When to explore rather than exploit?

Readings for today

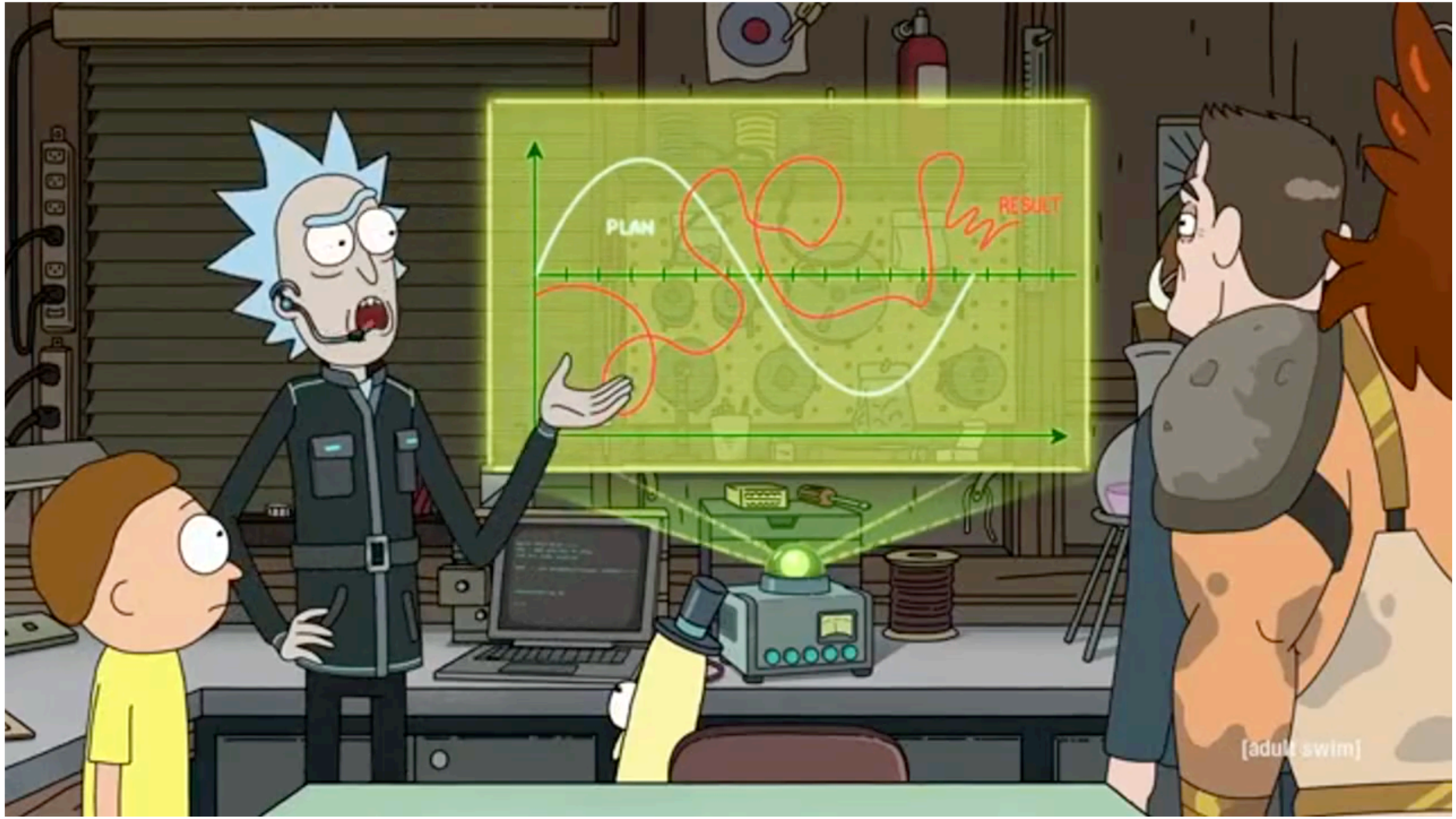
- Mehlhorn, K., Newell, B. R., Todd, P. M., Lee, M. D., Morgan, K., Braithwaite, V. A., & Gonzalez, C. (2015). Unpacking the exploration–exploitation tradeoff: A synthesis of human and animal literatures. Decision, 2(3), 191

