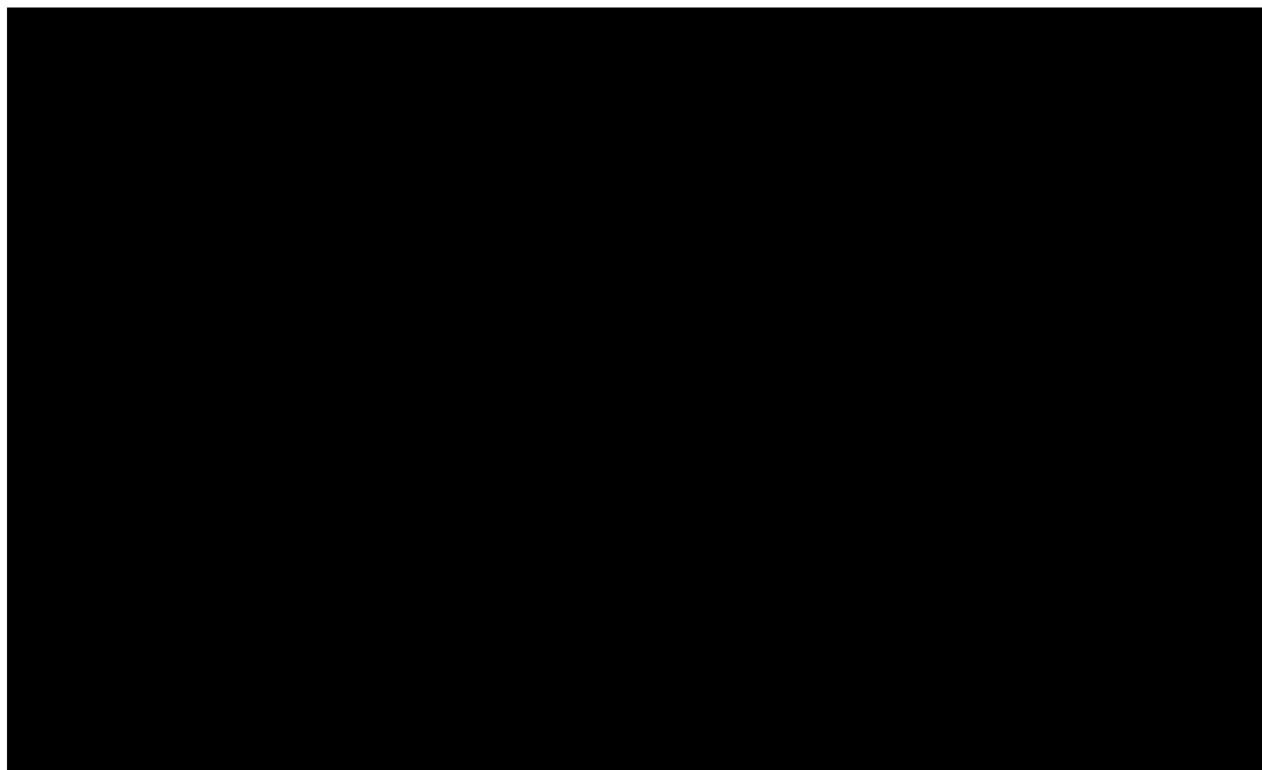
Cognitive Modeling

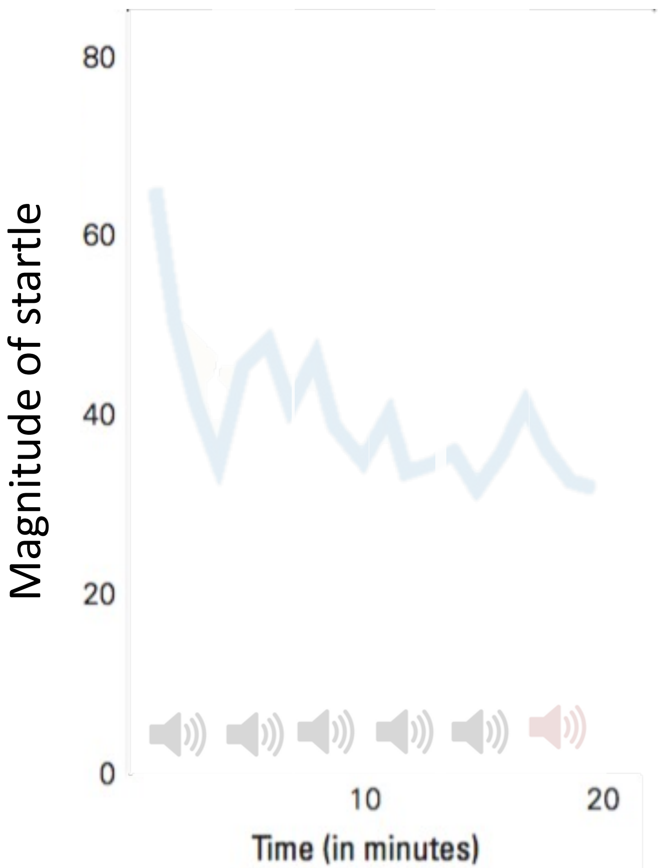
L2 Latent Learning: Automatic Statistical Analyses of the World

Habituation

habituation. A decrease in the strength or occurrence of a behavior after repeated exposure to the stimulus that produces that behavior.



Habituation



(a) Startle in rats

stimulus specificity &
stimulus generalization

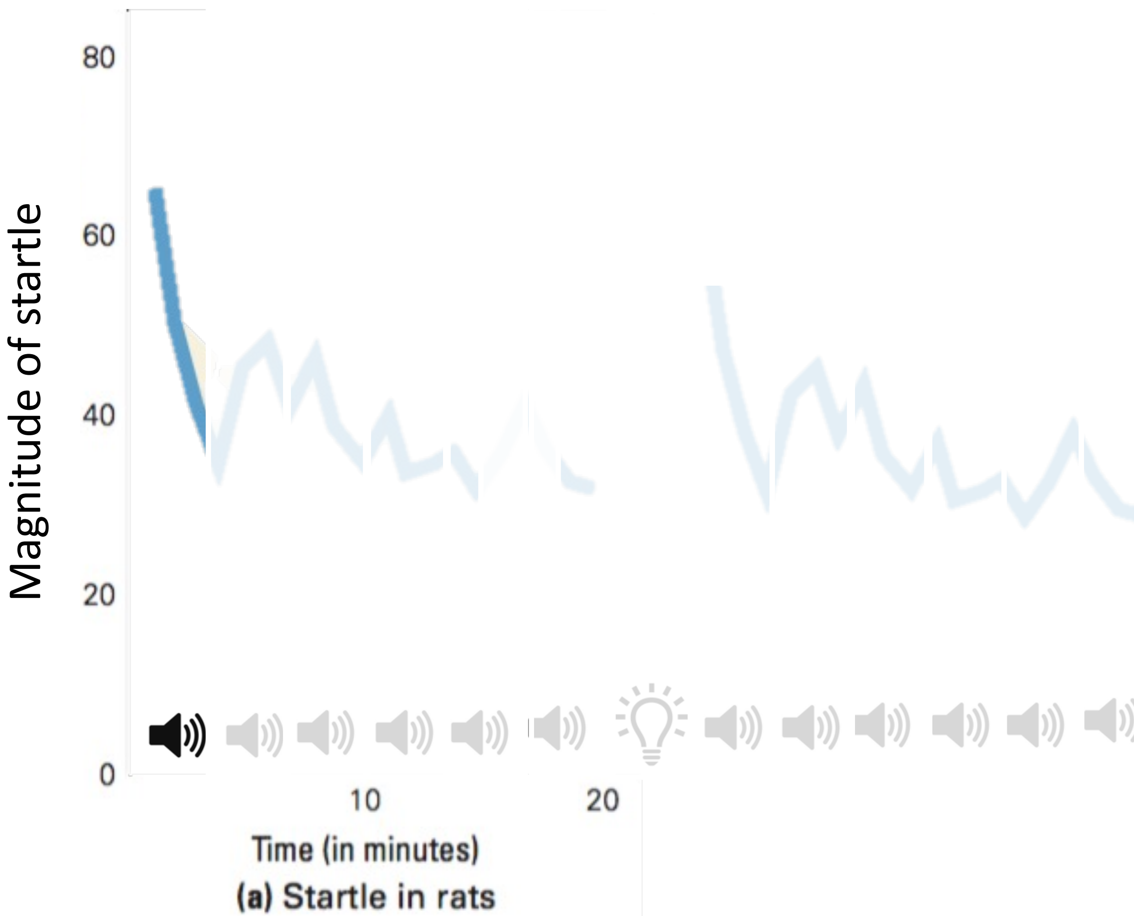
If the stimulus is very similar
habituation will transfer,
But not when it is very different.

Habituation

Factors Influencing the Rate and Duration of Habituation

- Magnitude / salience
  - Bigger is better
- Number of exposures
  - More is faster
- Time (massed vs. spaced)
  - Massed is faster <u>but</u> effects are shorter (short vs. long term habituation)

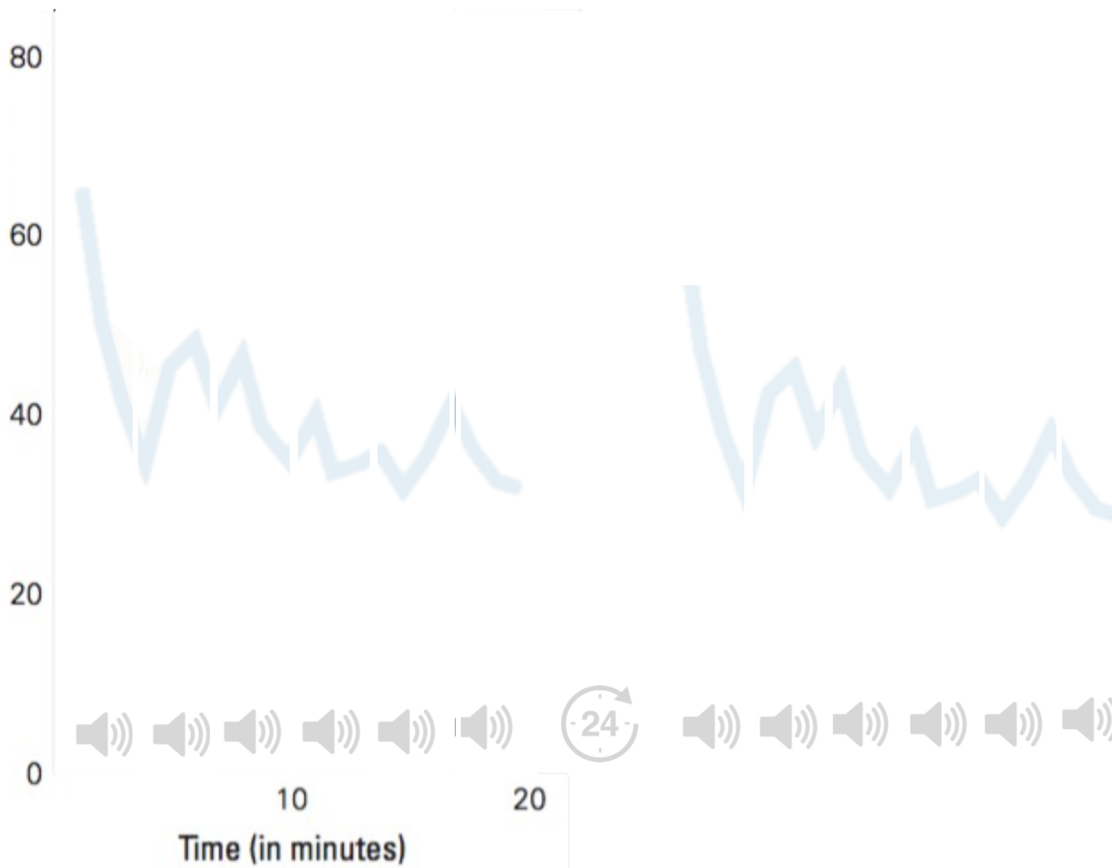
Habituation



dishabituation.

A renewal of a response, previously habituated, that occurs when the organism is presented with a novel stimulus.

Habituation



(a) Startle in rats

Spontaneous recovery

Reappearance (or increase in strength) of a previously habituated response after a short period of no stimulus presentation.

Habituation

Why would habituation be a good thing

Habituation

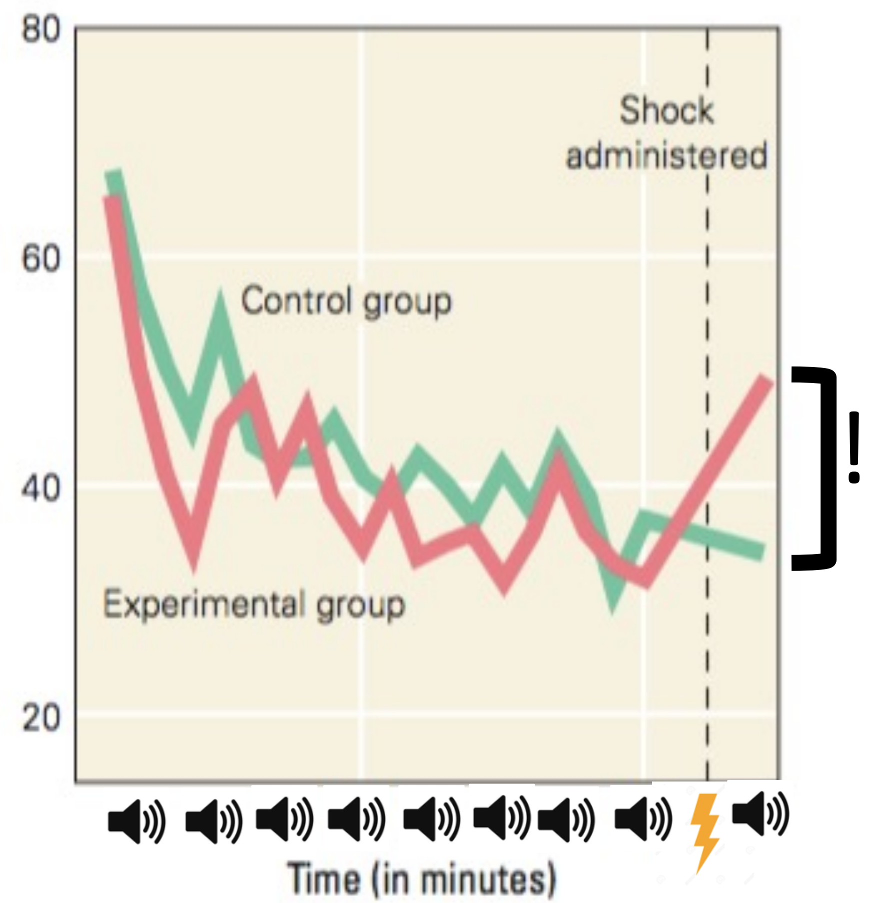
Why would habituation be a bad thing?

Sensitization

Sensitization

<u>Sensitization</u>

A phenomenon in which a salient stimulus (*such as an electric shock*) temporarily increases the strength of responses to other stimuli *(including the habituated stimulus)*.

