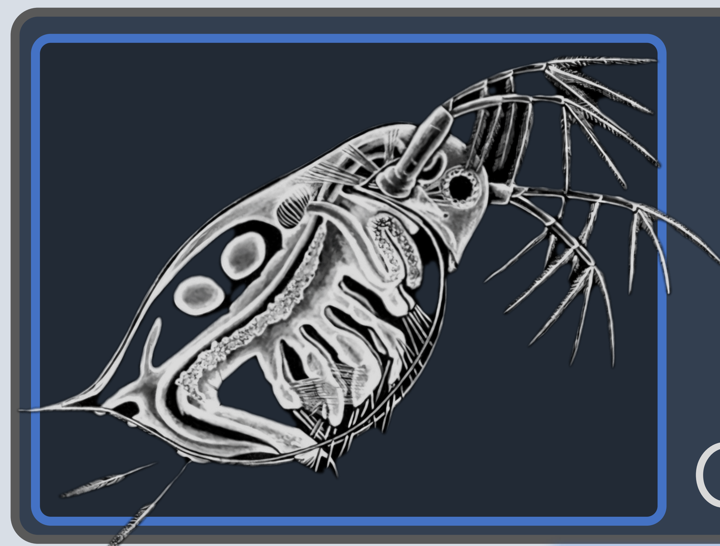

Collective Behavior of Daphnia

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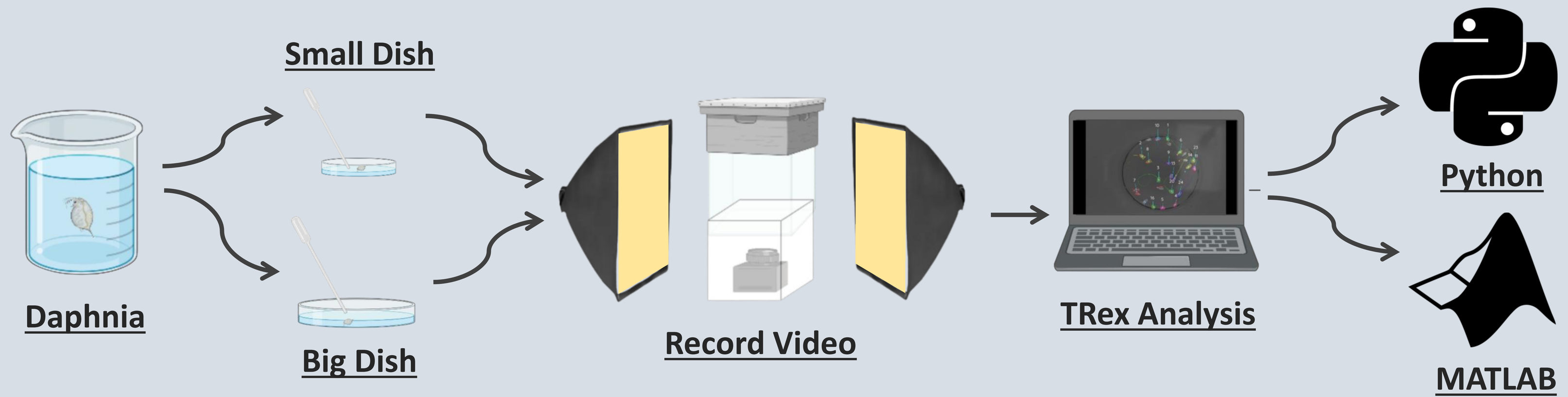
INTRODUCTION

Collective animal behavior, exemplified by the **Random Turning** observed in *Daphnia magna*, is a fundamental aspect of the animal kingdom. We assume random turning as the baseline for collective movement. Understanding these patterns helps us comprehend how animals respond to changing environments and the factors that influence deviations from this assumed behavior.

Daphnia magna

Do collective Daphnia deviate from random turning behavior?



