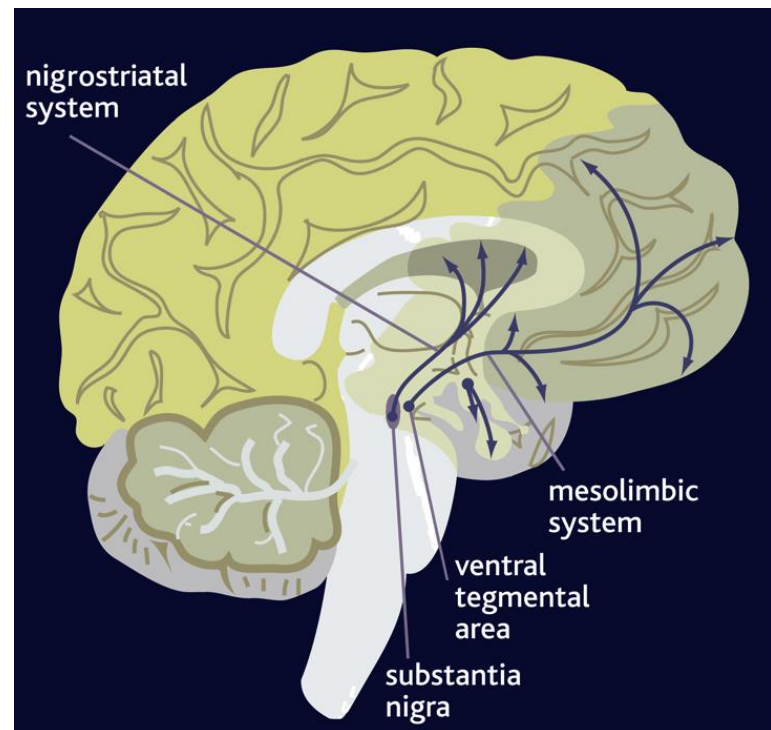
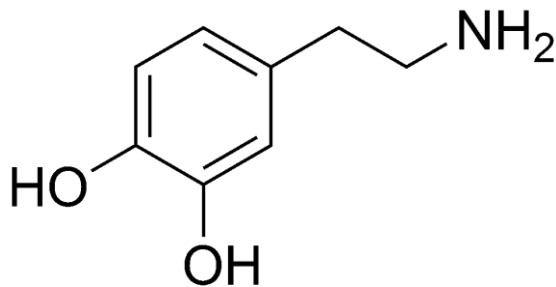