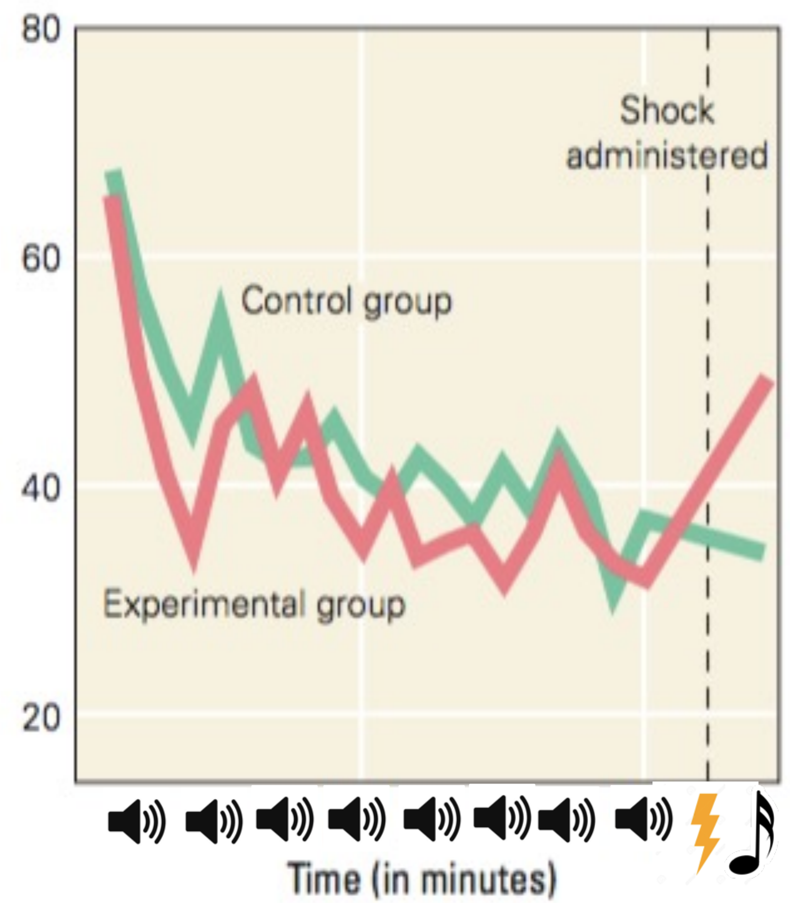


Sensitization

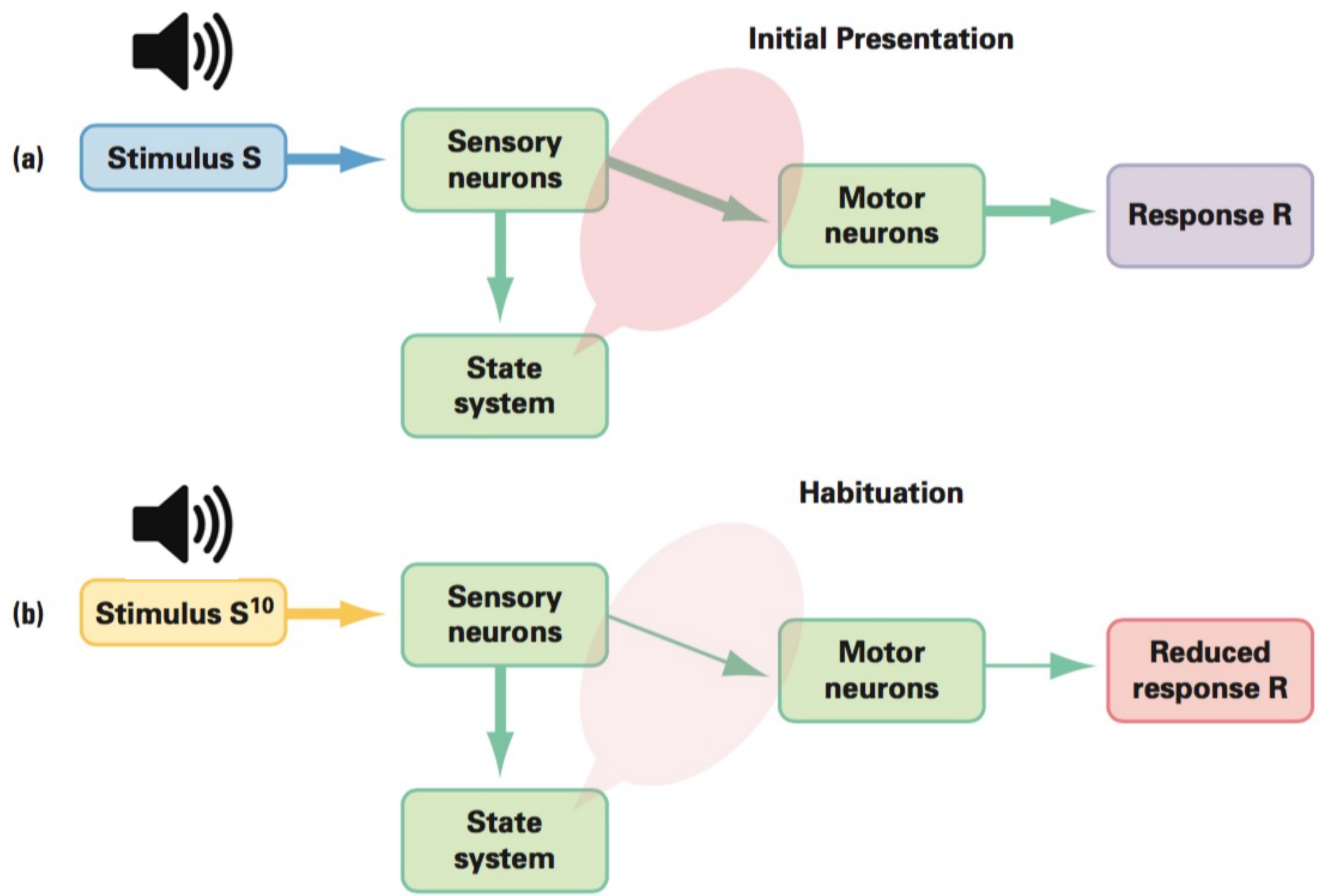
<u>Sensitization</u>

Is non-specific may even increase startle reflex to typically non-startling stimuli.

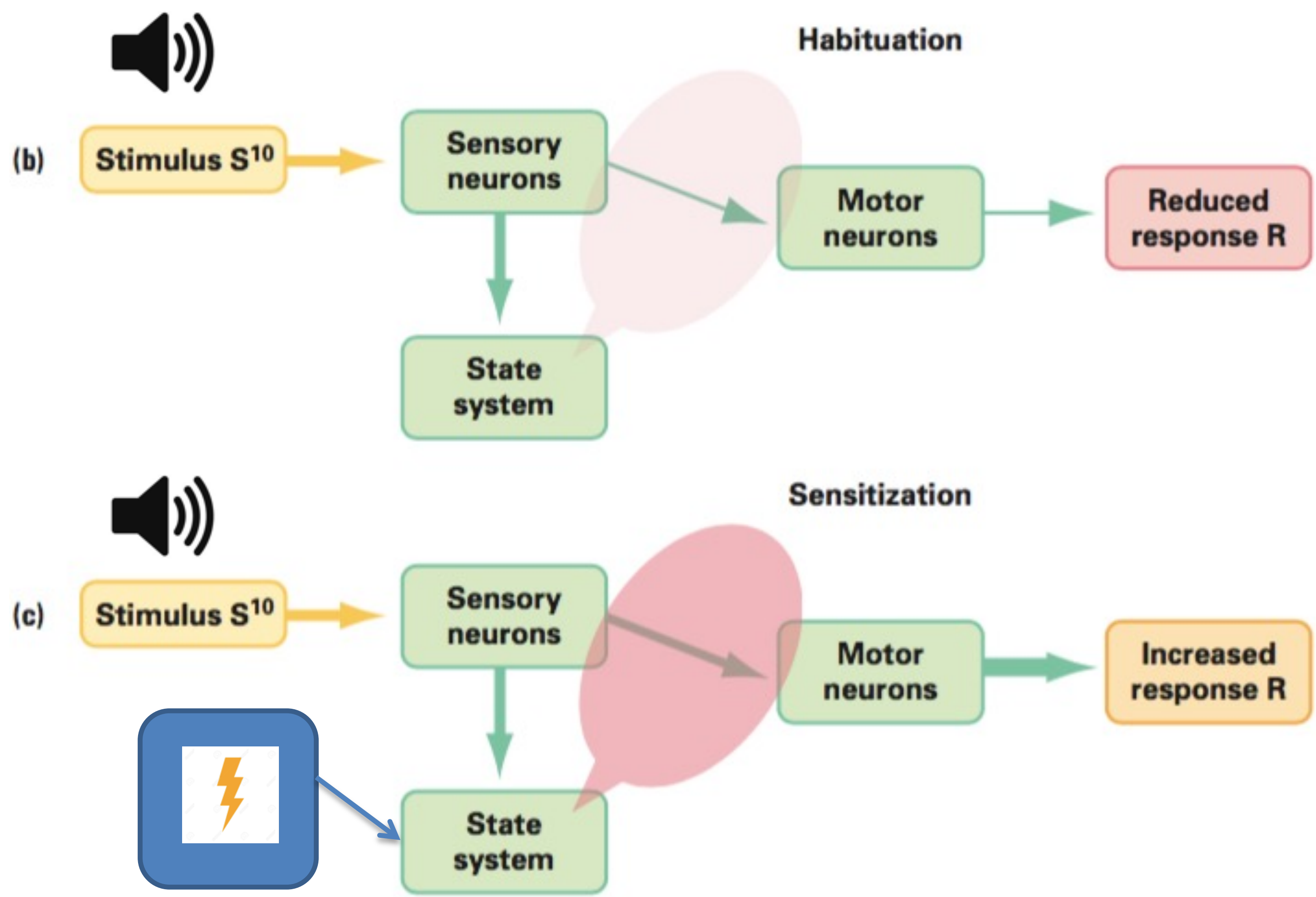
(difference with dishabituation)



Sensitization & Habituation



Sensitization & Habituation



Mere exposure learning

Real life example of exposure learning

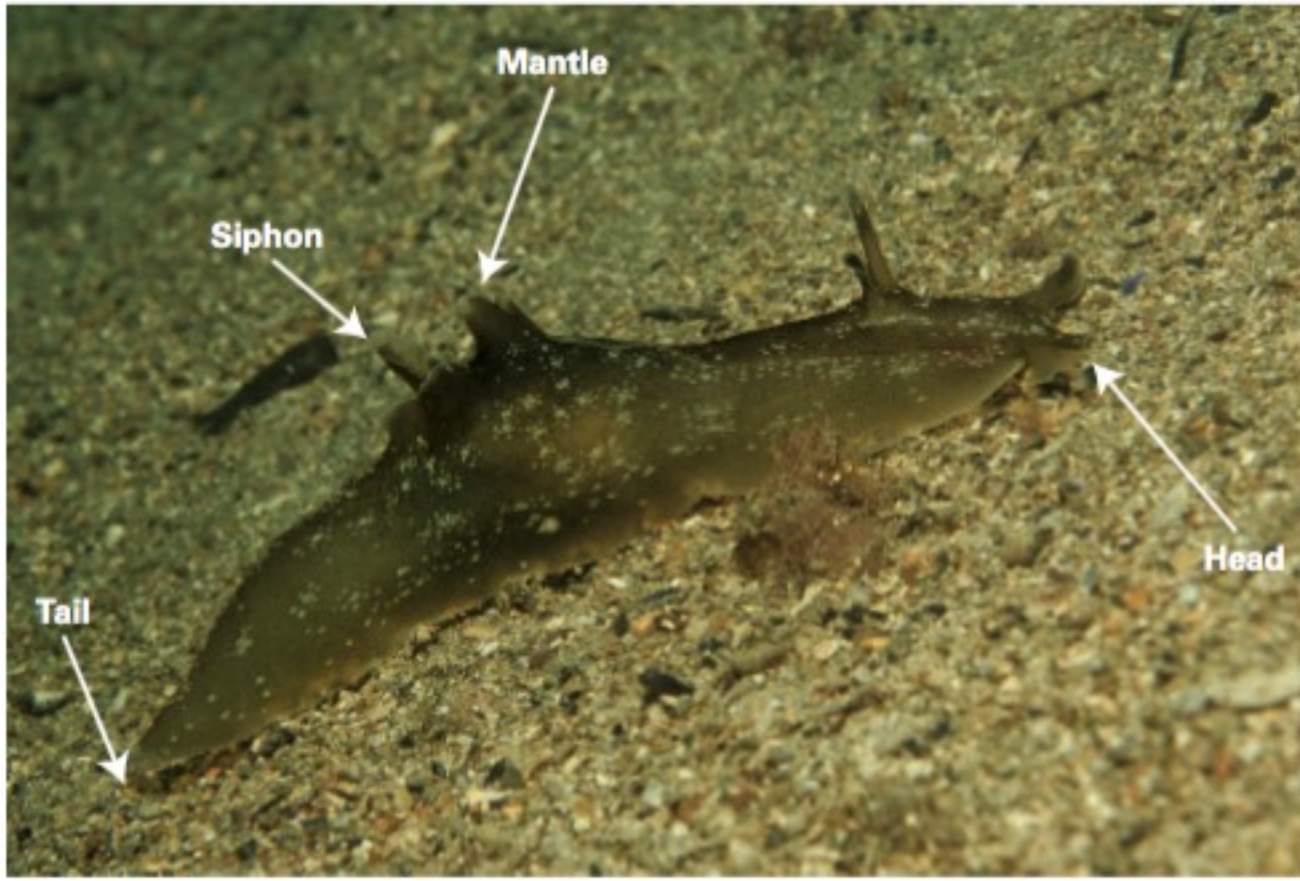
Mere exposure learning

<u>mere exposure learning.</u>

Combination of habituation (to similarities) and Sensitization (to differences).

Neural substrates

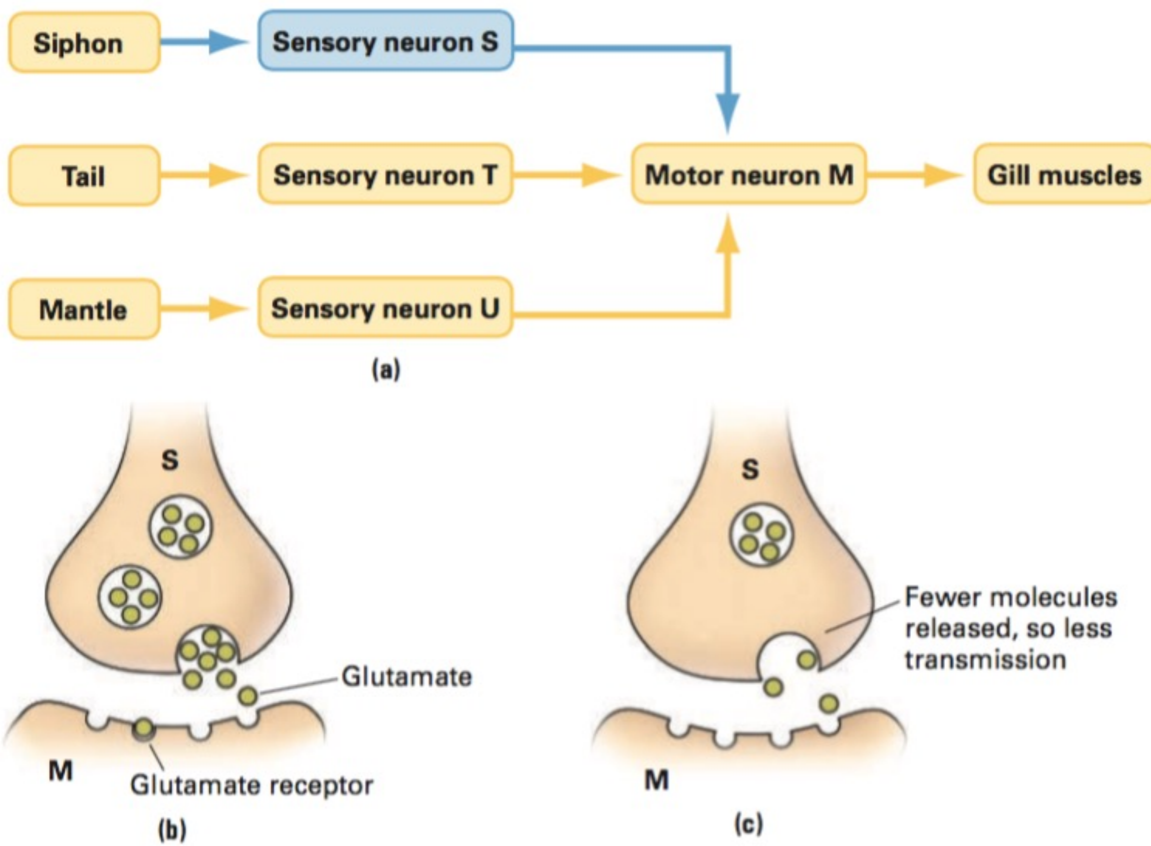
only about 20,000 neurons !



