Instrumental Conditioning VI:

There is more than one kind of learning

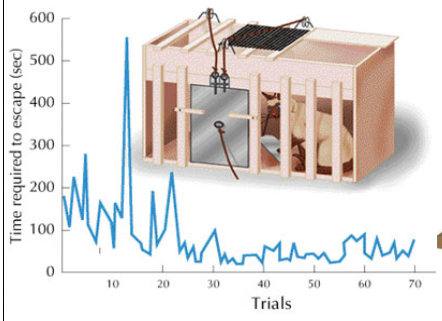
"That's the thing when you start living with someone -- you discover all of their little habits."

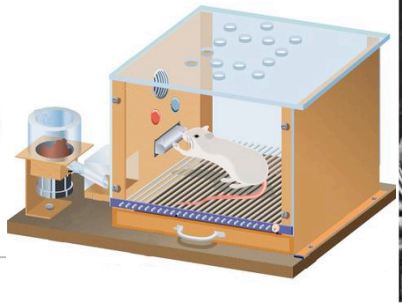
PSY/NEU338: Animal learning and decision making: Psychological, computational and neural perspectives

outline

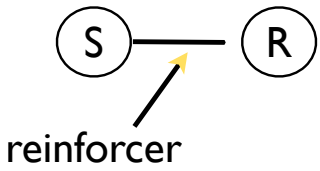
- what goes into instrumental associations?
- goal directed versus habitual behavior
- neural dissociations between habitual and goal-directed behavior
- how does all this fit in with reinforcement learning?

what is associated with what?



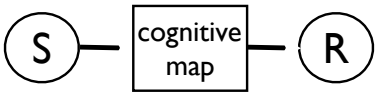


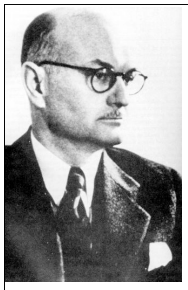
Thorndike:



Skinner:
what is the S?

Tolman:

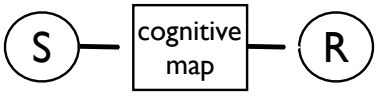




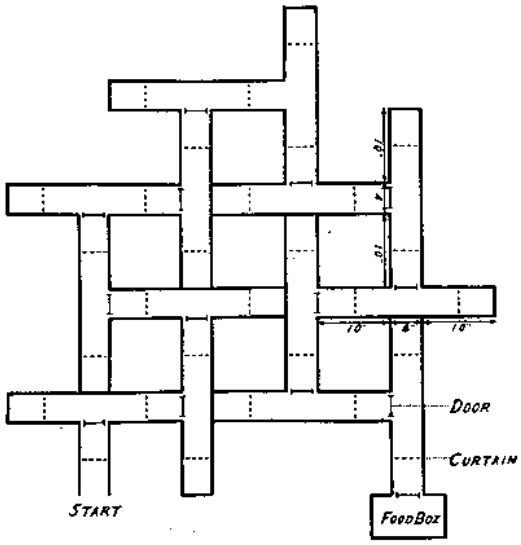
Tolman

"*The stimuli are not connected by just simple one-to-one switches to the outgoing responses. Rather, the incoming impulses are usually worked over and elaborated in the central control room into a tentative, cognitive-like map of the environment. And it is this tentative map, indicating routes and paths and environmental relationships, which finally determines what responses, if any, the animal will finally release.*"

Tolman:

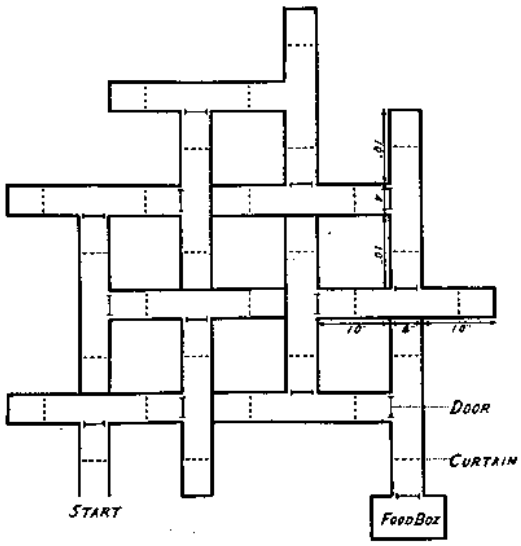


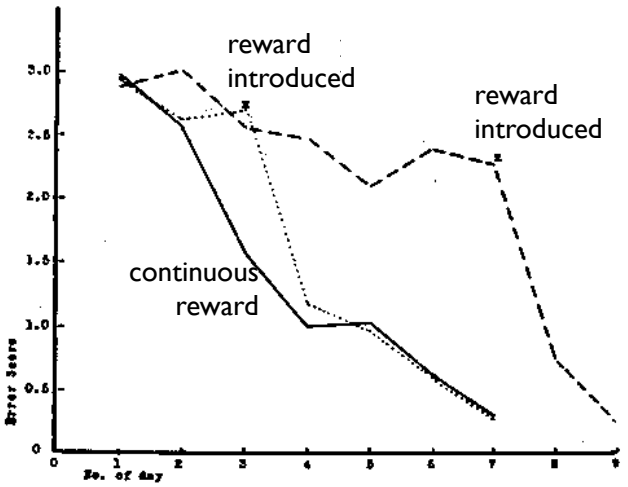
Maze task



- train rats to find food in a maze
- second group: exposed to maze but without food
- compare the groups in subsequent test with food
- what do you think will happen?
- what does this demonstrate?

Maze task: Latent learning

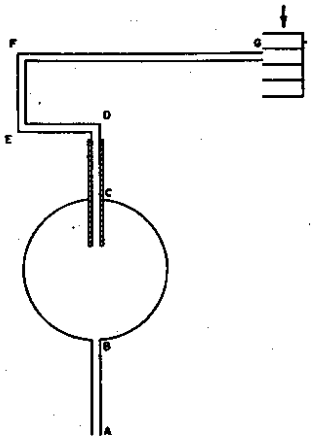




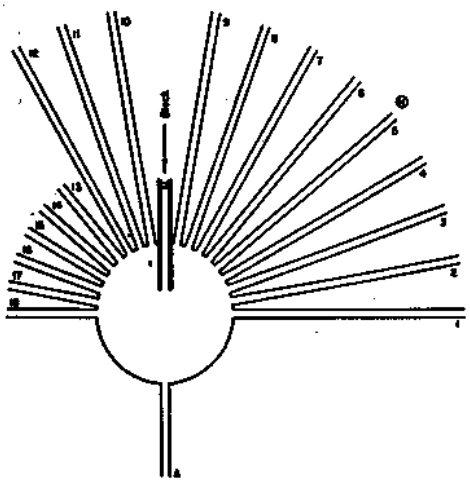
Blodgett (1929)

another example: shortcuts

training:



test:



result:

Tolman et al (1946)

summary so far...

- Even the humble rat can learn & internally represent spatial structure, and use it to plan flexibly
- Tolman relates this to all of society
- Note that spatial tasks are really complicated & hard to control
- Next: search for modern versions of these effects
- Key question: is S-R model ever relevant? and what is there beyond it? (especially important given what we know about RL)