METHODOLOGIES

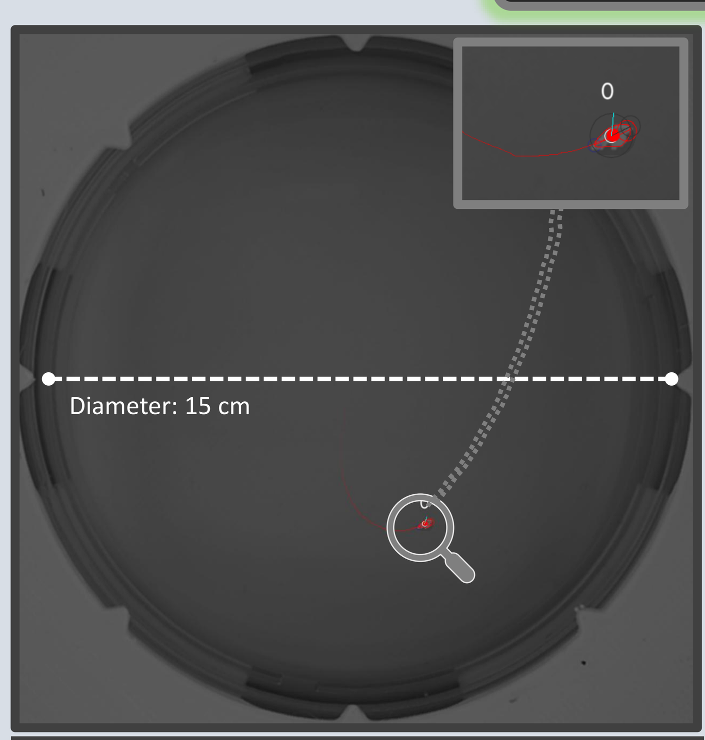


Fig. 1: Daphnia Tracking in TRex

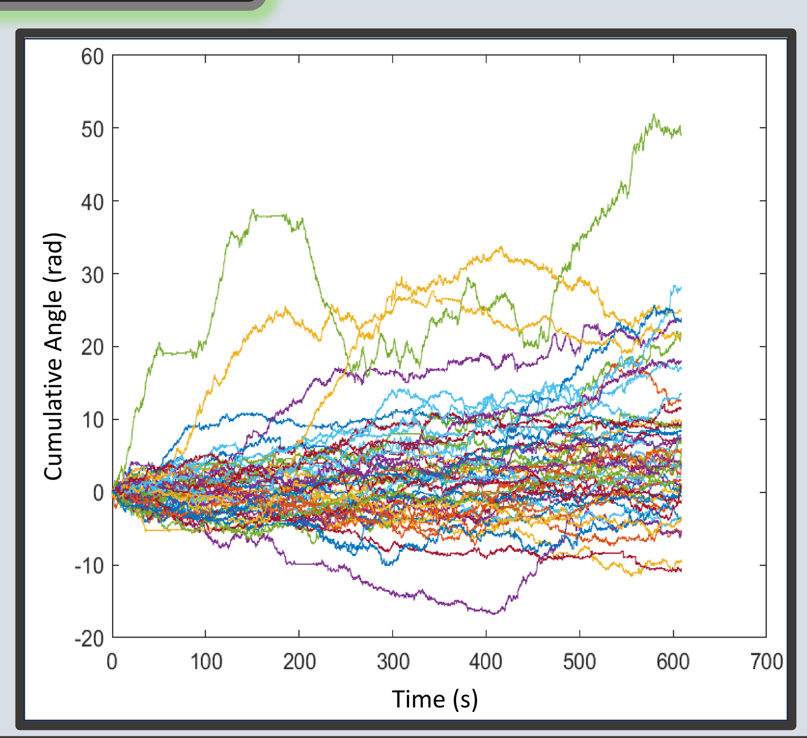


Fig. 2: Cumulative Angle Plot of 1 Daphnia in 50 videos

- A video of an individual Daphnia swimming in a petri dish (diameter: 15 cm) is recorded under controlled condition to capture its movement patterns.
- The recorded video is processed using `TGrabs` within **TRex**, converting the visual data into a `.pv` format.
- The `.pv` data file is analyzed in TRex to extract the X and Y positional coordinates, which are then modeled in Python to quantify the Daphnia's displacement over time.
- After obtaining position & velocity data for a daphnia, we compute the angle increments $d\phi$ from velocity vectors using the differential equation (**Fig. 3**) and sum $d\phi$ over time to get "cumulative angle."

