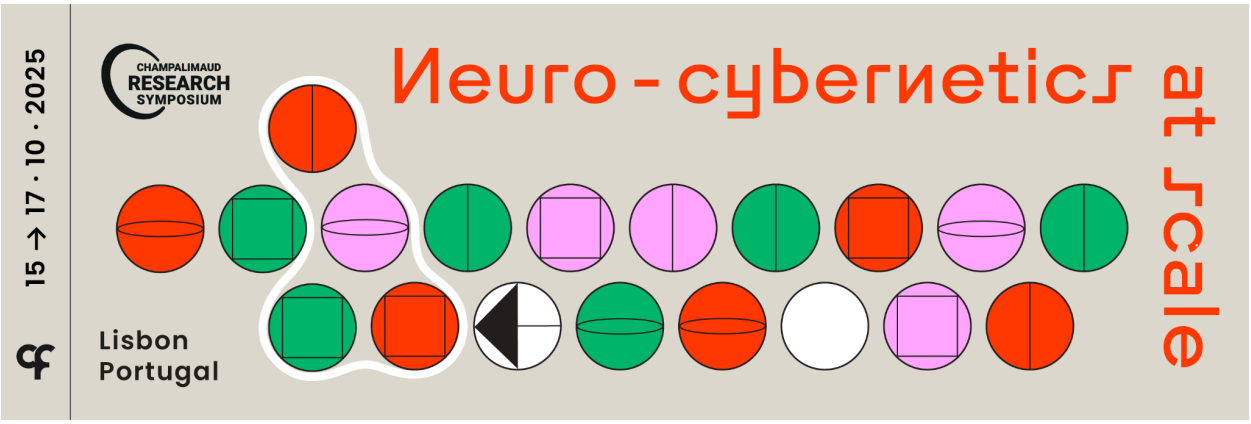

Freezing Duration in Drosophila Reflects Bounded Accumulation of Evidence about Safety

Marco Colnaghi 1, Juan Castiñeiras 1, Mirjam Heinemans 1, Clara Ferreira 2, Marta Moita 1, Alfonso Renart 1

1. Champalimaud Foundation, Lisbon, PT
2. Northumbria University, Newcastle, UK

Freezing is a conserved defensive strategy observed in many species in response to threat. In Drosophila, both the probability and duration of freezing depend on several factors, including the animal's social context and internal state [1,2]. To gain a mechanistic understanding of how these factors quantitatively influence freezing duration, we analyzed data from a paradigm in which flies were exposed to looming stimuli of different speeds in the presence of conspecifics whose movement was under experimental control [3].

We developed a theory in which the dynamics of freezing are governed by bounded accumulation of evidence (BAE; [4]) about safety, where a single decision bound represents the amount of safety deemed appropriate by the animal to resume movement. Our analysis revealed two coexisting processes even within individuals - a short and a long freezing mode - which are selected probabilistically by flies at the time of loom.

How do the drift and decision bound of each freezing mode, as well as the probability of entering either, depend on experimental conditions such as loom speed? Freezing duration is very accurately described by a model where freezing mode probability is a logistic function of all experimental conditions, but where the evidence that is integrated towards the bound depends only on the moment-to-moment fluctuations in the amount of social motion experienced by the fly.

Our model accurately describes the whole spectrum of variation of the full freezing duration distribution across all conditions in our experiments with great accuracy and parsimony. The mathematical precision of the behavior together with the powerful toolkit for circuit mapping in Drosophila, uniquely positions this paradigm as an ideal model for unraveling a neural implementation of BAE, a canonical computational motif for the temporal sequencing of behavior.

freezing, social, behavioral modelling, evidence accumulation, drosophila