We have 16 billion

NOVA

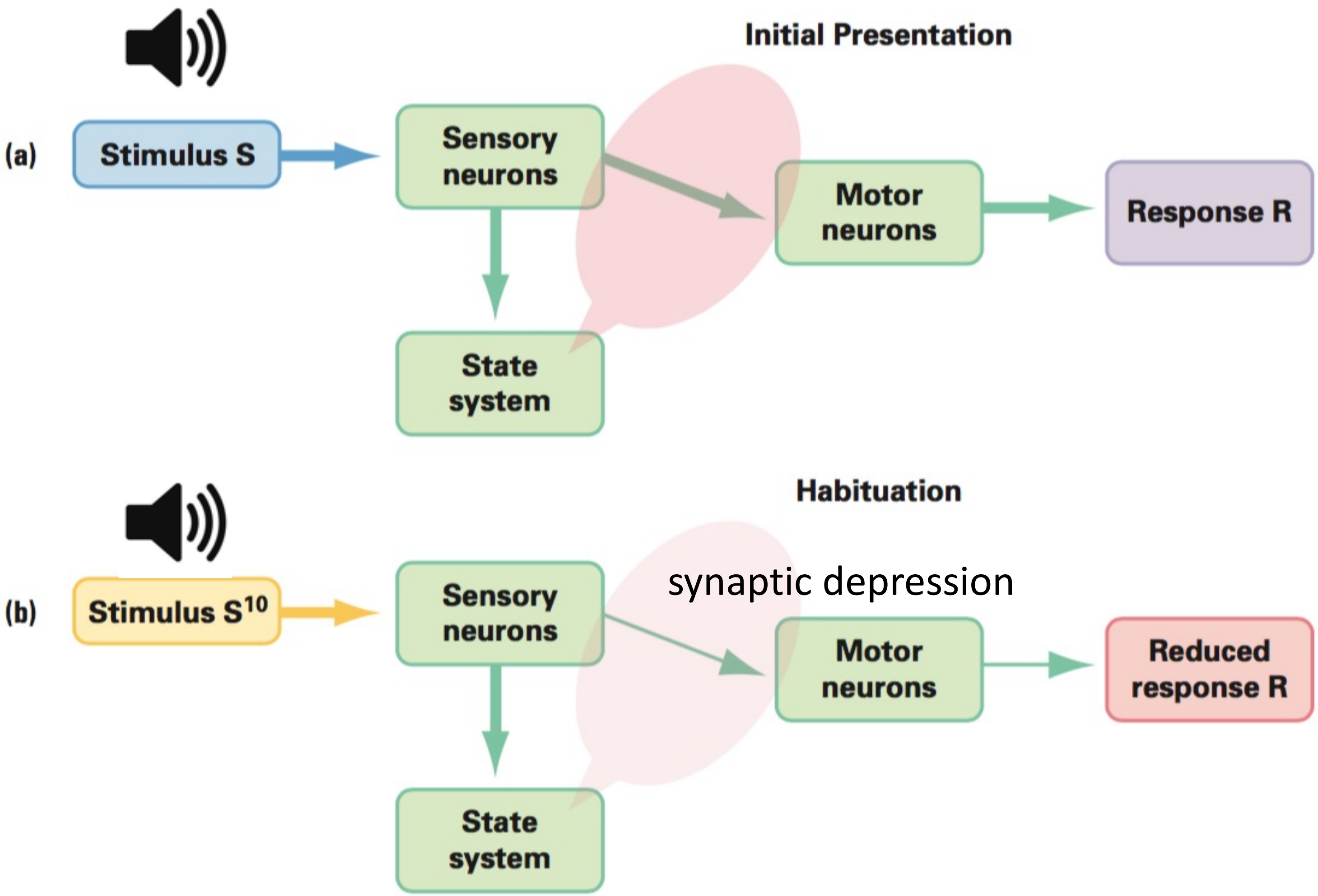
Neural substrates



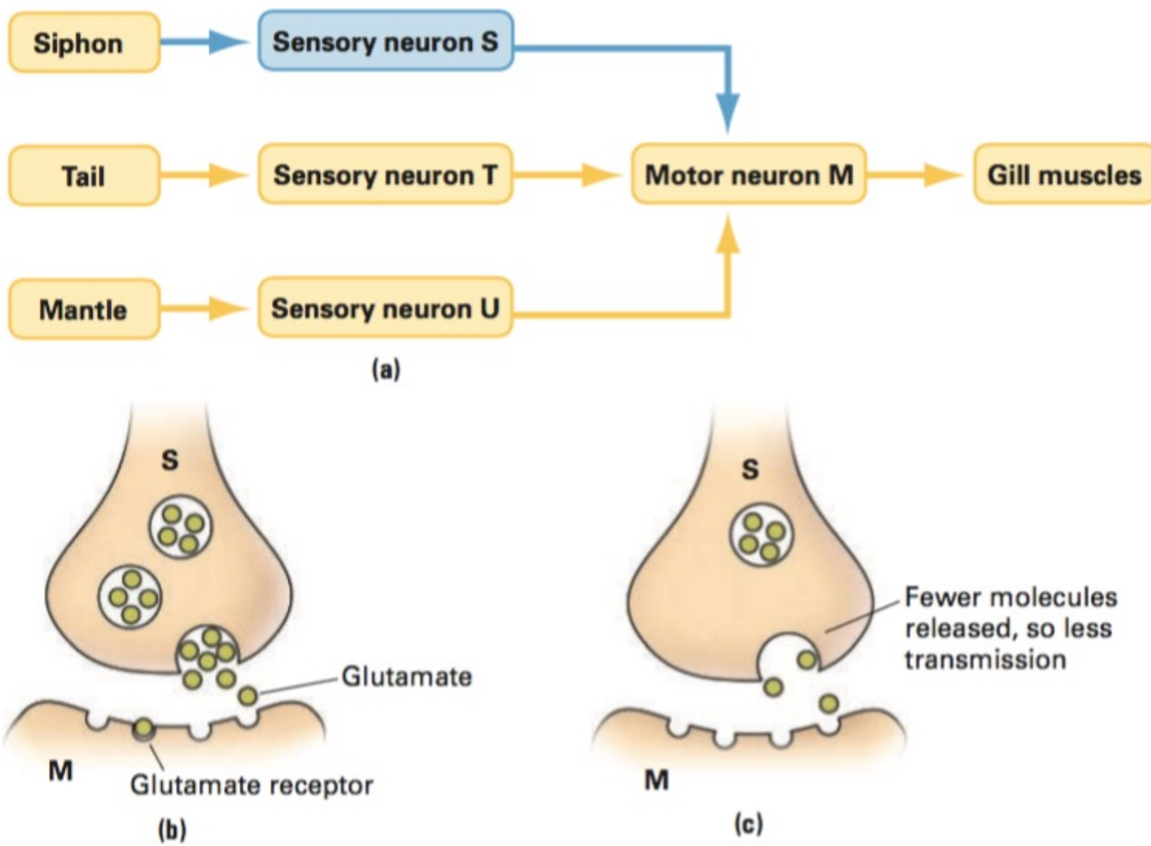
synaptic depression. A reduction in synaptic transmission; a possible neural mechanism underlying habituation.

Glutamate

Sensitization & Habituation



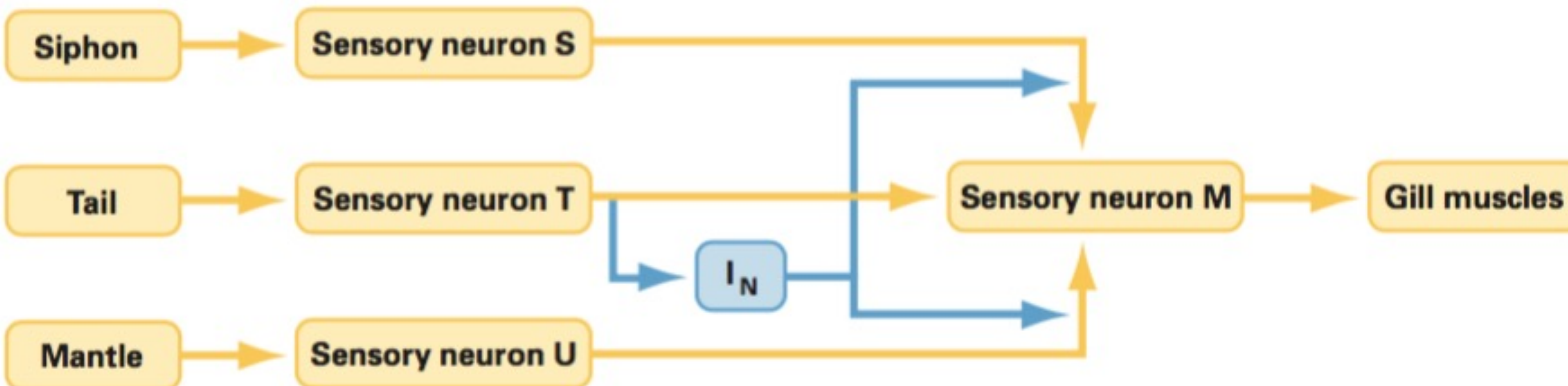
Neural substrates



homosynaptic. Occurring in one synapse without affecting nearby synapses.

Long-term habituation Elimination of presynaptic terminals

Neural substrates

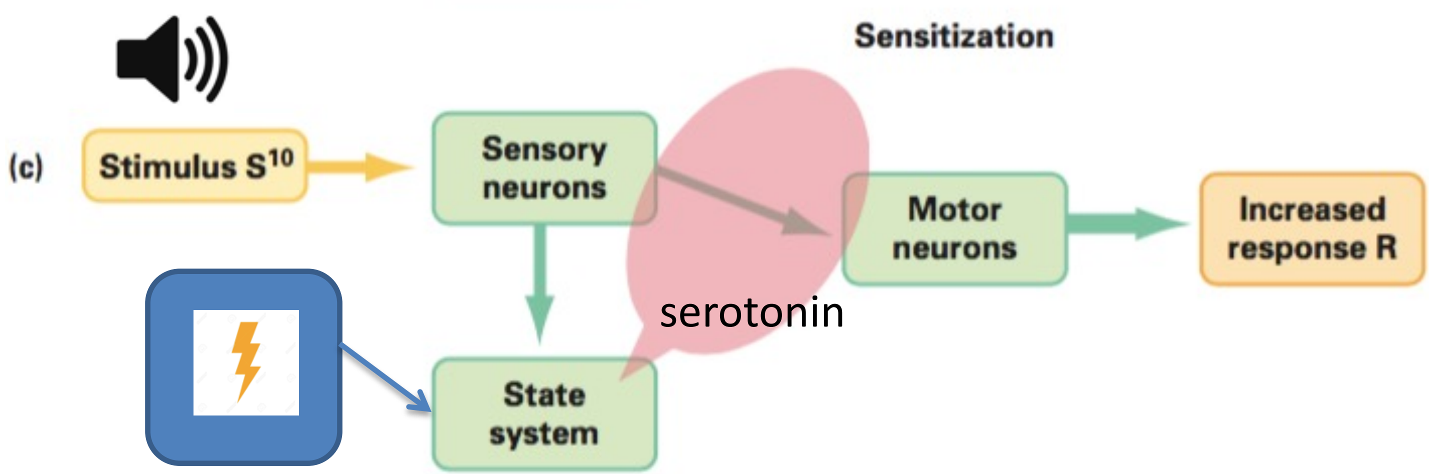


(a)

Sensitization is caused by *modulatory interneuron* that have **heterosynaptic** effects. In this case the *neuromodulator* serotonin increases the pre-synaptic release of **glutamate.**

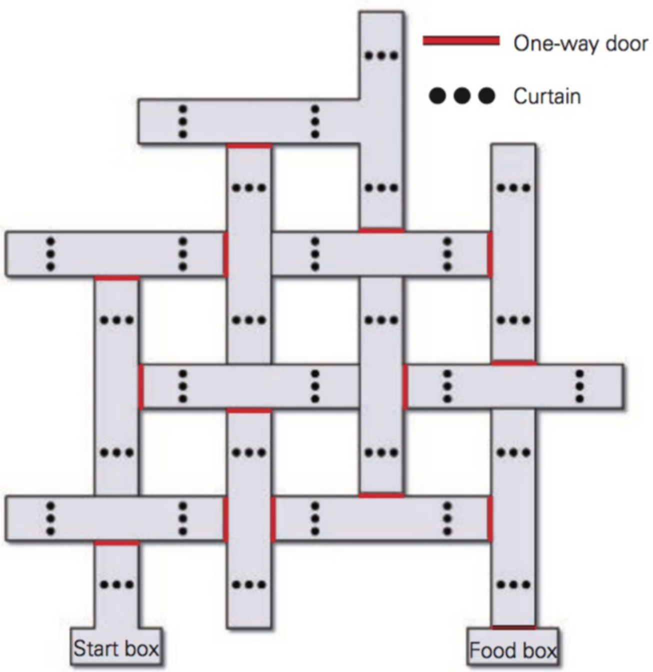
Heterosynaptic effects

Sensitization

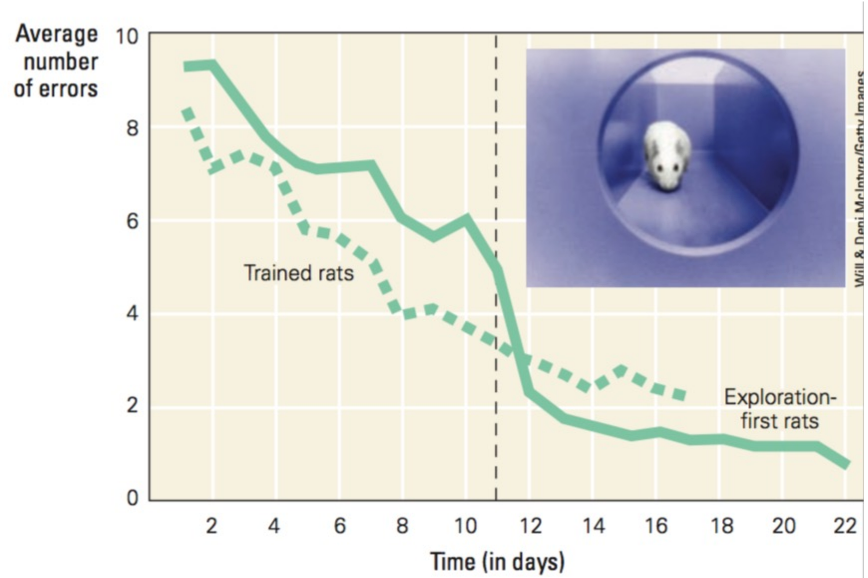


Spatial Learning

Reward based vs. Latent learning



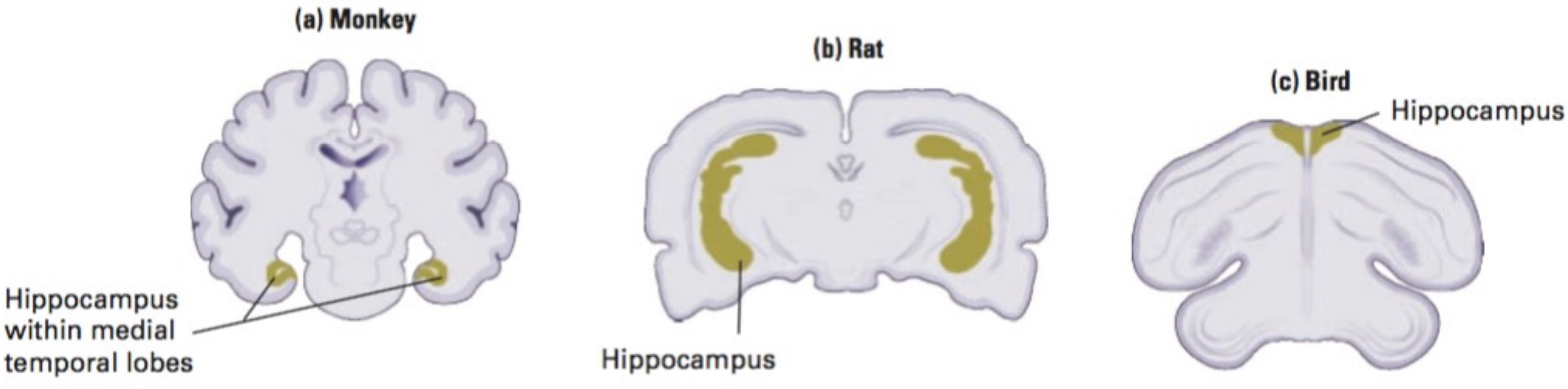
(a)



(b)

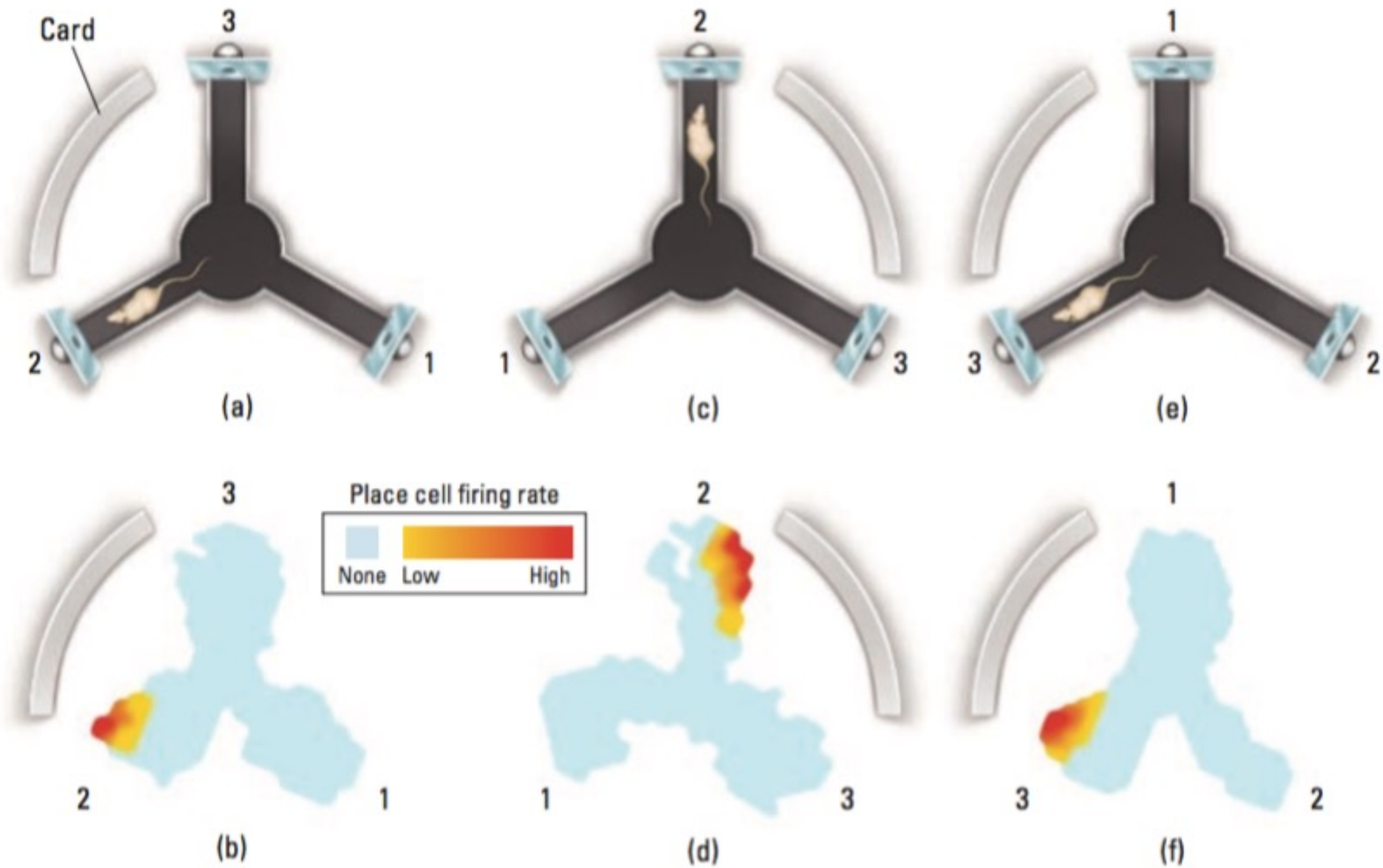
Spatial Learning (states)

