Forebrain decision circuits weigh expected value, novelty, and task-relevance

Events constantly force us to re-evaluate options and to choose whether to continue a current task or to redirect our behavior along a new course. Making good decisions requires forebrain circuits to balance considerations of several types. The striatum of the basal ganglia, long known for its pivotal role in Parkinson’s disease, is also a key neural center for weighing information in the service of good decisions. Supported by the NSF Center of Excellence for Learning in Education, Science, and Technology (CELEST; PI: Stephen Grossberg), computational neuroscientists Daniel Bullock (Boston University) and Can Tan (Harvard University) are constructing an intricate neural-circuit model to enable simulations of how the striatum achieves high-quality decisions. For their October 2008 report in *J. Neurophysiology*, they computed a decision surface (figure below) for tonically active neurons (TANs), whose pauses are implicated in decisions to redirect behavior. The striatal TANs’ decision surface implies that within a broad range, a higher thalamic “rating” of a stimulus can often compensate for a lower dopaminergic (expected-value) “rating” of a stimulus. This is important for two core aspects of adaptive behavior. Novel stimuli with no reward history, which lead to large thalamic responses and modest dopaminergic responses, will also be able to generate a TAN pause and thereby redirect behavior. Even non-novel (habituated) stimuli, which do not ordinarily generate large thalamic responses, have been shown to do so if the actor has learned that success at the current task requires selective attention to, and response control by, such stimuli. Thus the ability of novelty and learned task-relevance to affect decisions, even in competition with cues with intermediate expected-reward values, can be mediated by the thalamic and striatal (TAN) operating characteristic revealed by the simulation. Beyond decision-making, this research contributes to basic understanding of Parkinson’s disease, in which striatal levels of the neurotransmitters acetylcholine (released by TANs) and dopamine are critical.

Right: Computed striatal TAN decision surface. The plot shows how a TAN’s membrane potential would equilibrate during sustained combinations of inputs to striatum from thalamic (CM-Pf) neurons and midbrain dopaminergic (DA) neurons. The modeled dopaminergic input increases along the abscissa, and the thalamic input increases on the ordinate. The resultant TAN membrane potential is represented with the color code shown at far right. Colors below deep red indicate a pause response.