Dopamine and decision making

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A framework for value-based decision making

Adapted from Rangel, Camerer & Montague (2008) Nat Rev Neurosci
Is dopamine the reward molecule?
Is dopamine the reward molecule?

Rats will press a lever continuously to get intracranial electrical stimulation, even to the point of skipping feeding.

Olds & Milner (1954)
Reward prediction error (RPE)

\[ \text{RPE} = \text{experienced reward} - \text{predicted reward} \]

Typical reinforcement learning model

\[ \text{RPE} = \text{updated cue value} - \text{learning rate} \times (\text{current reward} - \text{current cue value}) \]

Value estimates guide decision making

\[ V(t+1) = V(t) + \alpha [ r(t) - V(t) ] \]

Schultz, Dayan & Montague (1997) Science
Dopamine concentrations can encode RPEs

BOLD activity in the striatum can represent RPEs

Rutledge, Dean, Caplin & Glimcher (2010) J Neurosci
Caplin, Dean, Glimcher & Rutledge (2010) Q J Econ
Substantia nigra in the Parkinson’s brainstem
Arvid Carlsson revives catatonic rabbits with L-DOPA

Deplete catecholamines

Inject L-DOPA
Wait 15 minutes
Dopamine drugs affect learning in Parkinson’s disease

Rutledge et al. (2009) J Neurosci
Does L-DOPA affect decision making?

30 subjects, 2 sessions, 150 mg L-DOPA or placebo
300 trials, £20 endowment

mean 1.6s

Rutledge, Skandali, Dayan & Dolan (under review)
L-DOPA increases gambling in gain trials

Mixed trials (n=100)
Gain trials (n=100)
Loss trials (n=100)

L-DOPA increases gambling in gain trials

Rutledge, Skandali, Dayan & Dolan (under review)
Prospect theory does not account for L-DOPA effects

\[ U(\nu) = \nu^{\alpha+} \quad \nu \geq 0 \]
\[ = -\lambda (-\nu)^{\alpha-} \quad \nu < 0 \]

Prospect theory model fit

Rutledge, Skandali, Dayan & Dolan (under review)
Prospect theory does not account for L-DOPA effects

\[
P_{\text{gambles}} = \begin{cases} 
\frac{1 - \beta_{\text{gain}}}{1 + e^{\mu(U_{\text{gambles}} - U_{\text{certain}})}} + \beta_{\text{gain}} & \text{if } \beta_{\text{gain}} \geq 0 \\
\frac{1 + \beta_{\text{gain}}}{1 + e^{\mu(U_{\text{gambles}} - U_{\text{certain}})}} & \text{if } \beta_{\text{gain}} < 0
\end{cases}
\]

Rutledge, Skandali, Dayan & Dolan (under review)
L-DOPA increases approach behaviour in gain trials

P<0.05

Approach-avoidance model fit

Pavlovian approach for gains

Pavlovian avoidance for losses

Rutledge, Skandali, Dayan & Dolan (under review)
Dopamine declines with age

Economic risk taking decreases over the lifespan (Dohmen et al., 2005; Deakin et al., 2004; Tymula et al., 2010)

Kaasinen & Rinne (2002)
Crowdsourcing for cognitive science - the utility of smartphones.
Brown, Zeidman, Smittenear, Adams, McNab, Rutledge, Dolan.

working memory    impulsivity    attentional blink    decisions and happiness
The Great Brain Experiment ‘What makes me happy?’

30 choices per play, 12 happiness ratings

\[
Happiness(t) = w_0 + w_1 \sum_{j=1}^{t} \gamma^{t-j} CR_j + w_2 \sum_{j=1}^{t} \gamma^{t-j} EV_j + w_3 \sum_{j=1}^{t} \gamma^{t-j} RPE_j
\]

Rutledge, Skandali, Dayan & Dolan (2014) PNAS
The Great Brain Experiment ‘What makes me happy?’

N=24,706 subjects (1,533,450 decisions)

Rutledge, Smittenaar et al. (in prep)
Dopamine and decision making

Dopamine can represent a reward prediction error signal

Dopamine drugs affect learning about the values of actions

Dopamine drugs affect decision making independent of learning, increasing risk taking for potential gains

Aging, associated with dopaminergic decline, reduces risk taking for potential gains