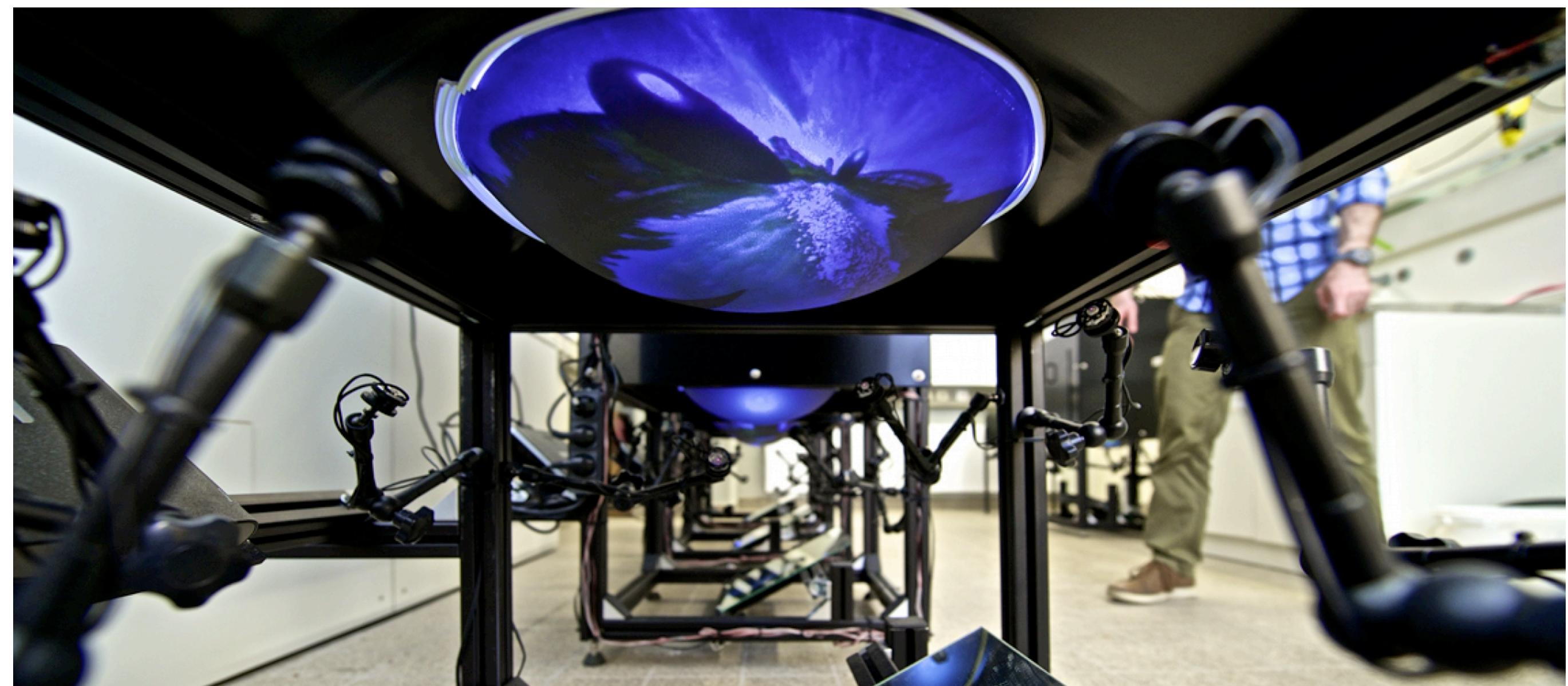
The N choice problem



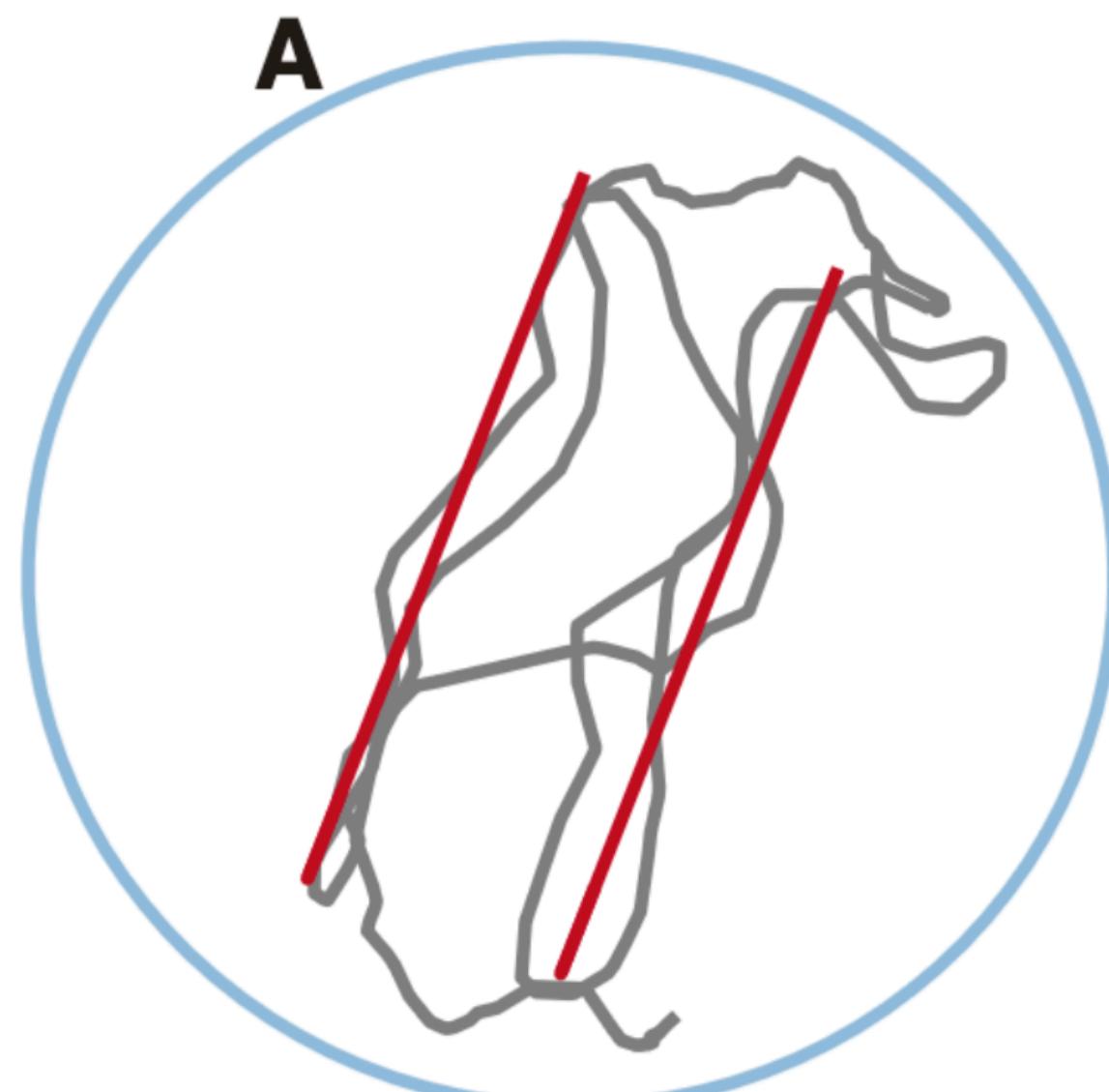
The simple threshold model extends to predict unique geometries for any number of targets.