Place cells & cognitive map



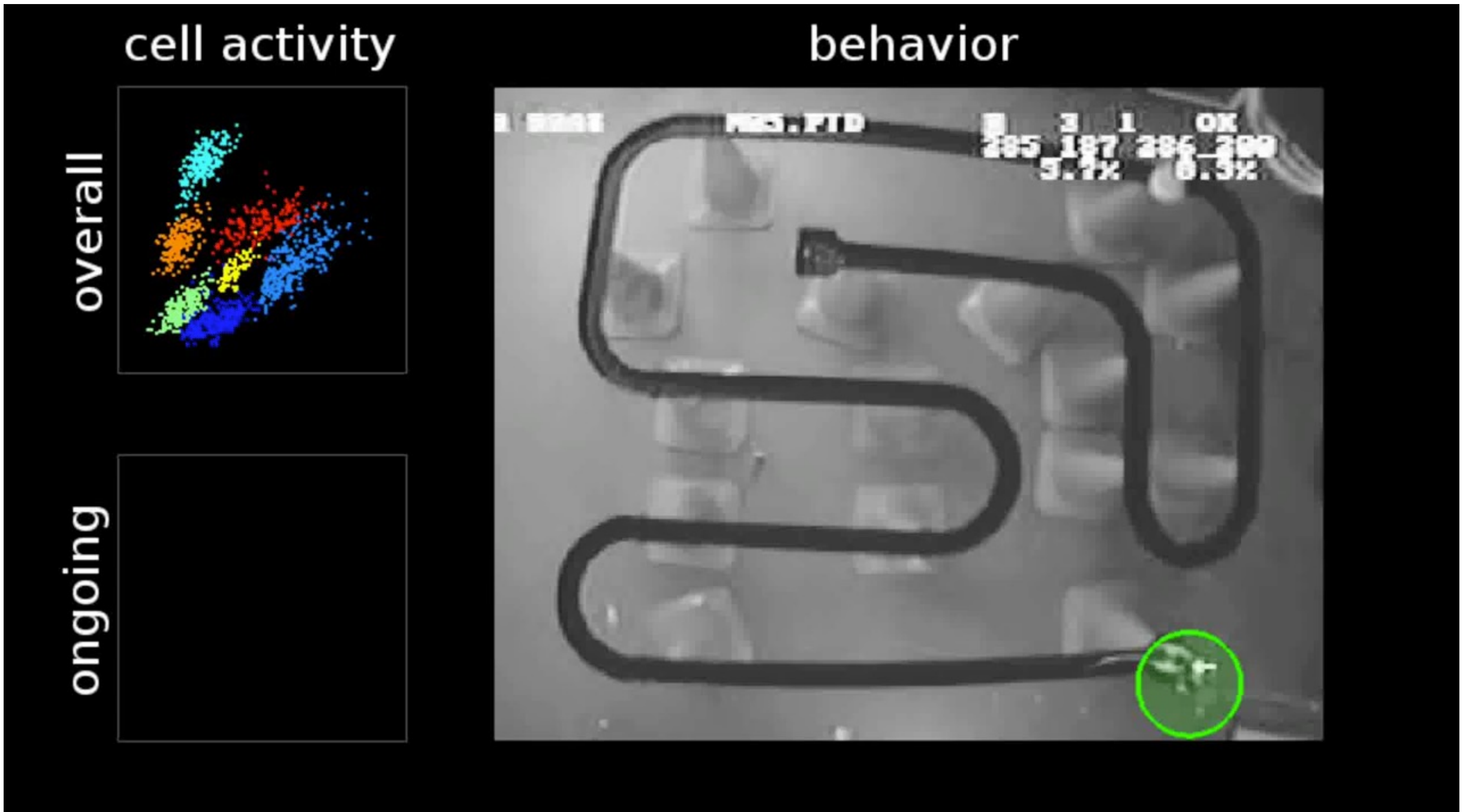
Hippocampus


Spatial Learning



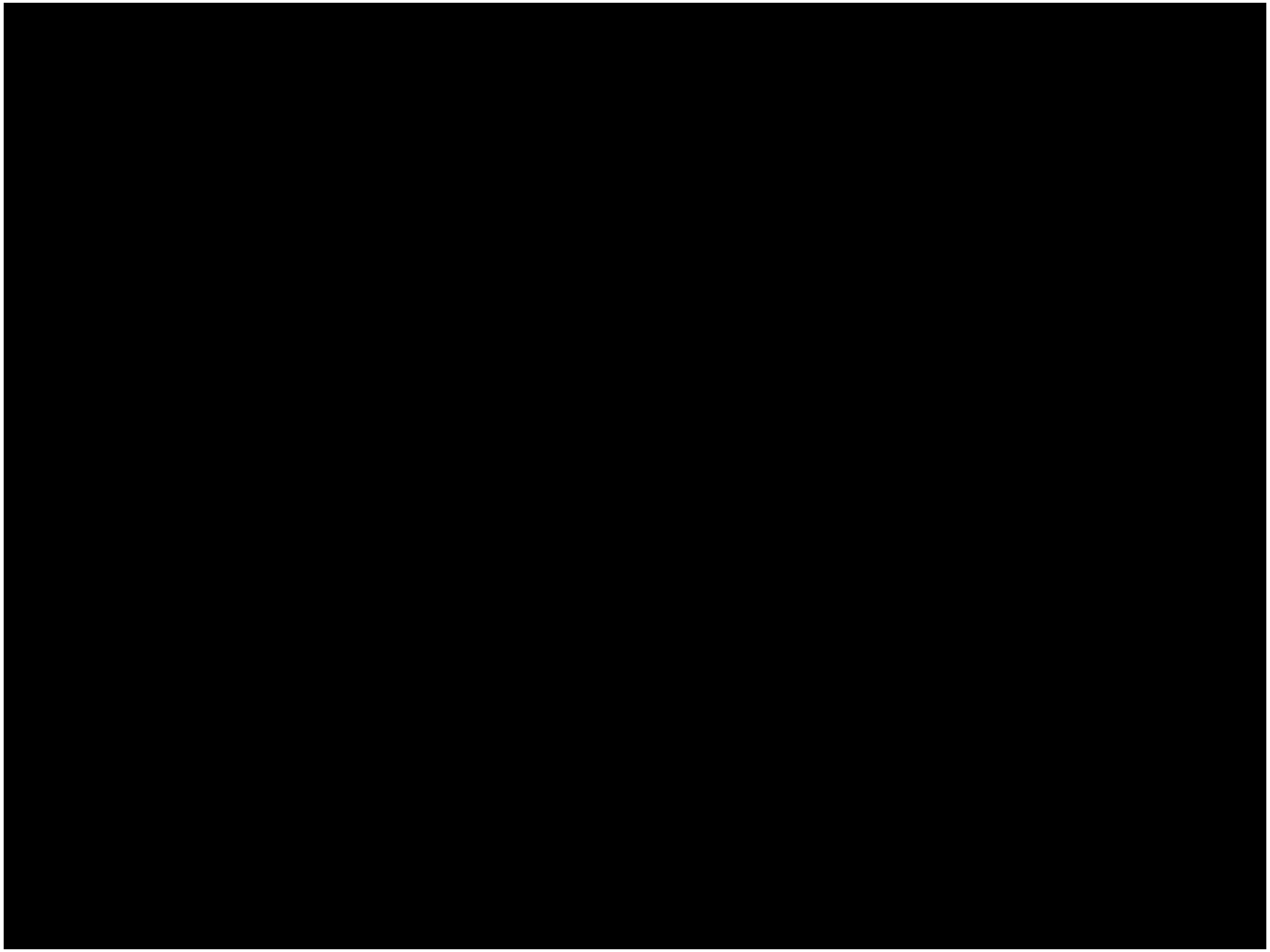
Spatial Learning

Place cells, cognitive map & experience replay



http://web.mit.edu/wilsonlab/

Spatial Learning



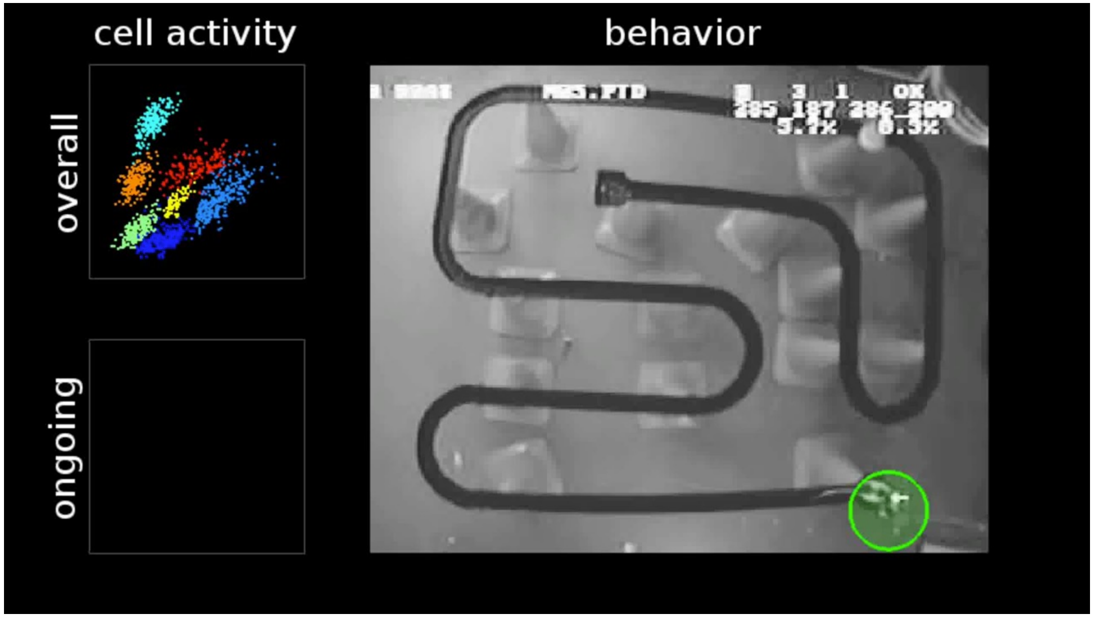
Live brain decoding!

Spatial Learning

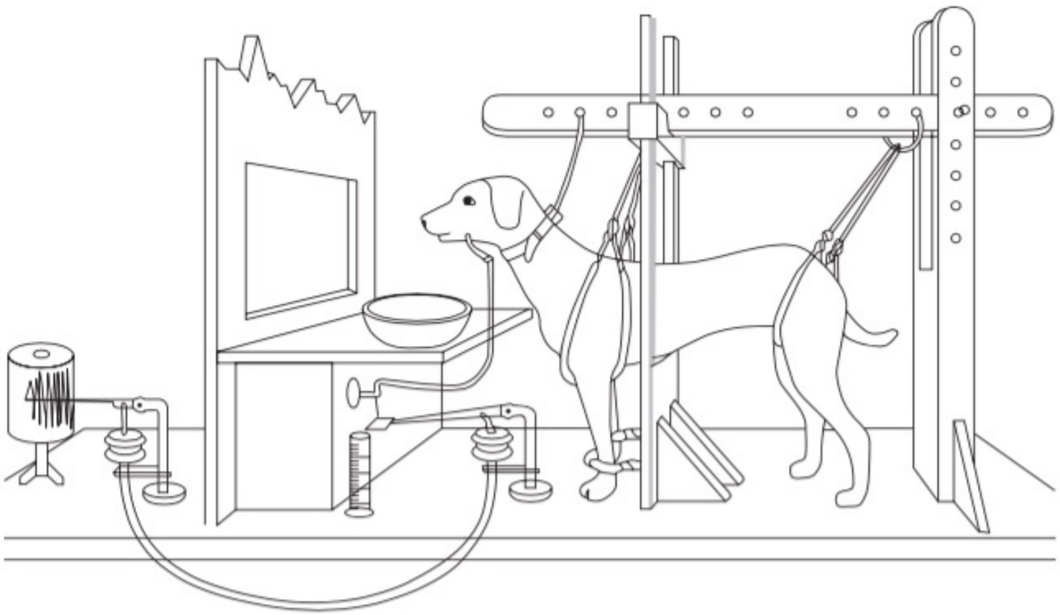
Note, replay of maze also happens during sleep at accelerated pace

Spatial Learning

Cognitive maps – used to <u>predict</u> states of the world

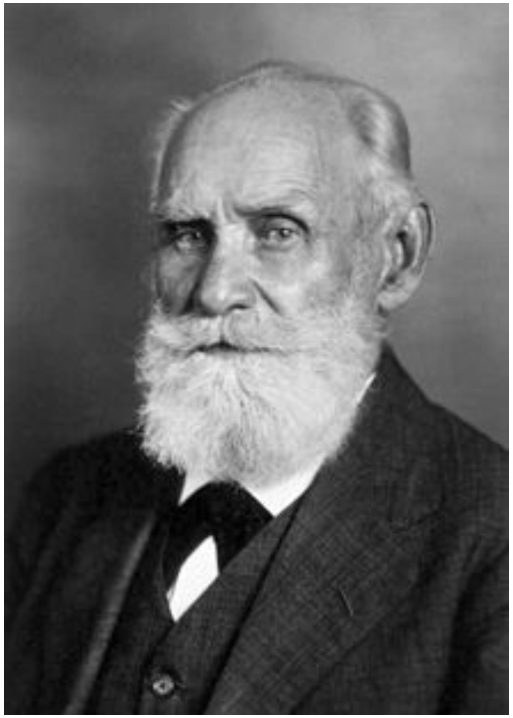


Cognitive Modeling



Classical Conditioning

Pavlov – conditioning



Ivan Pavlov
(1849 –1936)

http://clipsforclass.com/

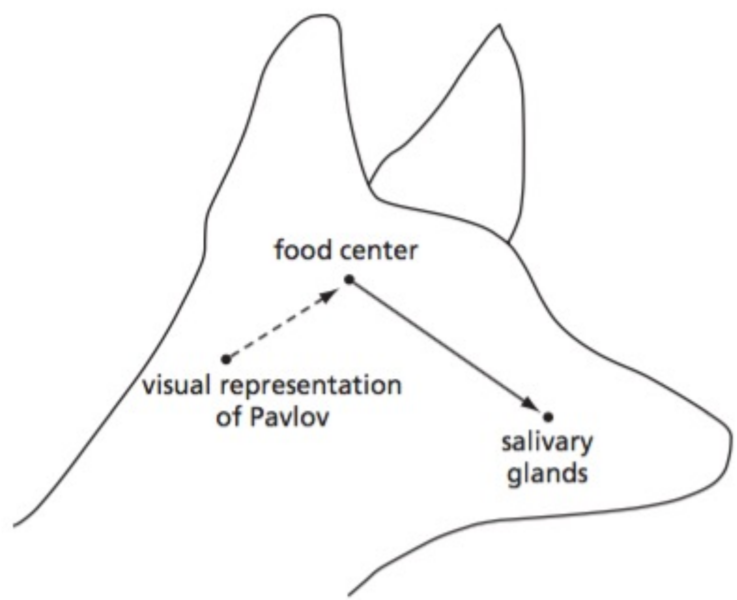
Classical Conditioning

Pavlov believed, <u>all education and training</u>:

"*are really nothing more than the results of an establishment of new nervous connections*"

