Randomness in the choice of neighbours promotes cohesion in mobile animal groups

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Collective motion

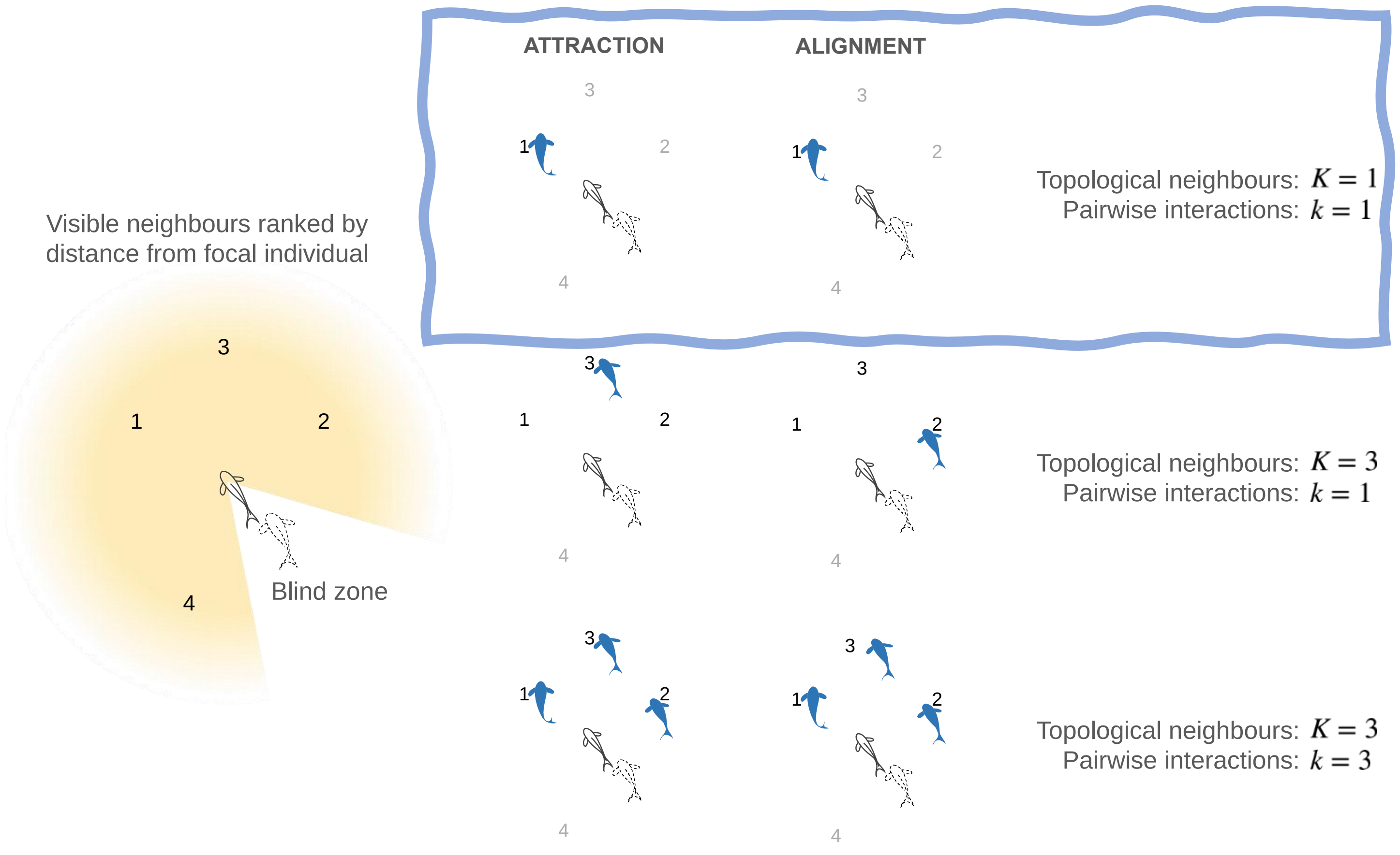
Background

- Classic models of collective motion assume that an agent moves along the average direction of its near neighbours.
- Recent empirical studies have shown that organisms interact through rules simpler than averaging information of several individuals.
- Fish interact with a single randomly chosen neighbour or with the nearest neighbour.
- In echolocating bats, the returning echoes are faint and masked by their neighbours' loud calls. So, bats detect only one neighbour at a time.
- While group polarisation is well studied, the mechanisms that keep the group cohesive – particularly the role of stochastic decision making—are not explored.