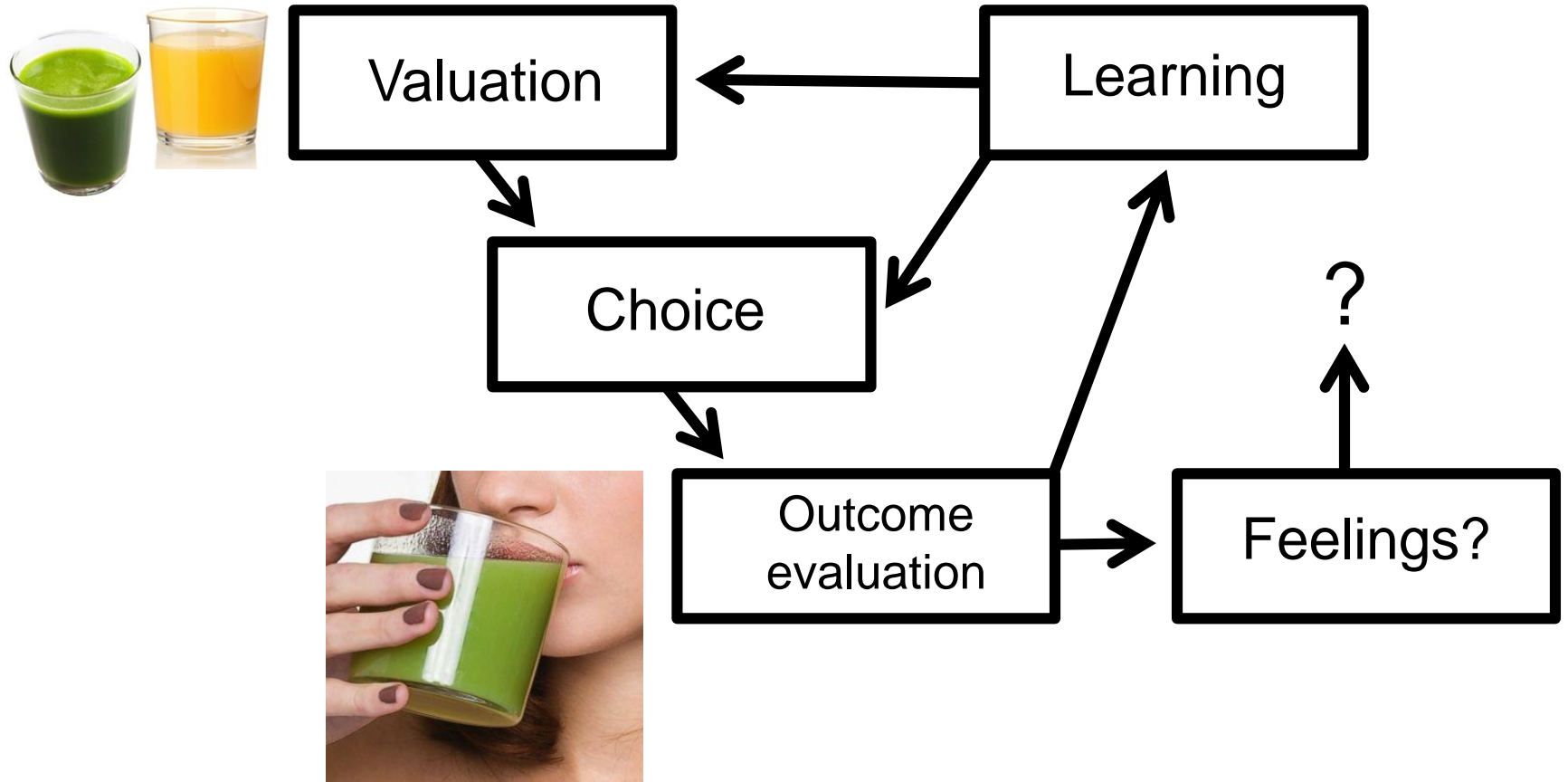
# Dopamine and decision making

Robb Rutledge  
University College London

SiNAPSA Neuroscience Conference  
Neuroeconomics symposium  
May 15, 2015

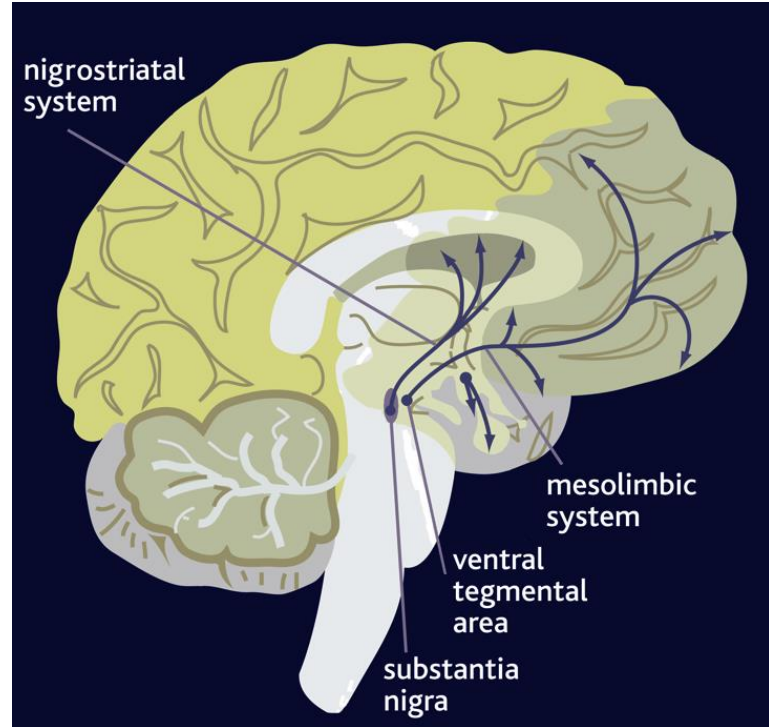
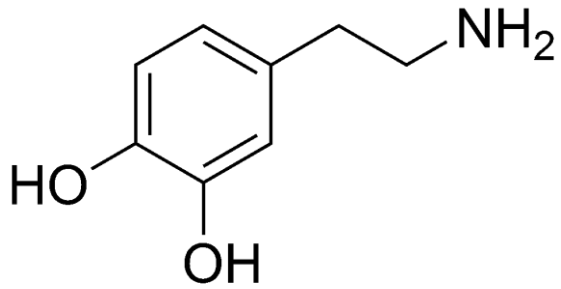


