Dark Control: The Default Mode Network as a Reinforcement Learning Agent

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Abstract

The default mode network (DMN) is believed to subserve the baseline mental activity in humans. Its highest energy consumption compared to other brain networks and its intimate coupling with conscious awareness are both pointing to an overarching function. Many research streams speak in favor of an evolutionarily adaptive role in envisioning experience to anticipate the future. In the present work, we propose a *process model* that tries to explain *how* the DMN may implement continuous evaluation and prediction of the environment to guide behavior. The main purpose of the DMN, we argue, may be to perform optimization based on Markov Decision Processes through vicarious trial and error. Our formal account of DMN function naturally accommodates as special cases previous interpretations based on (1) predictive coding, (2) semantic associations, and (3) a sentinel role. Moreover, this process model for the neural optimization of complex behavior in the DMN offers parsimonious explanations for recent experimental findings in animals and humans.

keywords: systems neuroscience, artificial intelligence, reinforcement learning, mind-wandering

1 Introduction

In the absence of external stimulation, the human brain is not at rest. At the turn to the 21st century, brain-imaging may have been the first technique to allow for the discovery of a unique brain network that would subserve baseline mental activities (Raichle et al., 2001; Buckner et al., 2008; Bzdok and Eickhoff, 2015). The "default mode network" (DMN) continues to metabolize large quantities of oxygen and glucose energy to maintain neuronal computation during free-ranging thought (Kenet et al., 2003; Fiser et al., 2004). The baseline energy demand is only weakly modulated at the onset of defined psychological tasks (Gusnard and Raichle, 2001). At its opposite, during sleep, the decoupling of brain structures discarded the idea of the DMN being only a passive network resonance and rather supported an important role in sustaining conscious awareness (Horovitz et al., 2009).

This *dark matter of brain physiology* (Raichle, 2006) begs the question of the biological purpose underlying DMN activity. Despite observation of similar large-scale networks of co-varying spontaneous activity in electrophysiological investigations (De Pasquale et al., 2010;