Topics

- Explore vs. exploit
- Random vs. directed exploration

Explore vs. exploit

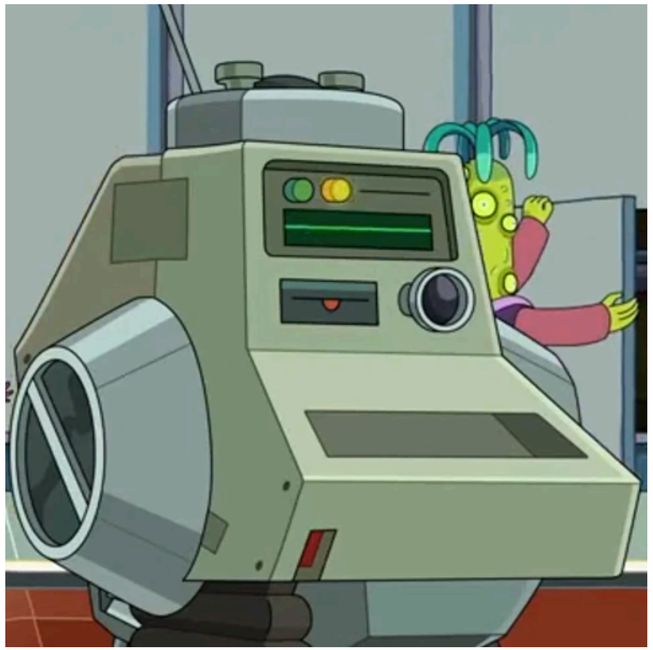
The dilemma



Rick & Morty: One Crew Over the Crewcoo's Morty

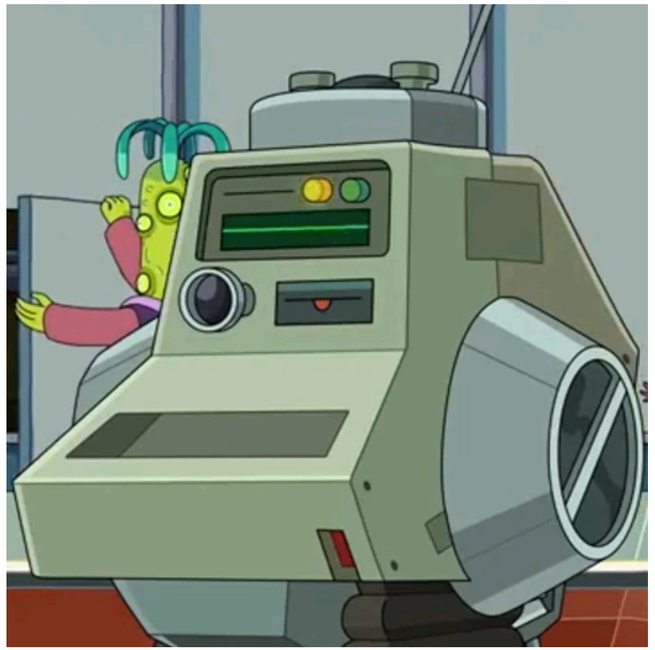
Battle of the bots

Heistotron



- Exploitative
- Strategic
- Resource maximizing

Randotron



- Exploratory
- Random
- Entropy maximizing

The exploitation-exploration (e-e) dilemma

Exploitation: Choosing a behavior that is most likely to produce the best outcome.

- Choosing a “hot” slot machine
- Going to your regular restaurant
- Buying a Honda Civic

Exploration: Choosing a behavior with a less certain outcome on the chance that it will produce more desirable outcome.