# A framework for value-based decision making

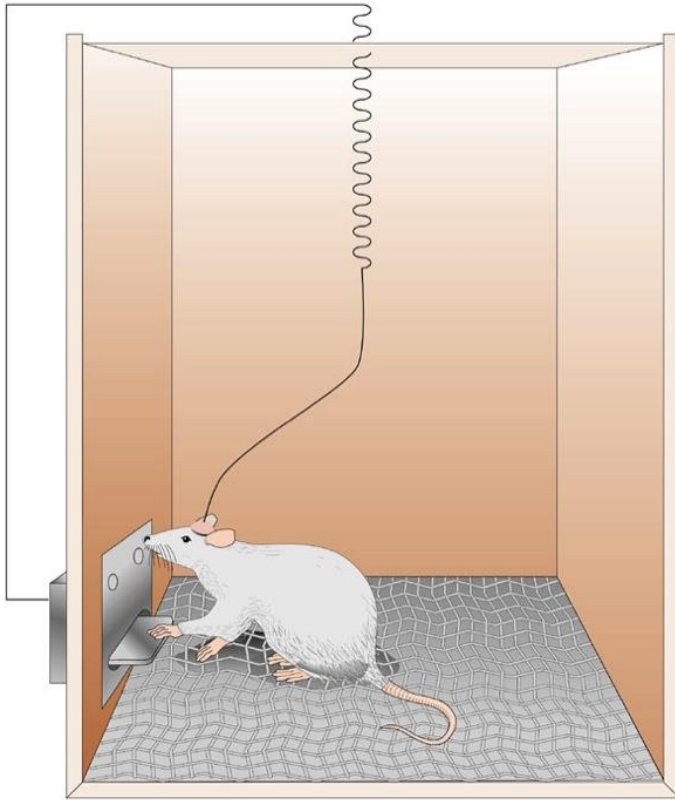


*Adapted from Rangel, Camerer & Montague (2008) Nat Rev Neurosci*

# Is dopamine the reward molecule?

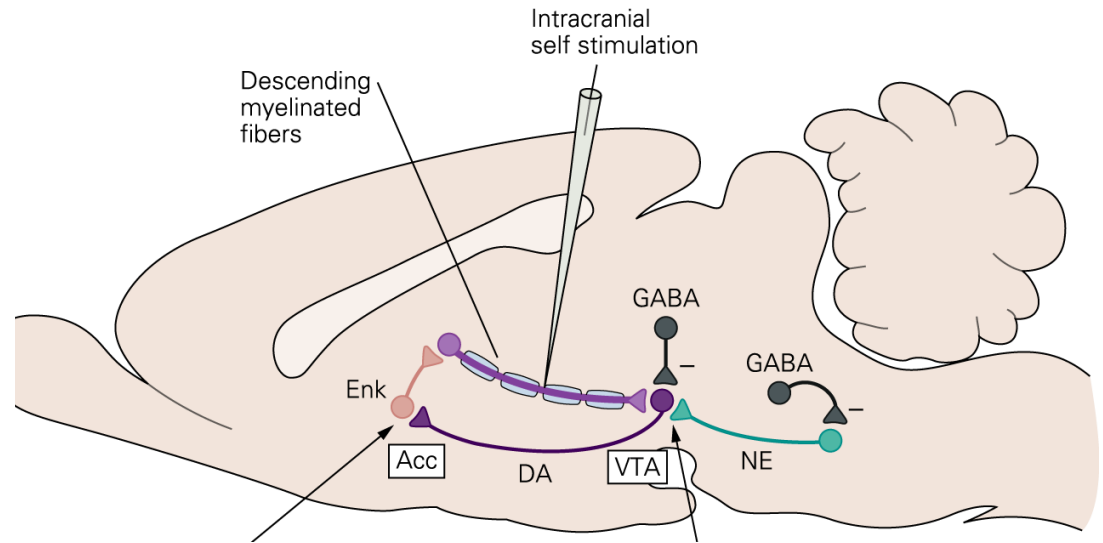


# Is dopamine the reward molecule?



© 2001 Lippincott Williams & Wilkins

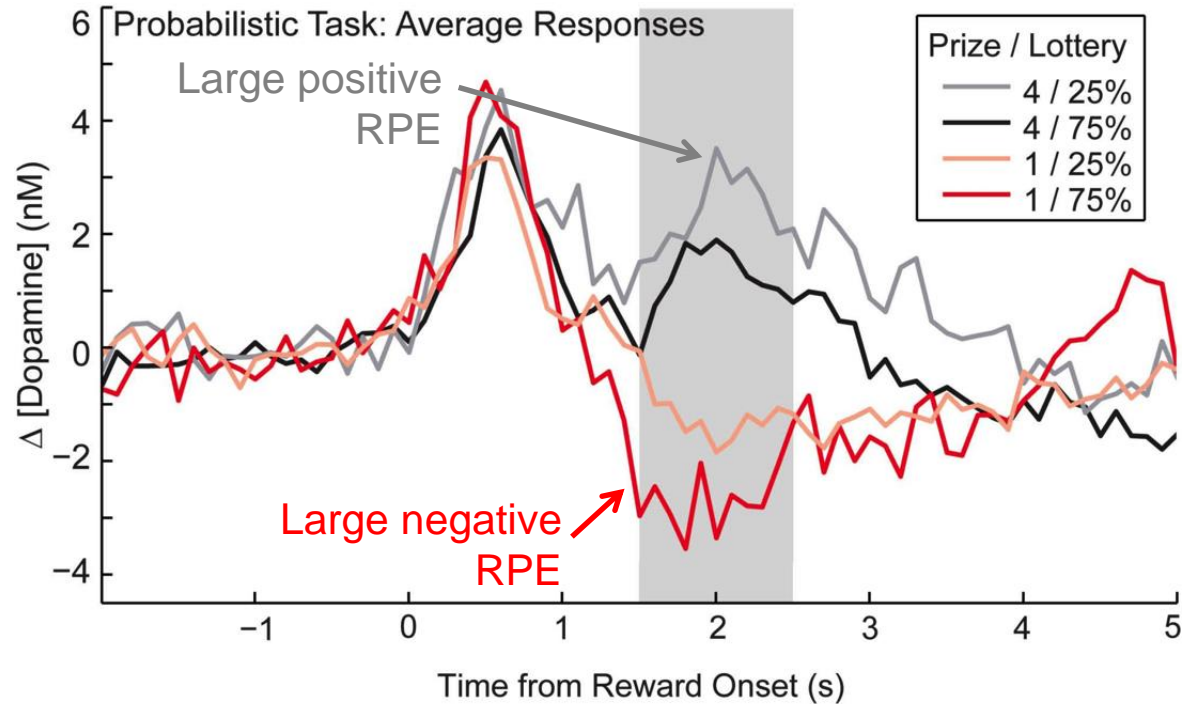
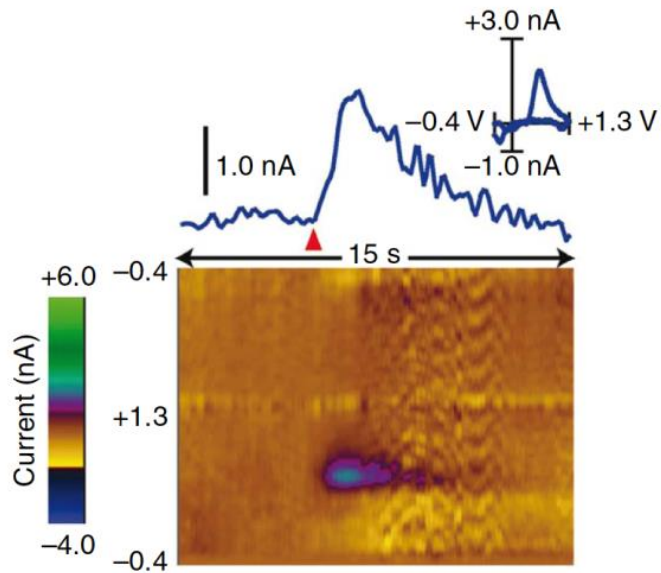
