Decentralized Multi-sensory Information Integration in Neural Systems

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Organisms face the constant challenge of extracting information reliably from ambiguous environments. The brain uses sensory evidence from multiple modalities to gather, from different aspects, as much information as possible about the same entity of interest. However, understanding how the brain integrates multiple sensory cues in its neural circuitry to form a coherent concept remains a challenge. While information integration was hypothesized to be accomplished by a single multi-sensory integration area, recent experimental evidence suggests that not a single multi-sensory brain area, but instead many multi-sensory brain areas are simultaneously involved in the integration of information from different modalities. Using biologically realistic neural network models, we here propose a novel mechanism of how multi-sensory information might be integrated in a distributed fashion across interconnected brain areas without the need for a central integration unit. We show that this decentralized system can integrate information optimally in a biologically realistic setting. Studying an example of combining visual and vestibular cues to infer heading-direction, we show further that the decentralized system is in good agreement with anatomically constraints and the experimental observations. Our decentralized framework suggests that optimally integrated information may emerge locally from the dynamics of the communication between brain areas and thus sheds new light on the interpretation of the connectivity between multi-sensory brain areas.