Dynamic decision making: neuronal, computational, and cognitive underpinnings

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Challenging Issues

As complexity in our everyday environment increases (e.g., mobile applications for monitoring energy consumption), how do we adapt and react to the changing demands placed on us? In dynamic decision making (DDM) problems, the environment changes over time due to previous decisions made and/or factors outside the control of the decision-maker. To maximize his/her reward, an agent effectively needs to control a complex dynamic system. This often involves planning in the face of uncertainty about how decisions change the state of the system and the rewards that can be obtained. Thus, DDM refers to a process by which an agent selects a course of action in a manner that achieves or maintains a desired state in a dynamic environment. This includes balancing exploration and exploitation, distinguishing between different sources of variability within the environment, and tracking the current state of the environment (i.e., filtering).

Thus far there has been little attempt at a synthesis of the amassing research from different areas of cognitive science directed towards understanding DDM. The objective of this symposium is to bring together the latest theoretical approaches and empirical research investigating DDM. The speakers range in expertise from comparative (Prof Watanabe), applied (Prof Harvey) and cognitive psychology (Dr Osman), computational neuroscience (Prof Dayan), and computational learning theory (Dr Speekenbrink). By bringing these diverse approaches together, the aim is to generate discussion around the following critical question: *What are the processes/mechanisms that enable us to adapt to changes in uncertain environments in terms of the information we process, the decisions we make, and the intrinsic and extrinsic goals that we pursue?* The symposium will consist of a general introduction (Osman), three talks (Dayan, Harvey, Wanatabe) and an extended discussion (moderated by Speekenbrink) involving all participants.

Peter Dayan

Peter Dayan’s work in computational and experimental neuroscience has contributed significantly to our understanding of the neural mechanisms underlying DDM and the learning of reward structures therein. Dayan is an expert on reinforcement learning and in recent work, has elucidated the distinction between “model-based” and “model-free” learning and the neural circuits supporting these.

Model-based learning, usually associated with declarative task-knowledge, can support complex planning. Model-free learning, due to its more procedural nature, supports quick and habitual decisions, but will not cope well in an environment that undergoes rapid, abrupt changes. Dayan's recent work has shown how both processes work concurrently to support effective DDM.

Dayan, P. (2009). Goal-directed control and its antipodes. *Neural Networks, 22*, 213-219.
Dayan P., & Daw, N.D. (2008). Decision theory, reinforcement learning, and the brain. *Cognitive, Affective & Behavioral Neuroscience, 8,* 429-453.

Nigel Harvey

How effective are judgments, and what role do they play in using evidence to plan actions in complex decision making environments? Nigel Harvey's work in cognitive and applied decision making has developed cognitive models of judgments and decisions, and the confidence placed therein, in a variety of domains including economic (e.g., consumer choice behavior), financial and medical (e.g., comparisons of clinical and actuarial judgment). More recently, Harvey has shown that in a variety of decision making situations people decide whether to focus their efforts on acquiring new information from feedback, or whether to implement their extant knowledge.

Harvey, N. (2011). Learning judgment and decision making from feedback: An exploration-exploitation trade-off? In M.K. Dhami, A. Schlottmann and M. Waldmann (Eds.) *Judgment and decision making as a skill: Learning, development, and evolution*. Cambridge: Cambridge University Press.
Reimers, S., Harvey, N. (2011). Sensitivity to autocorrelation in judgmental time series forecasting. *International Journal of Forecasting,* 27, 1196-1214.

Magda Osman

Magda Osman's recent work has advanced the proposal that successful learning in DDM environments can be achieved indirectly via prediction or directly via control processes. In two reviews of DDM, Osman brings together theoretical and empirical research from disparate disciplines spanning engineering, machine learning, management, social and cognitive psychology, and neuroscience, and shows that each has contributed to answering the question: *How do we isolate the effects of our actions from those generated independently in order to achieve desirable outcomes?*

Osman, M. (2010). Controlling uncertainty: A review of human behavior in complex dynamic environments. *Psychological Bulletin, 136,* 65-86.
Osman, M. (2011). The role of feedback in decision making. In *Parkinson's Disease* (Chapter 3), InTech Publishers.

Maarten Speekenbrink

In DDM environments, the potential consequences of actions can change over time, either due to previous actions or external factors. How do people adapt their representations of a task to such abrupt or gradual changes? In contrast with popular beliefs, the findings from Speekenbrink's research suggest that people are generally able to rapidly adapt their predictions to different types of changes in multiple cue environments.

Speekenbrink, M., & Shanks, D.R. (2010). Learning in a changing environment. *Journal of Experimental Psychology: General*, *139*, 266-298.
Speekenbrink, M., & Shanks, D.R. (2008). Through the looking glass: A dynamic lens model approach to MCPL. In: Chater, N., & Oaksford, M. (Eds.). *The probabilistic mind: Prospects for Bayesian cognitive science*. Oxford: Oxford University Press. (pp. 409-429).

Masataka Watanabe

Adaptive goal-directed behaviours can be acquired by neuronal mechanisms that can learn and anticipate the possible outcomes of actions, and determine the actions that might be successful for achieving desirable outcomes. Having close anatomical connections with high-order cortical and subcortical limbic areas, the prefrontal cortex (PFC) play the most important role in this process. In several primate studies, Masataka Watanabe has shown that neurons in the lateral PFC integrate cognitive (outcome probabilities) and motivational (rewards) representations that enable adaptive decision making in complex circumstances.

Watanabe, M. (2007). Role of anticipated reward in cognitive behavioral control. *Current Opinion in Neurobiology*, *17*, 213-279.
Watanabe, M. (2009) Role of the primate lateral prefrontal cortex in integrating decision-making and motivational information. In: J. Dreher, & L. Tremblay (Eds.). *Handbook of Reward and Decision Making.* Oxford: Academic Press, pp. 79-96.