Rats will press a lever continuously to get intracranial electrical stimulation, even to the point of skipping feeding.



*Olds & Milner (1954)*

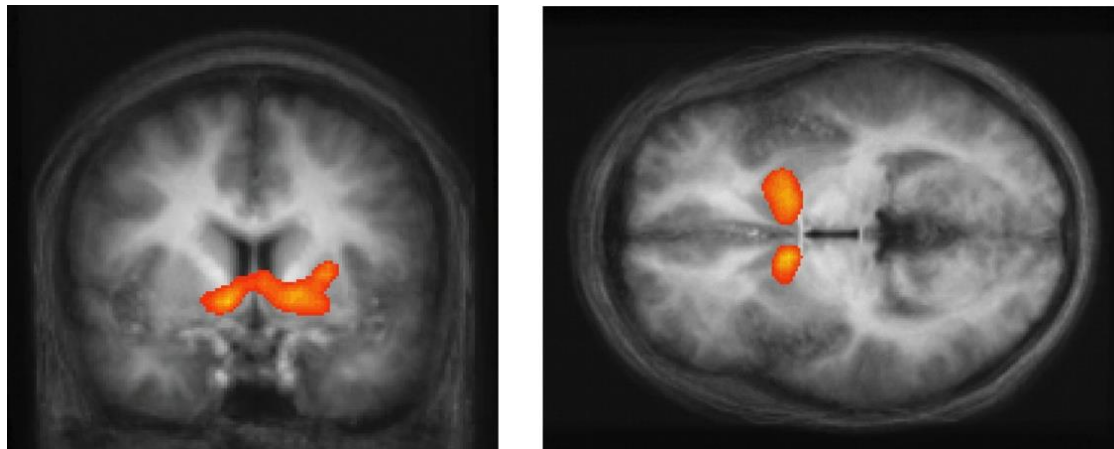


# Dopamine concentrations can encode RPEs



Hart\*, Rutledge\*, Glimcher & Phillips (2014) J Neurosci

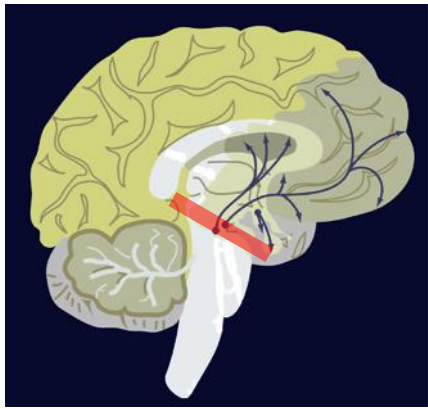
# BOLD activity in the striatum can represent RPEs



