

What is the value of information?

Readings for today

- Sheridan, T. B. (1995). Reflections on information and information value. IEEE transactions on systems, man, and cybernetics, 25(1), 194-196.
- Kobayashi, K., & Hsu, M. (2019). Common neural code for reward and information value. Proceedings of the National Academy of Sciences, 116(26), 13061-13066.

Information vs. rewards

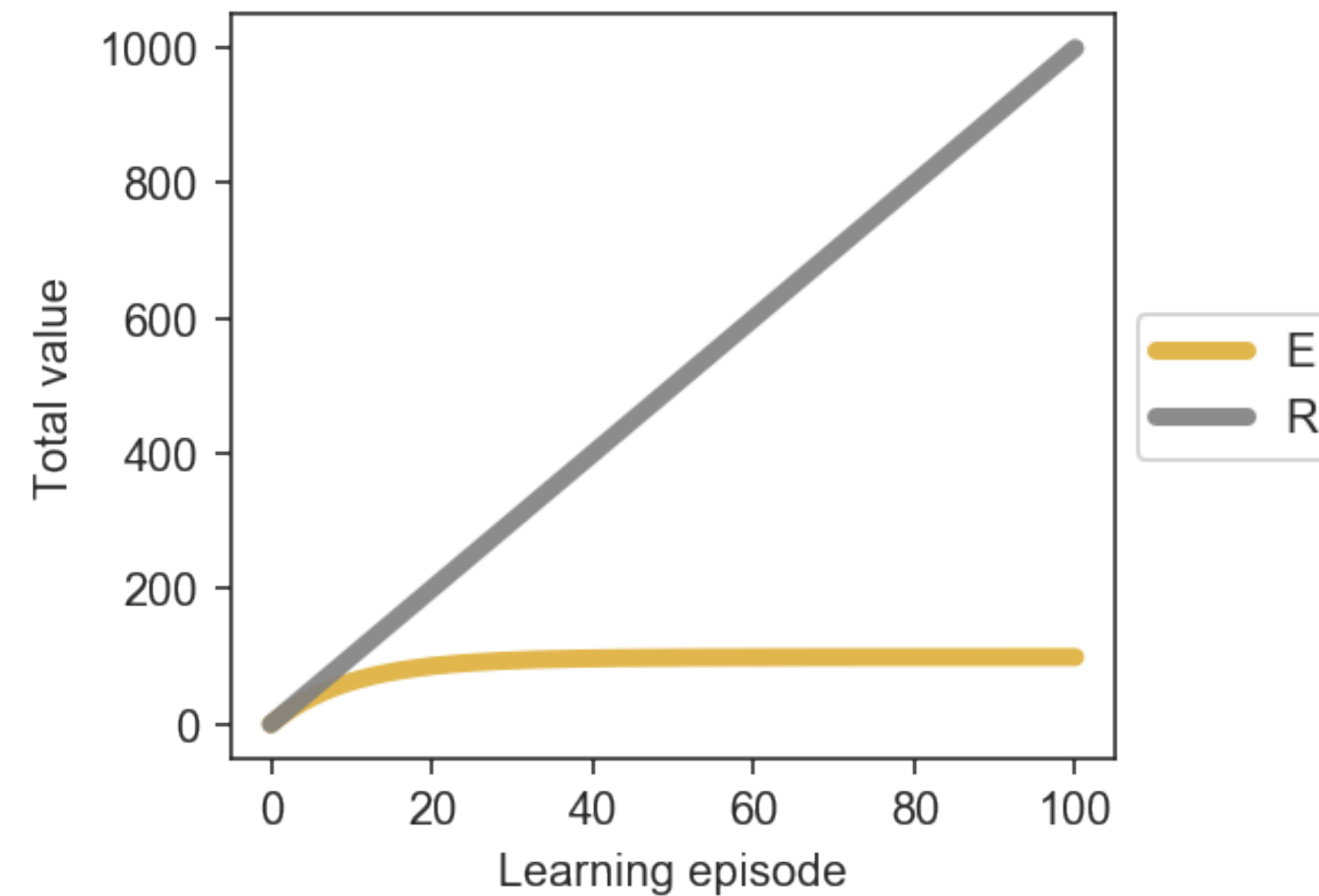
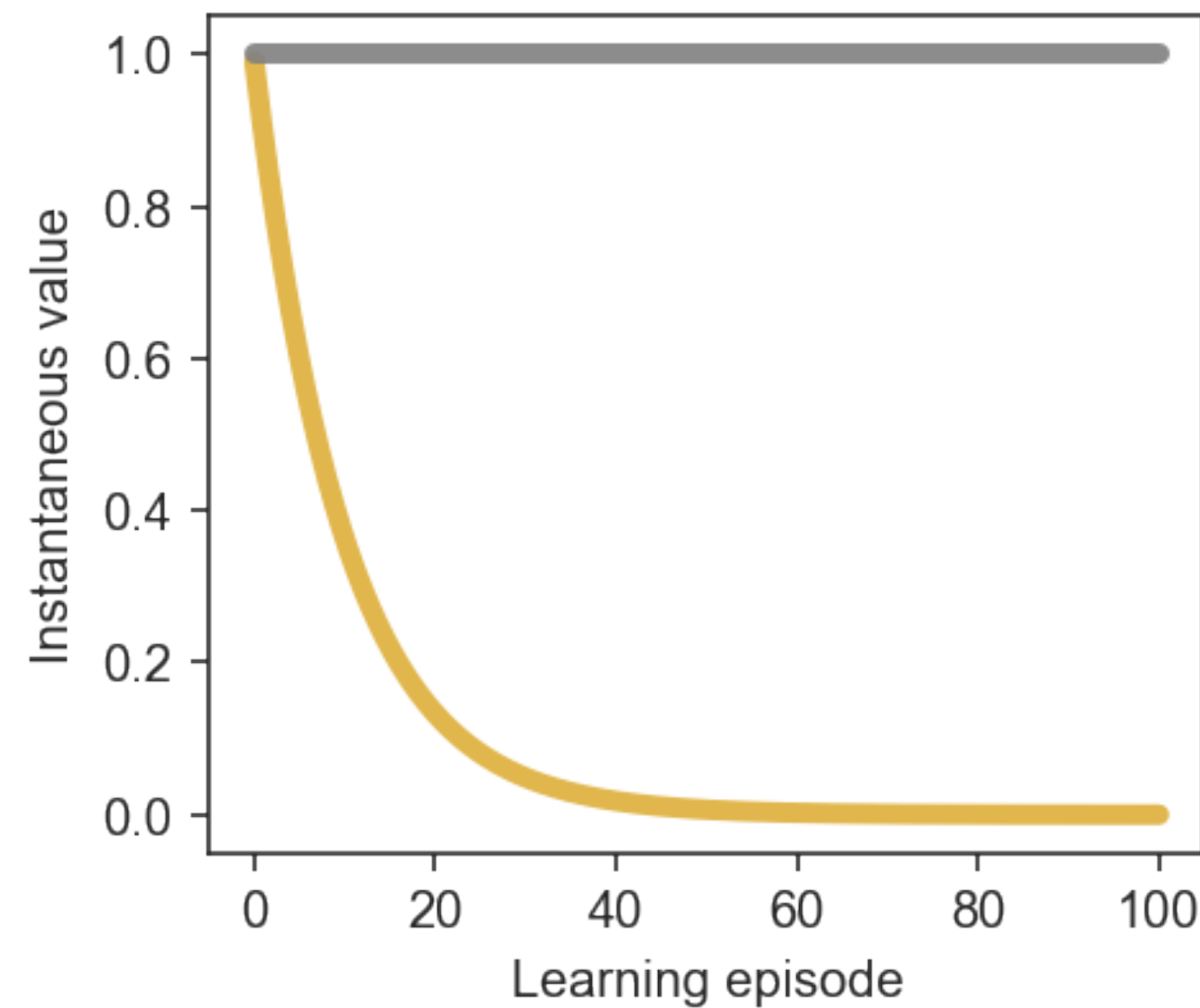
Rewards

- Always increasing (e.g., 4 potato chips > 2 potato chips > 1 potato chip)
- Rate limited (e.g., sharing a chip equally between 2 people means they each have 50% of a chip)
- Externally represented (e.g., you can count how many potato chips someone physically has).