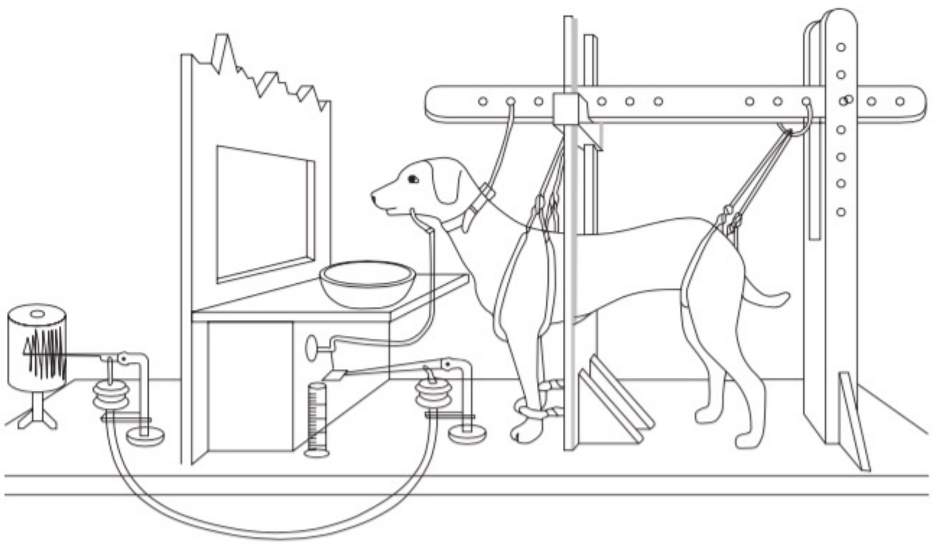
(Pavlov, 1927, p. 26),

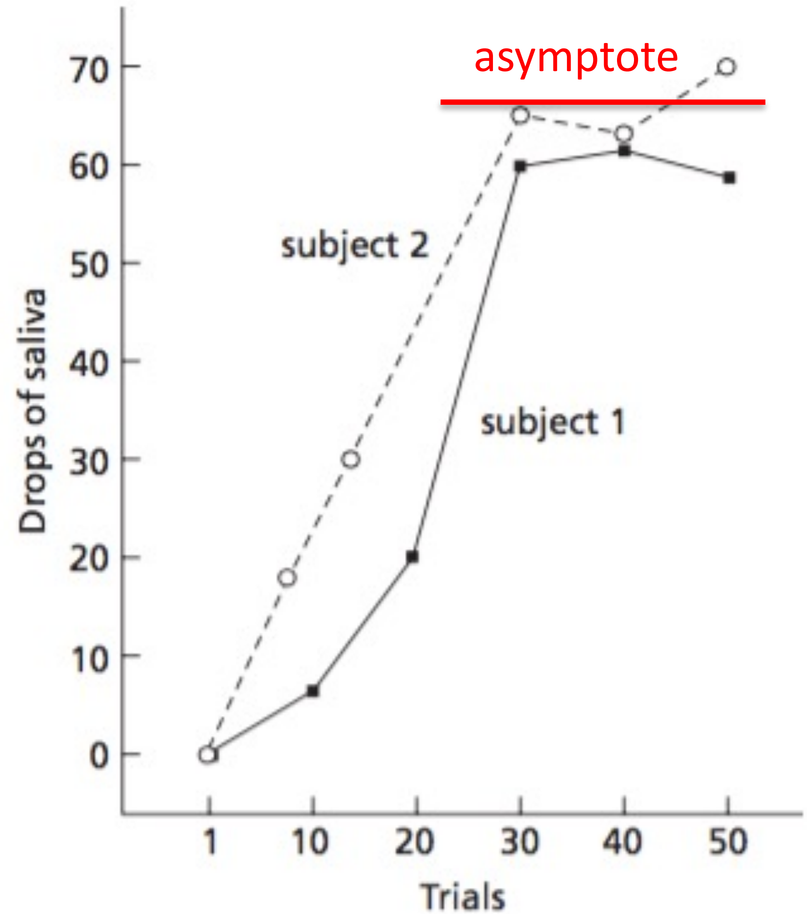
Thus studying how dogs learn to salivate might lead to an understanding of the neural mechanisms underlying all learning.



Classical Conditioning

Highly controlled experiments





Classical Conditioning

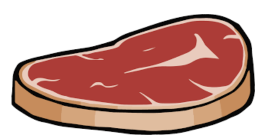
Terminology

Unconditioned response (UR)
A response for which no training was necessary to establish it

unconditioned stimulus (US)
A stimulus that elicits a response without training.

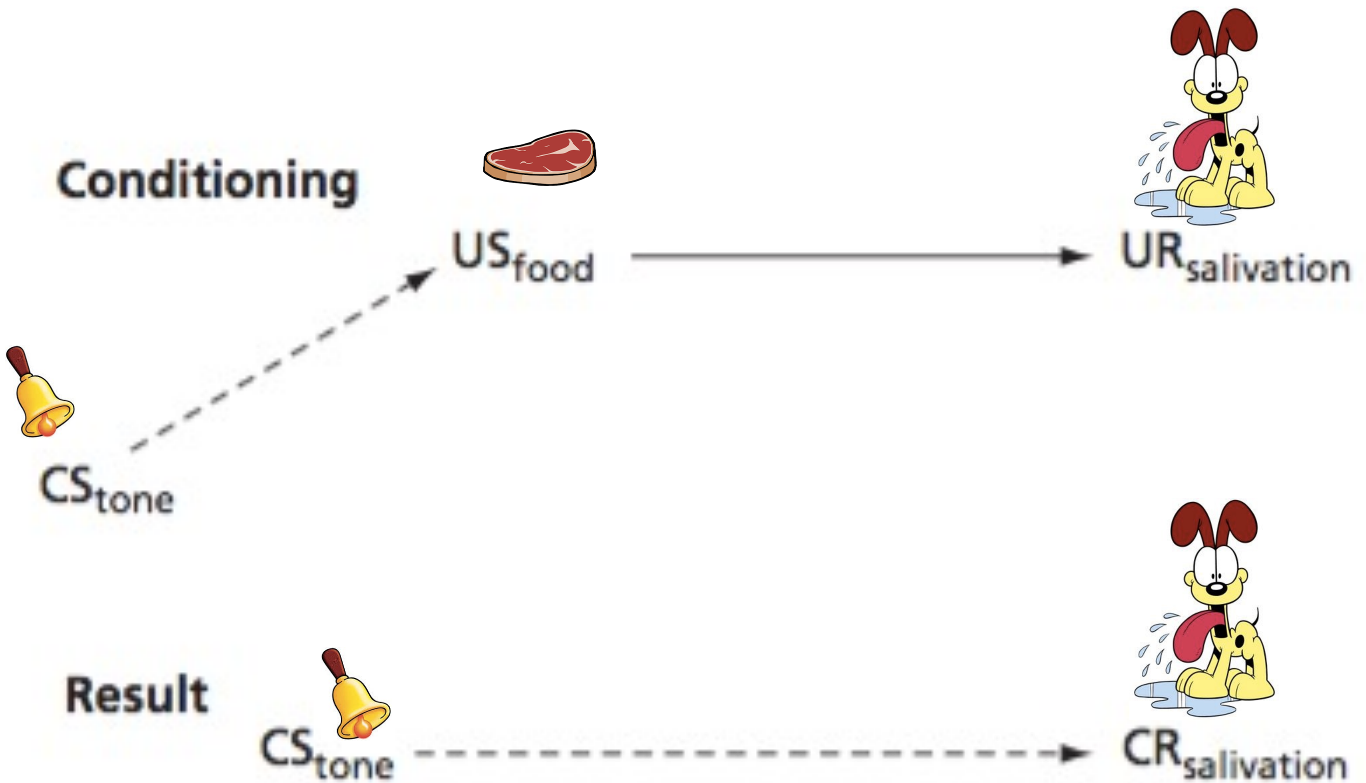
Conditioned response (CR)
A response whose occurrence depended on particular conditions of training.

Conditioned stimulus (CS)
A stimulus that, through training, elicits a response.



