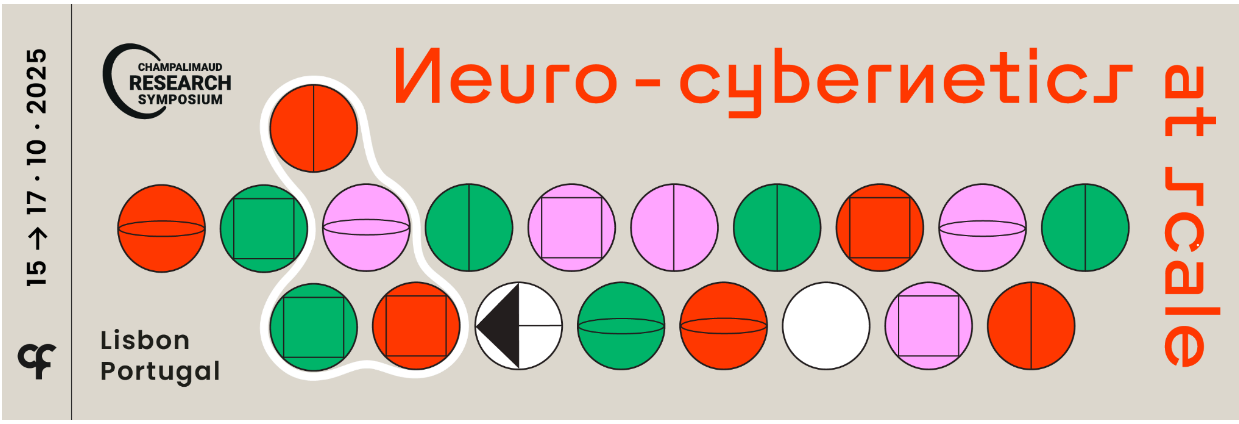

Dynamic Scale Equivariance in Retinal Neural Codes Supports Object Tracking

S. Azeglio* 1. 2., R. Baroux* 1., U. Ferrari 1., O. Marre 1.

1. Institut de la Vision, Sorbonne Université, INSERM, CNRS, 17 Rue Moreau, 75012, Paris, FR
2. Laboratoire des Systèmes Perceptifs, Ecole Normale Supérieure, 24 Rue Lhomond, 75005, Paris, FR

Various animals, including mice, can approach and catch prey in different environments. Their visual system must track moving targets across visual space, and be robust to changes in position and scale. Retinal ganglion cell (RGC) mosaics provide translation equivariance: if an object is represented by a feature map of ganglion cells, translating this object will trigger a similar translation in the feature map, making the code robust to changes in positions. However, how encoding is robust to changes of scale is unclear, and we don't know if there is a similar equivariance to scale in the retina.
Here, we demonstrate that specific RGC types achieve functional scale equivariance, enabling a robust representation of a target across scales during ethological tasks like prey capture. We developed a novel paradigm combining multi-scale visual stimuli simulating the visual experience of a mouse during prey hunting with high-density multielectrode array recordings from ex vivo mouse retina responding to these stimuli. We adapted Scale-Equivariant Steerable Networks (SESN) from geometric deep learning [1], together with a Scale-Factorized Readout layer to model and predict RGC responses.
Our SESN model significantly outperformed standard CNNs in predicting RGC responses with greatest gains for transient OFF alpha cells, which are implicated in looming detection and object tracking [2,3]. Systematic ablation experiments revealed these cells implement a key trade-off: strong center-surround antagonism impairs scale equivariance, so these cells have a weak surround to ensure scale equivariance, balancing contrast sensitivity with scale-tracking.
These findings highlight equivariance as a valuable framework for understanding neural computation, linking the symmetries of natural stimuli to sensory system responses and complementing recent developments in geometric deep learning.

equivariance, retina, neural coding, object tracking, geometric deep learning