Information

- Depends on what you already know (e.g., the value of someone telling you an answer on an exam is low if you already have the key)
- Rate unlimited (e.g., telling someone the capital of New Mexico does not reduce the fact in your own mind)
- Internally represented (e.g., difficult to quantify facts in a memory... particularly human).

Information vs. rewards



- Information value decays with experience in stable environments.
- Reward value value does not.

Information or information value

Information (Shannon 1949)

$$H = \sum_i p(x_i) \log_2 \left[\frac{1}{p(x_i)} \right] = - \sum_i p(x_i) \log_2 p(x_i)$$

- x : event
- i : state
- $p(x_i)$: probability of event i
- u : action

Information value (Howard 1966)

$$V_{avg}^* = V_{avg} - V'_{avg}$$

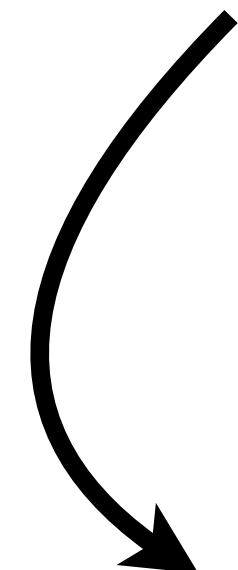
$$= \sum_i p(x_i) \left\{ \max_j [V(u_j | x_i)] \right\} - \max_j \left\{ \sum_i p(x_i) V(u_j | x_i) \right\}$$

Gain in taking best action vs. gain in taking action in ignorance of each specific x_i

Information and information value

Information value (Sheridan 1995)

$$V_{net}^* = \underbrace{V_{avg}^*}_{\text{best vs overall}} - \underbrace{H_{avg}^*}_{\text{info cost}}$$


$$V_{net}^* = \begin{cases} > 0, & \text{seek info} \\ \leq 0, & \text{do not} \end{cases}$$

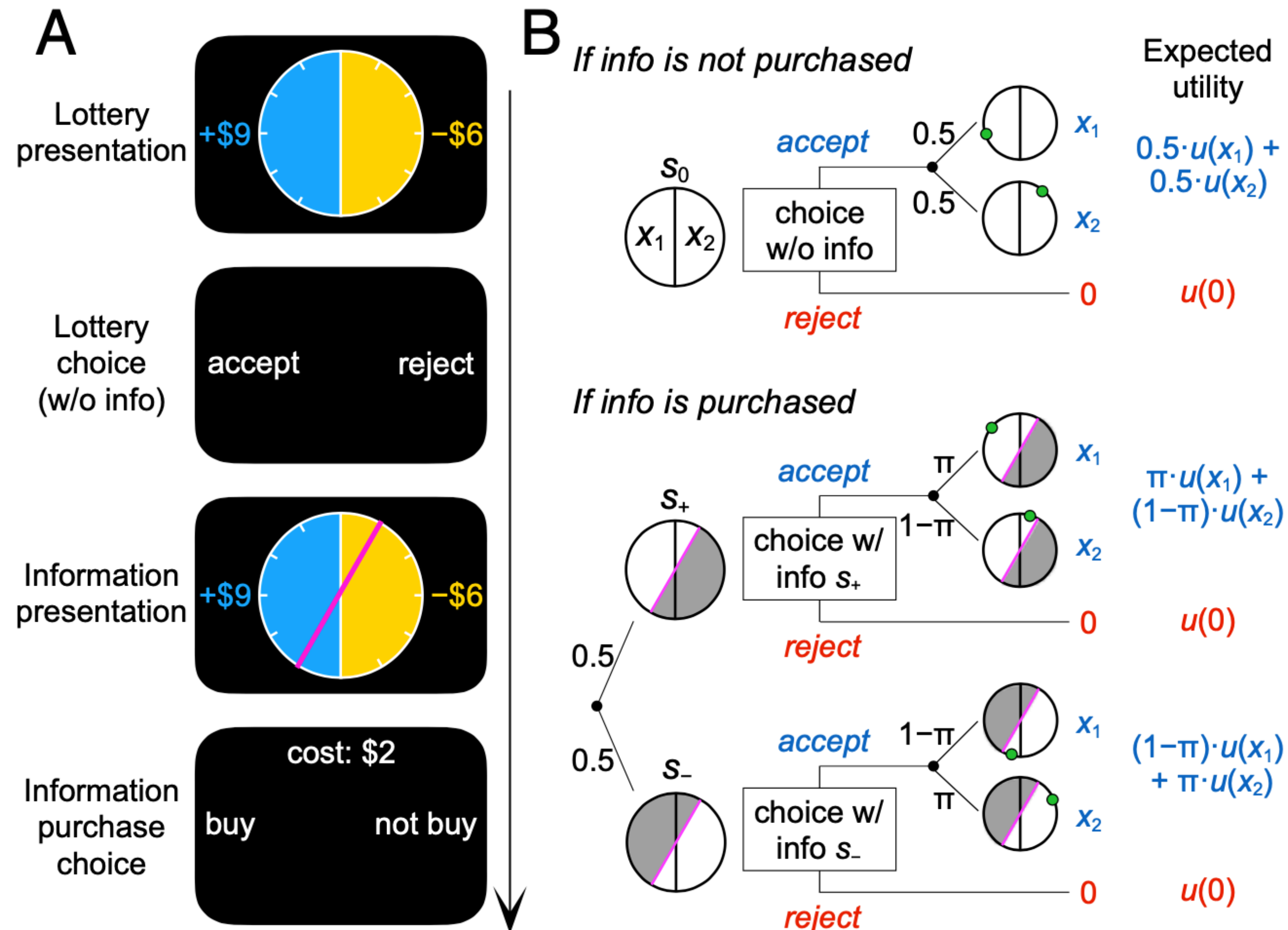
- x : event
- i : state
- $p(x_i)$: probability of event i
- u : action
- C : cost per bit