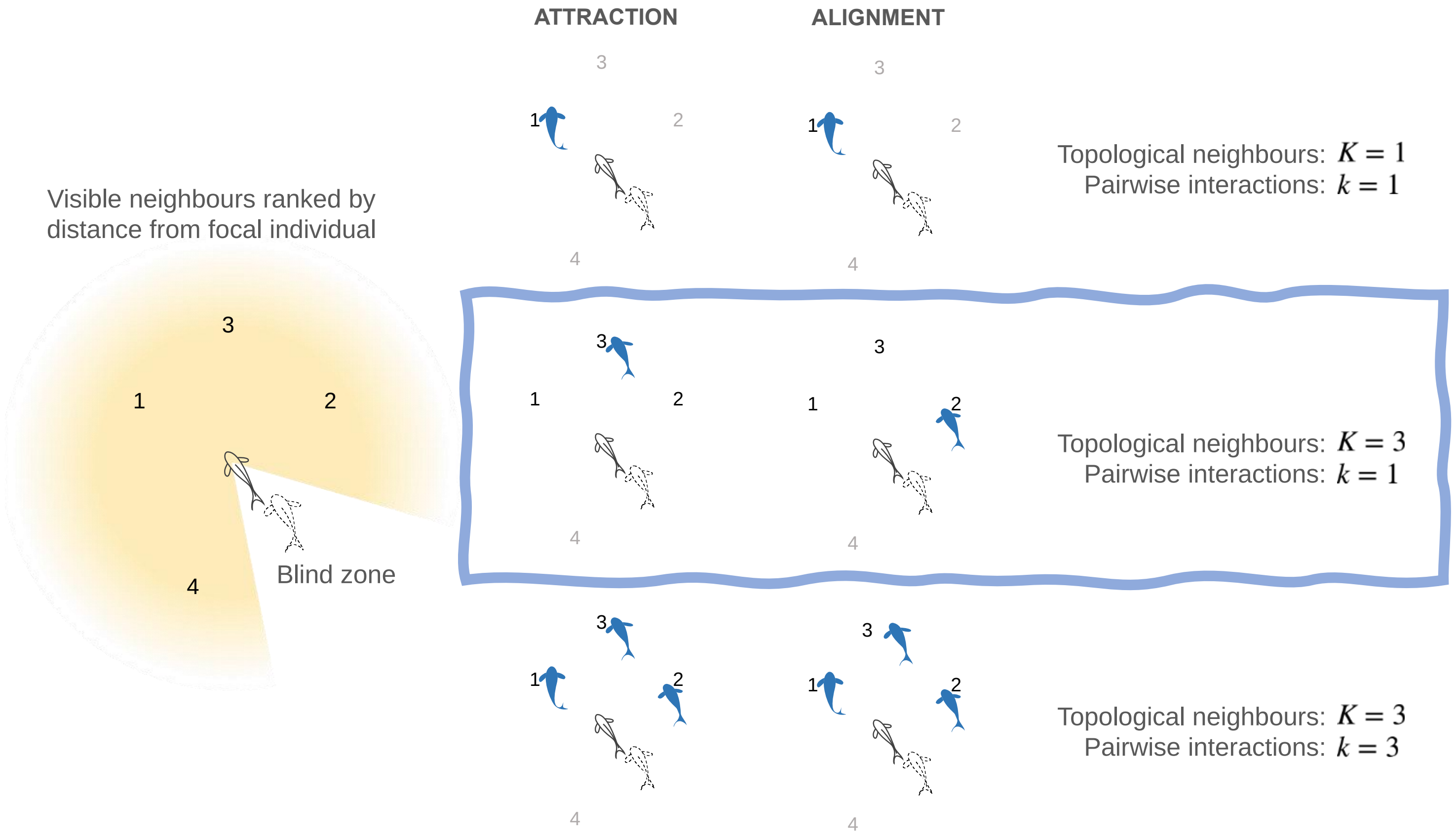
Model

- We developed an agent-based spatially explicit model to study the dynamics of collective motion.
- While the model broadly follows the principles (alignment, attraction and spontaneous turning) of classic self-propelled particle models of collective motion, we make two key distinctions. Interactions are ***probabilistic*** and ***asynchronous***.

