Ramping risk-taking: Progressing value function increases gambling in humans

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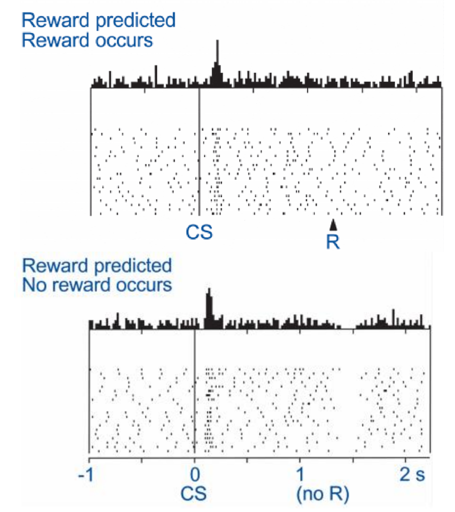
Background

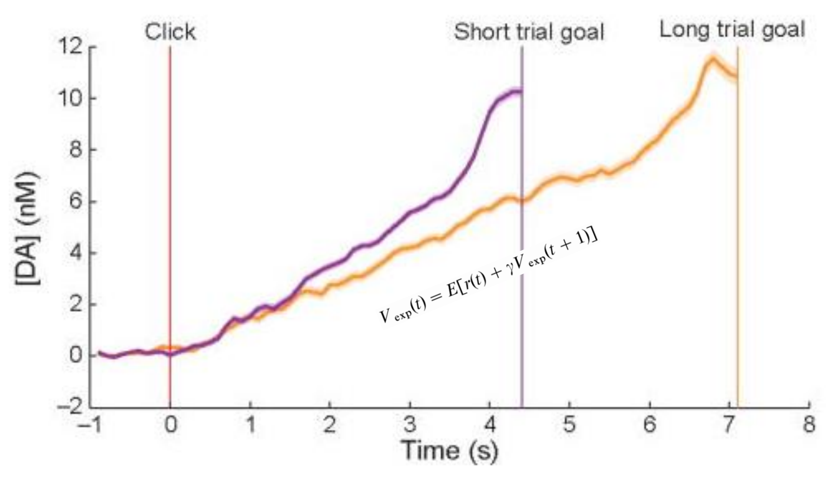
- Phasic dopamine (DA) spikes in the striatum occur when agents experience an unexpected reward. These fast DA spikes, called Reward Prediction Errors, (RPEs) are instrumental in learning how to maximize reward (Fig 1A).
- Aside from providing phasic RPEs that drive learning, DA may also organize motivated behavior at the time of action selection. Striatal DA may generally promote vigor in responding (Niv et al., 2007), and/or affect an agent's instantaneous willingness to work for reward (Hamid et al., 2016).
- Recent work has shown that striatal DA ramps as animals progress through a series of states towards an anticipated reward. The magnitude of this dopaminergic ramp is independent of the overall number of states (Fig. 1B).
- Dopamine agonists have been shown to increase gambling propensity in humans (Rigoli et al., 2016). More generally, increasing striatal DA tone is hypothesized to bias the expression of the benefits of actions relative to their costs (Fig 1C).
- Thus, we can capitalize on the dopaminergic ramp naturally happening to test whether performance (choice) is modulated by DA, independent of any effect DA has on learning.
- To test the hypothesis that humans' value calculations should change as a function of proximity to reward, we offered risky gambles to test the specif prediction that human participants will become increasingly likely to gamble as gambles are offered closer in time to an anticipated reward.