Subjective value of information



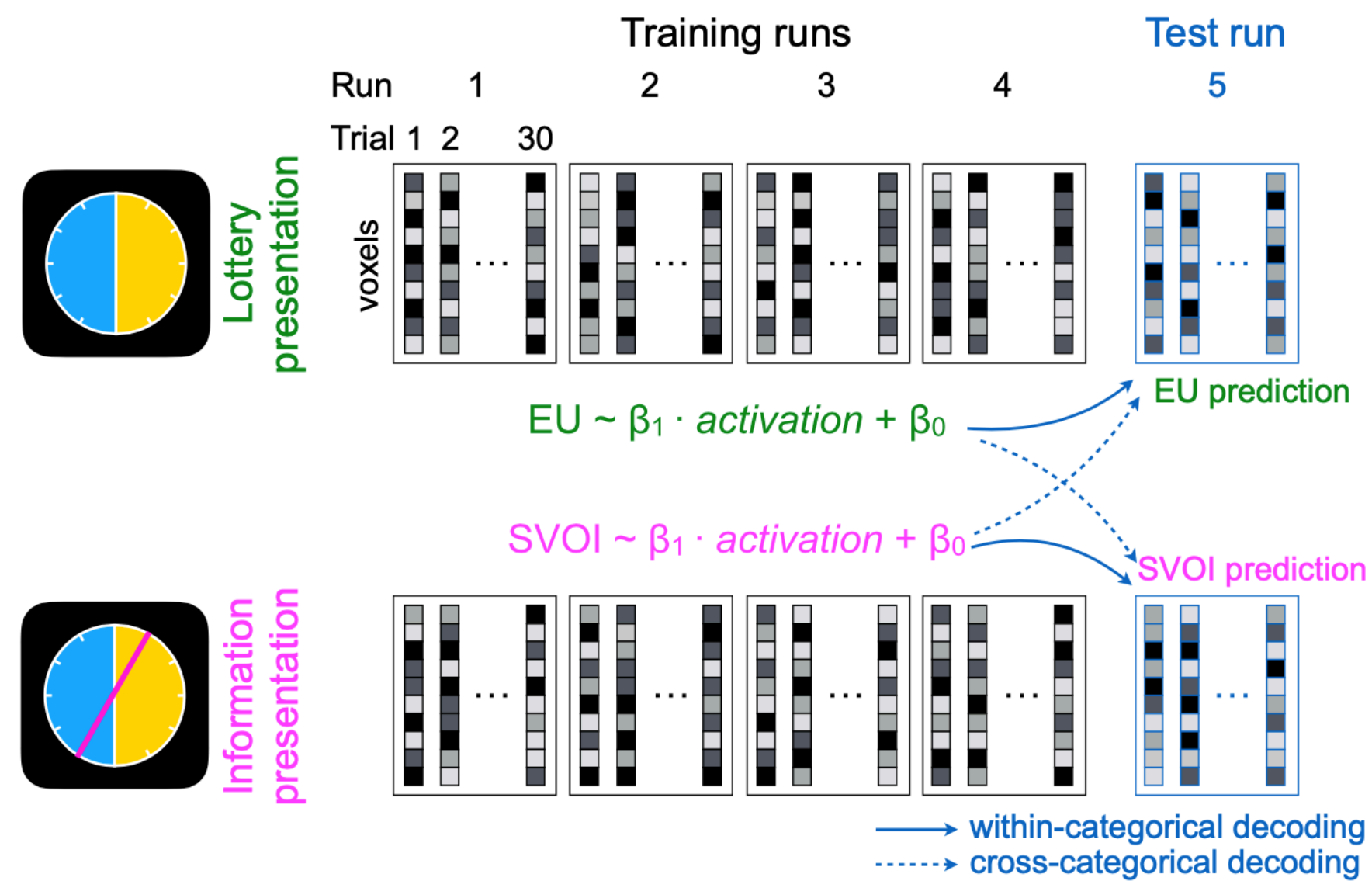
Sometimes the value of an action is driven by subjective preferences as well as the value of information itself.