- Trying a new slot machine
- Going to a restaurant that has just opened
- Buying a BMW

The ϵ-greedy method

Action value

$$Q_t(a) = \frac{\sum_{i=1}^{t-1} R_i \,|\, A_t = a}{\sum_{i=1}^{t-1} A_t = a}$$

Best action

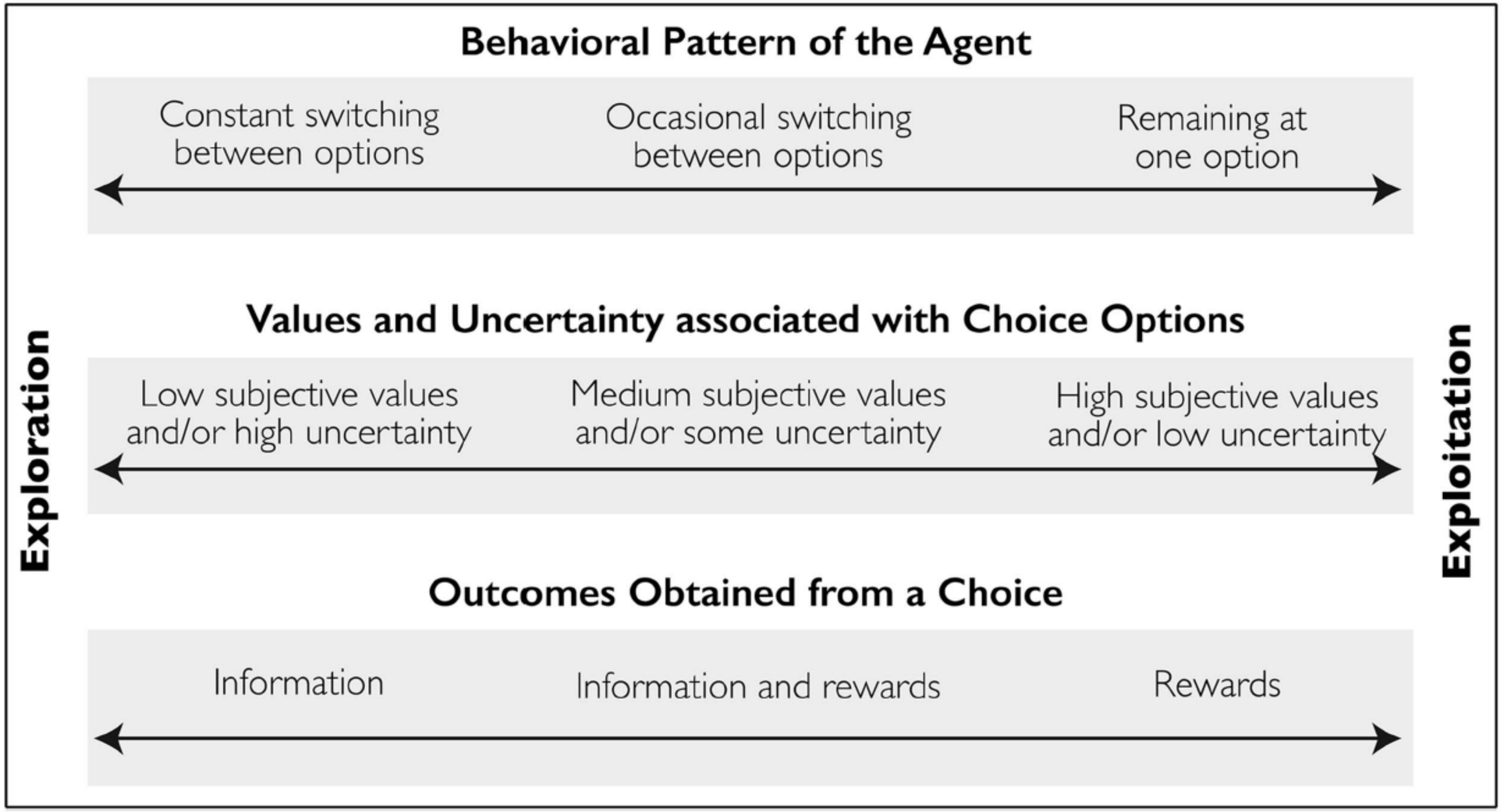
$$A_t = \arg\max_a Q_t(a)$$

Decision policy

$$\begin{cases} \max Q_t(a), & \text{with probability } 1 - \epsilon \\ \text{any } a, & \text{with probability } \epsilon \end{cases}$$