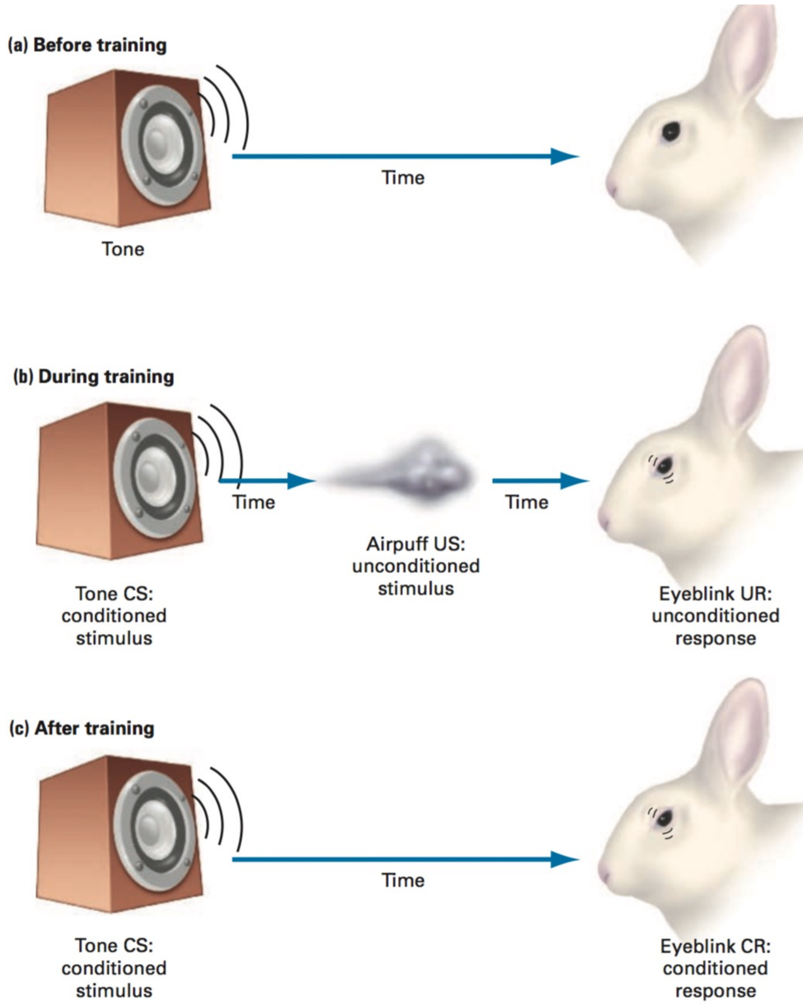
Classical Conditioning

Schematics

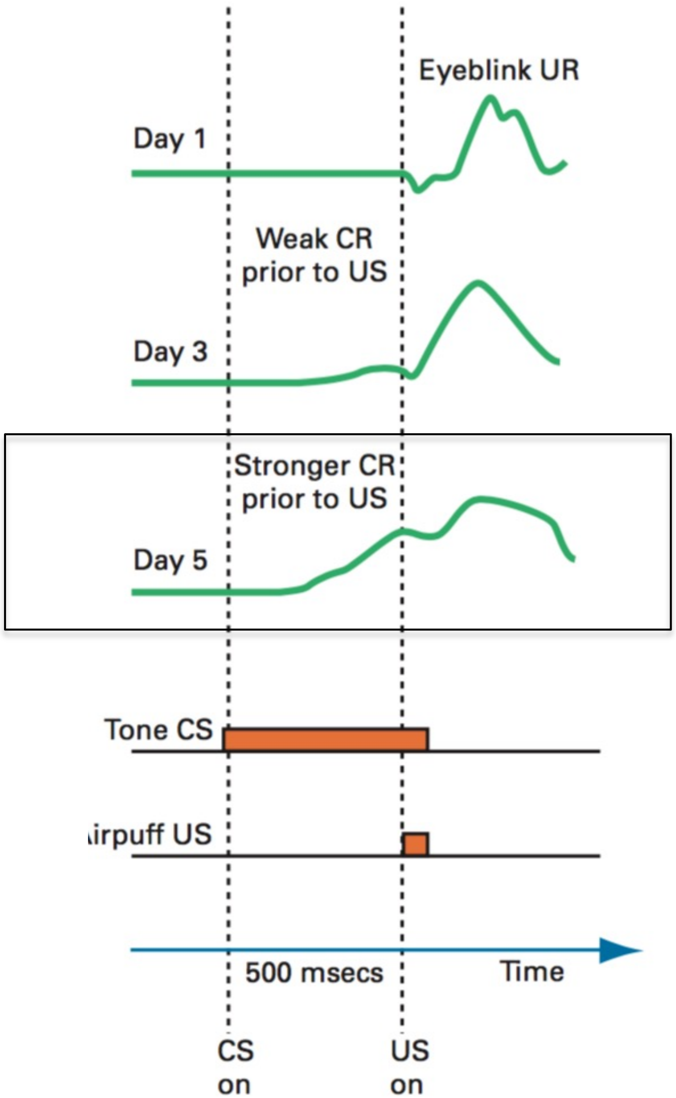


Classical Conditioning

Appetitive & Aversive conditioning

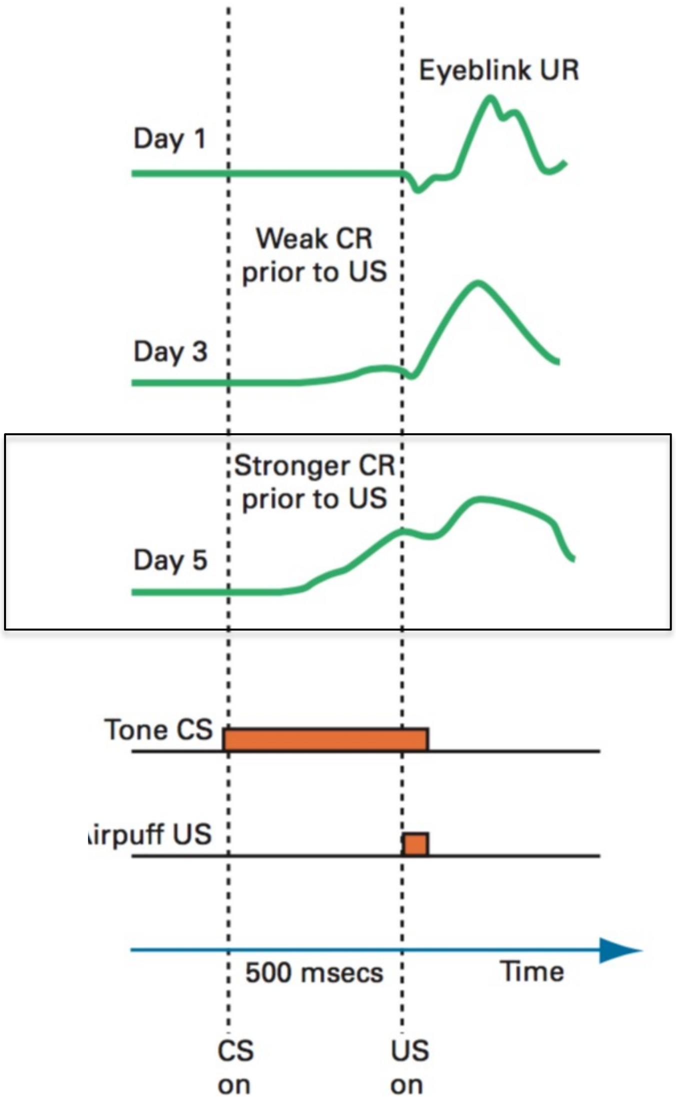


Classical Conditioning

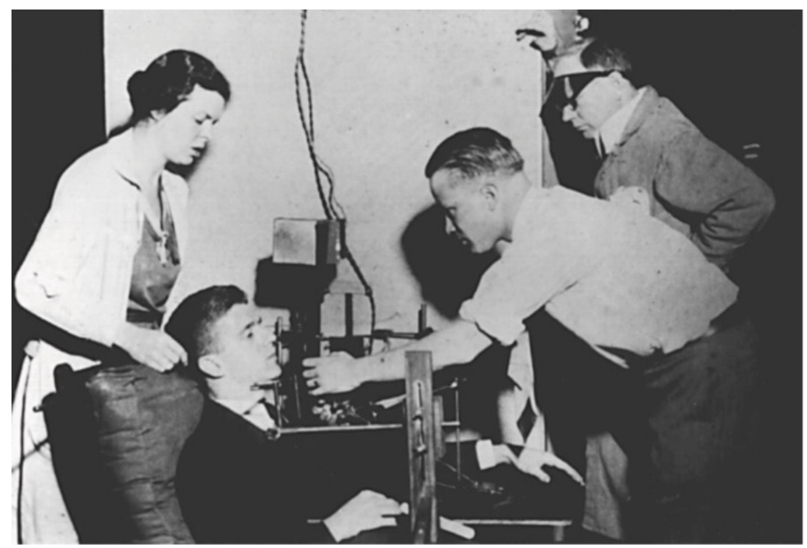


Just like salivating, closing the eyes is a <u>preparatory</u> response

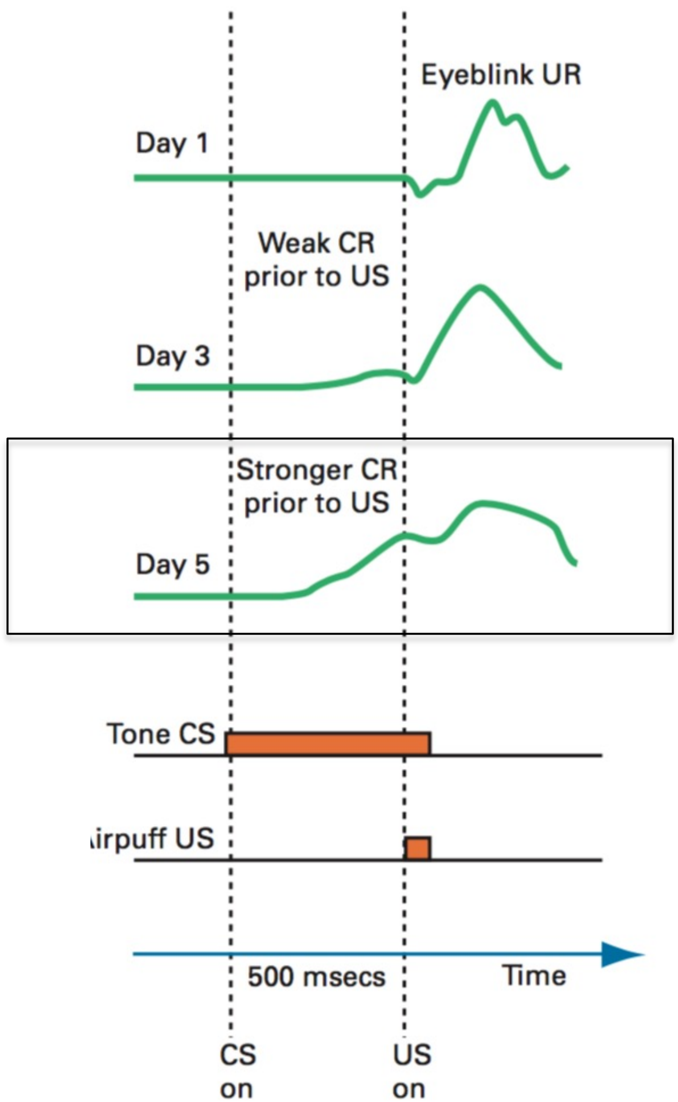
Classical Conditioning



Just like salivating, closing the eyes is a preparatory response



Classical Conditioning

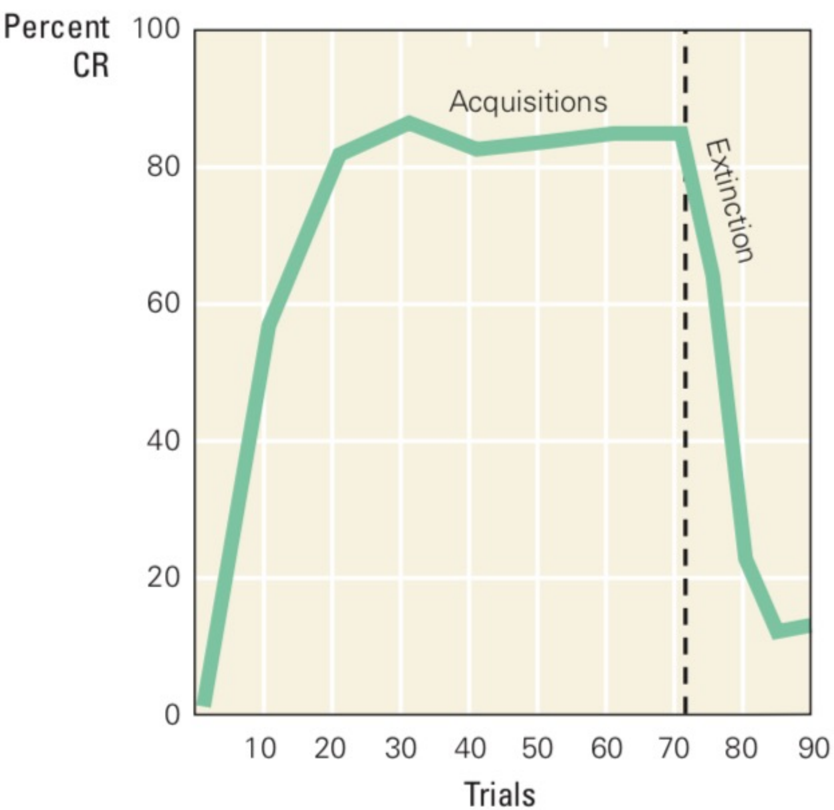


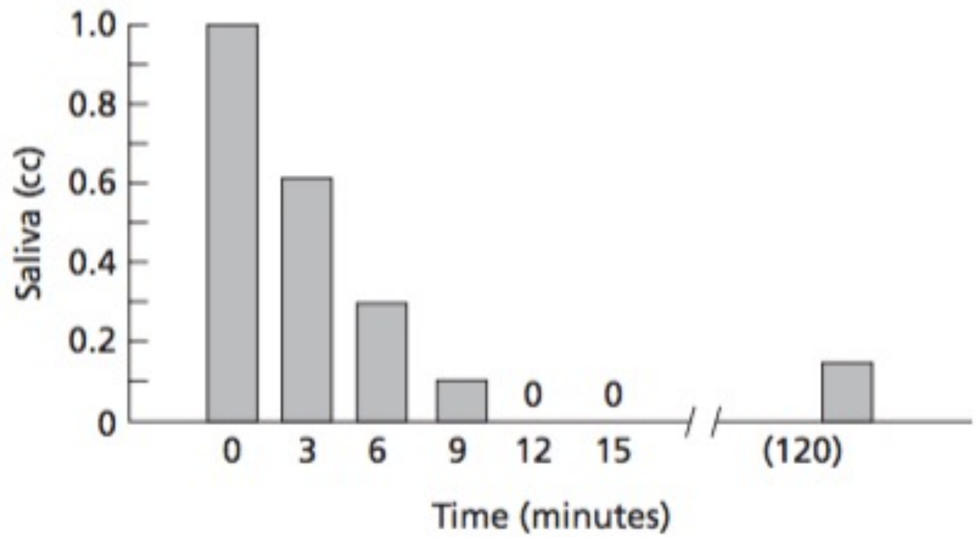
Conditioning is about <u>predicting.</u>

Learning about the <u>structure of the world</u> and **responding** to expected effects.

Classical Conditioning

Extinction & spontaneous recovery

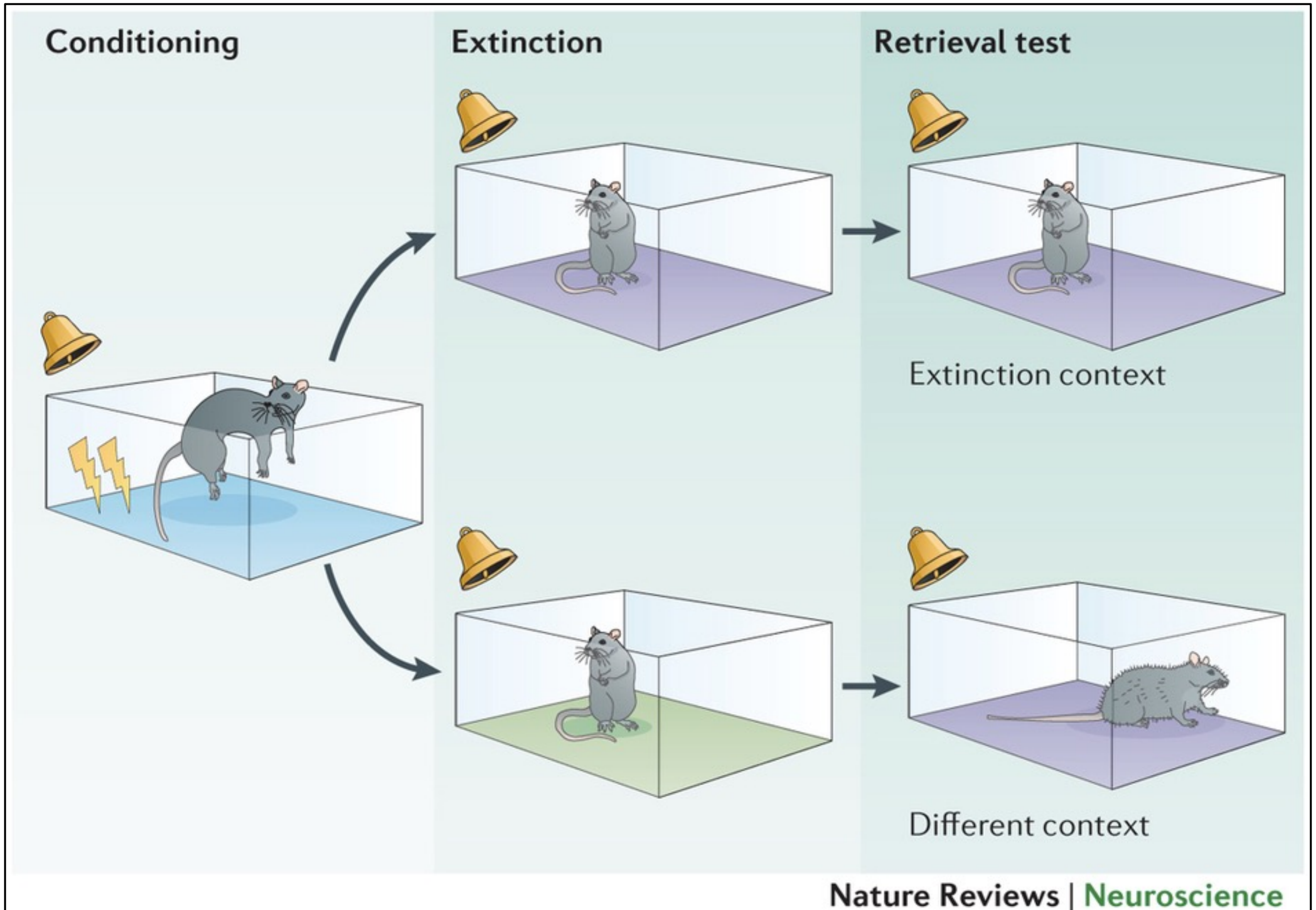




Why is extinction not same as forgetting ?