$$d\phi = \frac{v_x dv_y - v_y dv_x}{v_x^2 + v_y^2} dt$$

Fig. 3: Cumulative Angle Differential Equation

RESULTS/DISCUSSIONS

Individual Daphnia Rotational Mechanics

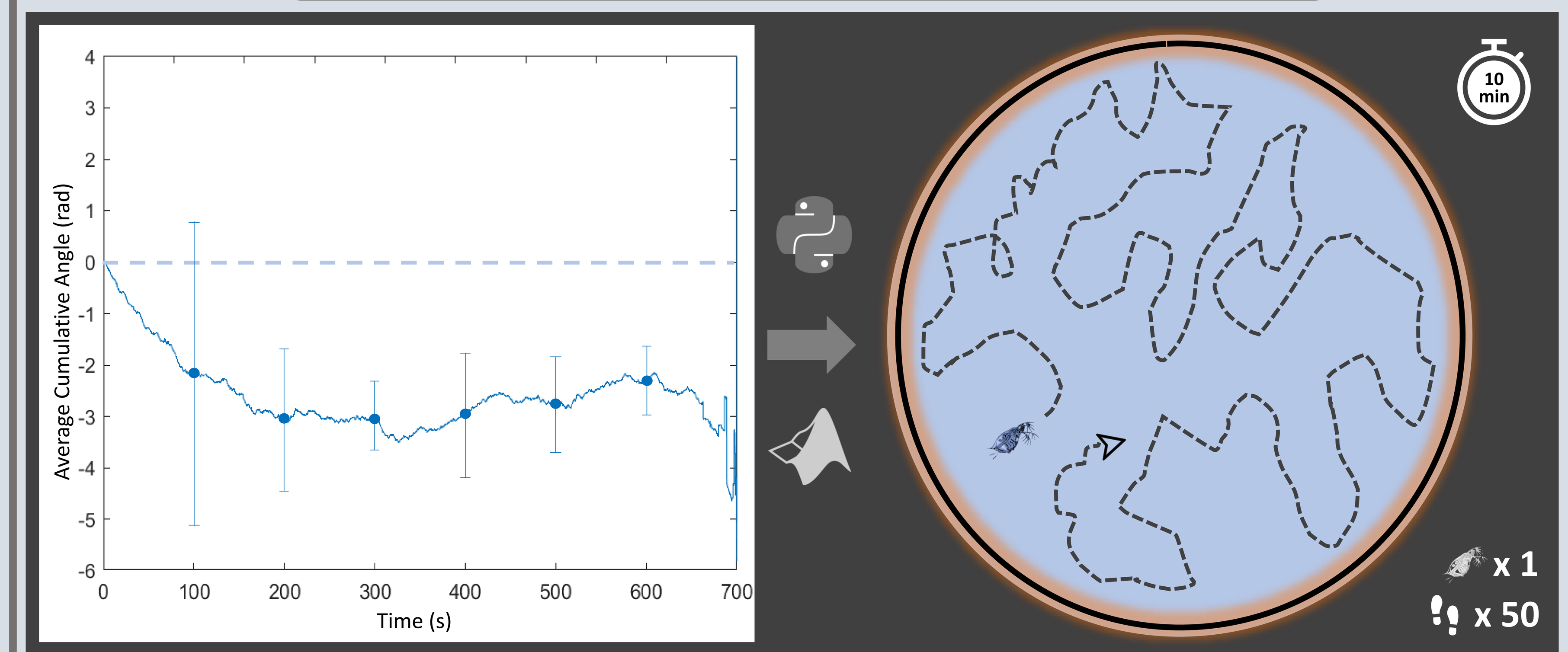


Fig. 5: Cumulative Angle Plot of Single Daphnia in 50 videos vs. Its Path Schematic

- We calculated the cumulative angle for one Daphnia, then recorded the same Daphnia 50 times to capture overall angular motion (**Fig. 2**).
- These 50 angular displacement trials were averaged at each time step to produce a single average cumulative angle vs. time plot (**Fig. 5**).
- The resulting cumulative angle Plot in **Fig. 5** shows no discernable trend or structure over time, suggesting that when isolated, a Daphnia's turning behavior maybe better described as randomized and unstructured with no dominant pattern.