(Sutton & Barto, 2020)

The e-e dilemma



(Melhorn et al. 2018)

Factors that drive the e-e dilemma

Individual Factors

- Cognitive capacity (e.g., memory span)
- Aspiration levels (e.g., greediness)
- Internal latent state (e.g., energy level, drive)
- Prior knowledge (e.g., experience-dependent expectations)
- Morphology (e.g., larger animals more likely to explore)
- Demographics (e.g., delayed discounting changes with age)
- Neurotransmitters (e.g., levels of norepinephrine determine exploration)

(Melhorn et al. 2018)

Factors that drive the e-e dilemma

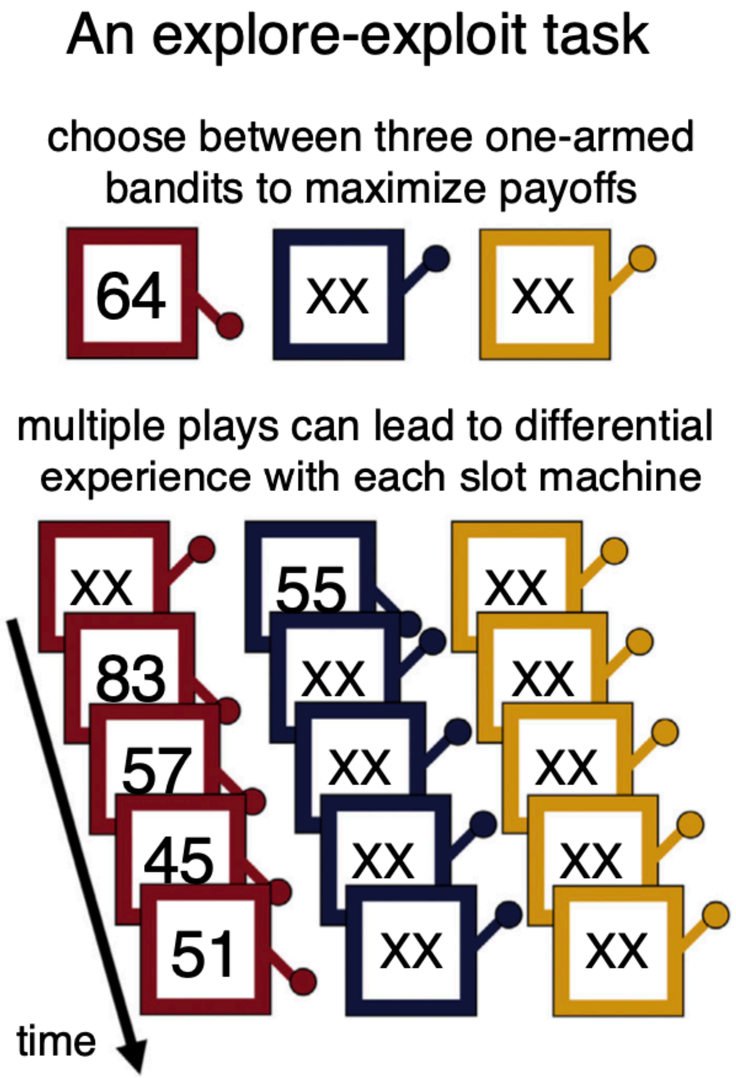
Environmental Factors

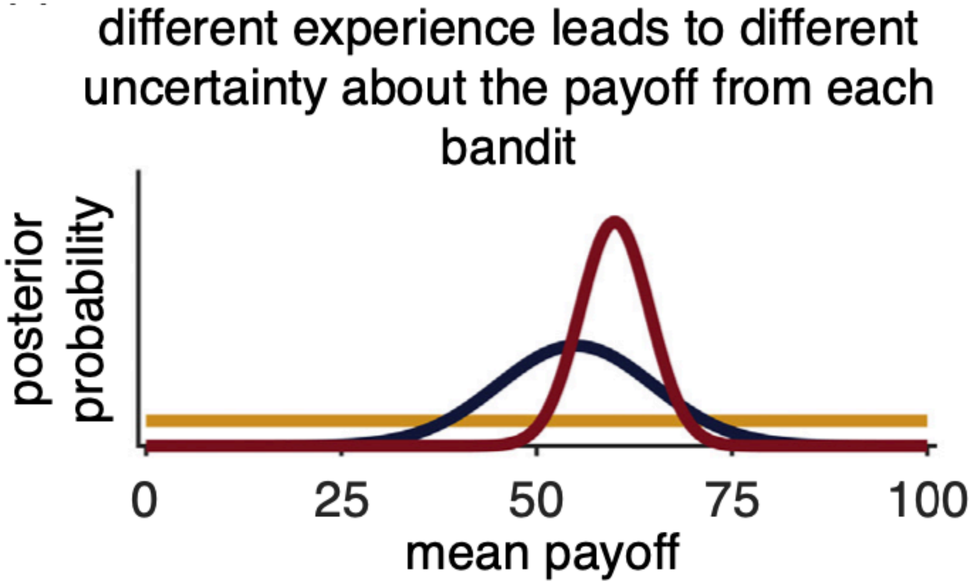
- Availability of resources (e.g., depletion of food sources)
- Availability of information about options (e.g., foregone payoff information)
- Cost of information vs. value of reward (e.g., search effort)
- Structure of the environment (e.g., distribution of food sources)
- Probability of gains and losses (e.g., over exploring during “rare disasters”)
- Stability of environmental contingencies (e.g., volatility)
- Shape of reward distributions (e.g., bimodal distributions = more sampling)
- Range of possible actions (i.e., the behavioral “horizon”)

(Melhorn et al. 2018)

Random vs. directed exploration

The bandit task





(Wilson et al. 2020)