*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

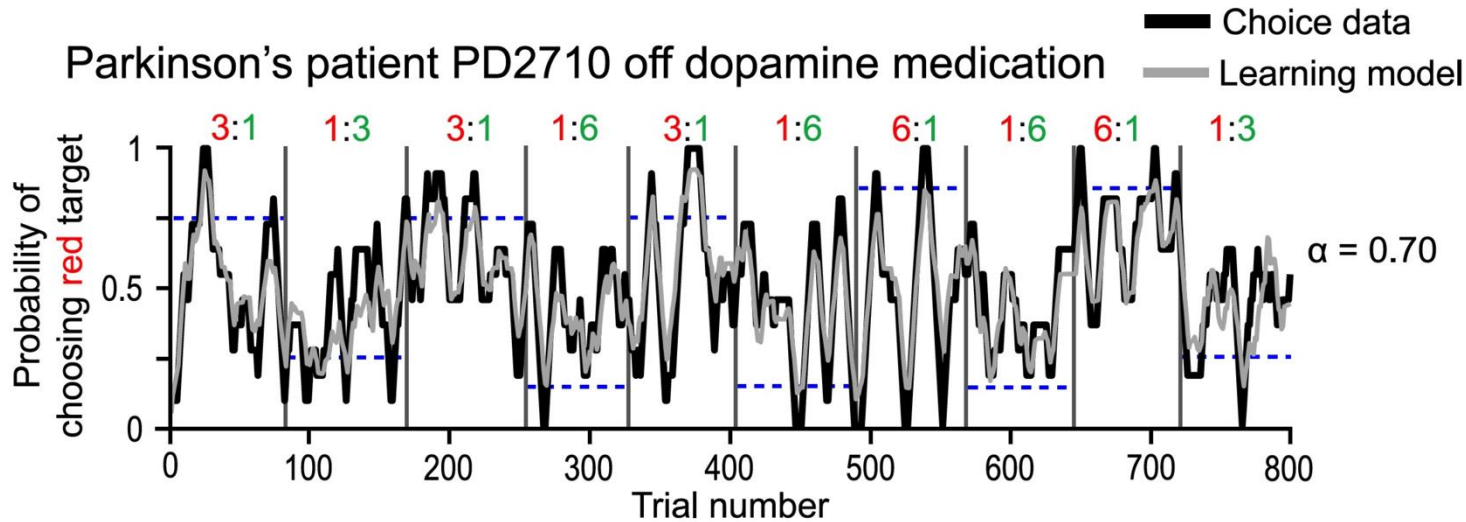


Deplete  
catecholamines

Inject L-DOPA  
Wait 15 minutes



# Dopamine drugs affect learning in Parkinson's disease



updated cue value

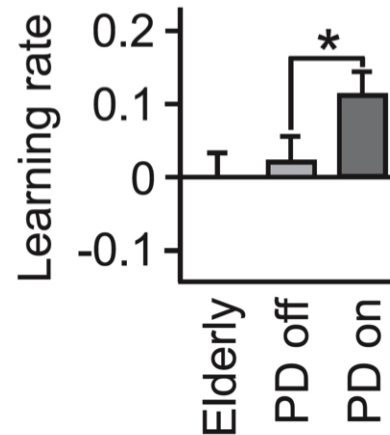
learning rate

current reward

current cue value

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

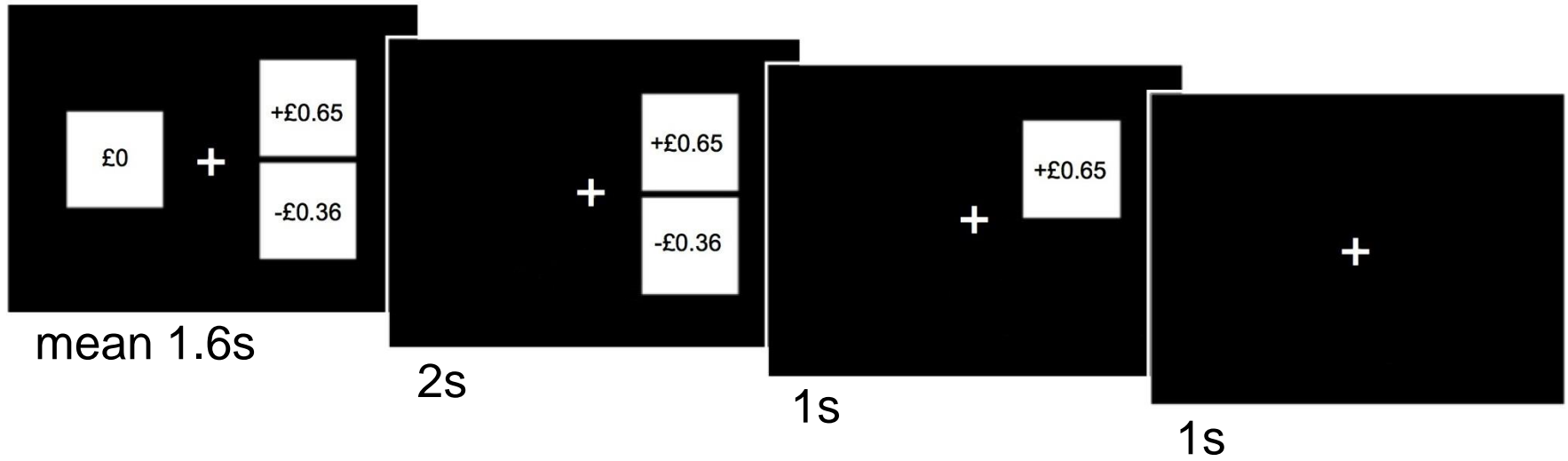
**RPE**



Rutledge et al. (2009) *J Neurosci*

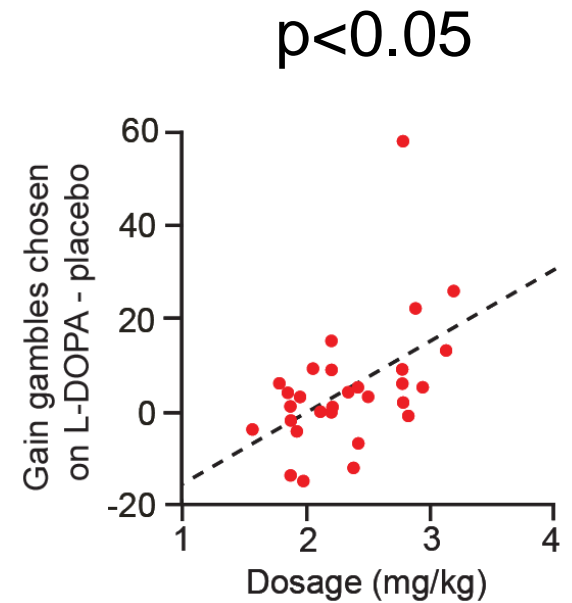
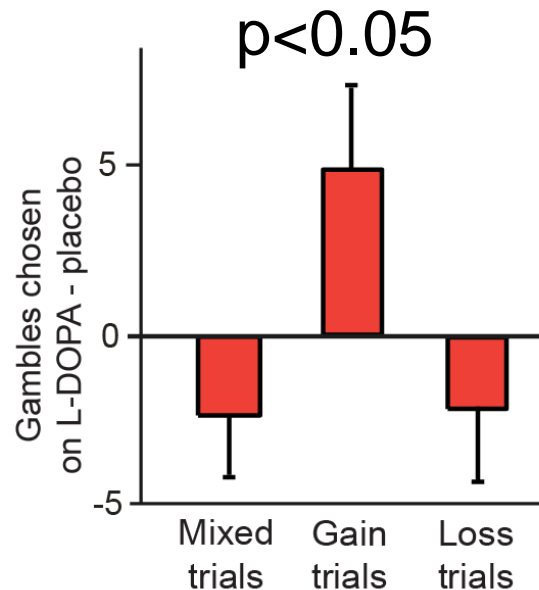
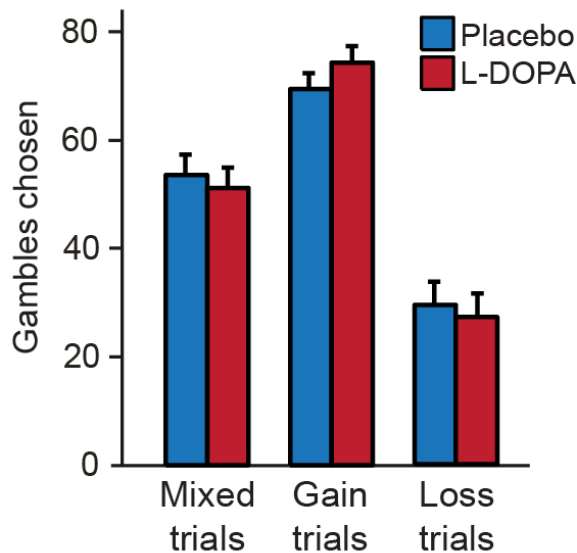
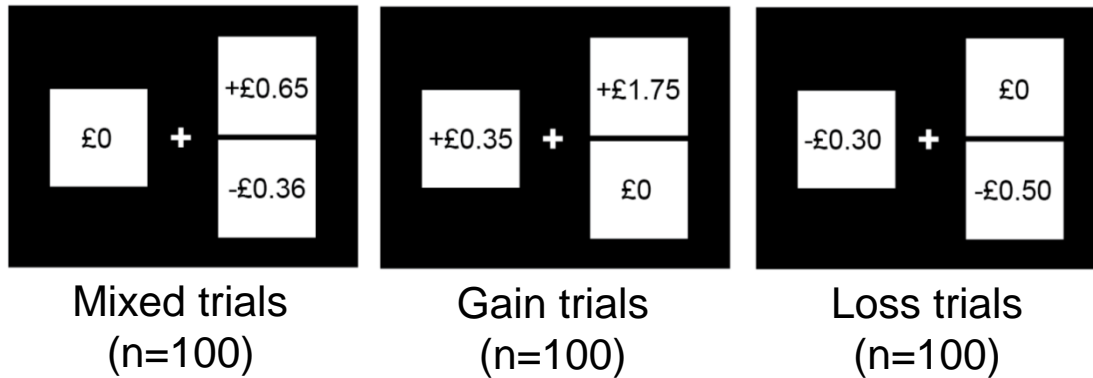
# Does L-DOPA affect decision making?