A



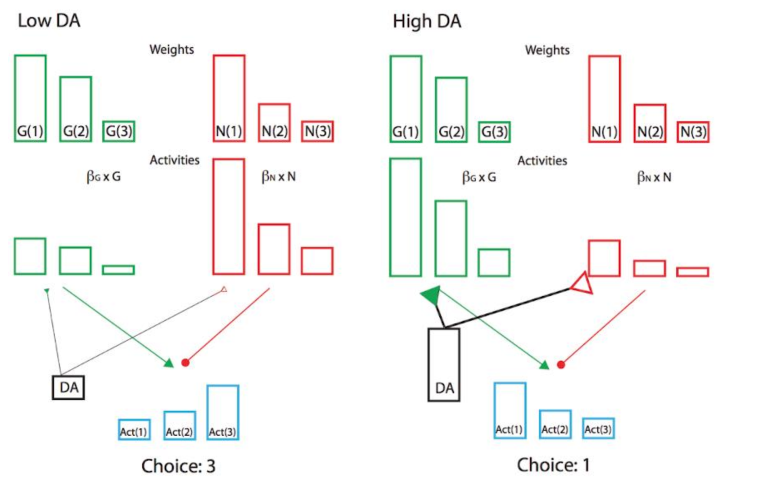
Adapted from Schultz, W. (2001). Book review: Reward signaling by dopamine neurons. *The Neuroscientist*, *7*(4), 293-302

B



Adapted from Fig. 2e Howe, M. W., Tierney, P. L., Sandberg, S. G., Phillips, P. E., & Graybiel, A. M. (2013). Prolonged dopamine signalling in striatum signals proximity and value of distant rewards. *Nature*, *500*(7464), 575.

C

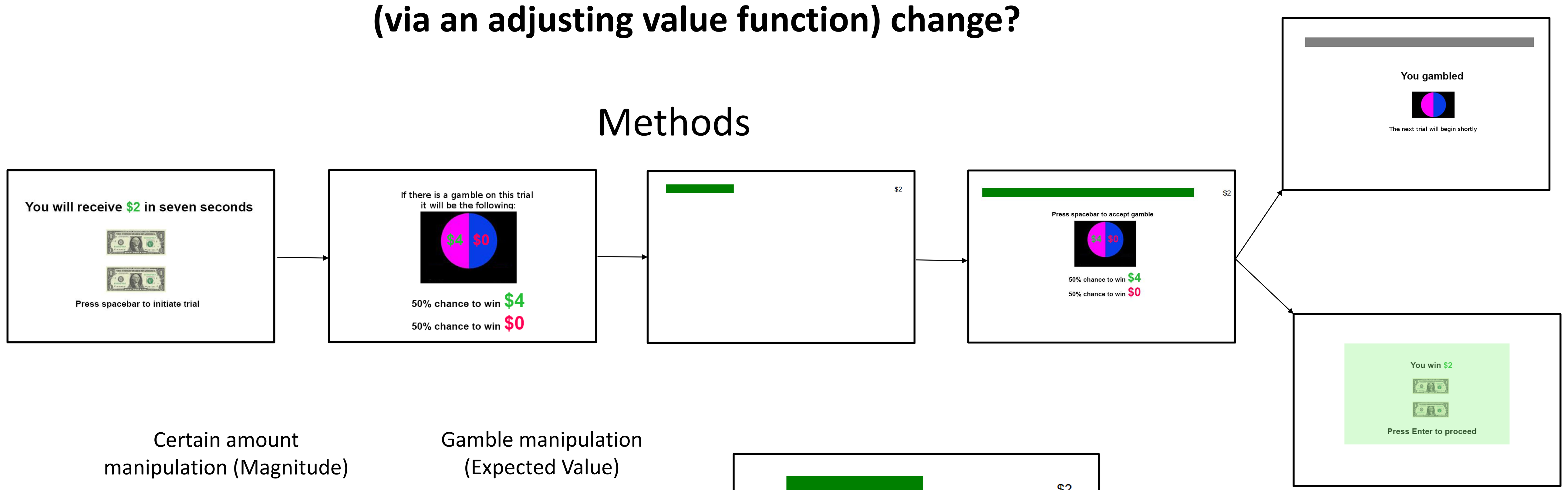


Adapted from Fig. 1B Collins, A. G., & Frank, M. J. (2014). Opponent actor learning (OpAL): Modeling interactive effects of striatal dopamine on reinforcement learning and choice incentive. *Psychological review*, *121*(3), 337.

