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Neural Mechanism of Optimal Performance

Dr. Mazzucato is a theoretical physicist by training. He obtained his PhD in Theoretical Particle Physics at SISSA/ISAS in Trieste, Italy, in 2005 and worked on string theory and beyond the Standard Model physics at the Department of Particle Physics at Tel Aviv University (2005-2008) and as a Visiting Researcher at the Racah Institute of Physics at Hebrew University (2006). He was a Member at the Simons Center for Geometry and Physics (2008-2011), and a Visiting Scientist at the Kavli Institute for Theoretical Physics, Santa Barbara (2009). He began his neuroscience research in 2012 at the Department of Neurobiology and Behavior, Stony Brook University. He was a Swartz Fellow in Theoretical Neurobiology (2013-2014) and, since 2014, a NIH-funded Principal Investigator. He was an Associate Research Scientist at the Center for Theoretical Neuroscience at the Zuckerman Mind Brain Behavior Institute at Columbia University (2017/2018).

Abstract: When we attend a demanding task, our performance is poor at low arousal (when drowsy) or high arousal (when anxious), but we achieve optimal performance at intermediate arousal, yielding the celebrated Yerkes-Dodson inverted-U law. Despite decades of investigations, the neural mechanisms underlying this inverted-U law are unknown. In this talk, I will elucidate the behavioral and neural mechanisms linking arousal and performance under the Yerkes-Dodson law in a mouse model. I will show that mice during auditory and visual decision-making express an array of discrete strategies, including optimal, suboptimal and disengaged. The optimal strategy occurs at intermediate arousal, measured by pupil size, consistent with the inverted-U law. Using neuropixels recordings from large neural populations in auditory cortex, I will show that sound encoding is optimal at intermediate arousal, suggesting that performance modulations occur as early as primary sensory areas. To explain the computational principle underlying this inverted-U law, I will show that in a recurrent network with E/I populations arousal induces a phase transition from a multi-attractor to a single attractor phase, and performance is optimized near the critical region. The model further predicts a monotonic decrease in neural variability induced by arousal, which was confirmed in the empirical data. Our results establish a biologically plausible theory of optimal performance near phase transitions in recurrent networks, whose implications for brain-inspired AI models will be briefly outlined.