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



*Rutledge, Skandali, Dayan & Dolan (under review)*

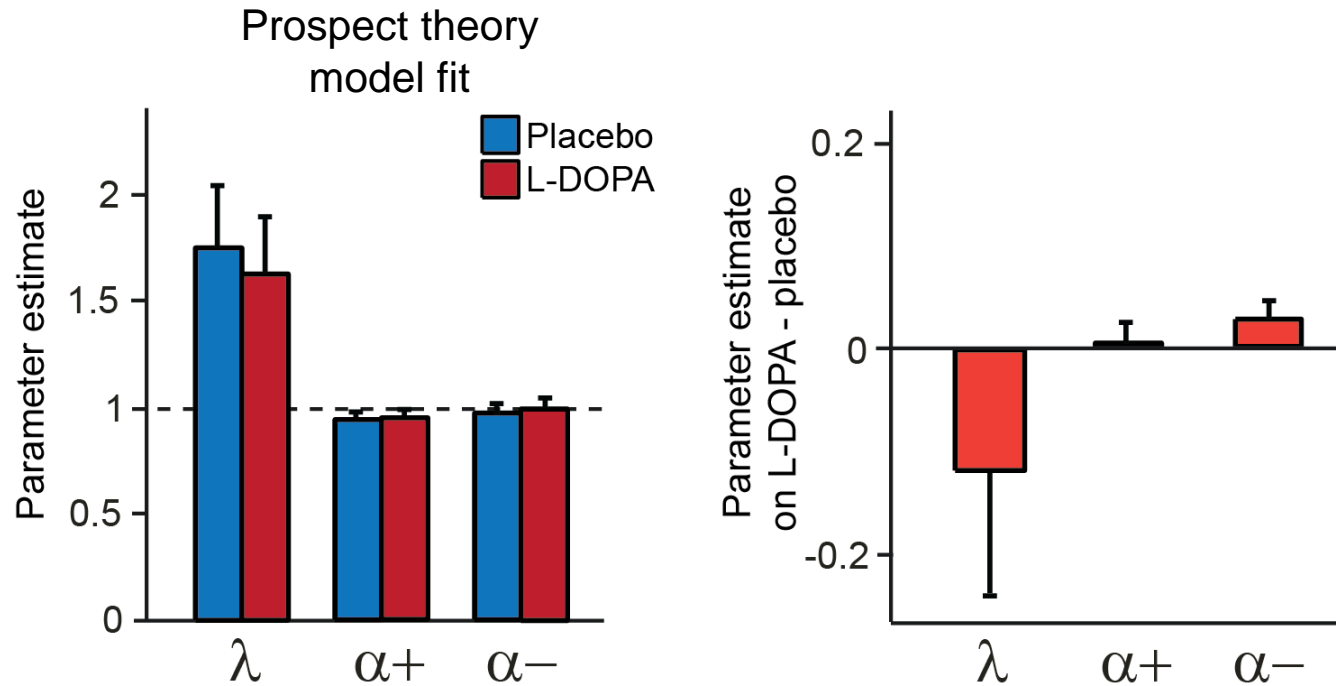
# L-DOPA increases gambling in gain trials



*Rutledge, Skandali, Dayan & Dolan (under review)*

# Prospect theory does not account for L-DOPA effects

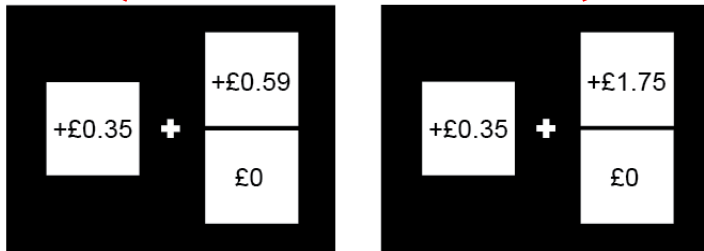
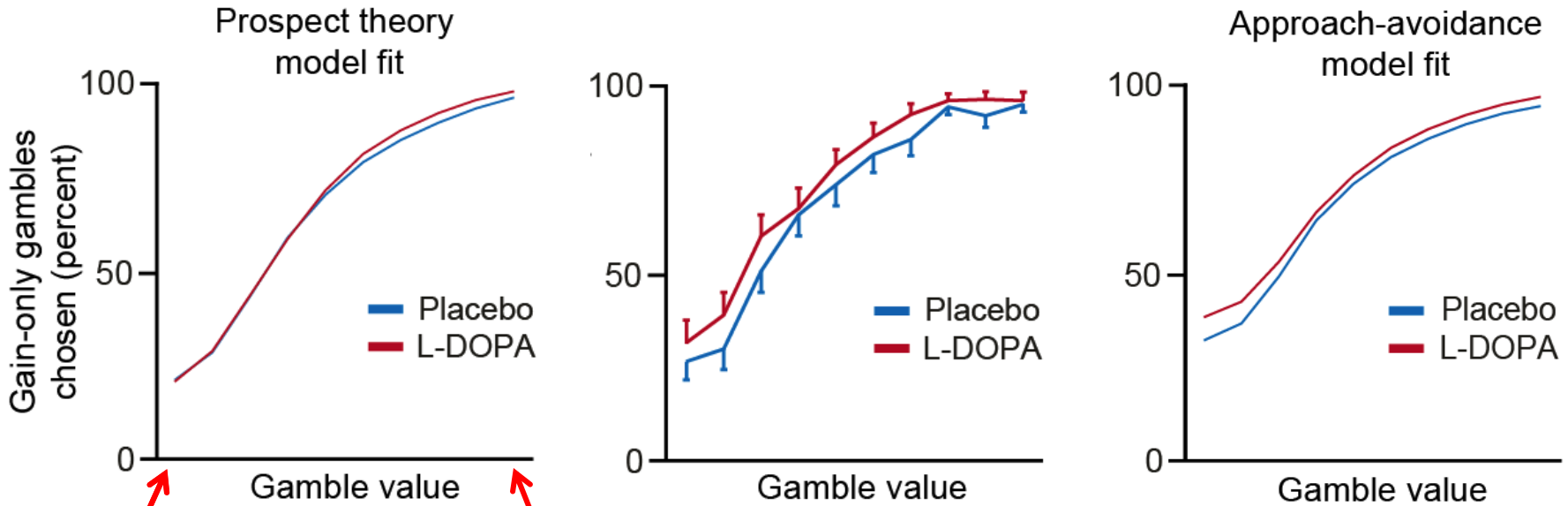
$$U(v) = v^{\alpha_+} \quad v \geq 0$$
$$= -\lambda(-v)^{\alpha_-} \quad v < 0$$