Choice of neighbours and interaction types



Choice of neighbours and interaction types



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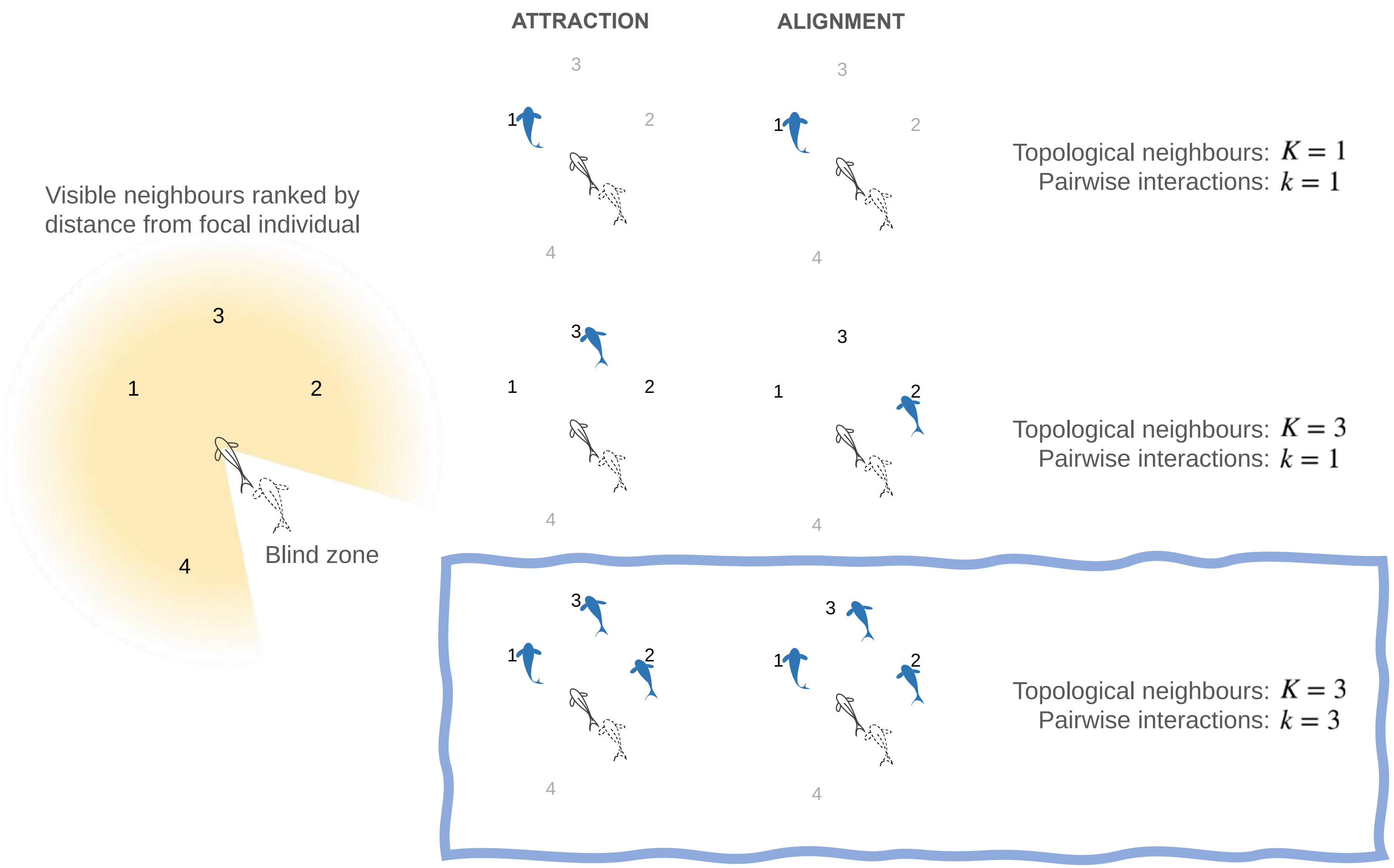
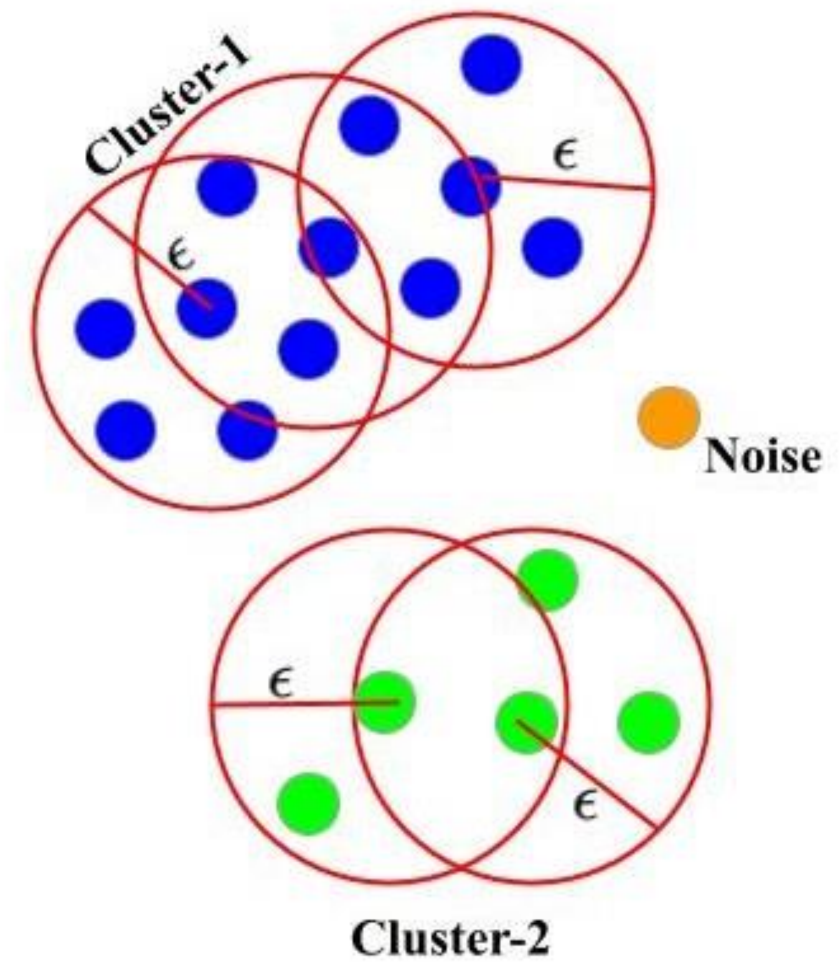
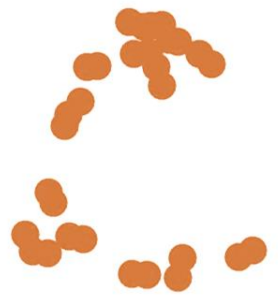