Fish virtual reality

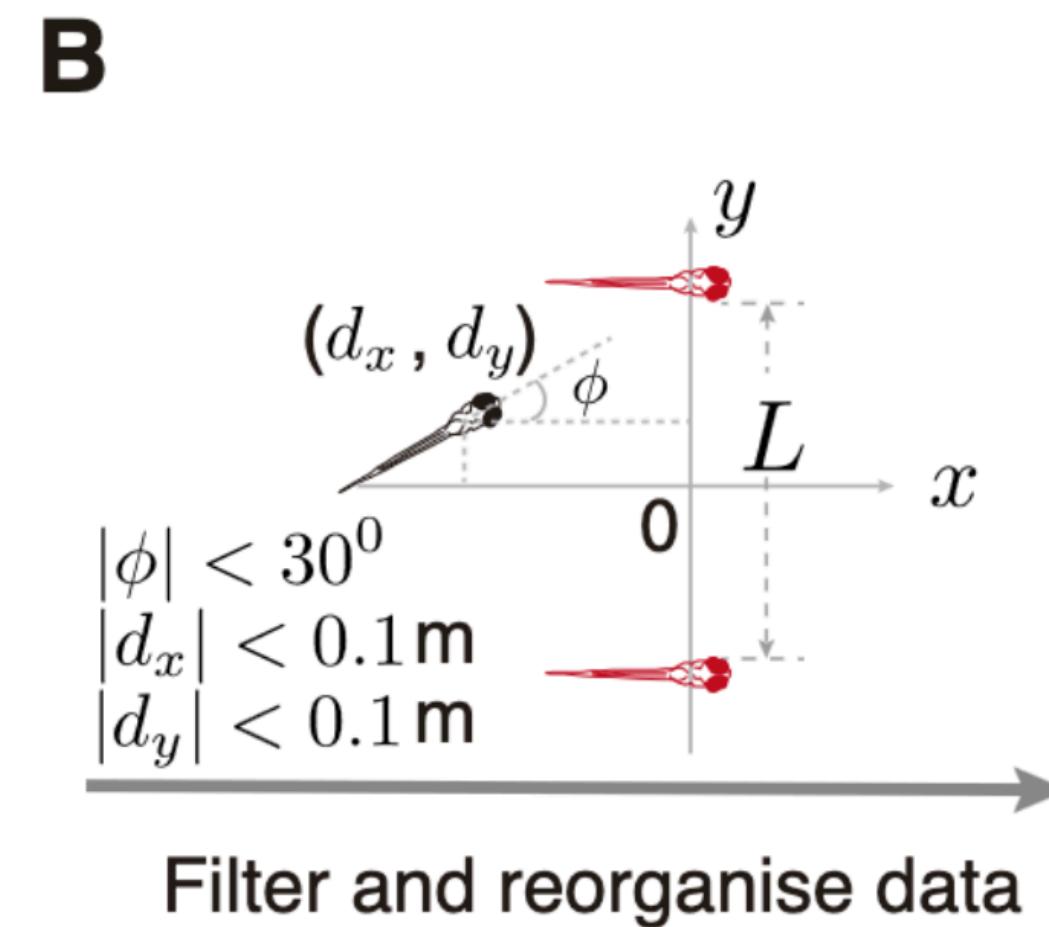
VR fish bowl



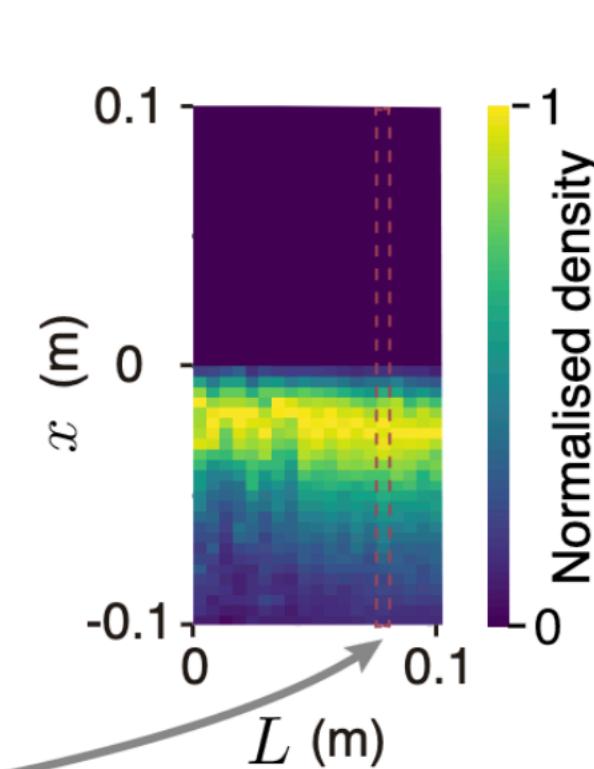