Multiple Daphnia Rotational Mechanics

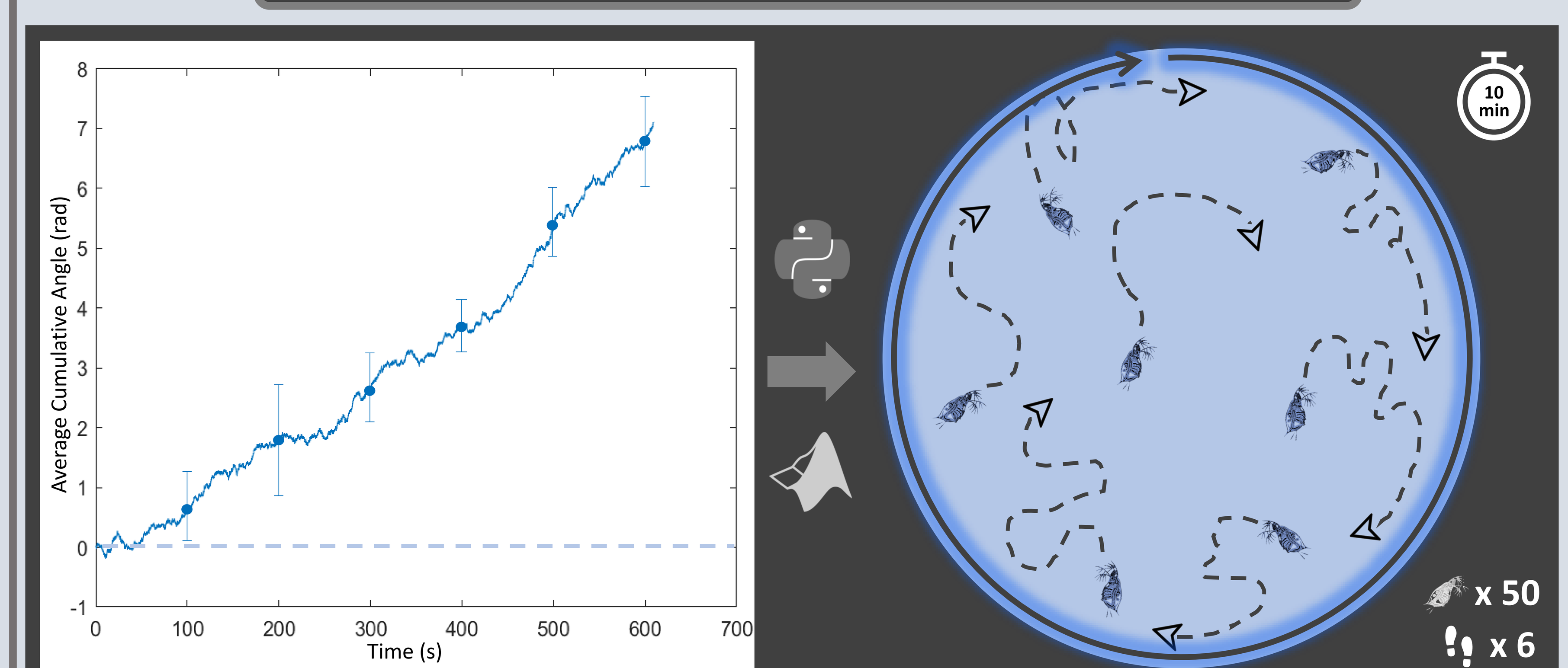


Fig. 6: Cumulative Angle Plot of 50 Daphnia in 6 videos vs. Their Path Schematic

- We recorded 50 Daphnia swimming together for six 10-min trials, calculating cumulative angles for all individuals and averaging them per time step.
- These trial-averaged angle curves were then averaged again to create a single comprehensive average cumulative angle vs. time plot (**Fig. 6**).
- The resulting upward trend in **Fig. 6** indicates a consistent group-level rotational bias, absent in individual trials, suggesting that collective interactions induce coordinated turning behavior.

