A neurocomputational account of reward and novelty processing and effects of psychostimulants in attention deficit hyperactivity disorder.

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Abstract

Computational models of reinforcement learning have helped dissect discrete components of reward-related function and characterize neurocognitive deficits in psychiatric illnesses. Stimulus novelty biases decision-making, even when unrelated to choice outcome, acting as if possessing intrinsic reward value to guide decisions toward uncertain options. Heightened novelty seeking is characteristic of attention deficit hyperactivity disorder, yet how this influences reward-related decision-making is computationally encoded, or is altered by stimulant medication, is currently uncertain. Here we used an established reinforcement-learning task to model effects of novelty on reward-related behaviour during functional MRI in 30 adults with attention deficit hyperactivity disorder and 30 age-, sex- and IQ-matched control subjects. Each participant was tested on two separate occasions, once ON and once OFF stimulant medication. OFF medication, patients with attention deficit hyperactivity disorder showed significantly impaired task performance (P = 0.027), and greater selection of novel options (P = 0.004). Moreover, persistence in selecting novel options predicted impaired task performance (P = 0.025). These behavioural deficits were accompanied by a significantly lower learning rate (P = 0.011) and heightened novelty signalling within the substantia nigra/ventral tegmental area (family-wise error corrected P < 0.05). Compared to effects in controls, stimulant medication improved attention deficit hyperactivity disorder participants' overall task performance (P = 0.011), increased reward-learning rates (P = 0.046) and enhanced their ability to differentiate optimal from non-optimal novel choices (P = 0.032). It also reduced substantia nigra/ventral tegmental area responses to novelty. Preliminary cross-sectional evidence additionally suggested an association between long-term stimulant treatment and a reduction in the rewarding value of novelty. These data suggest that aberrant substantia nigra/ventral tegmental area novelty processing plays an important role in the suboptimal reward-related decision-making characteristic of attention deficit hyperactivity disorder. Compared to effects in controls, abnormalities in novelty processing and reward-related learning were improved by stimulant medication, suggesting that they may be disorder-specific targets for the pharmacological management of attention deficit hyperactivity disorder symptoms.