Economic risk preference for gains

*Rutledge, Skandali, Dayan & Dolan (under review)*

# Prospect theory does not account for L-DOPA effects



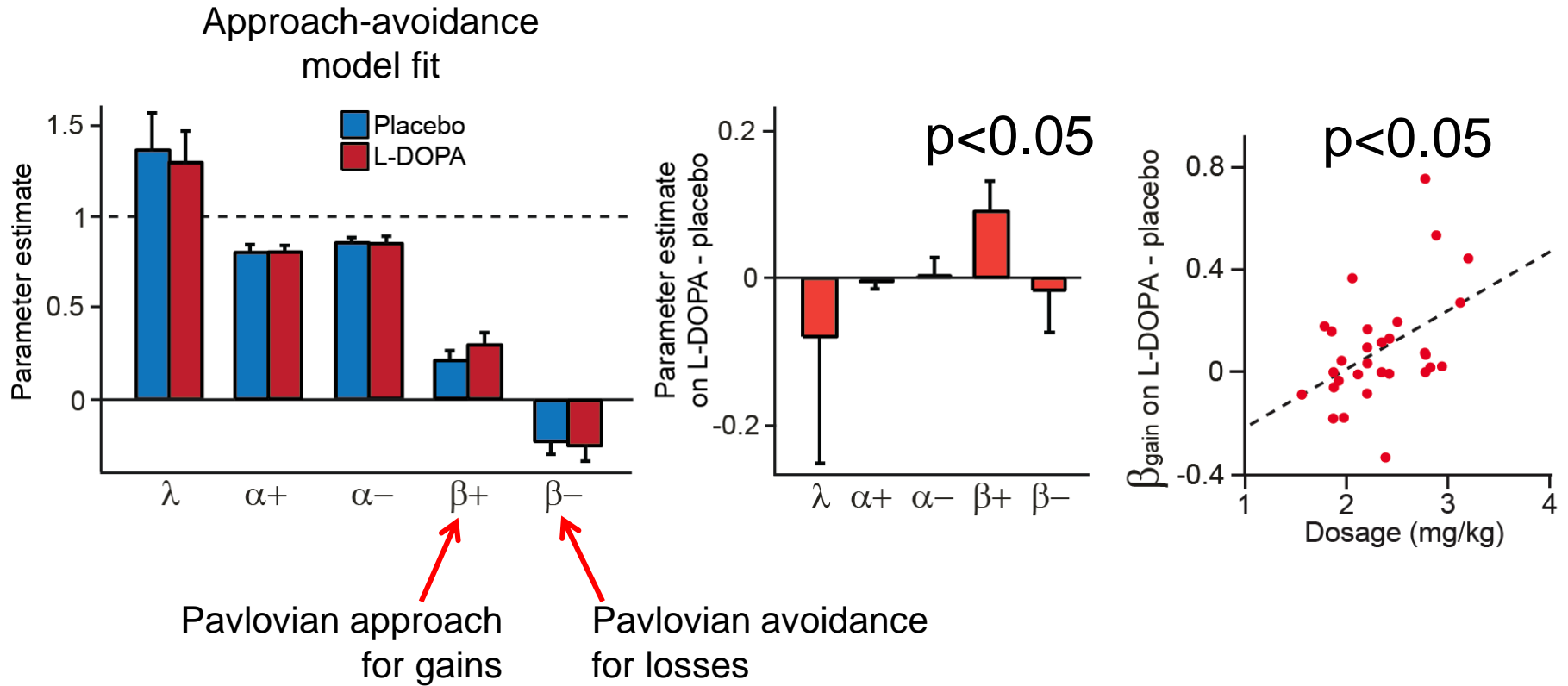
$$P_{\text{gamble}} = \frac{(1 - \beta_{\text{gain}})}{1 + e^{\mu(U_{\text{gamble}} - U_{\text{certain}})}} + \beta_{\text{gain}} \quad \text{if } \beta_{\text{gain}} \geq 0$$

$$P_{\text{gamble}} = \frac{(1 + \beta_{\text{gain}})}{1 + e^{\mu(U_{\text{gamble}} - U_{\text{certain}})}} \quad \text{if } \beta_{\text{gain}} < 0$$

*Rutledge, Skandali, Dayan & Dolan (under review)*



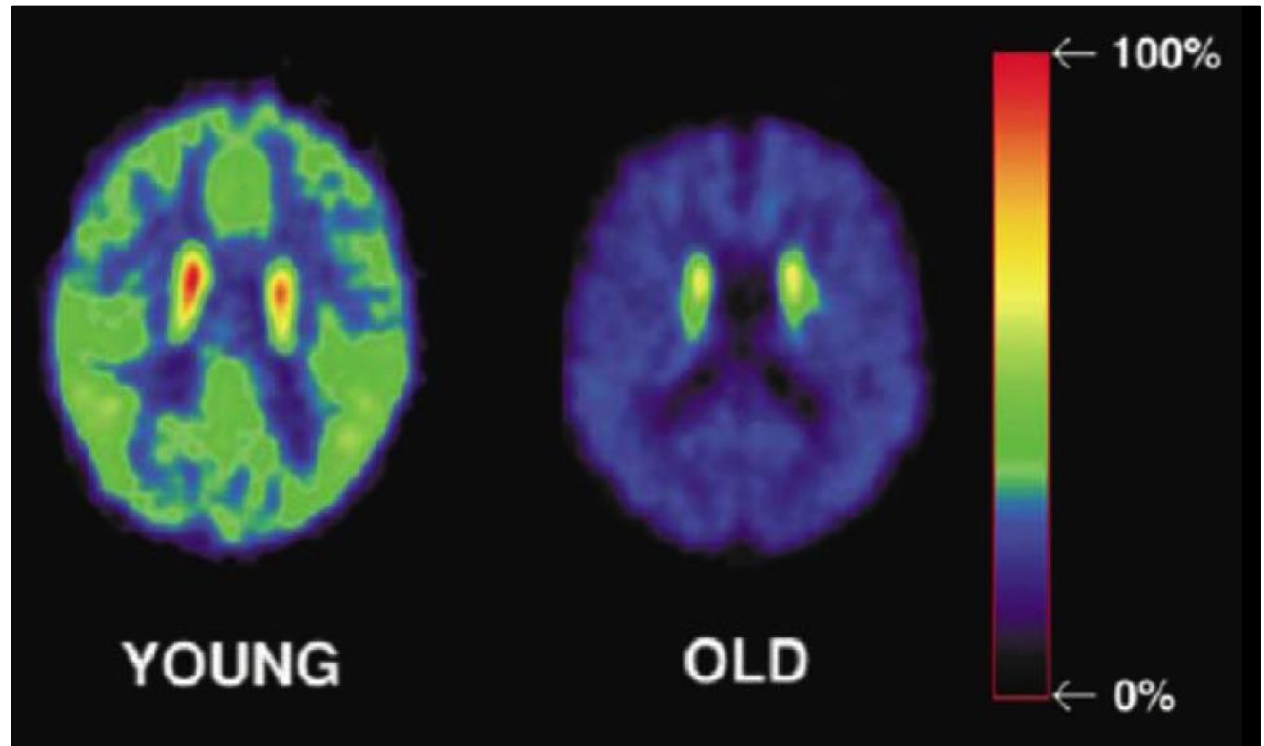
# L-DOPA increases approach behaviour in gain trials



*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)*

# The Great Brain Experiment

Be part of a unique scientific experiment by playing games on your phone.

Test your memory, your impulsivity, your attention and decision making. Learn about the neuroscience of every day life.