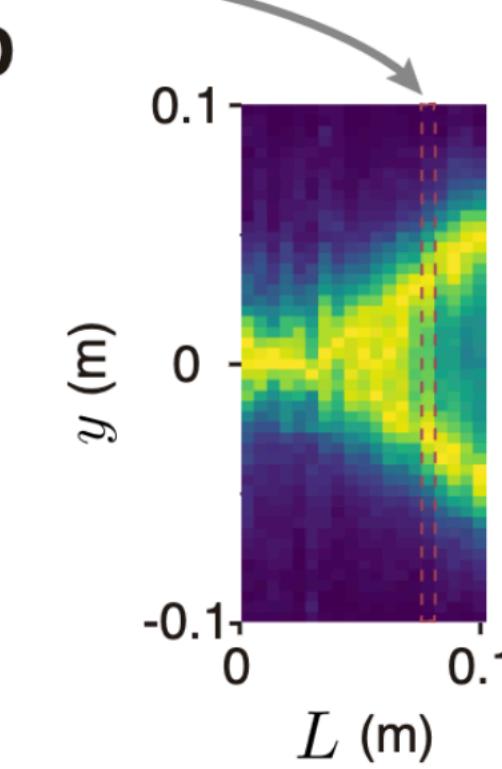
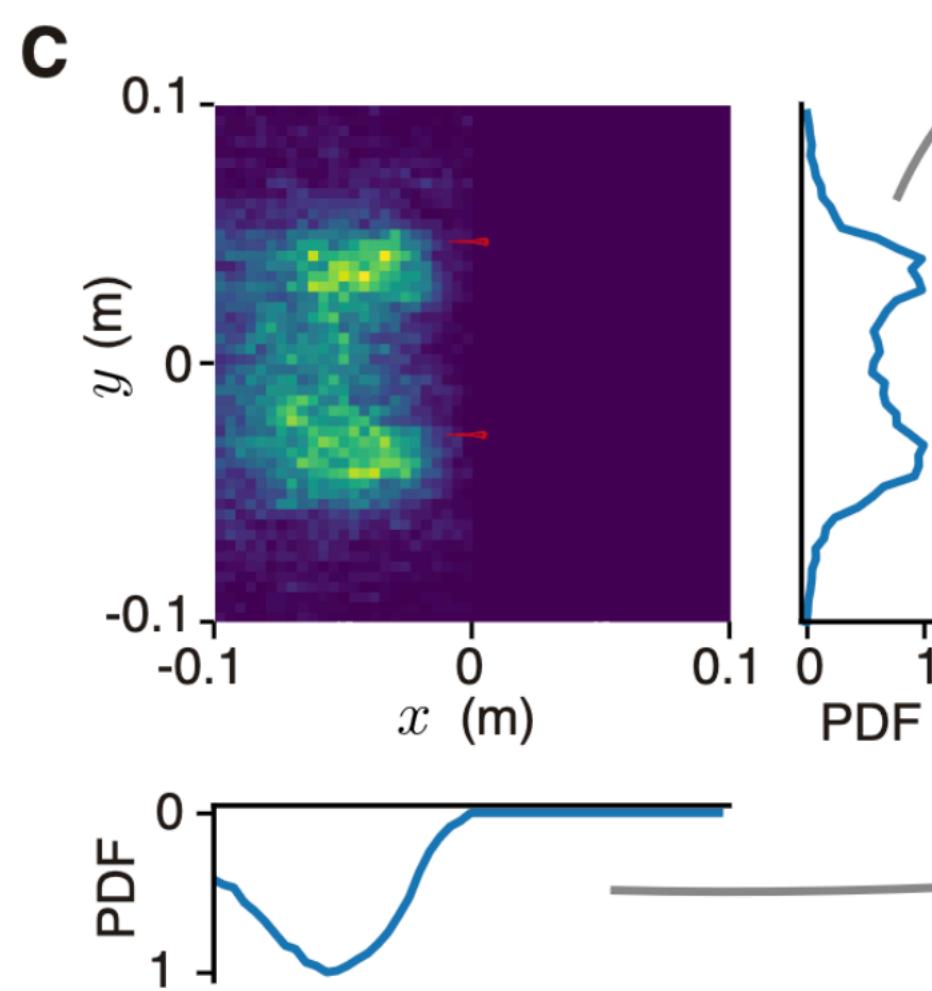
Follow the leader task



