

The role of dopamine in behavioral exploration and action selection

ABSTRACT:

We are constantly faced with the trade-off between exploiting past actions with known outcomes and exploring novel actions whose outcomes may be better. This exploration-exploitation balance is thought to be influenced by dopaminergic neurons of the substantia nigra pars compacta (SNc) and noradrenergic neurons of the locus coeruleus (LC). However, little is known about SNc and LC network dynamics during exploration. We aimed to characterize dopaminergic and noradrenergic signaling during these distinct behavioral states. We developed a novel behavioral paradigm in mice to investigate exploratory and exploitative behavioural states. Mice were presented with three equidistant nose poke ports and had to explore the environment to discover a sequence of three nose pokes that was rewarded. We then performed calcium imaging in either the SNc or LC of freely behaving mice during performance of this task. Actions were variable as mice explored to find the rewarded sequence, but became stable as they learned to exploit the rewarded sequence. When the rewarded sequence was changed, mice returned to a more variable state. Dopaminergic networks expressed higher levels of sustained activity when mice were exploiting relative to exploring, and these differences could not be accounted for by low-level differences in reward occurrence. Conversely, noradrenergic networks exhibited higher levels of sustained activity when mice were exploring relative to exploiting. These experiments suggest that exploitation is associated with higher sustained levels of dopaminergic activity and lower sustained levels of noradrenergic activity, with potentially important consequences for downstream circuits.

Keywords

Dopamine, Exploration, Action selection, Basal ganglia

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