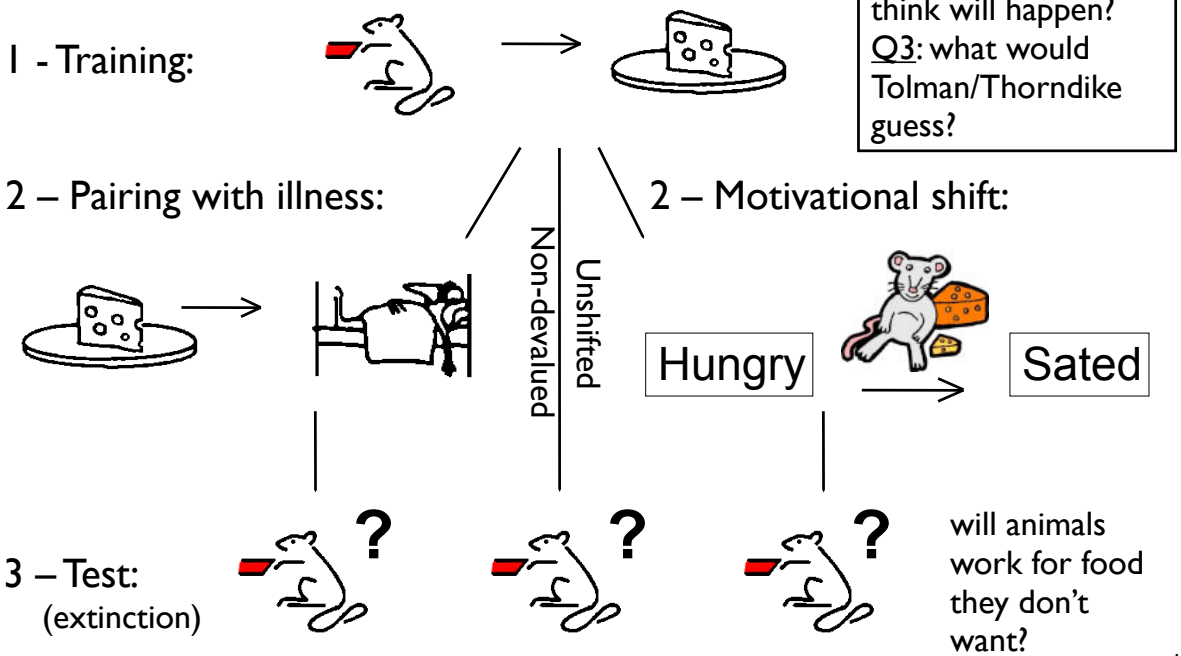
the modern debate: S-R vs R-O

- S-R theory:
  - parsimonious - same theory for Pavlovian conditioning (CS associated with CR) and instrumental conditioning (stimulus associated with response)
  - but: the critical contingency in instrumental conditioning is that of the response and the outcome…
- alternative: R-O theory (also called A-O)
  - among proponents: Rescorla, Dickinson
  - same spirit as Tolman (know 'map' of contingencies and desires, can put 2+2 together)

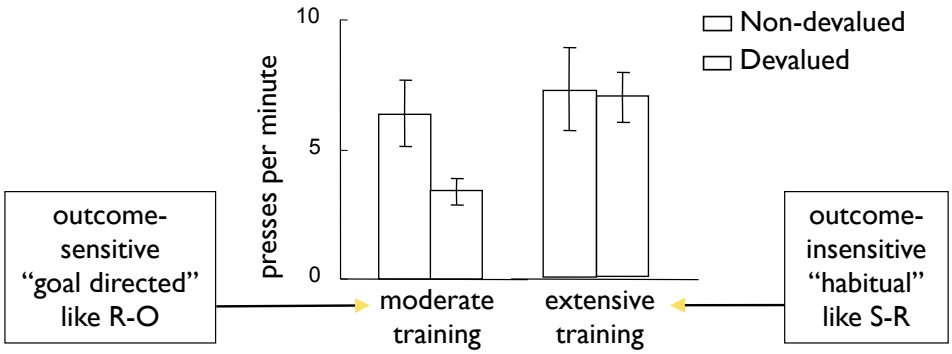
How would you test this?

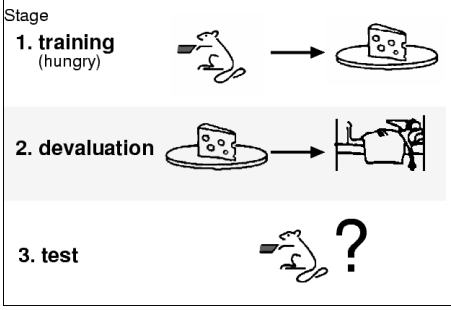
outcome devaluation

Q1: why test without rewards?
Q2: what do you think will happen?
Q3: what would Tolman/Thorndike guess?



devaluation: results





Animals will *sometimes* work for food they don't want!