Two types of ways to explore

Random exploration

$$Q(a) = r(a) + \eta(a)$$

How good we expect a to be

Random noise

Example: softmax selection policy

$$p(a) = \frac{e^{Q(a)/\tau}}{\sum_{i=1}^{A} e^{Q(i)/\tau}}$$

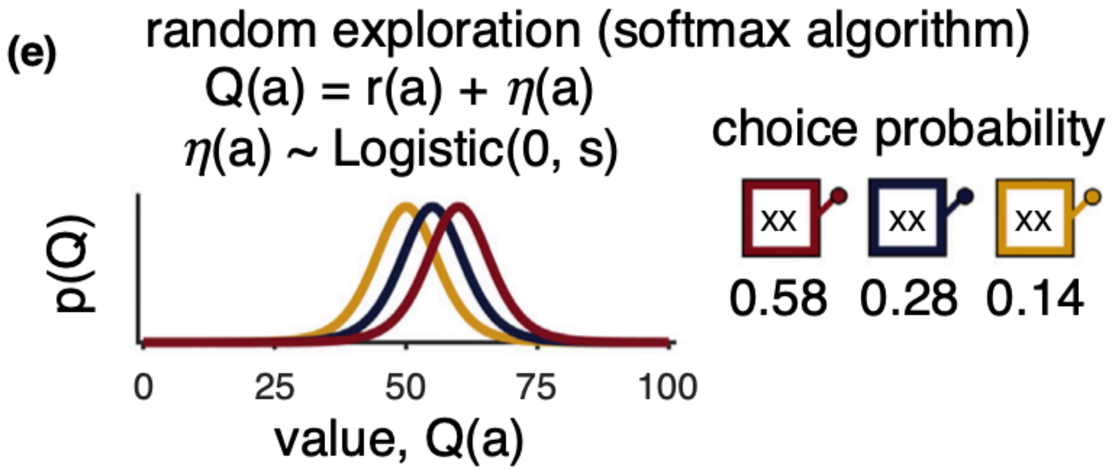
"temperature" parameter

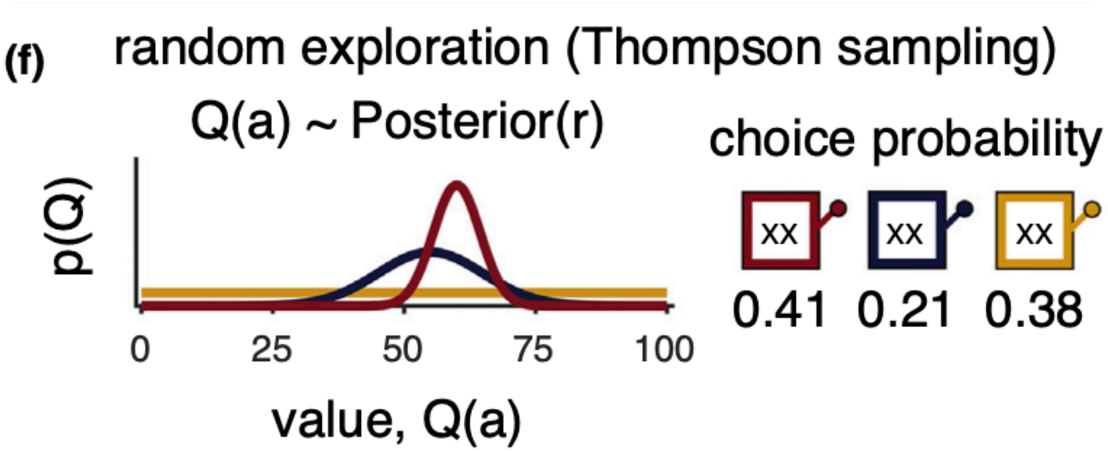
larger τ = more random

(Wilson et al. 2020)

Two types of ways to explore

Random exploration





(Wilson et al. 2020)