CONCLUSION

Our analysis reveals that Daphnia exhibit either clockwise (CW) or counterclockwise (CCW) rotational bias only when swimming in groups — a pattern entirely absent in isolated individuals. This directional turning emerges from collective interaction, suggesting that the presence of neighboring individuals breaks the angular randomness typical of solitary motion. These findings indicate that handedness is not hardwired, but can arise dynamically as an emergent property of group behavior. Such spontaneous symmetry breaking highlights the coordination behind collective systems and invites further study of the cues that shape such behavior.

WHAT IS OUR FUTURE VECTOR?

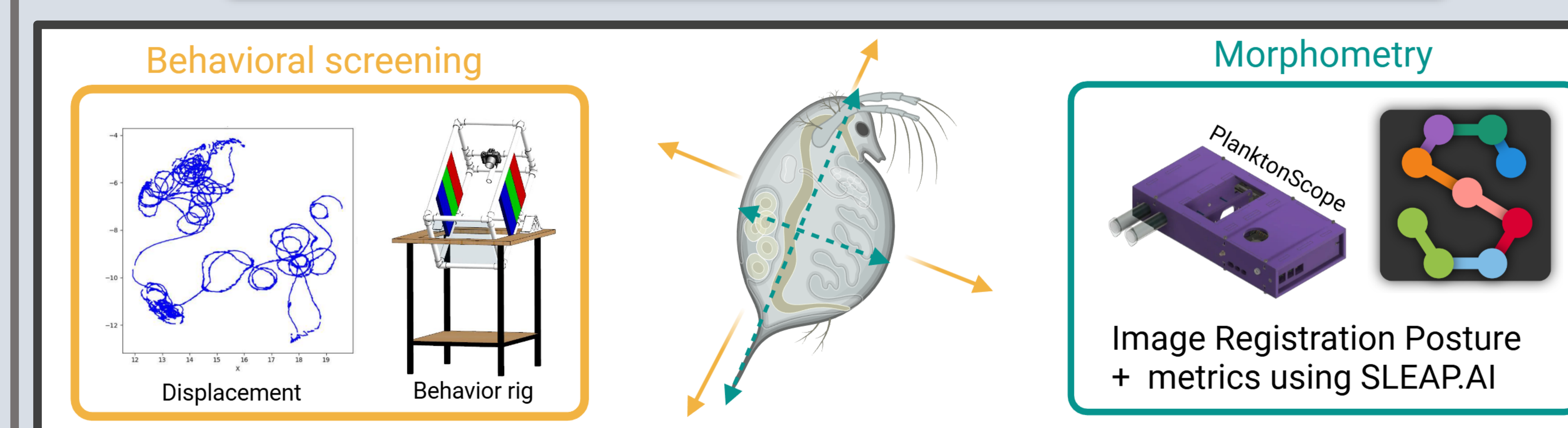


Fig. 7: Our Daphnia Research Group Future Direction Schematic

- **Expand Beyond the 2D Constraint**
  All current experiments have been conducted in a standard petri dish (**Fig. 1**), where motion is primarily restricted to the X-Y plane, with minimal exploration of Z-directional dynamics.
- **Evaluate Environmental Influence on Behavior**
  The small dish size may be introducing artificial spatial constraints, but we do not yet know how strongly dish geometry affects collective behavior. Investigating this is necessary to validating the generality of our findings.
- **Introduce Multi-Axis Behavior Rig for 3D Mapping**
  To address these limitations, we developed a new multi-angle behavioral recording rig **(Fig. 7, left)**, capable of recording both traditional horizontal (X-Y) and vertical (X-Z) motion by rotating the arena orientation.
- **Apply Morphometric Analysis in New Plane**
  Using tools like PlanktonScope and SLEAP.AI **(Fig. 7, right)**, we can analyze Daphnia posture in 2D by recording from either X-Y or X-Z. Posture dynamics in each orientation will help us detect whether body configuration shifts contribute to collective turning bias.
- **Link Morphology to Collective Rotational Bias**
  Our goal is to test whether posture alignment or vertical body asymmetries contribute to the emergence of collective rotational directionality, further exploring the biomechanical underpinnings of the phenomena observed in both **Figs. 5 & 6**.

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