— Real fish
— Virtual fish



Filter and reorganise data

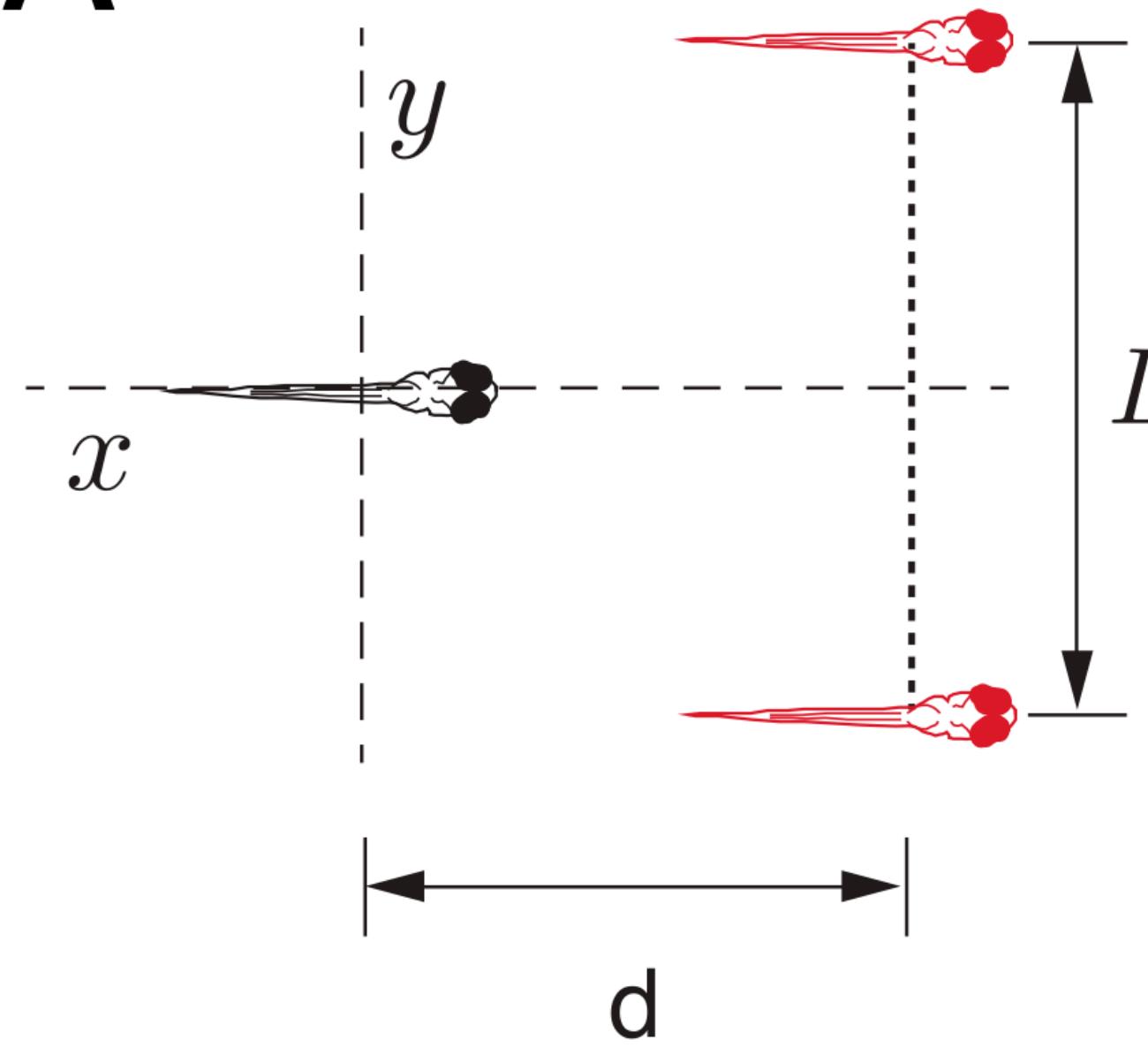


Which virtual fish do you follow?

