On the emergence of bistable perception through circular inference

A. Garcia-Duran [1], M. Molano-Mazón [2], A. Hyafil [1]

[1] Centre de Recerca Matemàtica, Barcelona, Spain
[2] IDIBAPS, Barcelona, Spain

During perception the brain is continuously processing sensory information from the world, accepting and rejecting alternative, competing interpretations. This inference problem relies on the propagation of beliefs between high- and low-level sensory representations until a consistent interpretation of the state of the world is achieved. Typically the degree of confidence in one's perception lawfully scales with the strength of sensory evidence. However one particular class of stimuli, bistable percepts, elicits faulty inference, whereby only one single interpretation is confidently perceived at a given time, yet alternates over time despite no change in the stimulus. What properties of bistable stimuli are responsible for this unique behavior? We hypothesize that bistability emerges due to strong probabilistic coupling between beliefs associated with different stimulus features, which causes reverberatory loops (circular inference), and hence over-confidence. We formalize perception as an approximate probabilistic inference problem using a Probabilistic Graphical Model (PGM) that we apply to the Necker cube, a classical bistable stimulus. The PGM represents the different features of a stimulus and their probabilistic coupling. We then compare a dynamical system implementation of three popular inference algorithms which have been claimed to subserve human perception: Gibbs sampling, mean-field inference (MF) and loopy belief propagation (LBP). We show analytically that, for all algorithms, bistability emerges when the coupling is larger than a critical value, due to circular inference. Thus, bistability is always associated with over-confidence. However, we found a key difference between models in the subcritical regime (i.e. for non bistable stimuli): while Gibbs sampling and LBP models approximate the true posterior, MF still yields over-confidence. In conclusion, our work provides a mathematical framework that explains how perceptual bistability emerges due to the coupling between stimulus features. Moreover, it shows a promising path for identifying specific behavioral and neural signatures of the computational principles used by the brain during perception.