→ in daily life: actions become automatic (habitual) with repetition

Holland (2004)

outline

- what goes into instrumental associations?
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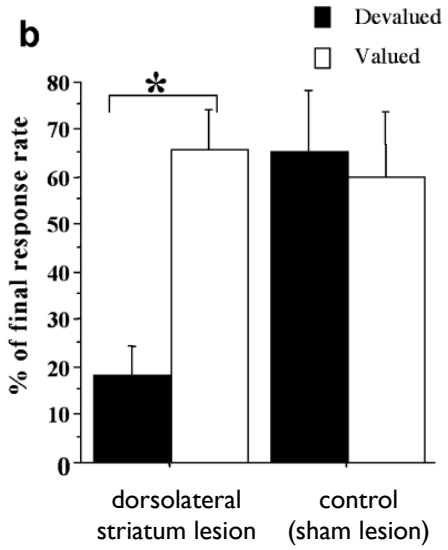
devaluation: results from lesions I

overtrained rats



→ animals with lesions to DLS *never develop habits* despite extensive training

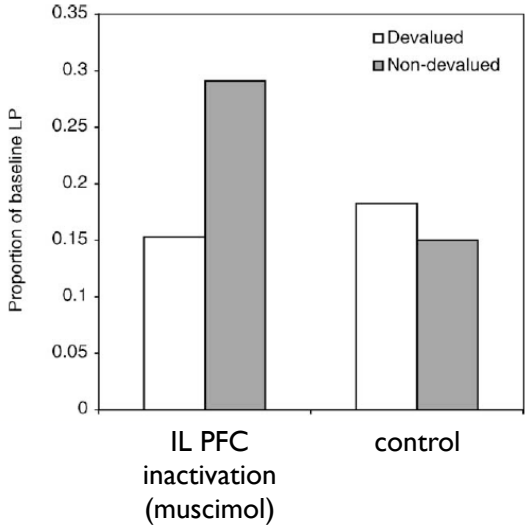
→ also treatments depleting dopamine in DLS

→ also lesions to infralimbic division of PFC (same corticostriatal loop)

Yin et al (2004)

devaluation: results from lesions II

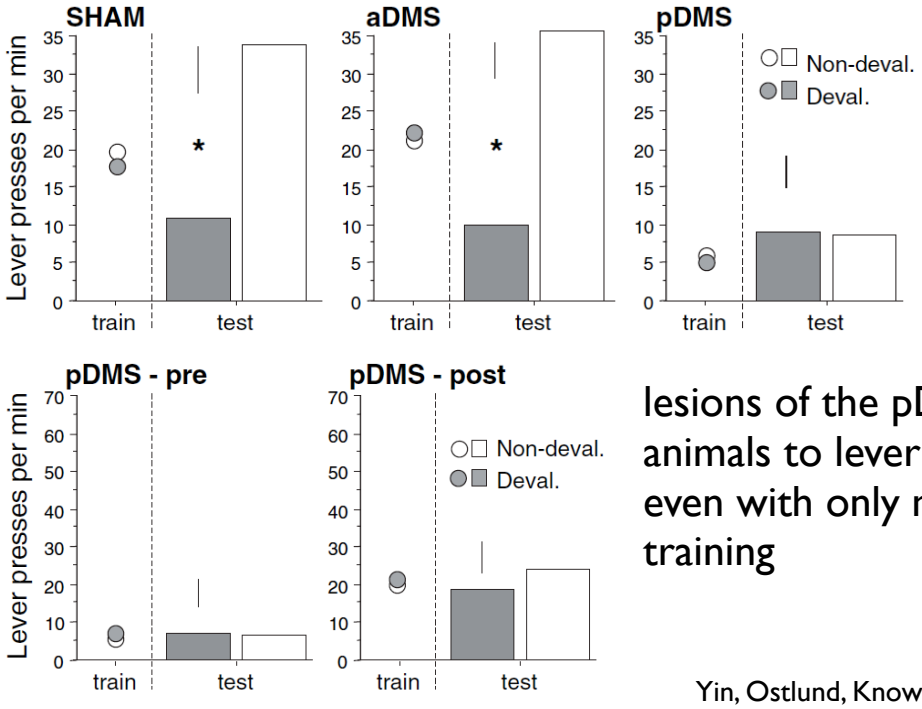
overtrained rats



after habits have been formed, devaluation sensitivity can be *reinstated* by temporary inactivation of IL PFC

