LETTER

Duality of salience in dopamine neurons

Brischoux et al. (1) may have finally provided the evidence necessary to bridge a recent, but well developed controversy between dopamine (DA) theories. Major theories of DA have described functional correlates for both appetitive (2, 3) or aversive outcomes (4, 5) but have fallen short at the crossroads of these concepts. DA neurons clearly exhibit phasic increases in firing rate in response to rewards (2), which presumably increases DA in mesolimbic regions. Although DA is increased by footshock in mesocortical and mesolimbic regions (4, 5), phasic increases in firing rate of ventral tegmental area (VTA) neurons in response to footshock have not been demonstrated (2). Brischoux et al. (1) demonstrate that, in the sparsely researched ventral portion of the VTA, neurochemically identified DA neurons exhibit phasic increases in firing rate in response to footshock, suggesting that mesencephalic outcome prediction might function using distinct modalities.

Surely the majority of stimuli, as well as differing schedules of reinforcement, contain both rewarding and aversive properties. The author's demonstration that the VTA exhibits increases in firing rates in response to both the onset of an aversive stimulus as well as its termination, which could have reinforcing properties, allows one to apply rationality to previously enigmatic findings among DA theories. For example, Young (5) has shown that the pairing of 2 neutral stimuli produces an increase in extracellular accumbal DA. If DA neurons signal positive or negative outcomes, the results of Brischoux et al. (1) may predict the neophobic or excitatory reactions typically generated by novel stimuli. Further, increased extracellular accumbal DA concentrations during high-effort as compared with low-effort food-seeking tasks (6) might also be explained by the dual valence of DA neuron signaling. That is, the increased DA in high-effort tasks might reflect the punishing properties of an increased "response cost" (7), which are more economically aversive than low-effort tasks.

It seems likely that the ambiguous valence of a given stimulus, possibly signaled by DA neurons, might contribute to a number of previously inscrutable results. Still, one must concede that the present results must be replicated in the awake, freely moving animal in order to present a truly analogous comparison to prior theories. Regardless, the findings presented by Brischoux et al. (1) have added a breath of fresh air to the DA literature and leave the greater research community with an intriguing new set of questions: Will neurons which fire to the onset of footshock fire towards predictors of footshock? Do these same neurons show reward-prediction properties as well as aversive? Can the same neuron show differential firing rates at varying levels of a given outcome (e.g., footshock intensity)? Are the regional projections of neurons encoding reinforcing or aversive stimuli different or the same? Is DA differentially released by targets of reinforcing or aversive firing neurons? How do these neurons respond to situations of ambiguity or conflict?

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