Subjective value of information

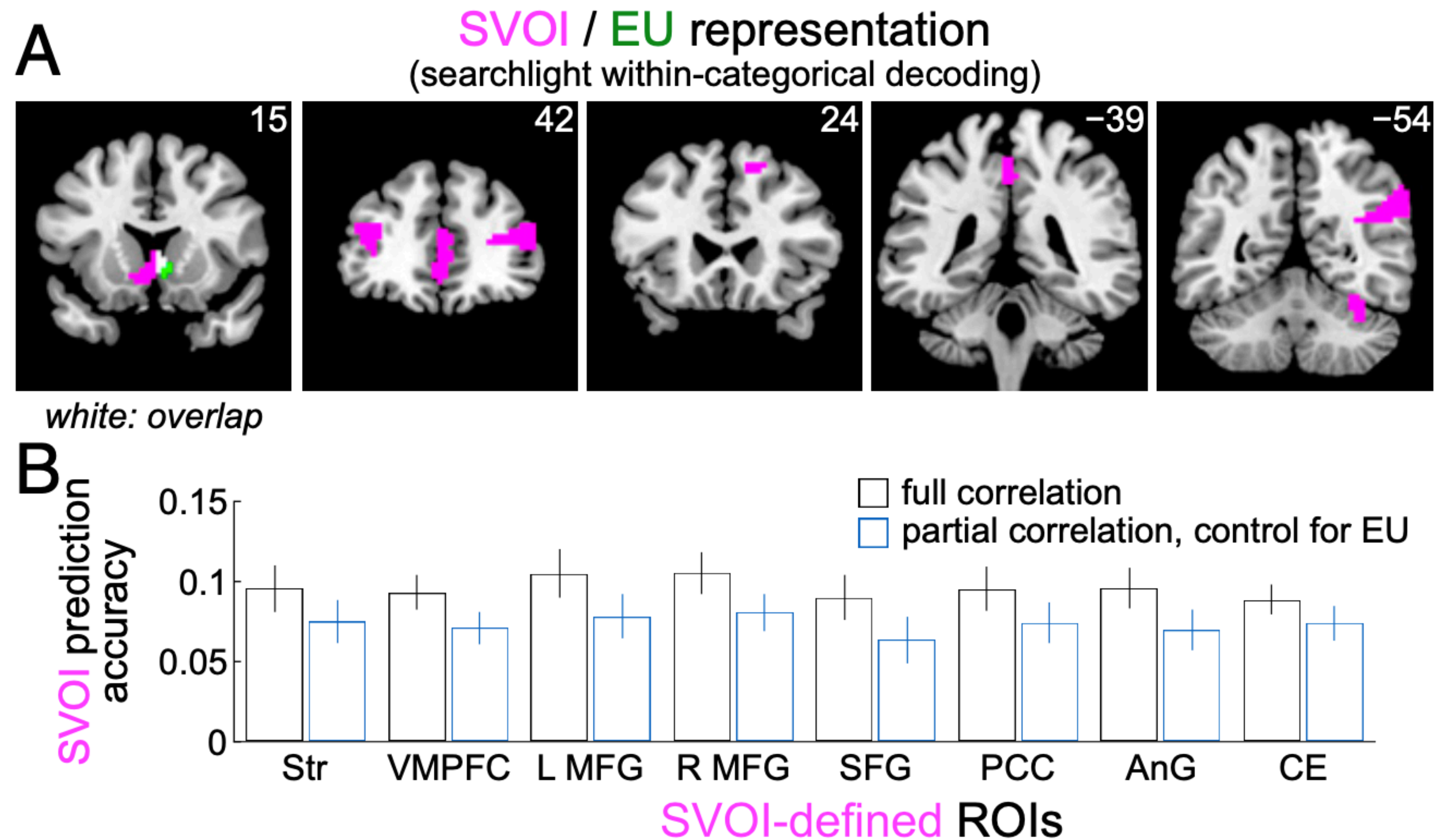


- Presented with roulette-style lottery.
- Initial accept/reject decision.
- Given option to buy information about choice.
