This Week in The Journal

Dopamine Release Patterns Differ in Accumbal Core and Shell

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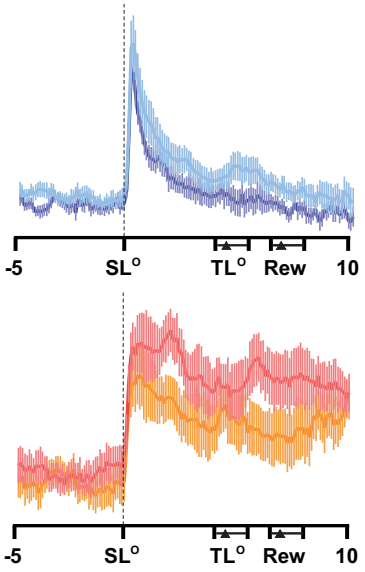
(see pages 11572–11582)

Dopaminergic neurons are prominent players in reward-driven behaviors, but their precise role remains a matter of debate. The firing rate of dopaminergic neurons increases when unexpected rewards (or cues predicting such rewards) occur, firing rates are unchanged when expected rewards are received, and firing rates decrease when expected rewards are absent. This firing pattern led researchers to hypothesize that dopaminergic neurons encode reward prediction errors that help animals learn which cues signal rewards. An alternative hypothesis is that dopamine motivates animals to obtain a reward that the animal predicts is available based on previously learned associations. As is often the case in longstanding scientific debates, both of these hypotheses may be correct.

Saddoris et al. suggest that different aspects of reinforced behavior are influenced by dopamine actions in different brain areas. To test this, they first trained rats to press two sequentially presented levers to receive a reward, then used fast-scan cyclic voltammetry to measure real-time dopamine release in the core or shell of the nucleus accumbens (NAc) as rats performed the task. Consistent with their hypothesis, dopamine release dynamics differed in the two areas. In the core, dopamine levels increased upon appearance of the first reward-predicting cue, then declined to baseline levels before reward was received. In the shell, dopamine levels likewise increased when the initial cue appeared, but levels remained high throughout the task until after reward delivery. Furthermore, dopamine release in the core was similar in all trials of a session, whereas in the shell, dopamine release was greater in early trials than in late trials. Finally, during extinction training (when reward was withheld) dopamine release in response to the initial cue decreased in the core before rats' responses slowed, and importantly, dopamine levels in the core dropped below baseline at the time reward was expected. In contrast, dopamine levels in the shell did not decrease until rats stopped responding, and no drop below baseline was detected.

These results suggest that dopamine release in the NAc core represents a prediction error that only signals unexpected events, whereas dopamine release in the shell motivates animals to be engaged in a task until reward is received. Future experiments should determine how dopamine motivates action and whether the prediction error it encodes promotes or simply reflects learning.



Dopamine release in the NAc core (top) increases when the first reward-predicting cue appears (first lever inserted, SL ^{0}), then declines to baseline. The pattern is similar in early (light blue) and late (dark blue) trials. In contrast, dopamine levels in the shell (bottom) rise at SL ^{0} and remain elevated as the second lever is inserted (TL ^{0}) and reward is received (Rew). Release in the shell is higher in early trials (pink) than in late trials (orange). See Saddoris et al. for details.

Alcohol Intake Induces Plasticity Selectively in Striatal Neurons Expressing D1 Dopamine Receptors

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(see pages 11634–11643)

The striatum, which receives dopaminergic inputs from the midbrain, has a central role in learning, motivating, and performing goal-directed actions. The principal cells of the striatum are medium spiny neurons that express either D1- or D2-type dopamine receptors (D1-MSNs and D2-MSNs, respectively). Through direct projections to the output nuclei of the basal ganglia, D1-MSNs are thought to facilitate performance of specific behaviors. In contrast, D2-MSNs are thought to inhibit specific behaviors via indirect projections to the basal ganglia output nuclei. Reinforcement learning—including that underlying drug addiction—is thought to be mediated by plasticity in these striatal circuits. Therefore, characterizing this plasticity is an important aim of ongoing research.

Wang et al. previously reported that alcohol consumption enhanced induction of long-term potentiation in mouse dorsomedial striatum (DMS); what cells were involved remained unclear, however. They now show that at least some alcohol-induced changes in DMS occur selectively in D1-MSNs. Specifically, AMPA-induced currents were larger and the amplitude of miniature EPSCs was greater in D1-MSNs of mice that periodically consumed large amounts of alcohol than in D1-MSNs of mice that had not consumed alcohol. In addition, dendritic length, branching, and the density of mushroom-shaped spines were greater, while the density of immature-looking spines was lower, in D1-MSNs of alcohol-consuming mice than in controls. No such differences were detected between D2-MSNs of alcohol-consuming and control mice.

These data suggest that heavy alcohol consumption induces plasticity of glutamatergic synapses in D1-MSNs, but not in D2-MSNs of the DMS. This plasticity may promote further alcohol consumption. Consistent with this hypothesis, infusion of D1 dopamine receptor antagonists into the DMS of alcohol-consuming mice reduced subsequent alcohol intake, whereas D2 dopamine receptor antagonists did not.

All together, the data suggest that dopamine motivates the consumption of addictive substances by acting on D1-dopamine receptors, and that heavy alcohol consumption potentiates the responses of neurons expressing these receptors. Therefore, targeting this pathway may be helpful in suppressing craving in people with addictions.

This Week in The Journal is written by Teresa Esch, Ph.D.