Swarming as discrete decisions

Task

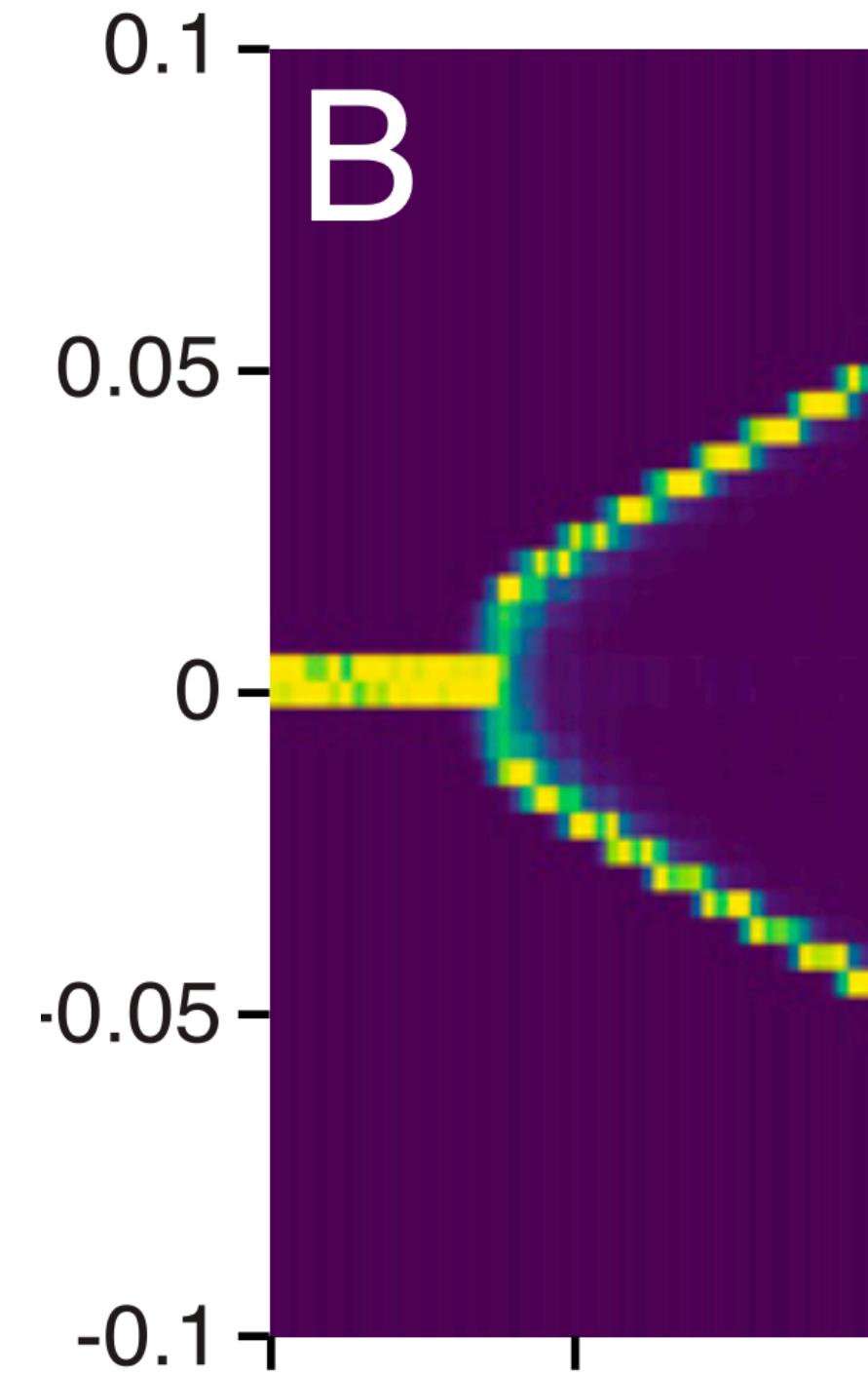
A



Discrete vector comparison model
works for following in swarming
behavior of fish.