Group Cohesion and Quantification

$$\text{Cohesion parameter } (C) = \frac{\text{Size of the largest cluster}}{\text{Group Size}}$$





Group cohesion when agents interact randomly with the nearest neighbour.

N = 30 *(Size of the group)*

K = 1 *(Number of visible neighbours)*

k = 1 *(Number of neighbours interacted with)*

Agents break into clusters of sizes 2-3 and drift apart from each other.

Group cohesion when agents interact randomly with **1 of 5** nearest neighbours

N = 30 *(Size of the group)*

K = 5 *(Number of visible neighbours)*

k = 1 *(Number of neighbours interacted with)*

The group stays more or less cohesive with occasional breakups.

Group cohesion when agents interact randomly with **1 of 9** nearest neighbours

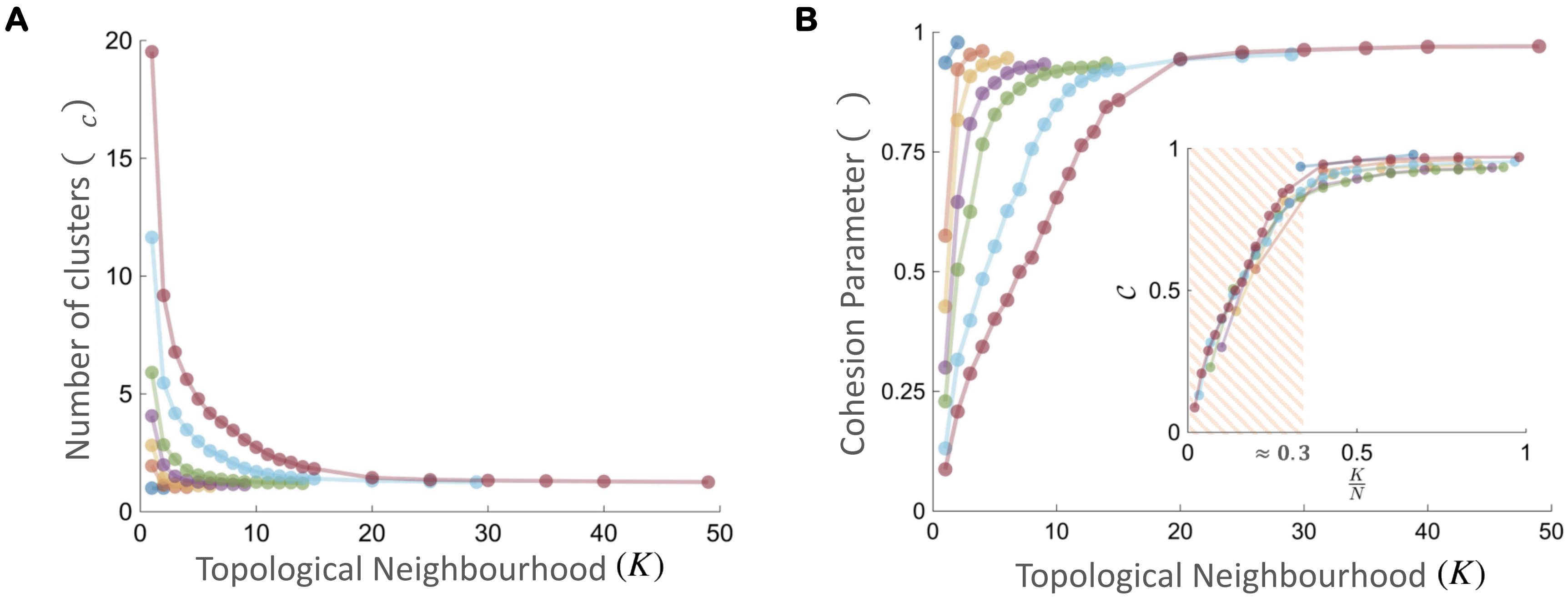
N = 30 *(Size of the group)*

K = 9 (Number of visible neighbours)