Coutureau & Killcross (2003)

devaluation: results from lesions III

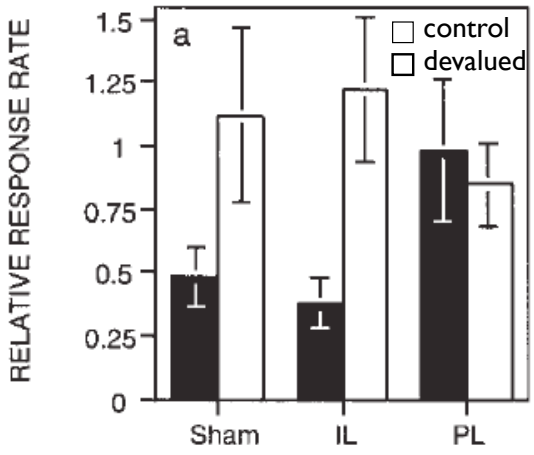


lesions of the pDMS cause animals to leverpress *habitually* even with only moderate training

Yin, Ostlund, Knowlton & Balleine (2005)

devaluation: results from lesions IV

moderate training

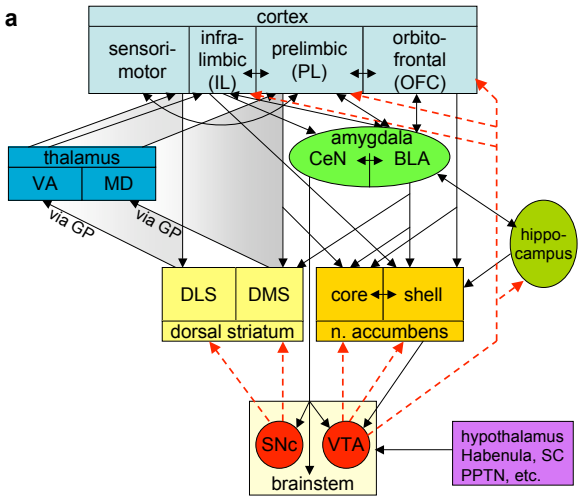


Prelimbic (PL) PFC lesions cause animals to leverpress *habitually* even with only moderate training

(also dorsomedial PFC and mediodorsal thalamus (same loop))

Killcross & Coutureau (2003)

complex picture of behavioral control



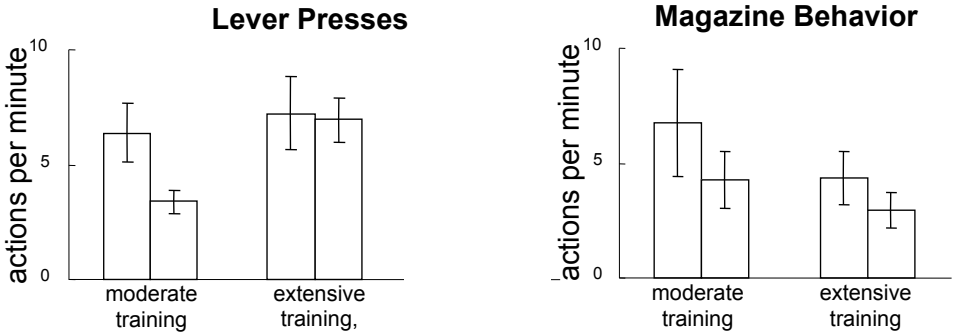
neural dissociation between goal-directed and habitual controllers

inspired by Balleine (2005)

what does all this mean?

- The same action (leverpressing) can arise from two psychologically & neurally dissociable pathways
  1. moderately trained behavior is "goal-directed": dependent on outcome representation, like cognitive map (also associated with hippocampus - literal or abstract map of environment)
  2. overtrained behavior is "habitual": apparently not dependent on outcome representation, like S-R
- S-R habits really *do* exist, they just don't describe *all* of animal behavior
- Lesions suggest two parallel systems, in that the intact one can apparently support behavior at any stage

devaluation: one more result



behavior is not always consistent:
leverpressing is habitual and continues for unwanted food…
...at same time nosepoking is reduced (explanations?)

Kilcross & Coutureau (2003)

why are nosepokes always sensitive to devaluation?