Classical Conditioning

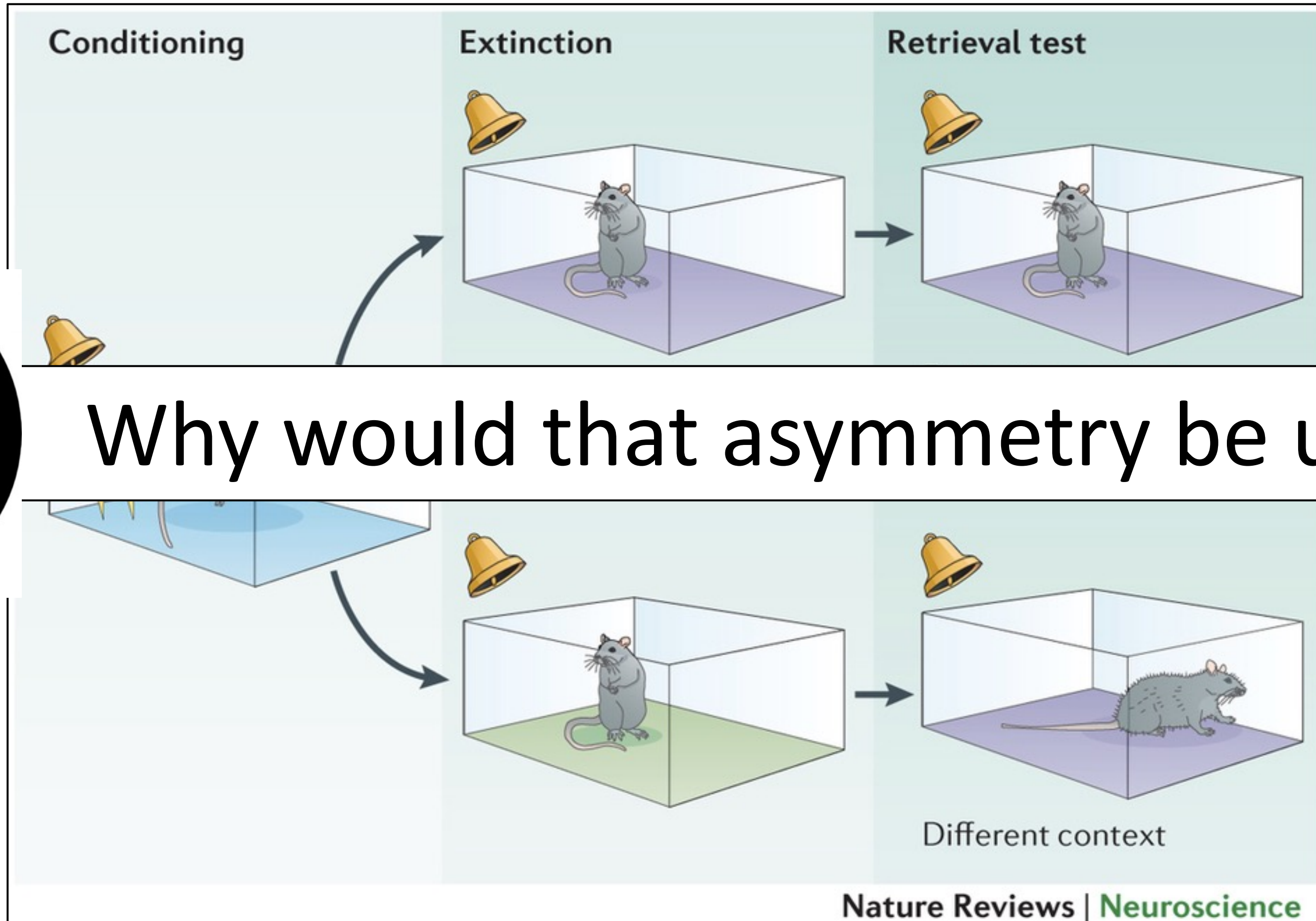
Context sensitivity



Conditioning leads to general effect, extinction to context specific changes

Classical Conditioning

Context sensitivity

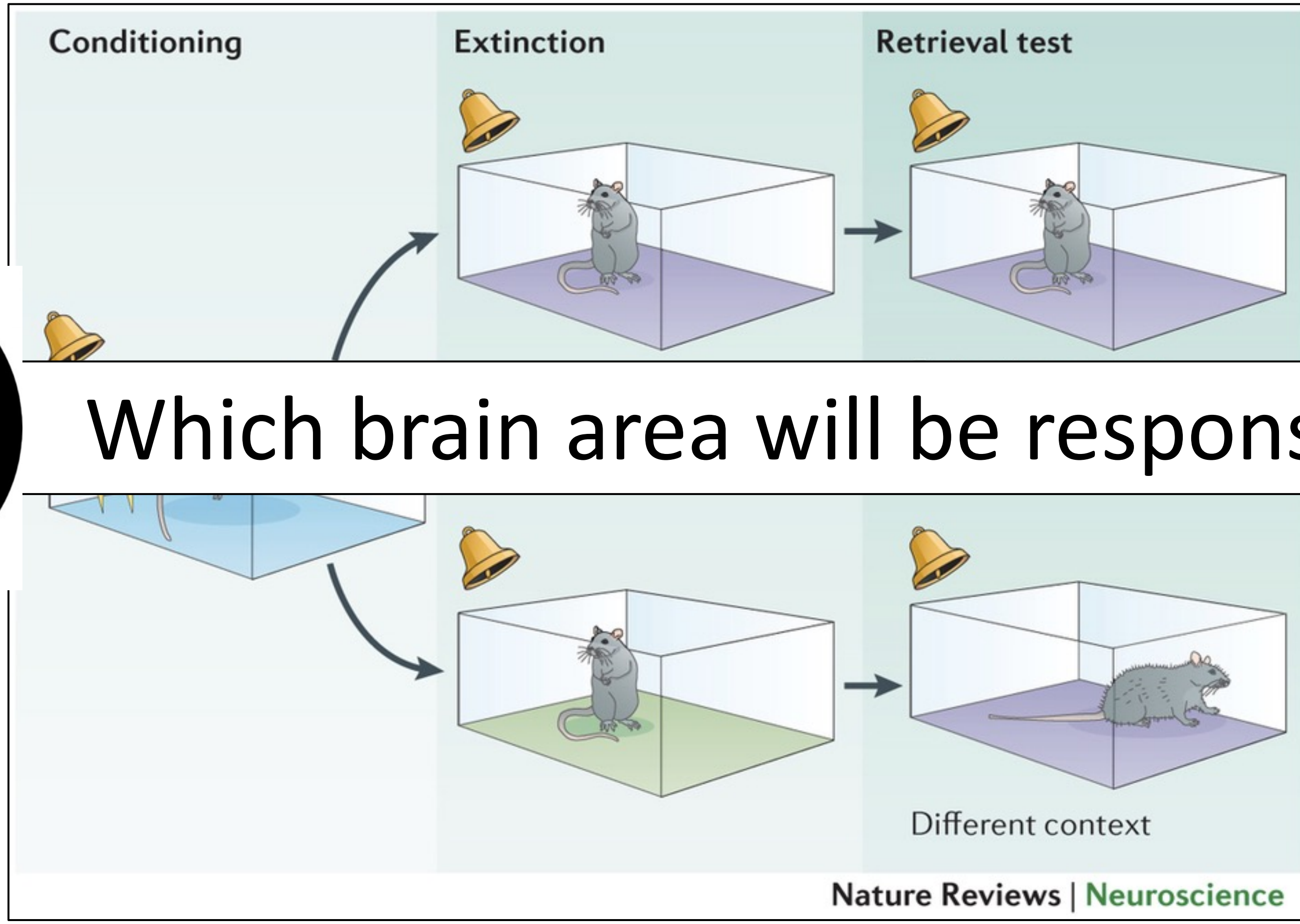


Why would that asymmetry be useful

Conditioning leads to general effect, extinction to context specific changes

Classical Conditioning

Context sensitivity

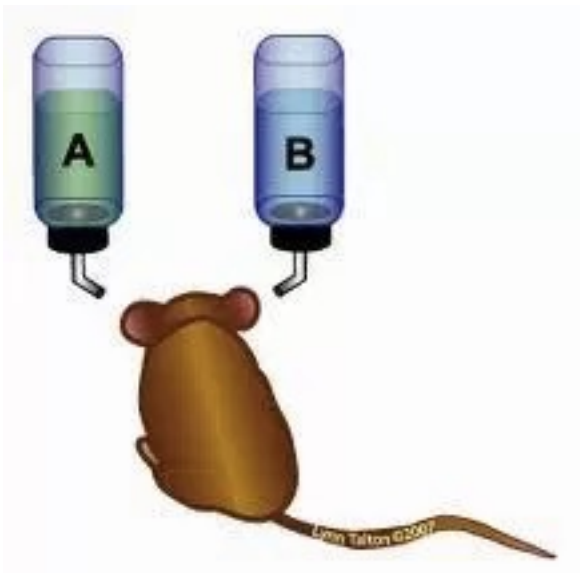


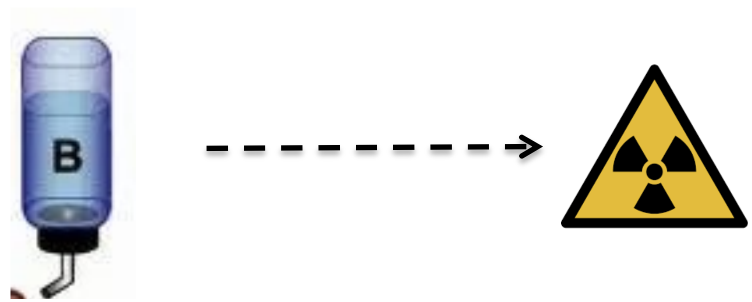
Which brain area will be responsible

Conditioning leads to general effect, extinction to context specific changes

Principles of conditioning

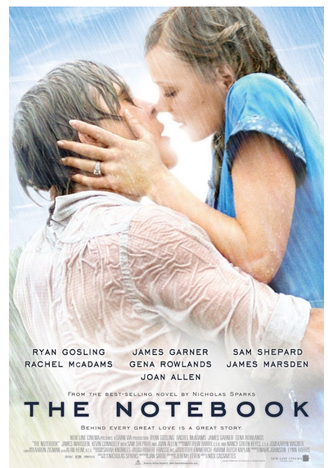
Taste aversion learning





* Note that the illness can come much later in time

Principles of conditioning



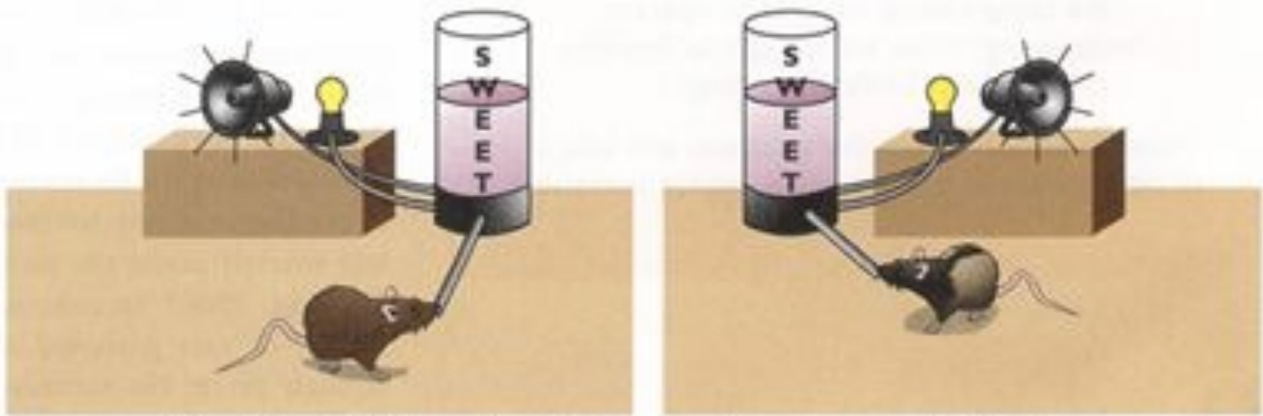
Credit Assignment Problem!

Principles of conditioning

Credit Assignment Problem!

Principles of conditioning

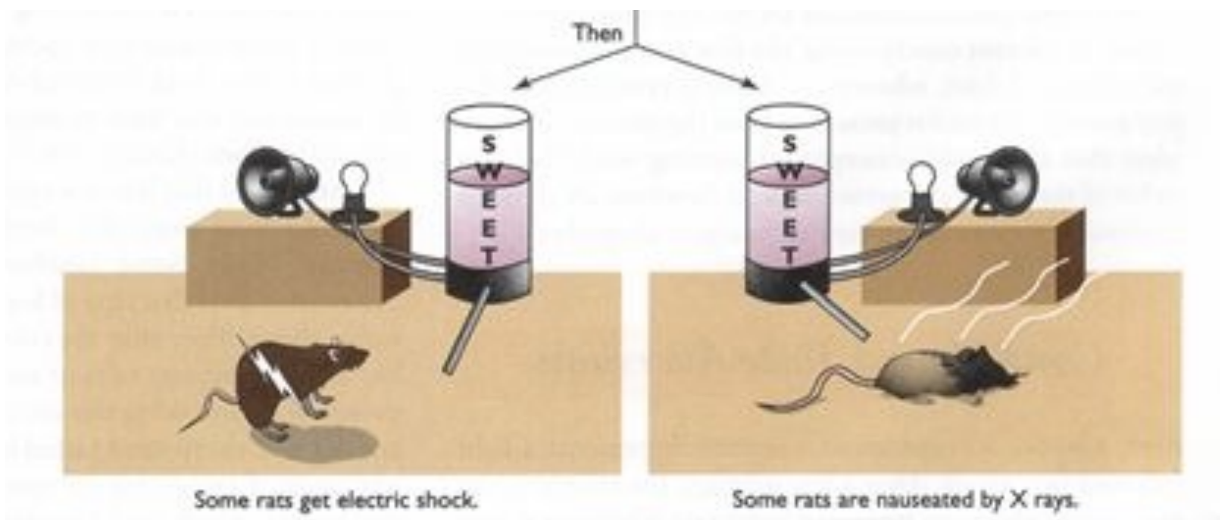
preparedness



Rats drink saccharin-flavored water. Whenever they make contact with the tube, they turn on a bright light and a noisy buzzer.

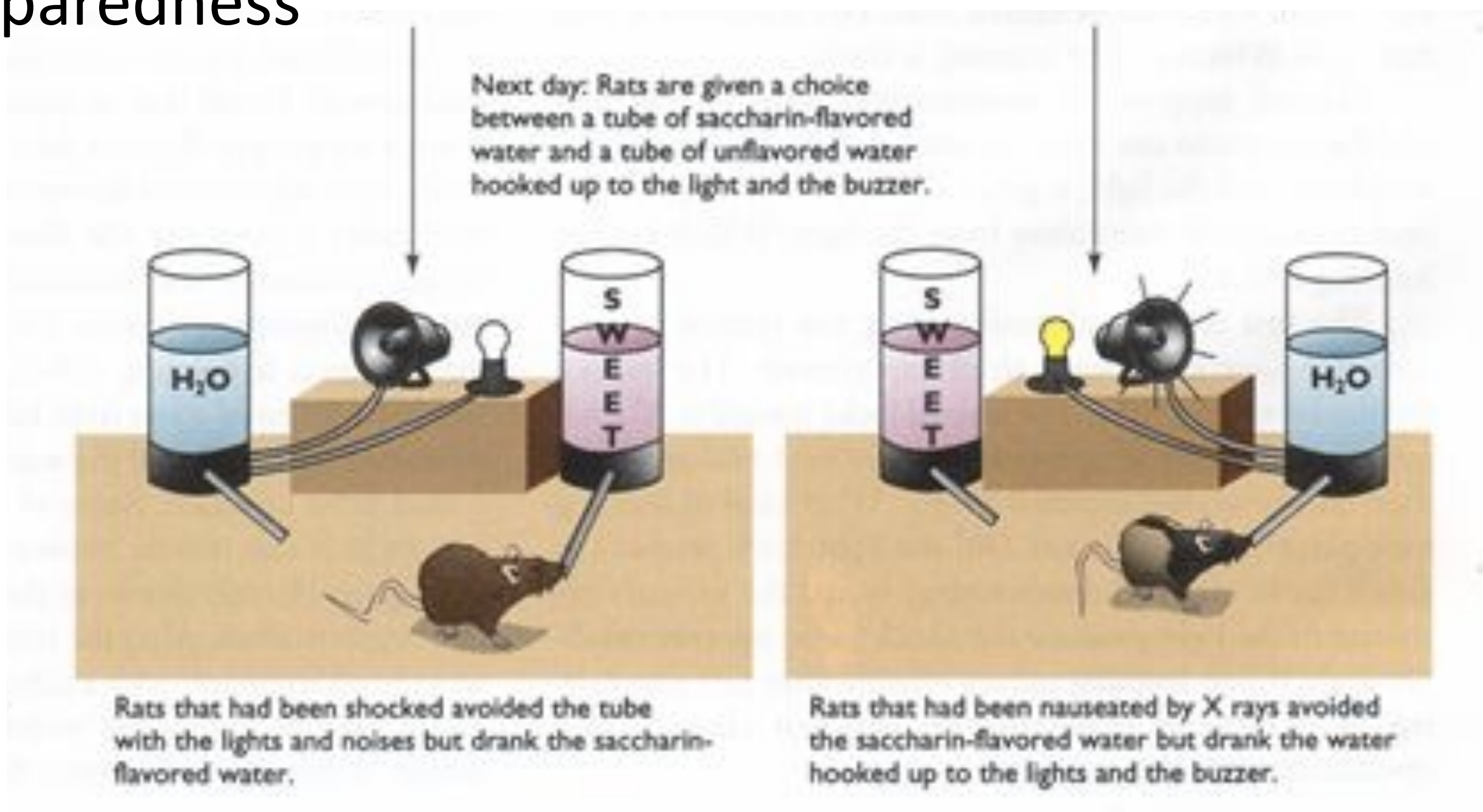
Principles of conditioning

preparedness



Principles of conditioning

preparedness

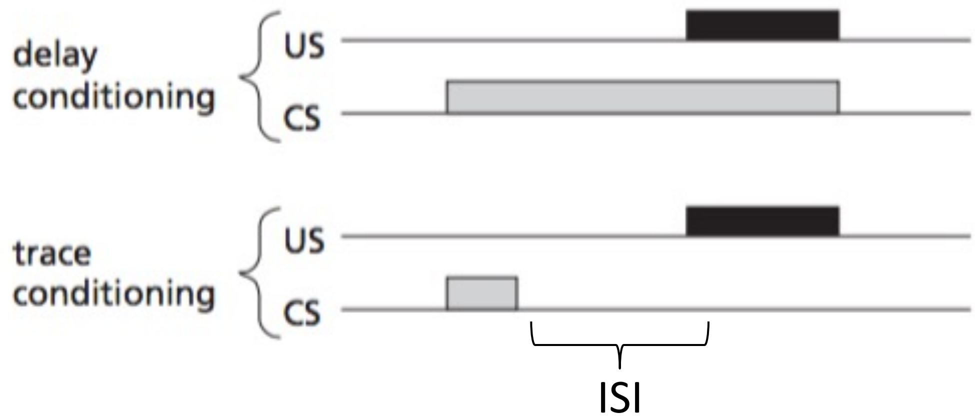


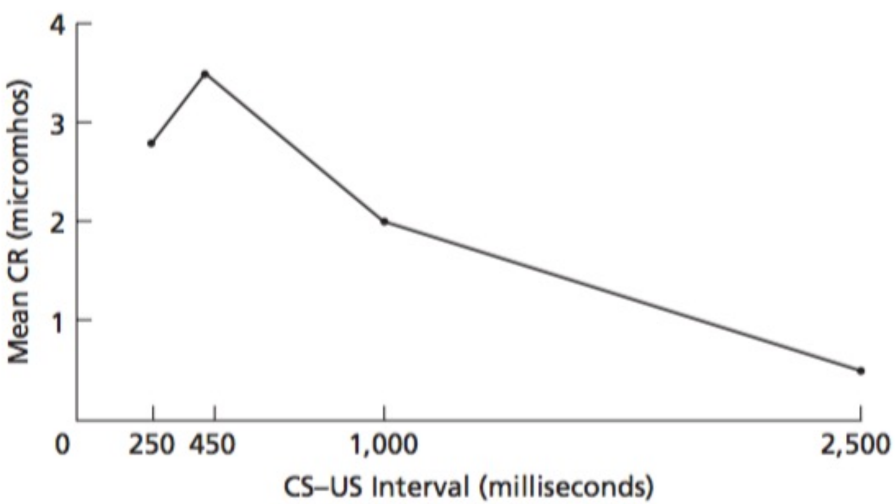
Suggests animal has *priors* on how the world works

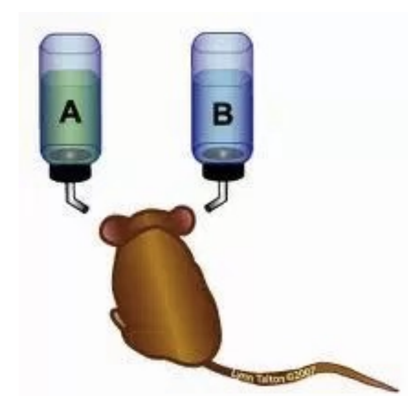
Principles of conditioning

Principles of conditioning

Contiguity







Principles of conditioning

Principles of conditioning

Contingency; contiguity is not enough!

1966

Predictability and number of pairings in Pavlovian fear conditioning[1]

ROBERT A. RESCORLA[2]
UNIVERSITY OF PENNSYLVANIA

Three groups of dogs were Sidman avoidance trained. They then received different kinds of Pavlovian fear conditioning. For one group CSs and USs occurred randomly and independently; for a second group, CSs predicted the occurrence of USs; for a third group, CSs predicted the absence of the USs. The CSs were subsequently presented while S performed the avoidance response. CSs which had predicted the occurrence or the absence of USs produced, respectively, increases and decreases in avoidance rate. For the group with random CSs and USs in conditioning, the CS had no effect upon avoidance.

