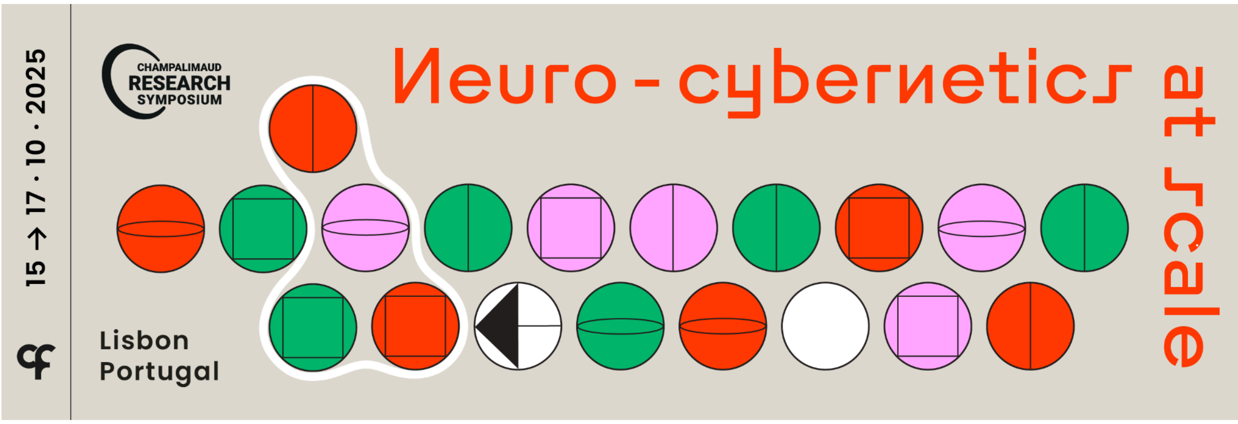

Adaptive behavioral strategies in Drosophila courtship pursuit

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Pursuit behaviors are inherently challenged by the dynamic and uncertain nature of moving targets. When tracking unpredictable targets, pursuers often adopt a reactive (lagging) strategy—aiming at the target's last observed position—a robust approach limited by sensorimotor delays. In contrast, when a target's trajectory is more consistent, predictive (leading) strategies become viable, aiming at an anticipated future position but risking failure if the target changes direction. Successful pursuit therefore requires the ability to flexibly adapt strategy based on the target's behavior—yet the principles of this strategy switching remain poorly understood.

We investigated these principles in the context of Drosophila courtship pursuit and uncovered a hierarchical control system that enables males to adjust their strategy in response to the female's ongoing movements. Using high-resolution tracking of males pursuing both real and virtual (avatar) females, we found that they flexibly switch between lagging and leading pursuit strategies. This behavioral flexibility arises from a hierarchical motor architecture: fast, reactive pathways control forward and angular velocity during lagging pursuit, while a slower, integrative pathway independently modulates side velocity. This slower pathway supports anticipation by accumulating motion information about the target, enabling the transition to leading strategies. Notably, this control architecture is shaped by biomechanics. Head-fixation experiments revealed that the integrative control of side velocity is constrained when the head is immobilized, highlighting the importance of coordinated head-body movement in adaptive pursuit while maintaining stable gaze on the female.

Contrary to classical models that emphasize strictly reactive strategies [1,2], our findings show that adaptive behavior emerges from the integration of fast feedback and slower predictive processes, combined with physical constraints of the body. These results establish Drosophila courtship pursuit as a powerful model to dissect core principles of neuro-cybernetics underlying flexible, goal-directed behavior in compact nervous systems.

sensorimotor control, pursuit, head-body coordination, adaptive control, drosophila courtship