- Balleine & Dickinson: 3rd system - Pavlovian behavior is directly sensitive to outcome value
- But: doesn't make sense... the Pavlovian system has information that it is withholding from the instrumental system?
- Also.. true for purely instrumental chain
- And anyway, it seems that all the information is around all the time, so why is behavior not always goal-directed?

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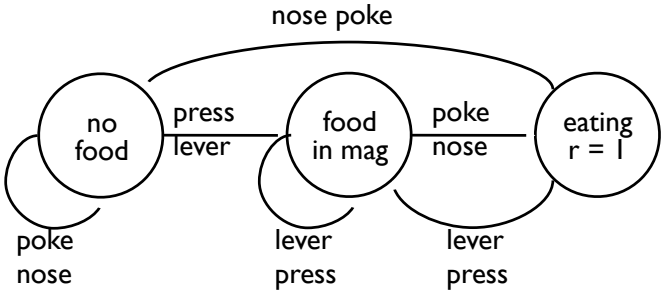
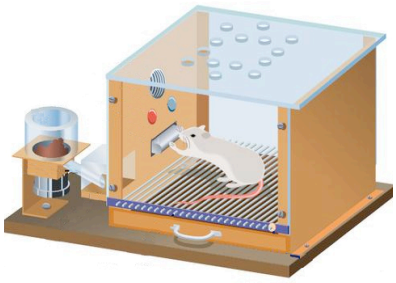
back to RL framework for decisions



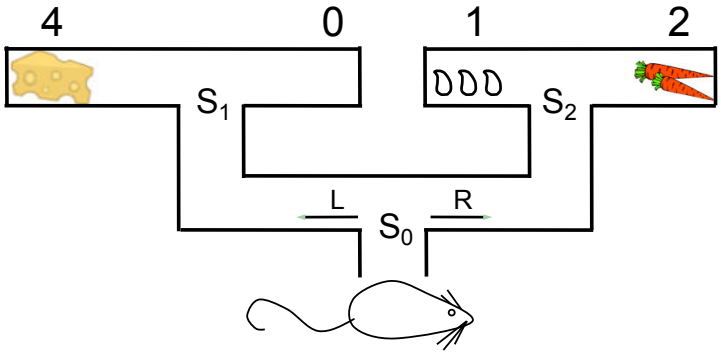


3 states: "no food", "food in mag", "eating"
2 actions: "press lever", "poke nose"
immediate reward is 1 in state "eating" and 0 otherwise

need to know long term consequences of actions Q(S,a) in order to choose the best one

how can these be learned?

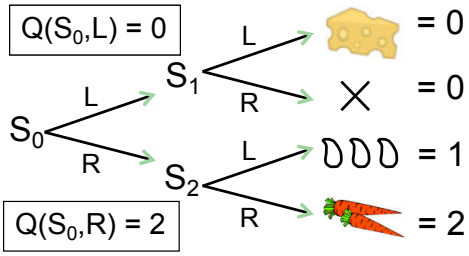
strategy 1: "model-based" RL



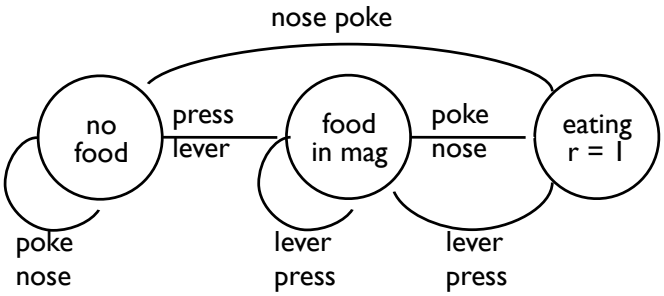
learn model of task through experience (= cognitive map)

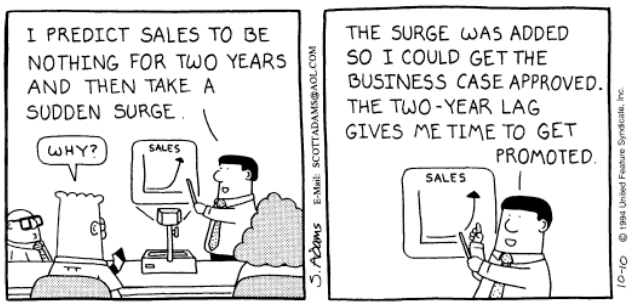
compute Q values by "looking ahead" in the map

computationally costly, but also flexible (immediately sensitive to change)

