Biomimetic Neural Network Models of Developmental Visual Crowding

A Project to be potentially funded by YÖK-ADP, 2026-2028

Project No: N/A

Fully funded M.S. and Ph.D. positions are available!

Project Description: Visual crowding—the inability to recognize objects in cluttered environments—sets a fundamental limit on conscious visual perception across most of the visual field. It is one of the main bottlenecks of object recognition and has profound implications for how we perceive, attend to, and interact with the world. Crowding constrains essential visual functions such as reading, face recognition, visual search, and navigation. Despite its ubiquity, the underlying mechanisms and developmental origins of crowding remain poorly understood. Crowding emerges early in life but undergoes a long developmental trajectory. Infants and young children show significantly larger crowding zones compared to adults, indicating that the neural mechanisms underlying spatial integration and feature binding continue to mature well into adolescence. Furthermore, atypical visual development—such as that seen in amblyopia, strabismus, or early visual deprivation—often leads to abnormal crowding patterns. These findings suggest that both innate neural architecture and experience-dependent plasticity contribute to how crowding emerges and stabilizes through development. The current project aims to model the developmental formation of visual crowding using deep neural networks (DNNs) as computational analogs of the human visual system. Unlike previous studies that have focused on static, adult-like network architectures, we will implement biomimetic training regimes that mimic the temporal dynamics, environmental structure, and sensory limitations of early visual experience. For instance, the networks will be exposed to progressively complex visual scenes and spatial frequencies over time, simulating the gradual refinement of visual acuity and perceptual organization observed in humans. By manipulating both architectural parameters (e.g., receptive field size, hierarchical connectivity) and developmental training conditions (e.g., exposure variability, noise, and clutter), we aim to determine how crowding-like phenomena emerge as a natural outcome of efficient visual learning. This will allow us to address two fundamental questions: (1) Does crowding arise as an adaptive mechanism for efficient coding, resource allocation, or generalization in cluttered environments? and (2) Under what developmental or architectural conditions does crowding become maladaptive, leading to reduced perceptual resolution or impaired object recognition? To further connect model behavior with human perception, we will quantify "crowding zones" in DNNs and compare their size, anisotropy, and task dependence to empirical data from psychophysical and developmental studies. We will also explore atypical training regimes—such as impoverished visual input or delayed complexity exposure—to simulate abnormal developmental trajectories and test their correspondence with clinical conditions like amblyopia. By integrating insights from developmental vision science and computational neuroscience, this project offers a novel, mechanistic framework for understanding how visual crowding emerges and evolves. The expected outcomes include (1) a biologically inspired model of crowding development, (2) new hypotheses about the functional role of crowding in perception, and (3) testable predictions about the effects of early experience and plasticity on visual organization. In the long term, this work may shed light on why the human visual system retains this perceptual limitation and how its adaptive properties could be harnessed for improving artificial vision systems and visual rehabilitation strategies.

Project Management:

1. Prof. Fazilet Keleş (PI), Dept. of Psychology at Bogazici University.
2. Prof. Suayb S. Arslan (Researcher), Dept. of Comp. Engineering at Bogazici University and Research Affiliate, Brain and Cog. Sciences at MIT.

Applications and Compensations: Funding is available for M.S. and Ph.D. degrees.

1. Master of Science (M.S), 40,000TL + benefits
2. Philosophy of Doctorate (Ph.D), 50,000TL + benefits

All applicants are encouraged to contact the PI and Co-PIs of the project if there is any interest in engaging and contributing to this new exciting field. All questions about the logistics and official applications (A resume with previous project experience and publication record) should be directed to ***fazilet.keles@bogazici.edu.tr***. The available positions will be filled on a first-come, first-served basis upon successful fulfillment of project requirements.