- If purchased, participant can change initial accept/reject decision.

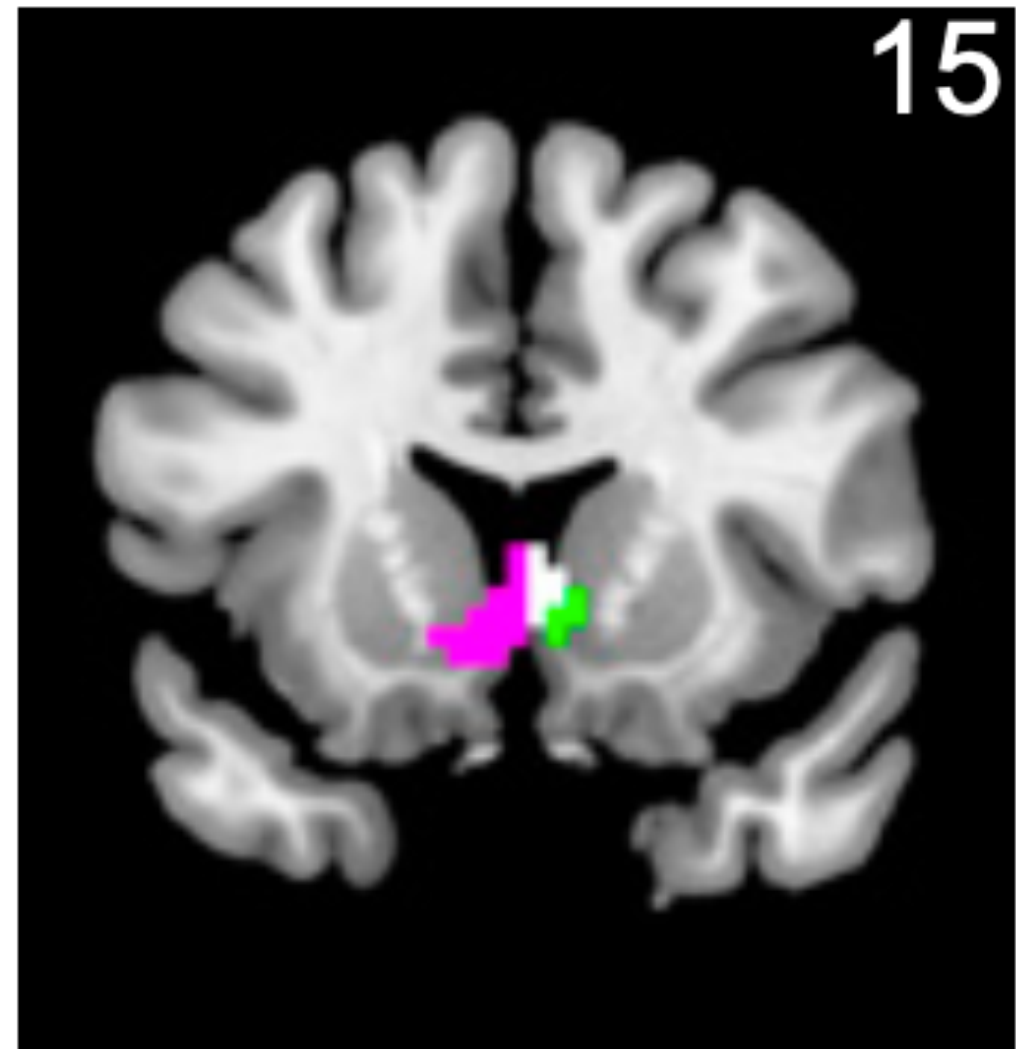
Neural representations



Overlapping regions of representation (reward & information)