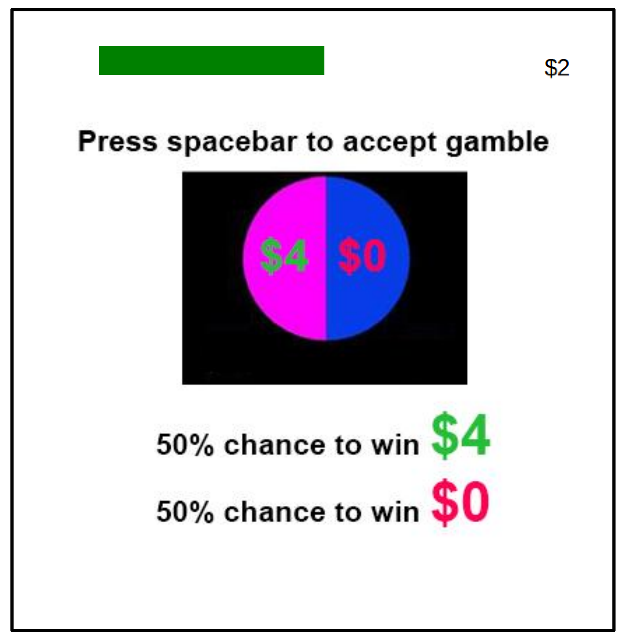
Question

As the distance to a reward decreases does a participant's propensity to gamble (via an adjusting value function) change?

Methods



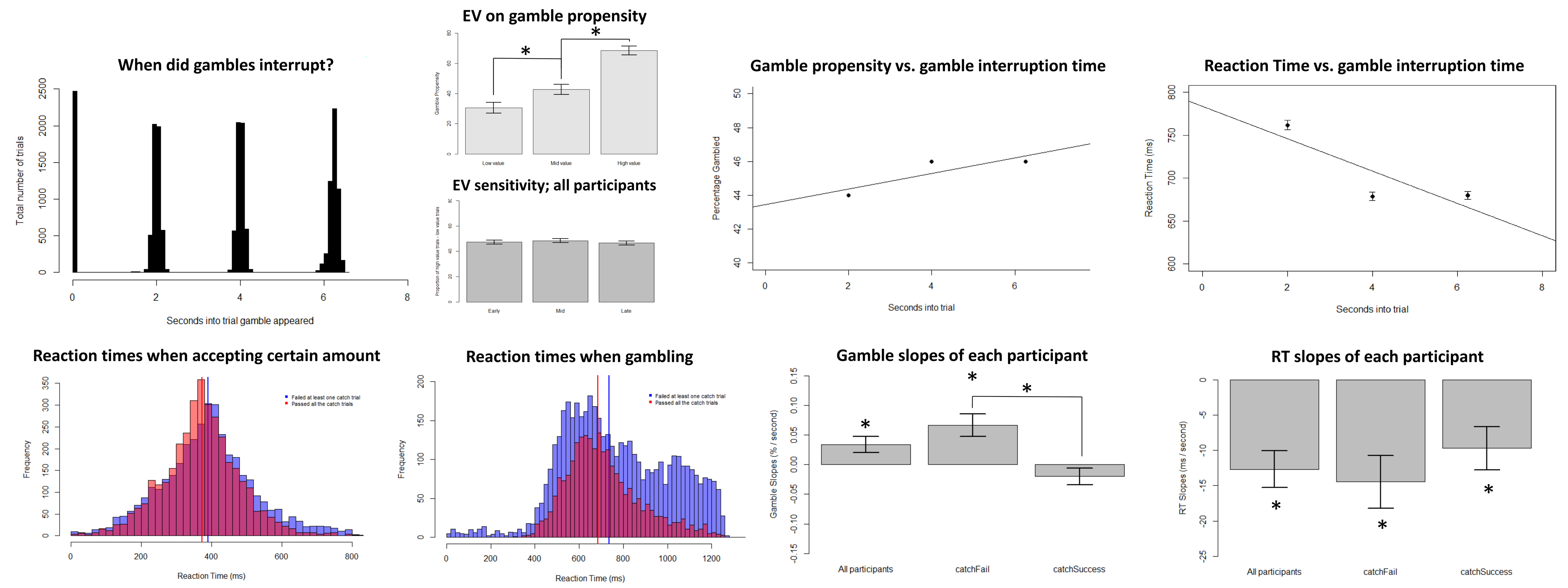
	Certain amount manipulation (Magnitude)	Gamble manipulation (Expected Value)
Low	Guaranteed amount = $1 or $2	Gamble possible reward = 1.5 x guaranteed amount
Mid	Guaranteed amount = $3 or $4	Gamble possible reward = 2 x guaranteed amount (EV of gamble matches EV of guaranteed amount)
High	Guaranteed amount = $5 or $6	Gamble possible reward = 3 x guaranteed amount