Two types of ways to explore

Directed exploration

$$Q(a) = r(a) + IB(a)$$

How good we expect a to be

Information bonus

Example: Upper confidence bound

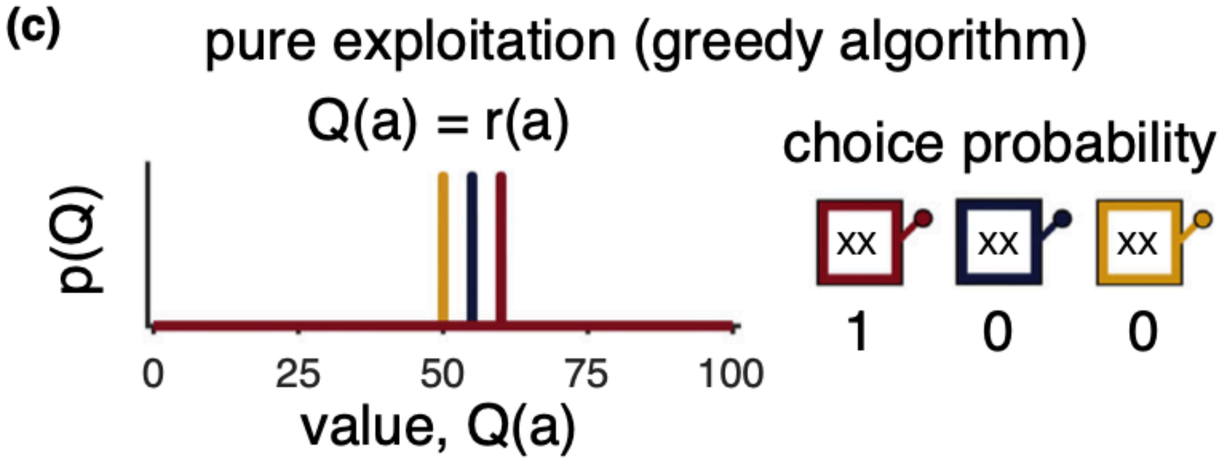
variance of the posterior distribution

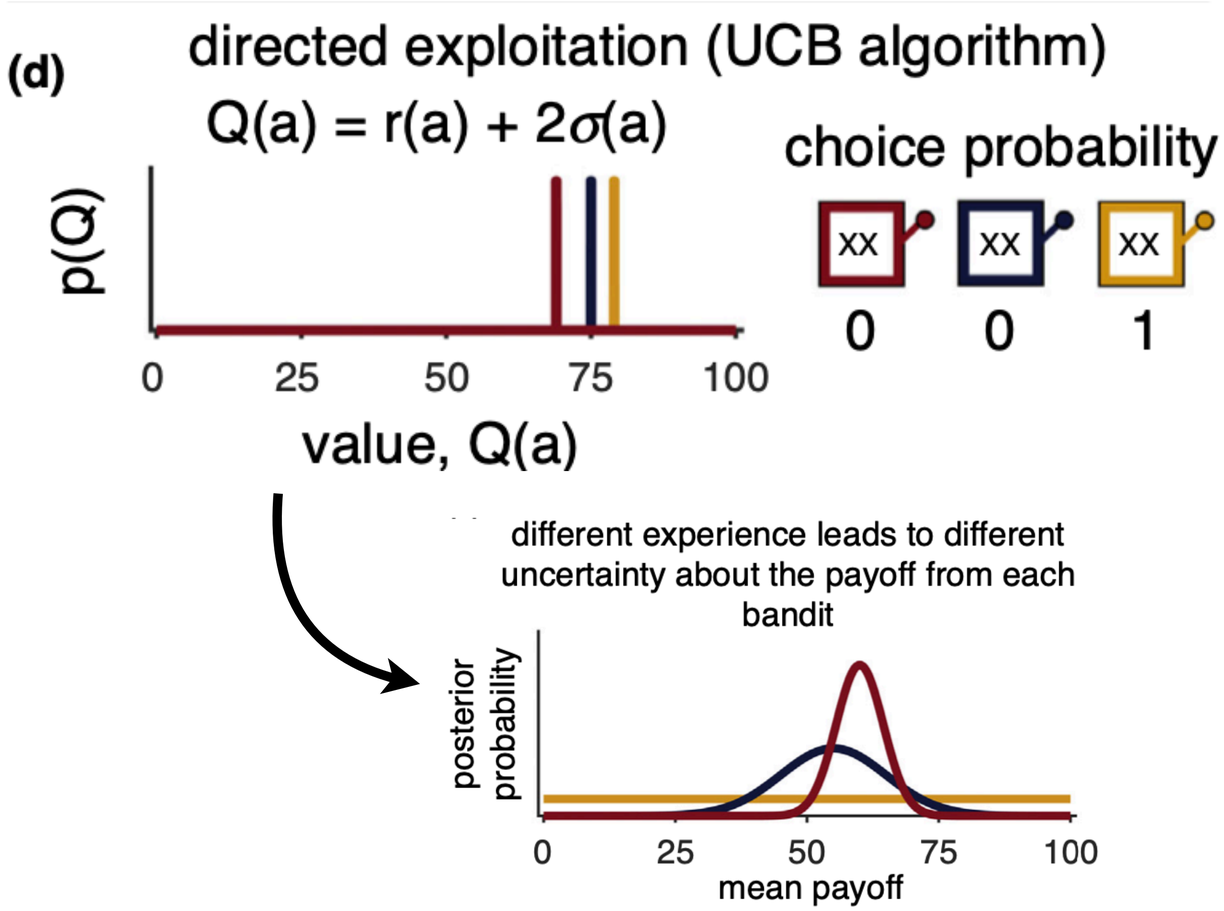
$$p(a) = Q(a) + 2\sigma(a)$$

(Wilson et al. 2020)

Two types of ways to explore

Directed exploration





Curiosity!

(Wilson et al. 2020)

Take home message

- Balancing exploration against resource gathering (exploitation) is a fundamental dilemma that seems intractable.
- While exploitation has a singular form, Eexploration can be random or directed (curiosity), with the latter being information seeking.

Grab some popcorn… we’re going on a heist