A Computational Model of Goal-Driven Behaviours and Habits in Rats

Francesco Mannella¹, Marco Mirolli¹ and Gianluca Baldassarre¹*

• ¹ Consiglio Nazionale delle Ricerche, Laboratory of Computational Embodied Neuroscience, Istituto di Scienze e Tecnologie della Cognizione, Italy

Research on animal learning has investigated learning on the basis of two main classes of experimental paradigms. The first, Pavlovian conditioning, can be explained mainly in terms of the formation of associations between the representations of ‘conditioned stimuli’ and ‘unconditioned stimuli’ (CS-US) which ‘transfer’ values from the latter to the former. An important locus of these associations is amygdala (Amg). The second, instrumental conditioning, can be explained in terms of the formation of stimulus-response associations (S-R or ‘habits’) mainly taking place within the basal-ganglia (BG) cortical ‘loop’ involving dorsolateral-striatum (DLS), globus-pallidum (GP), and premotor/motor cortex (PM).

Recently, the animal-learning literature has proposed a third class of experimental paradigms to study ‘goal-directed behaviours’. These are behaviours which are characterised by a sensitivity to the manipulation of the value of the outcomes of actions. For example, the experiments of ‘devaluation’ show that rats perform with less frequency an action (e.g., pressing a lever), which has been previously associated with a certain outcome (e.g., sucrose solution), if the value of the latter is decreased with either satiation or nausea, in comparison to a second action (e.g., pulling a chain) which has been previously associated with a second non-devalued outcome (e.g., food pellets). The selection of goals to be pursued might take place in a second important BG-cortical loop involving nucleus accumbens (NAcc) and medial prefrontal cortex (in particular prelimbic cortex, PL) as their lesion impairs the sensitivity to devaluation. Interesting, also lesions of Amg cause such impairment, likely as it store the value of outcomes (Balleine, Killcross, and Dickinson, 2003, Journal of Neuroscience).

Recently, research on brain anatomy (Haber, Fudge, and McFarland, 2000, Journal of Neuroscience) has started to show that there are at least two pathways linking different BG-cortical loops: the striato-nigro-striatal ‘spirals’, based on dopaminergic neurons, and the connections between the cortical portions of the loops. This suggests the existence of a hierarchical organisation of goal-directed behaviours and habits which, however, has not been fully understood. This work proposes a systems-neuroscience computational model which give, for the first time, a coherent account of some of the interactions existing between CS-US associations, habits, and goal-driven behaviours. In particular, the model proposes that: (a) the NAcc can influence, via dopaminergic spirals, the neural competition for action selection taking place within DLS/GP; (b) PL contributes to select specific outcomes and influences the selection of actions within the habit loop via the cortical pathways; (c) backward connections within loops can inform the striatum on actions which has been executed so as to strengthen or weaken habits and goal-related associations on the basis of the experienced value of their outcomes. The model is constrained with known brain anatomy and is validated by reproducing the results of a number different lesion experiments with rats.

Conference: Bernstein Conference on Computational Neuroscience, Frankfurt am Main, Germany, 30 Sep - 2 Oct, 2009.
Presentation Type: Poster Presentation
Topic: Decision, control and reward


Received: 25 Aug 2009; Published Online: 25 Aug 2009.

* Correspondence: Gianluca Baldassarre, Consiglio Nazionale delle Ricerche, Laboratory of Computational Embodied Neuroscience, Istituto di Scienze e Tecnologie della Cognizione, Rome, Italy, gianluca.baldassarre@gmail.com