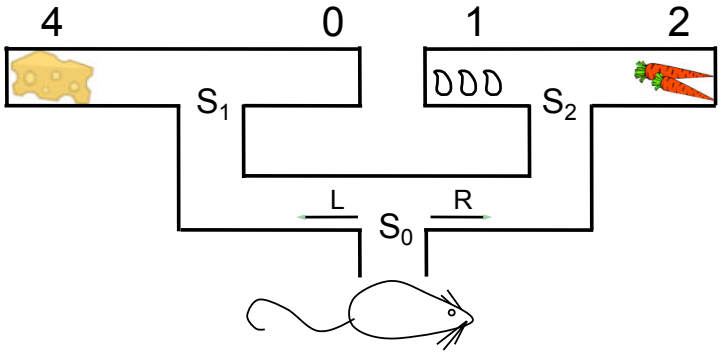


strategy 1: "model-based" RL





strategy 11: "model-free" RL



- Shortcut: store long-term values
  - then simply retrieve them to choose action
- Can learn these from experience
  - without building or searching a model
  - incrementally through prediction errors
  - dopamine dependent SARSA/Q-learning or Actor/Critic

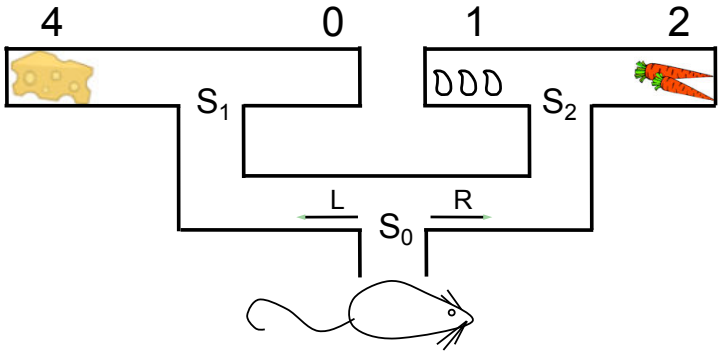
Stored:

$Q(S_0,L) = 4$
$Q(S_0,R) = 2$

$Q(S_1,L) = 4$
$Q(S_1,R) = 0$

$Q(S_2,L) = 1$
$Q(S_2,R) = 2$

strategy 11: "model-free" RL



- choosing actions is easy so behavior is quick, reflexive (S-R)
- but needs a lot of experience to learn
- and inflexible, need relearning to adapt to any change (habitual)

Stored:

$Q(S_0,L) = 4$
$Q(S_0,R) = 2$

$Q(S_1,L) = 4$
$Q(S_1,R) = 0$

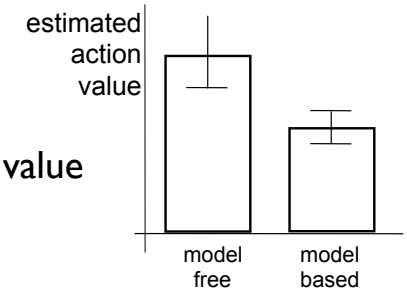
$Q(S_2,L) = 1$
$Q(S_2,R) = 2$

two big questions

- Why should the brain use two different strategies/ controllers in parallel?
- If it uses two: how can it arbitrate between the two when they disagree *(new decision making problem…)*

answers

- each system is best in different situations (use each one when it is most suitable/most accurate)
  - goal-directed (forward search) - good with limited training, close to the reward (don't have to search ahead too far)
  - habitual (cache) - good after much experience, distance from reward not so important
- arbitration: trust the system that is more confident in its recommendation
  - different sources of uncertainty in the two systems
  - compare to: always choose the highest value



back to animals pressing a lever for a devalued food, but not nose-poking to get it: can you explain this?

summary

- instrumental behavior is not a simple unitary phenomenon: the same behavior can result from different neural and computational origins
- different neural mechanisms work in parallel to support behavior: cooperation and competition
- useful tests: outcome devaluation, contingency degradation