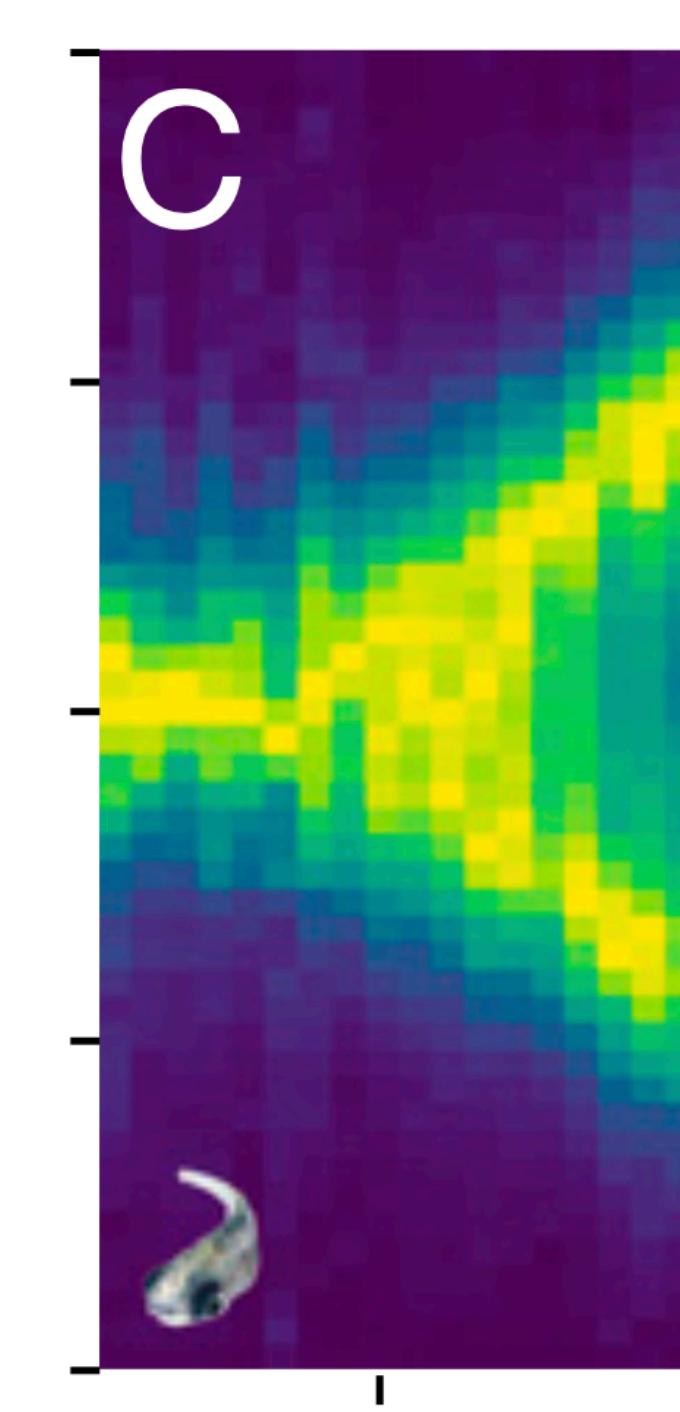
Model

Position of real fish along, y (m)

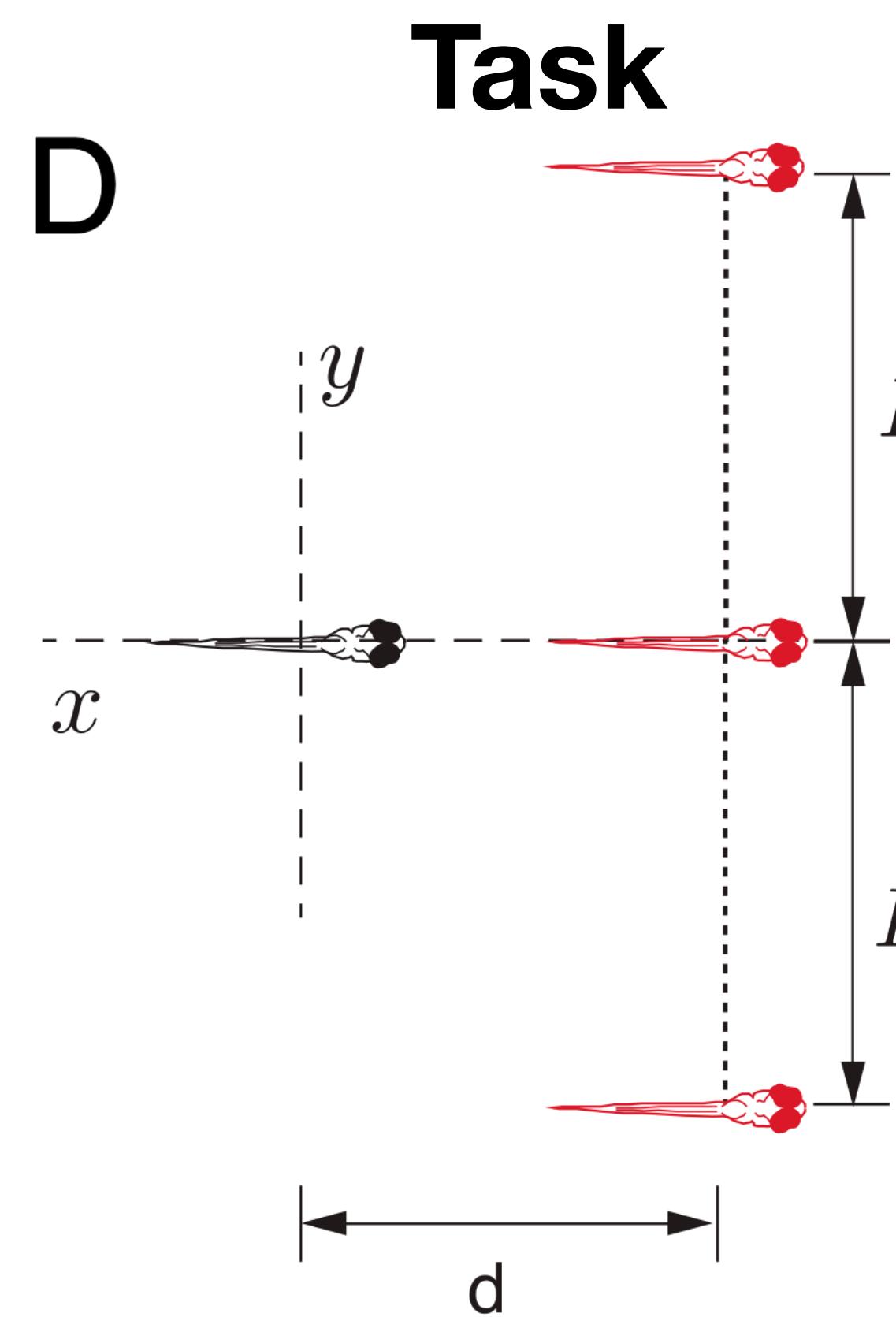


Lateral distance, L (m)