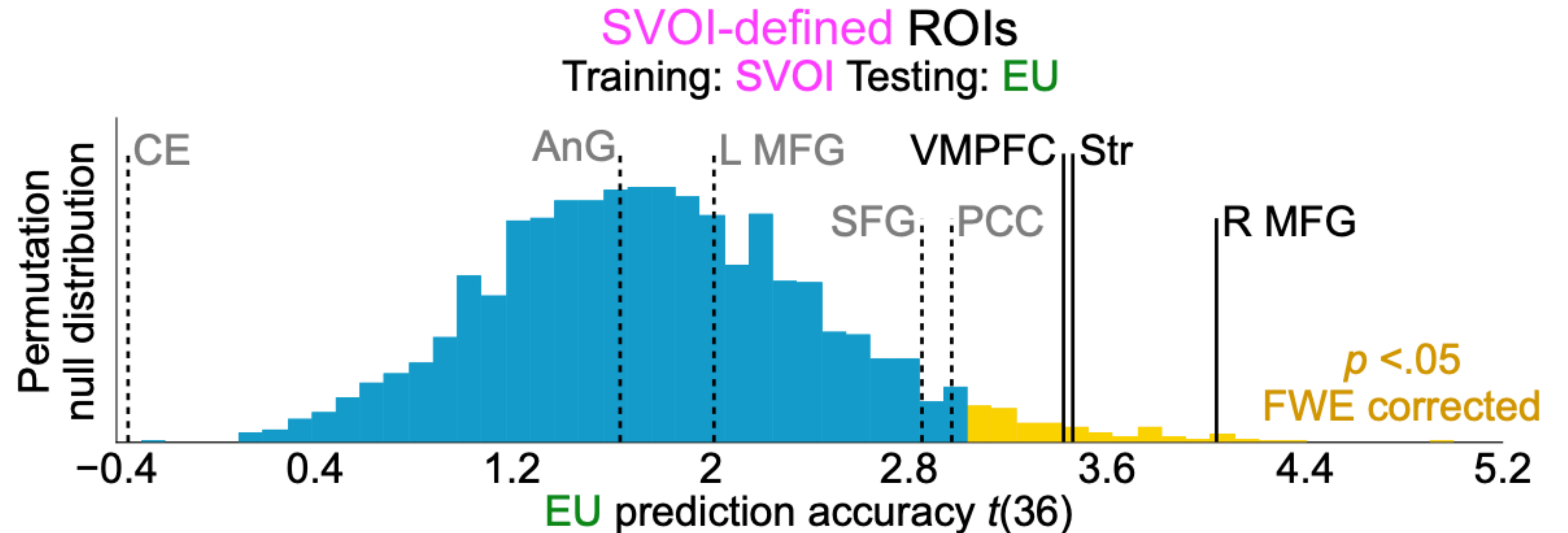


Mixture of representation



white: overlap

Ventral striatum (part of the “reward circuit”) shows a mixture of representations for expected reward and subjective information value



Food for thought

Information value (Sheridan 1995)

$$V_{net}^* = \underbrace{V_{avg}^*}_{\text{best vs overall}} - \underbrace{H_{avg}^*}_{\text{info cost}}$$

$$= (V_{avg} - V'_{avg}) - H_{avg}^*$$

$$= \sum_i p(x_i) \{ \max_j [V(u_j | x_i)] \}$$

$$- \max_j \{ \sum_i p(x_i) V(u_j | x_i) \} + C \sum_i p(x_i) \log_2[p(x_i)]$$

Small group project

1. Translate Sheridan's information value into non-technical English.
2. Present a “real world” example of this estimation process in practice.