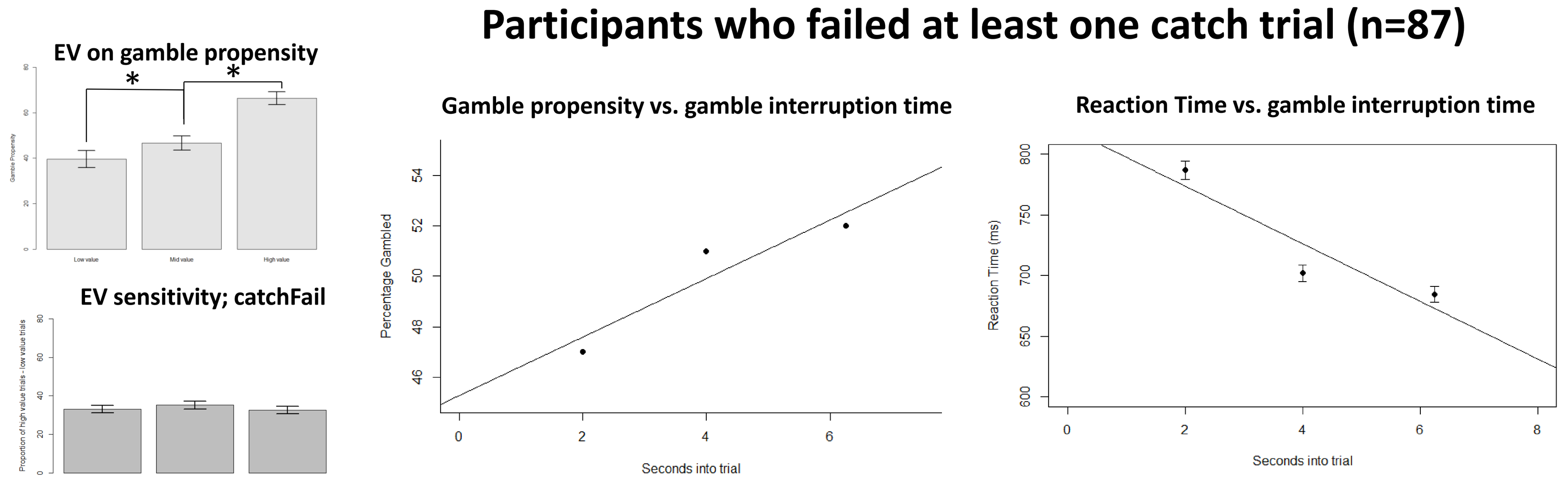
- 207 Participants via Amazon's mechanical turk; (127 male; 76 female; 4 declined to answer)
- 140 participants analyzed
- 18-40 years old
- 133 trials (~45 minutes)
- Option to gamble on 86.39 % of trials.
- Gamble probablilities were always 50%
- Gamble losses were always 0$
- 6 catch trials

