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Editorial

Computational cognitive neuroscience

Computational cognitive neuroscience is an emerging discipline that employs mathematical analysis and computational models to understand the neural basis of cognitive functions. The papers in this special issue are based on a selection of the best presentations at the 2007 meeting of the Computational Cognitive Neuroscience (CCN) conference. The CCN conference focuses on research at the intersection of neuroscience, cognitive psychology and computational modeling, where neuroscience-based computational models are used to simulate and understand cognitive functions such as learning, memory, attention, language, perception, decision making and cognitive control. Because CCN research complements traditional empirical approaches such as neuroimaging, cellular electrophysiology and behavioral measurements, a major goal of this conference is to encourage cross-disciplinary interactions between theoreticians and empiricists, across multiple levels of investigation within cognitive neuroscience. It is for this reason of encouraging cross-disciplinary interactions that the CCN conference partners with different host conferences each year: In 2007, the CCN meeting took place prior to the Society for Neuroscience conference in San Diego and in 2009, the meeting will be held in conjunction with the Psychonomics Society meeting in Boston.

The CCN program committee reviewed all oral and poster presentations at the 2007 conference and invited seven authors to submit full-length papers for this special issue based on their presentations. Selection criteria included a significant contribution to the field, a substantial computational modeling component, and a clear linkage between the neural and cognitive levels of explanation. All papers in this issue underwent a rigorous reviewing process, with 2–3 reviewers providing at least two rounds of reviews per article. While acceptance was not guaranteed from the outset, all seven of the invited submissions were finally accepted for inclusion.

The papers in this issue are grouped according to three themes: (1) Vision and visual working memory; (2) High-level memory systems; and (3) Reward and decision making. In the vision theme, two articles (by Rokem and Silver and by Johnson, Spencer, and Schner) span visual phenomena ranging from early sensory coding to high-level visual decision-making. In Rokem and Silver's article "A model of encoding and decoding in V1 and MT…" the authors first characterize psychophysically estimated tuning curves for oriented moving stimuli, and then present a computational model of directional tuning that captures the psychophysical data best relative to several other tested models. In Johnson et al.'s paper on visual working memory, a previously described model of working memory developed by Spencer and colleagues is extended to include mechanisms for simulating tasks based on comparison between observed stimuli and traces held in working memory. These two papers illustrate the power of developing neurocomputational models that make contact with a variety of levels of data, from unit recordings to human behavior. In the high-level memory systems theme, two papers (by van Vugt, Schulze-Bonhage, Sekuler, Litt, Brandt, Baltuch , and Kahana and by Becker, MacQueen, and Wojtowicz) focus on the medial temporal lobe memory system, how it interacts with prefrontal regions, and how it plays a role in stress-related psychiatric disorders. Van Vugt et al. employ intracranial electroencephalographic recordings to examine oscillatory rhythms in the medial temporal lobes and frontal cortices of human patients during visual recognition memory tasks. They observe evidence for distinct roles for these two brain regions, and compare their findings to predictions from computational models developed by the authors and other researchers. Becker et al. explore more specific functions of the hippocampal memory system and in particular hippocampal neurogenesis, both in a computational model and in humans. Human participants are given neuropsychological inventories for stress and depression, believed to correlate with neurogenesis levels, and they find evidence for a neurogenesis-specific memory deficit in individuals scoring high on the Beck depression inventory. In both of these articles, predictions from computational models have driven novel empirical studies, and will undoubtedly lead to further model development. Finally, in the reward and decision-making theme, three articles (by Doll, Jacobs, Sanfrey, and Frank, by Shah and Barto, and by Simon and Cohen) explore the relationship between simple reinforcement learning models often studied in this area and more complex cognitive processes, often studied separately. Doll et al. report a choice task investigating how humans reconcile conflict between instructed and experienced reward contingencies. The data are compared to a number of computational models that embody different hypotheses for the relationship

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between systems such as prefrontal cortex (thought to be associated with explicit instructional representations) and lower-level reinforcement learning machinery in the basal ganglia. Shah and Barto consider the implications of a broadly similar two-system learning architecture in the context of movement planning under ambiguous sensory information. In particular, they consider how the ability of a basal ganglia reinforcement learning system to produce quicker decisions than a more explicit (PFC) planning system might interact with the gradual analysis of sensory data, explaining a number of experimental results. Simon and Cohen take another approach to the question of the interaction between sensory analysis and action decision. In particular, they demonstrate a formal relationship between drift diffusion models descended from signal detection theory and often used to characterize the analysis of noisy percepts, and the matching law from animal conditioning, a relative of reinforcement learning models of reward-guided decision making. All three of these articles, then, make significant progress in extending the celebrated accounts of reinforcement learning in the basal ganglia to encompass additional neural territory and behavioral functions.

Taken together, the articles in this issue provide a compelling demonstration of how computational modeling can play a key role in interpreting experimental data and in guiding further experimentation to unravel the neural mechanisms that give rise to increasingly complex cognitive functions.

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