Higher-order and distributed synergistic functional interactions encode information gain in goal-directed learning

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Résumé

The goal-directed system enables us to form beliefs about the causal effect of actions and it provides the basis for rational decision-making. Goal-directed learning arises from a distributed neural circuit including the prefrontal, posterior parietal and temporal cortices. However, the role of cortico-cortical functional interactions in goal-directed learning remains unclear. To tackle this question, we combined information decomposition techniques with human magnetoencephalography (MEG). Our findings revealed that 'information gain' - or the decrease in uncertainty regarding the causal relationship between an action and its consequence - is represented within a distributed cortical network, incorporating the visual, parietal, lateral prefrontal, and ventromedial/orbital prefrontal cortices. Remarkably, cortico-cortical interactions encoded information gain in a synergistic manner, beyond what individual regions represented alone. Synergistic interactions encoded information gain at the level of pairwise and higher-order relations, such as triplets and quadruplets. Higher-order synergistic interactions were characterised by long-range relations gravitating over the ventromedial and orbitofrontal cortices, which played a receiving role in the broadcasting of information gain over cortical circuits. Overall, the current study provides evidence that information gain is encoded in both synergistic and higher-order functional interactions, as well as through the broadcasting of information gain signals toward the prefrontal reward circuitry. Moreover, our study offers a new perspective on how information relevant to cognition is encoded and broadcasted within distributed cortical networks and brain-wide dynamics.

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