Results

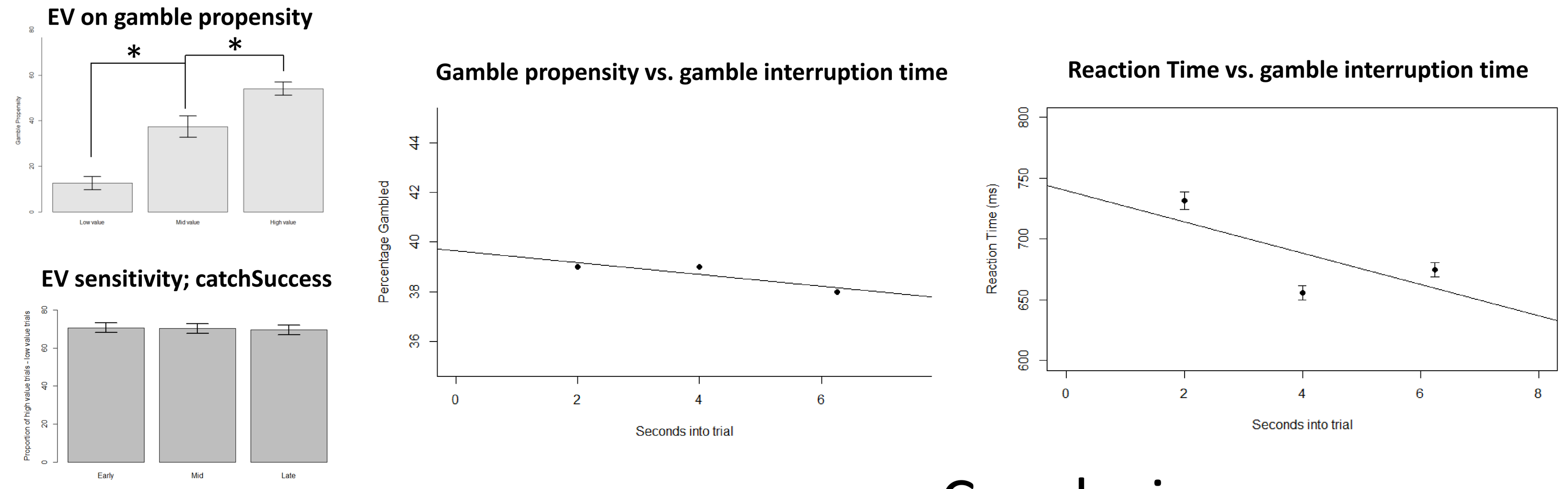
All participants (n=140)



Participants who failed at least one catch trial (n=87)



Participants who passed all the catch trials (n=53)



Catch trials

-3 trials where the possible reward of the gamble matched the certain amount (participants should never gamble)

-3 trials where the possible loss of the gamble matched the certain amount (participants should always gamble)

Future versions

1) Instrumental gamble yes/no required

2) A key press is required to ignore the gamble

3) Changing length of progress bar

4) EMG, EEG, and DA agonists

Conclusions

- The later the gamble interrupted the progress bar (i.e. the closer the participant was to the reward), the more likely a participant gambled and the lower their RT tended to be.
- These effects were especially robust in participants who failed at least one catch trial. In fact, participants who passed all catch trials tended to exhibit a negative relationship between gambling propensity and interruption time. These data are consistent with the possibility of a link between impulsivity and DA release (Buckholtz et al., 2010).
- The higher the EV of the gamble was, the more likely a participant gambled. This effect was strongest in participants who passed all catch trials, muted in participants who failed at least one catch trial, and was independent of gamble interruption time.
- These pilot data are consistent with the theory that DA dynamics affect how humans calculate the value of an acion and that the value of such a calculation may shift as a promixity to a reward.

References:

1. Schultz, W. (2001). Book review: Reward signaling by dopamine neurons. *The Neuroscientist*, *7*(4), 293-302
2. Niv, Y., Daw, N. D., Joel, D., & Dayan, P. (2007). Tonic dopamine: opportunity costs and the control of response vigor. *Psychopharmacology*, *191*(3), 507-520.
3. Hamid, A. A., Pettibone, J. R., Mabrouk, O. S., Hetrick, V. L., Schmidt, R., Vander Weele, C. M., ... & Berke, J. D. (2016). Mesolimbic dopamine signals the value of work. *Nature neuroscience*, *19*(1), 117.
4. Collins, A. G., & Frank, M. J. (2014). Opponent actor learning (OpAL): Modeling interactive effects of striatal dopamine on reinforcement learning and choice incentive. *Psychological review*, *121*(3), 337.
5. Howe, M. W., Tierney, P. L., Sandberg, S. G., Phillips, P. E., & Graybiel, A. M. (2013). Prolonged dopamine signalling in striatum signals proximity and value of distant rewards. *Nature*, *500*(7464), 575.
6. Buckholtz, J. W., Treadway, M. T., Cowan, R. L., Woodward, N. D., Li, R., Ansari, M. S., ... & Kessler, R. M. (2010). Dopaminergic network differences in human impulsivity. *Science*, *329*(5991), 532-532.