k = 1 *(Number of neighbours interacted with)*

The group stays cohesive most of the time

Group cohesion is achieved when organisms interact with just one neighbour



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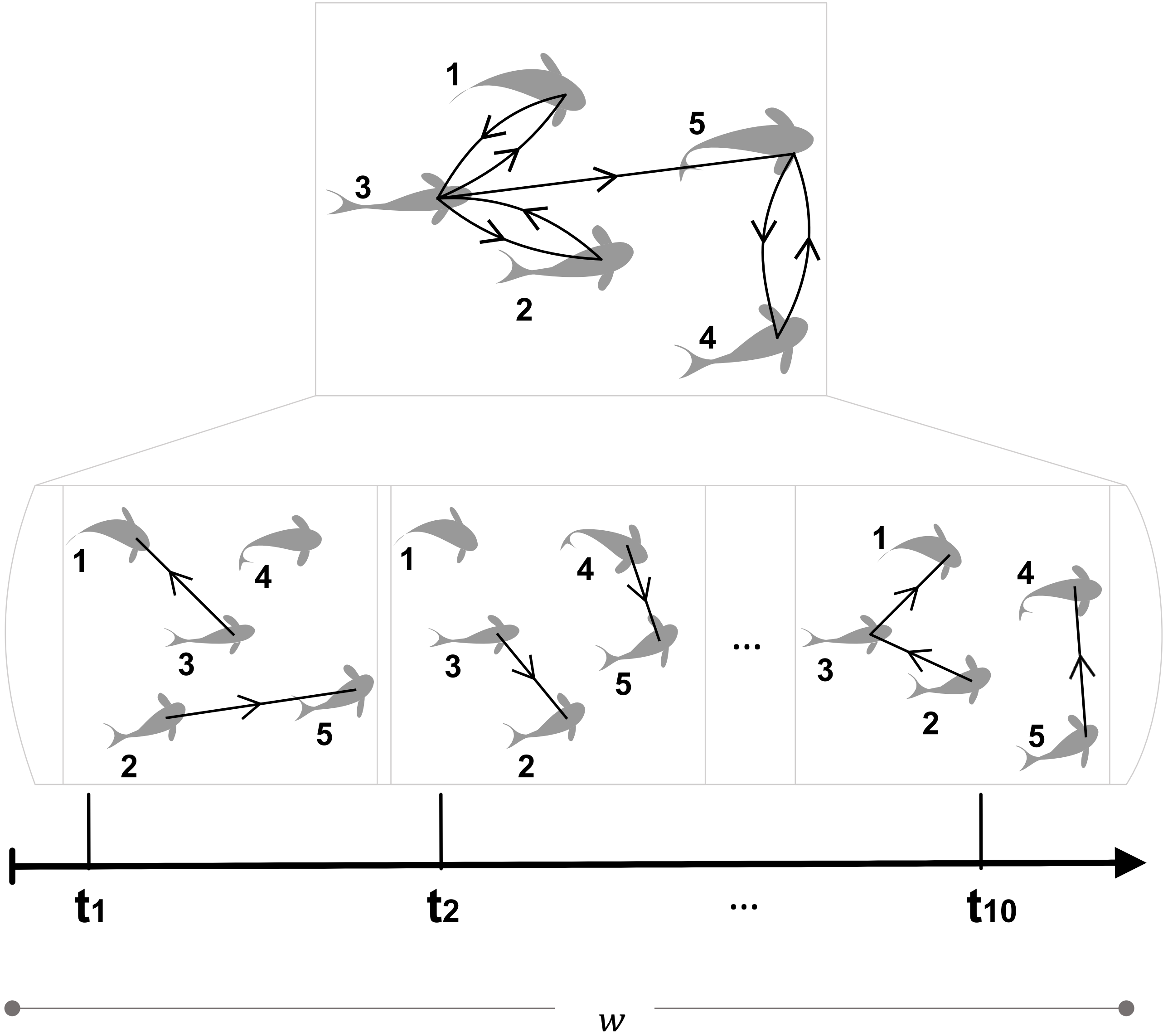
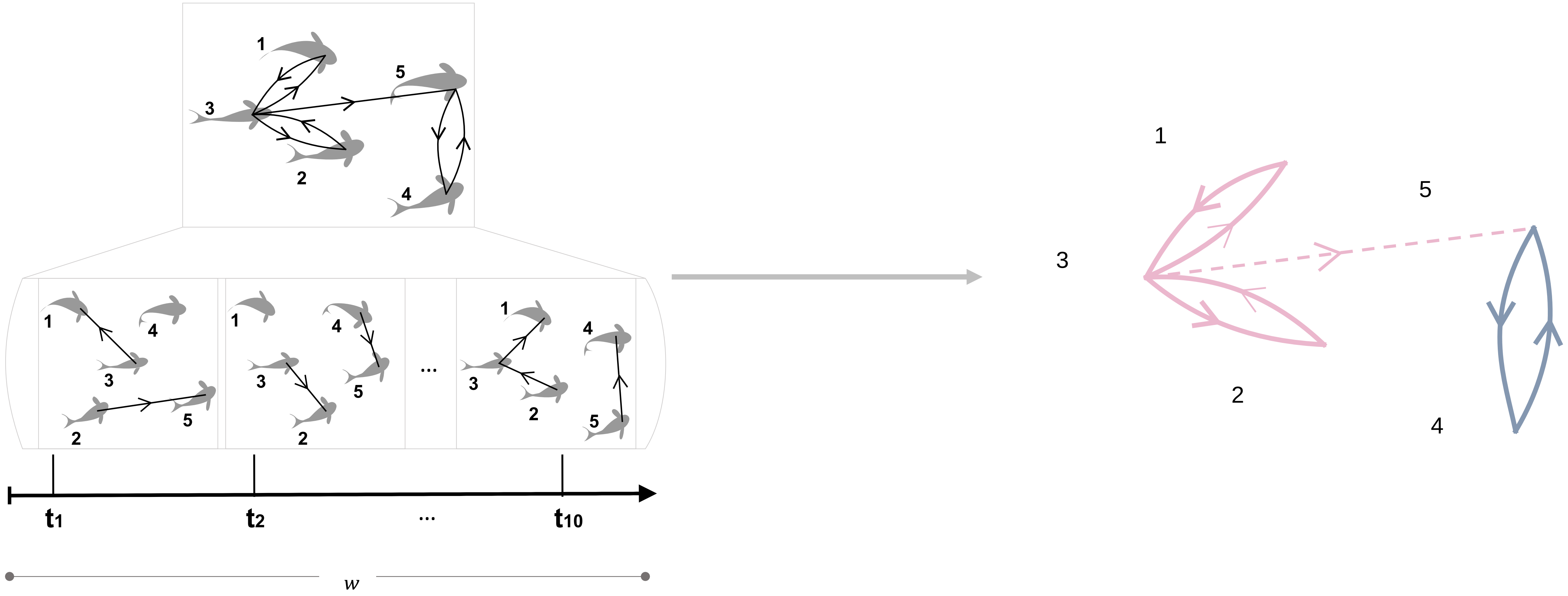
Attraction interaction network reveals why cohesion emerges