[www.thegreatbrainexperiment.com](http://www.thegreatbrainexperiment.com)

Crowdsourcing for cognitive science - the utility of smartphones.

Brown, Zeidman, Smittenaar, Adams, McNab, Rutledge, Dolan.

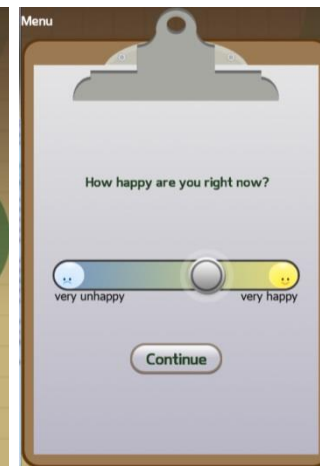
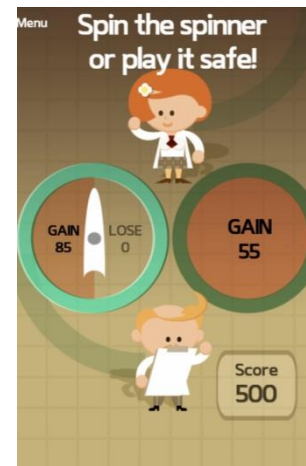
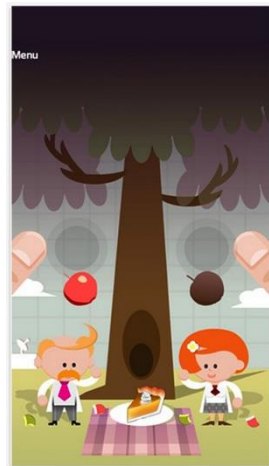
PLoS ONE (2014).

working memory

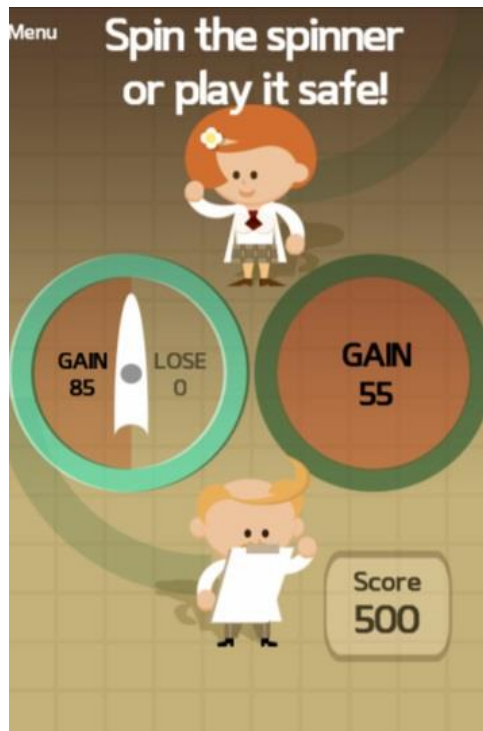
impulsivity

attentional blink

decisions and happiness



# The Great Brain Experiment 'What makes me happy?'



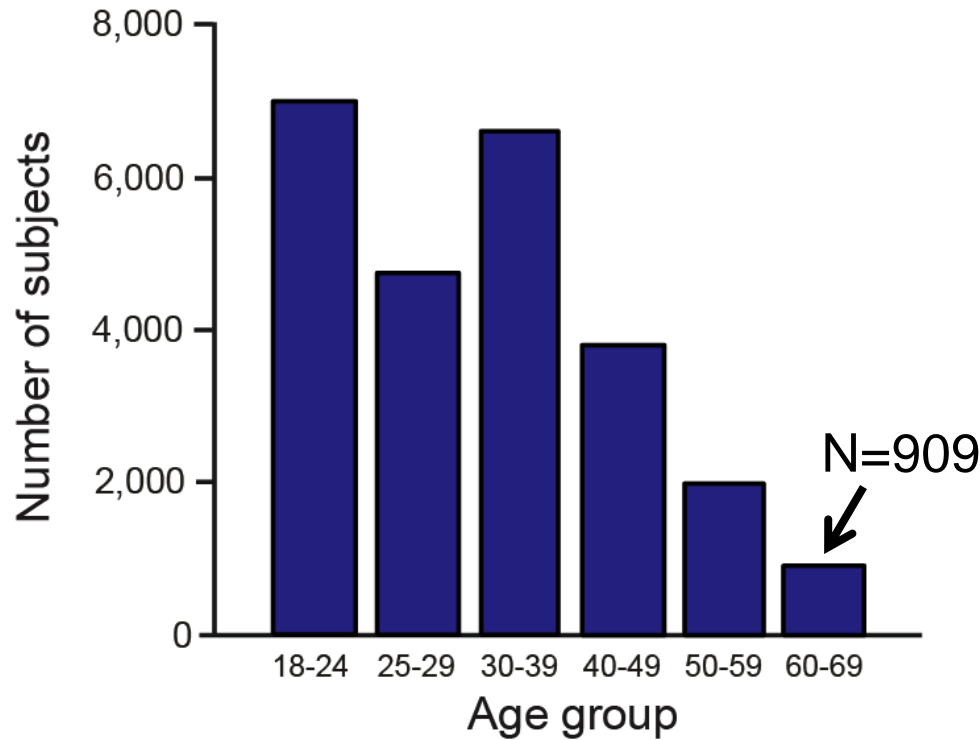
30 choices per play, 12 happiness ratings

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

*Rutledge, Skandali, Dayan & Dolan (2014) PNAS*

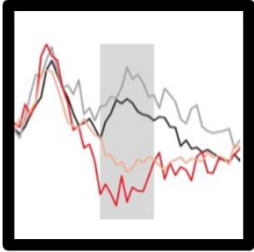
# The Great Brain Experiment 'What makes me happy?'

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

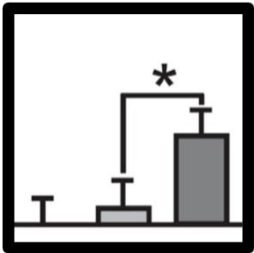


*Rutledge, Smittenaar et al. (in prep)*

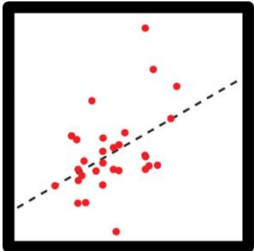
# Dopamine and decision making



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