Bistable perception emerges from loopy inference in strongly coupled probabilistic graphs

Alexandre Garcia-Duran Castilla | Centre de Recerca Matemàtica

Alexandre Garcia-Duran (1,2), Martijn Wokke (1), Neus Pou-Amengual (1), Manuel Molano-Mazón (2), Alexandre Hyafil (1)

1. Centre de Recerca Matemàtica (CRM), Bellaterra, Spain

2. Universitat Politècnica de Catalunya - BarcelonaTech (UPC), Barcelona, Spain

During perception the brain is constantly processing sensory information, accepting and rejecting alternative, competing interpretations about the environment. This probabilistic inference process also determines the certainty —confidence— associated with such interpretations, which typically correlates with the strength of sensory evidence. However, in bistable perception, one single interpretation is confidently perceived at a given time, yet alternates over time despite no change in the stimulus. Here, we investigate the properties of bistable stimuli that are responsible for such dissociation of stimulus strength and confidence. We propose that bistability emerges due to an approximate probabilistic inference process running in a strongly coupled binary Markov Random Field. We illustrate our framework in the Necker cube, a classical bistable stimulus. Here, the nodes in the graph represent the perceived depth of the 2D shape vertices: their coupling indicates that, in nature, horizontal and vertical lines usually bind features at the same depth. We derived analytical expressions for the dynamics of perception in three popular classes of approximate inference: Belief Propagation, Mean Field, and sampling. In all three classes, bistability emerges due to strong probabilistic coupling between different stimulus features, producing reverberatory loops that lead to circular inference. This creates a double-well energy potential for perception dynamics, with intrinsic noise generating alternations between the two high-confidence percepts. We thus predict that decreasing the coupling leads to a shift from bistable to monostable potential, whereas sensory evidence modulates the asymmetry in the potential. We tested these results experimentally with a bistable stimulus (rotating cylinder), where the level of coupling between features and stimulus strength are

independently modulated. Preliminary results show that high coupling leads to overconfidence in participant reports, irrespective of stimulus strength. Our work shows that bistability emerges from loopy inference in stimuli composed of strongly coupled features.