Attraction interaction network reveals why cohesion emerges



Attraction interaction network reveals why cohesion emerges

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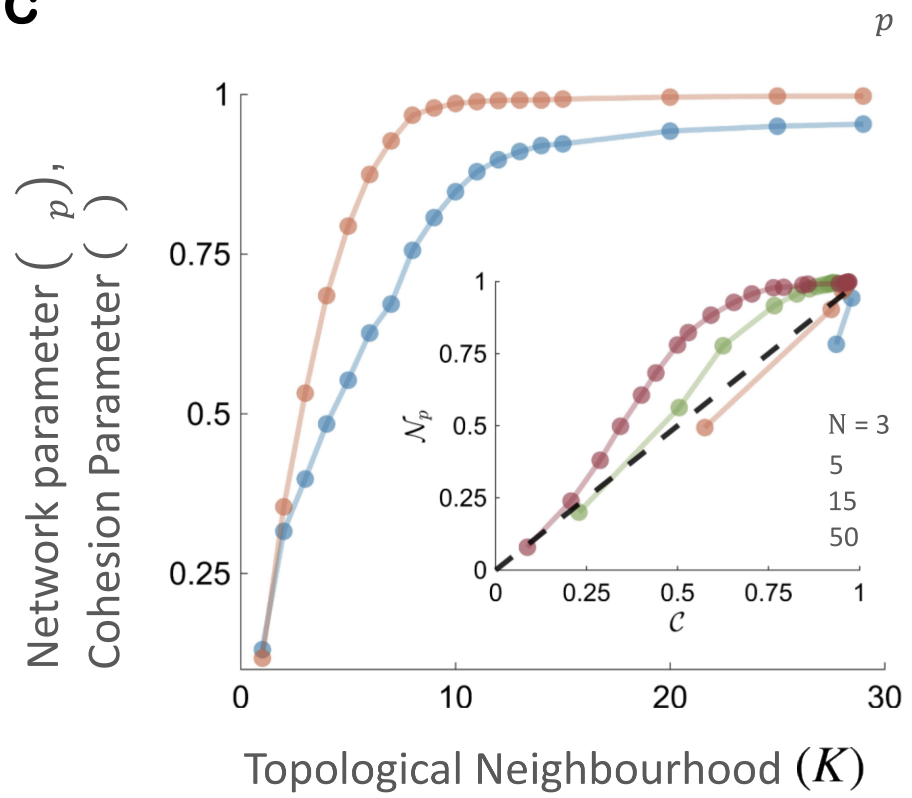
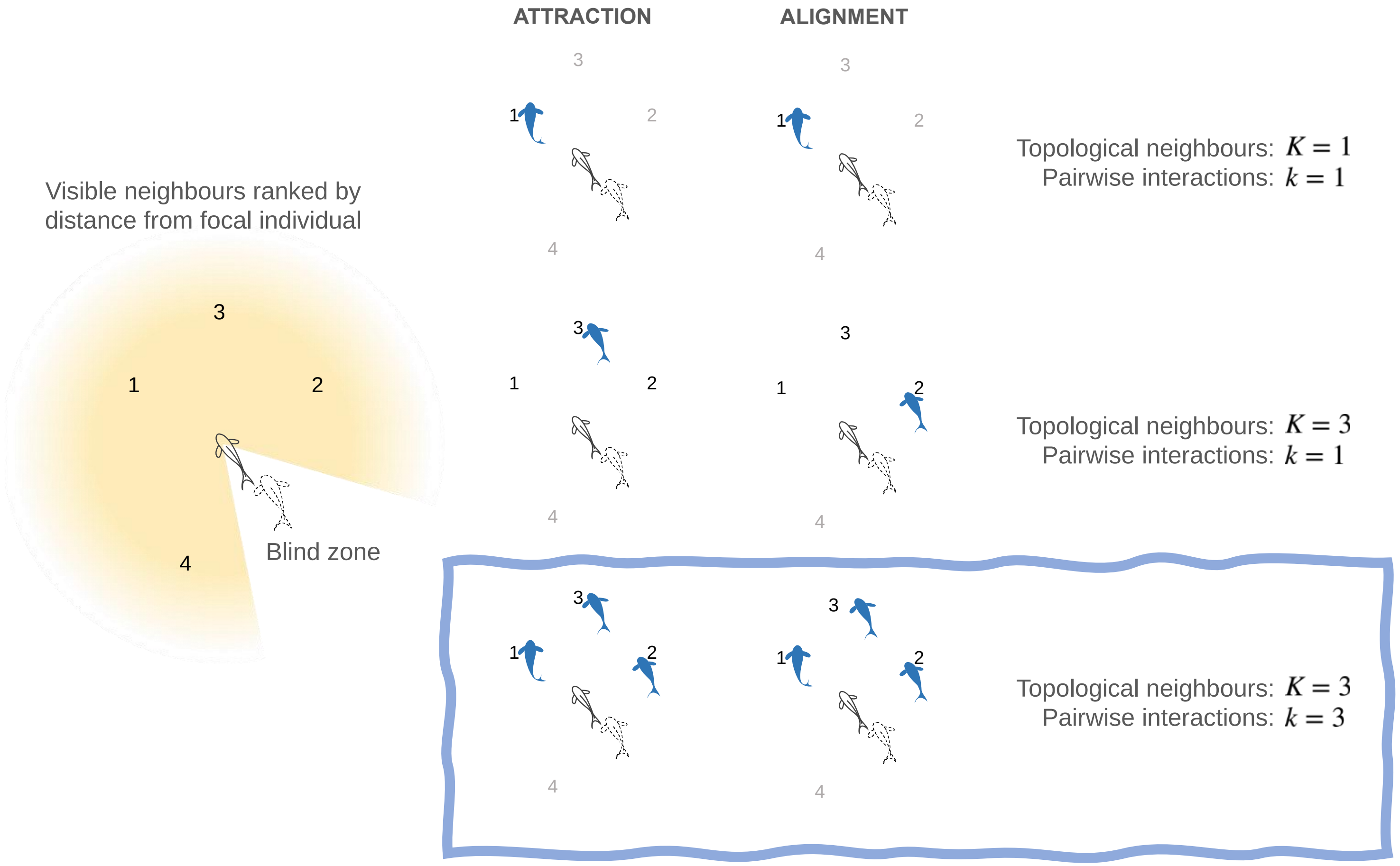
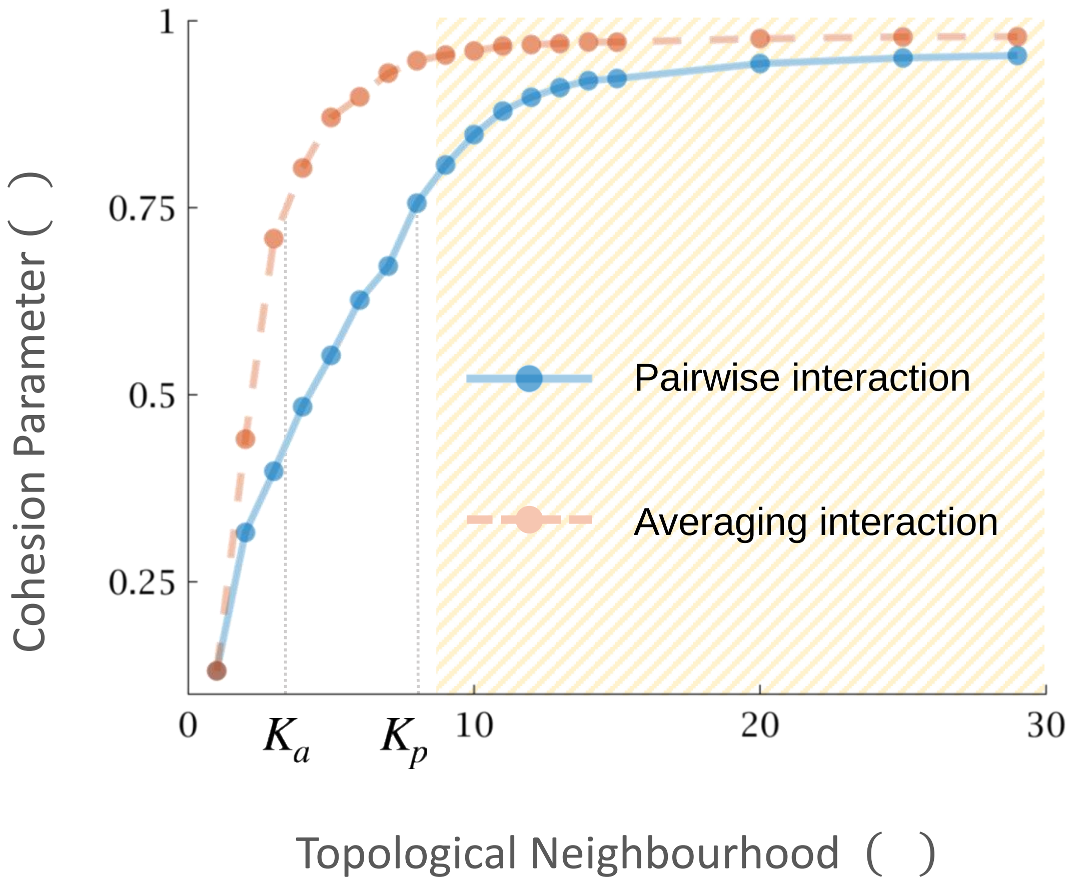


Cohesion due to averaging interactions



Cohesion due to averaging interactions



Conclusion

We show that group-level cohesion can emerge when organisms move towards randomly chosen nearby organism.

Cohesion emerges as choosing a neighbour randomly creates a well-connected long-ranged interaction network.

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