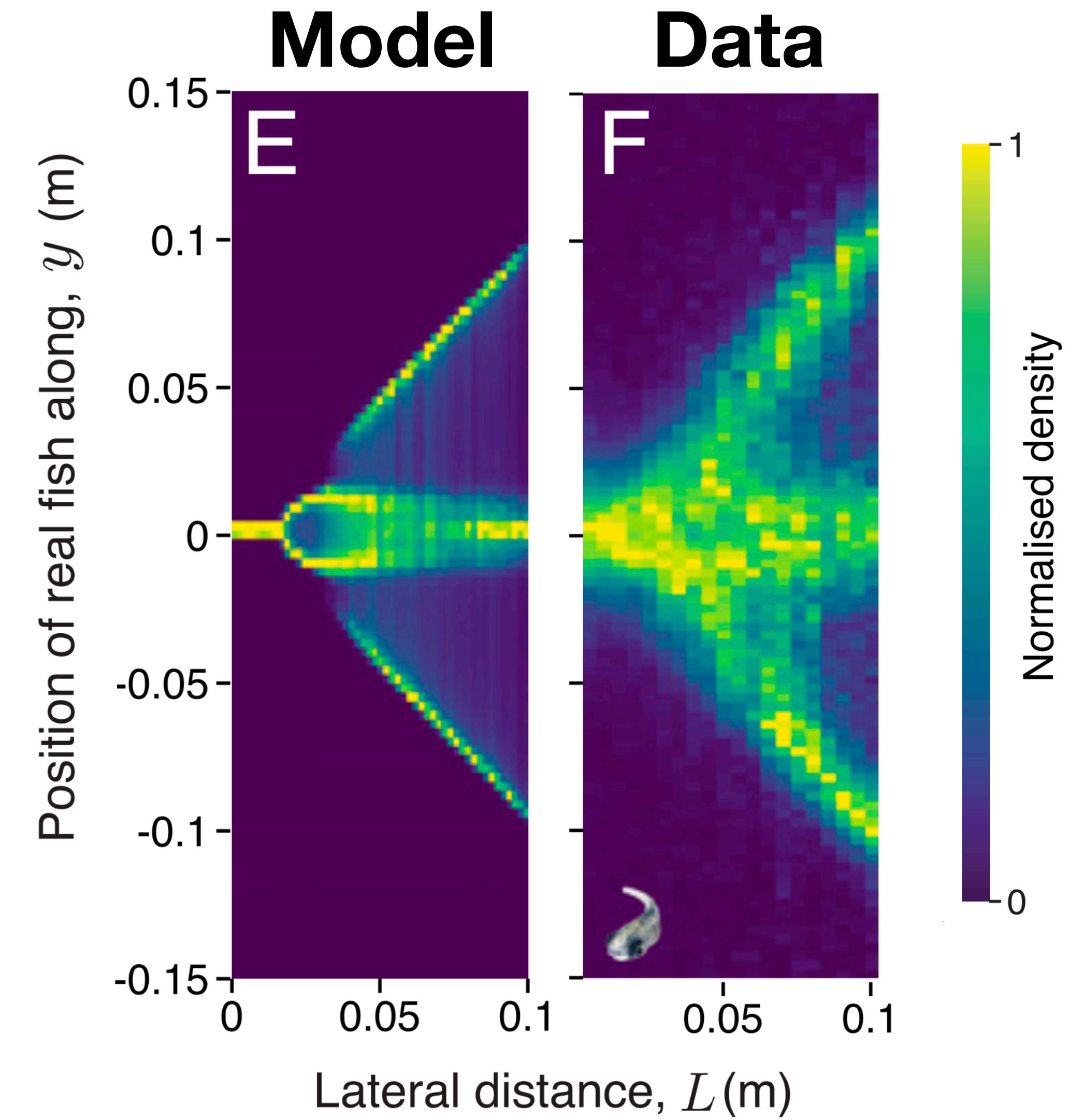
Data



Swarming as discrete decisions



Discrete vector comparison model
works for following in swarming
behavior of fish.



Take home message

- Actions can be represented as either discrete or continuous decisions.
- Analysis of insect & fish behavior suggests that even continuous decisions are made as discrete state-shifts.

Discussion time

Task: Find assumptions behind the design of the experiments in Sridhar et al. (2021) that might bias the results to look like discrete decisions. What are ways that decisions could still be represented in a continuous manner in their tasks?