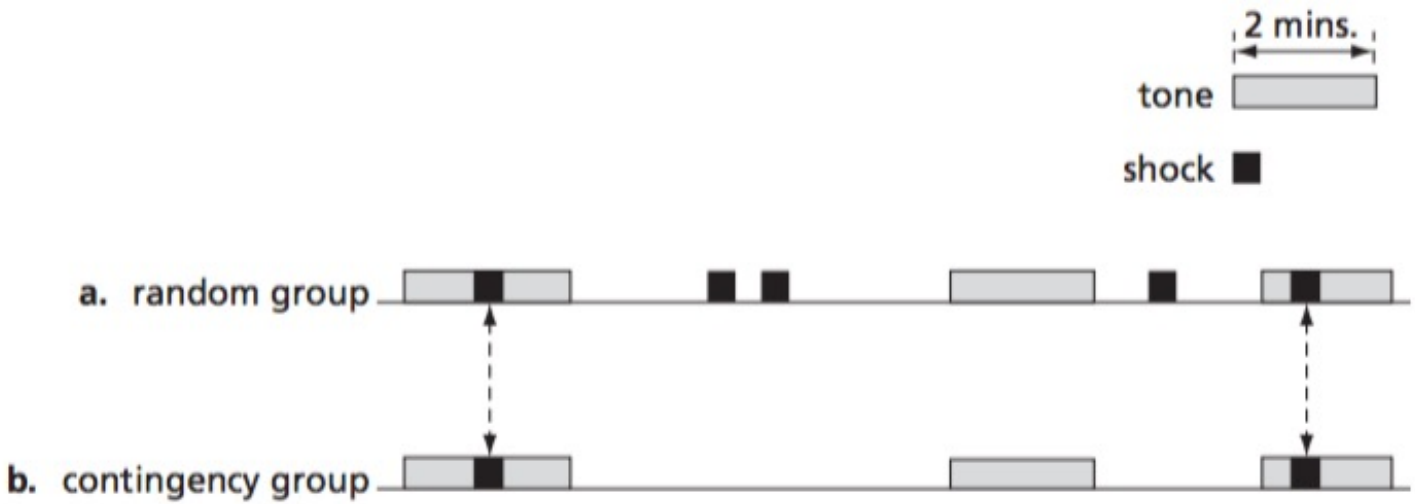
experiment. The apparatus was a two-compartment dog shuttlebox described in detail by Solomon & Wynne (1953). The two compartments were separated by a barrier of adjustable height and by a drop gate which, when lowered, prevented S from crossing from one compartment into the other. The floor was composed of stainless steel grids which could be electrified through a scrambler. Speakers, mounted above the hardware-cloth ceiling, provided a continuous white noise background and permitted the presentation of tonal stimuli.

The training procedure was similar to that described

Principles of conditioning

Principles of conditioning

Contingency; contiguity is not enough

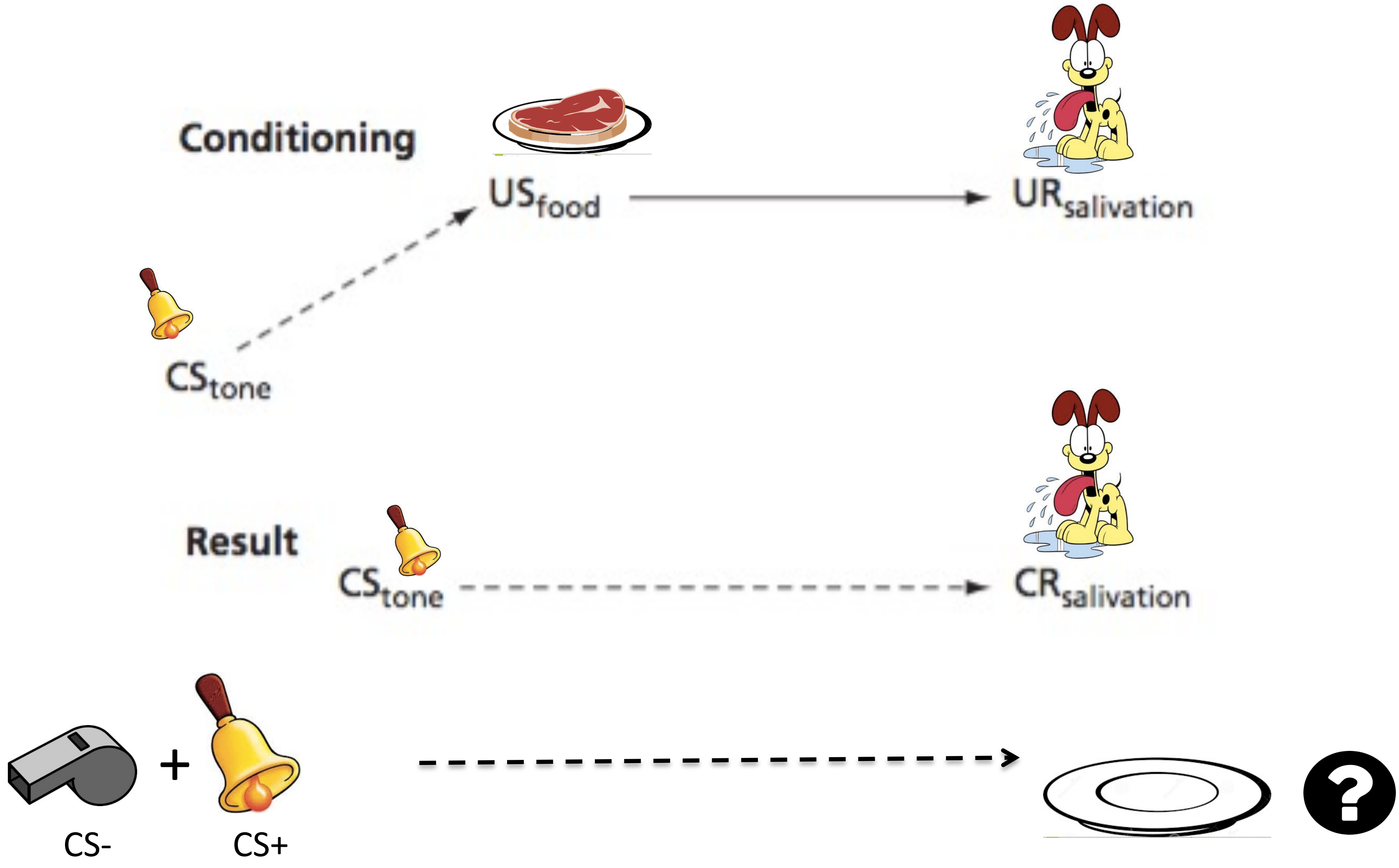


$$\text{contingency} = p(\text{US} \mid \text{CS}) - p(\text{US} \mid \text{no CS})$$

A) = .66 - .60 = .06
B) = .66 – 0 = .66

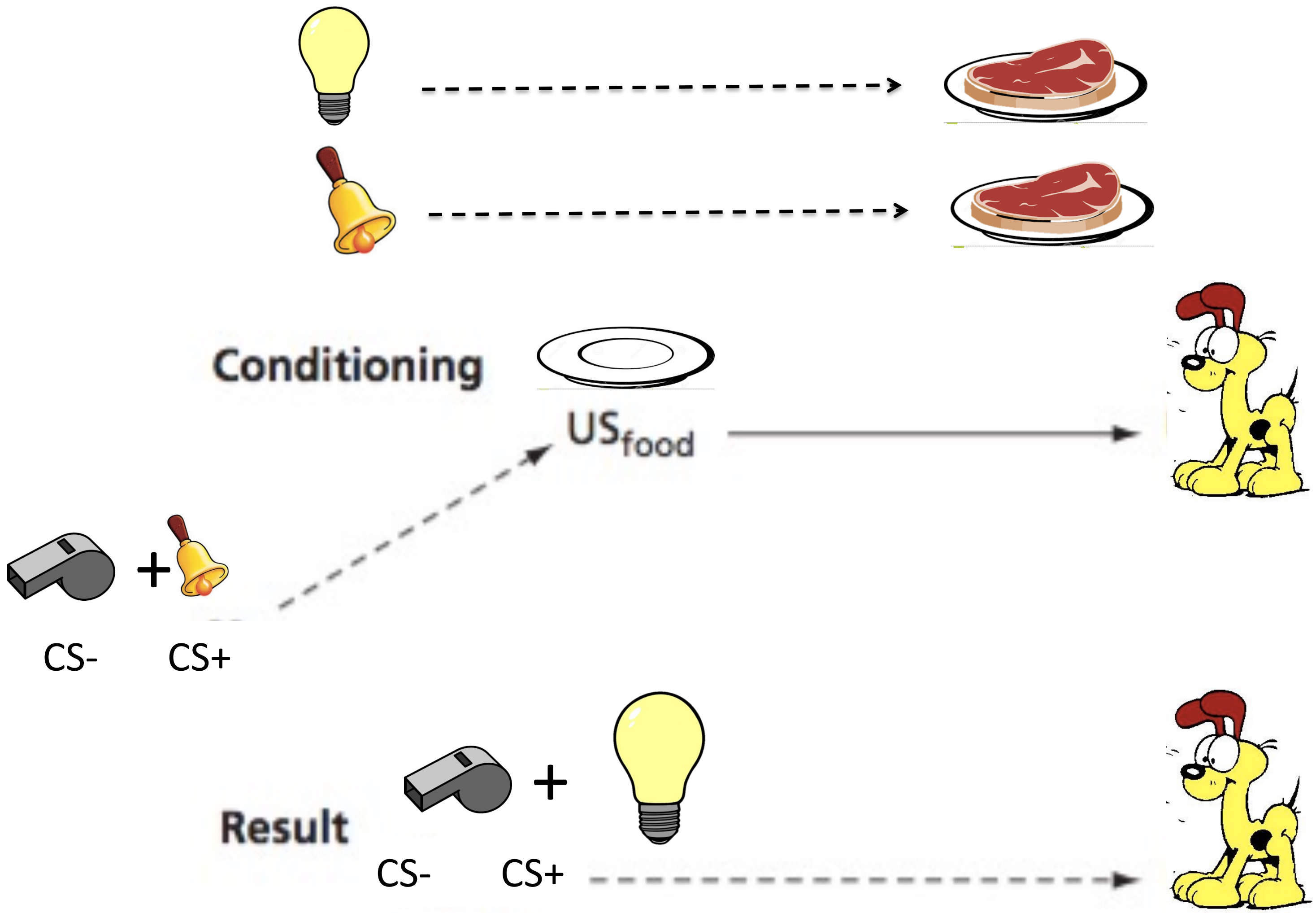
Classical Conditioning

Conditioned Inhibition



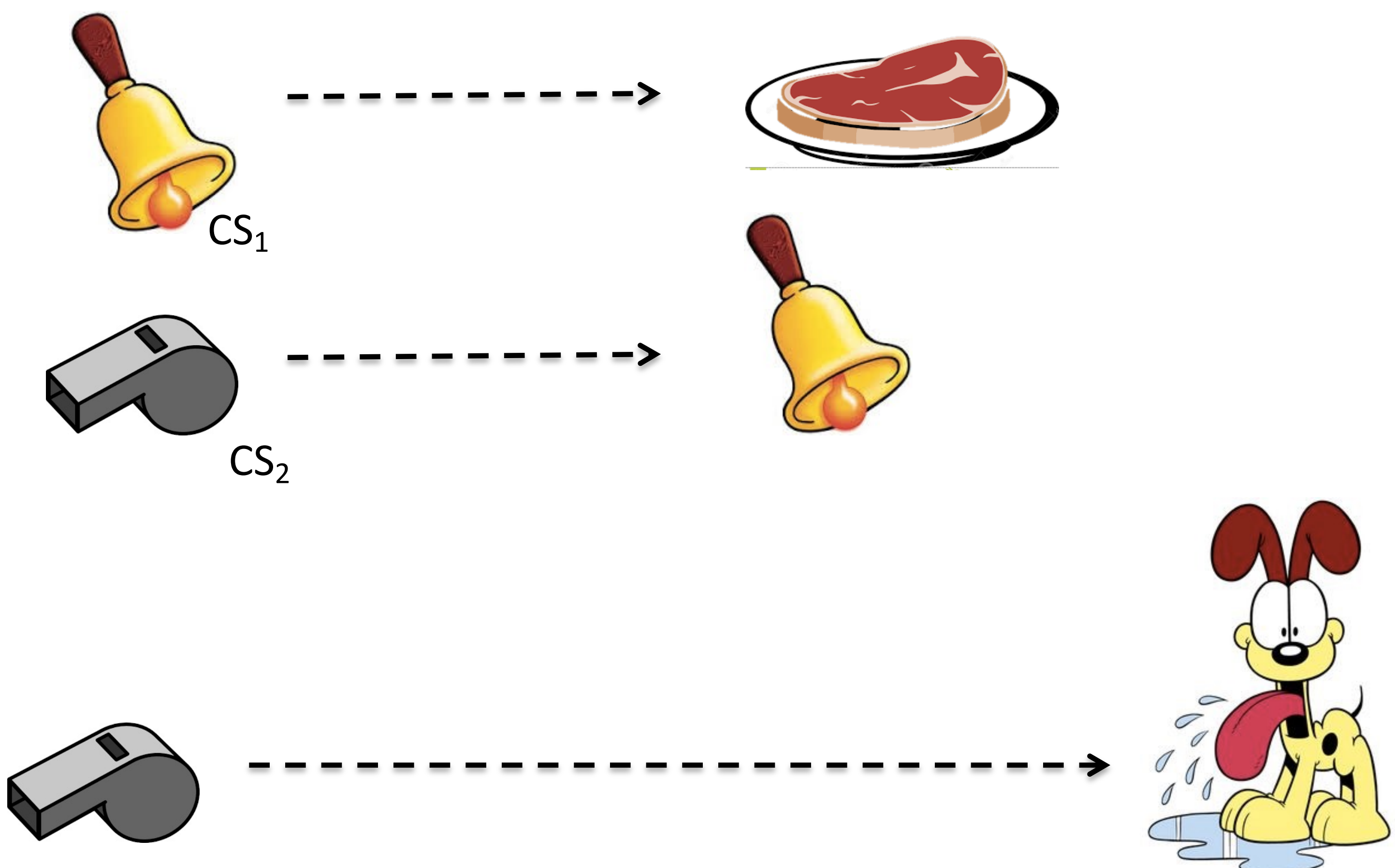
Classical Conditioning

Conditioned Inhibition



Classical Conditioning

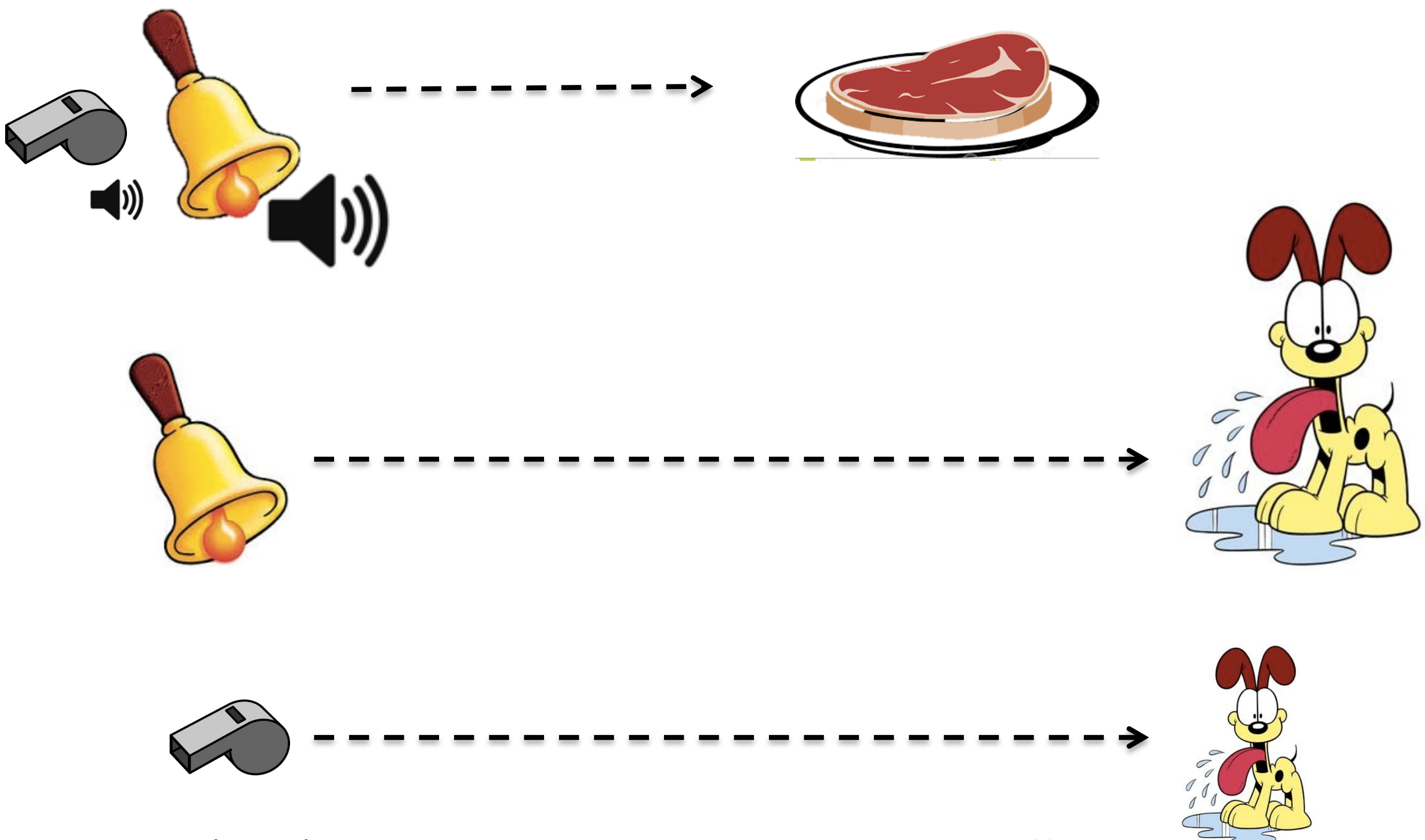
Second order conditioning



The CR shift to the new CS_2+ that predicts the old CS_1+

Classical Conditioning

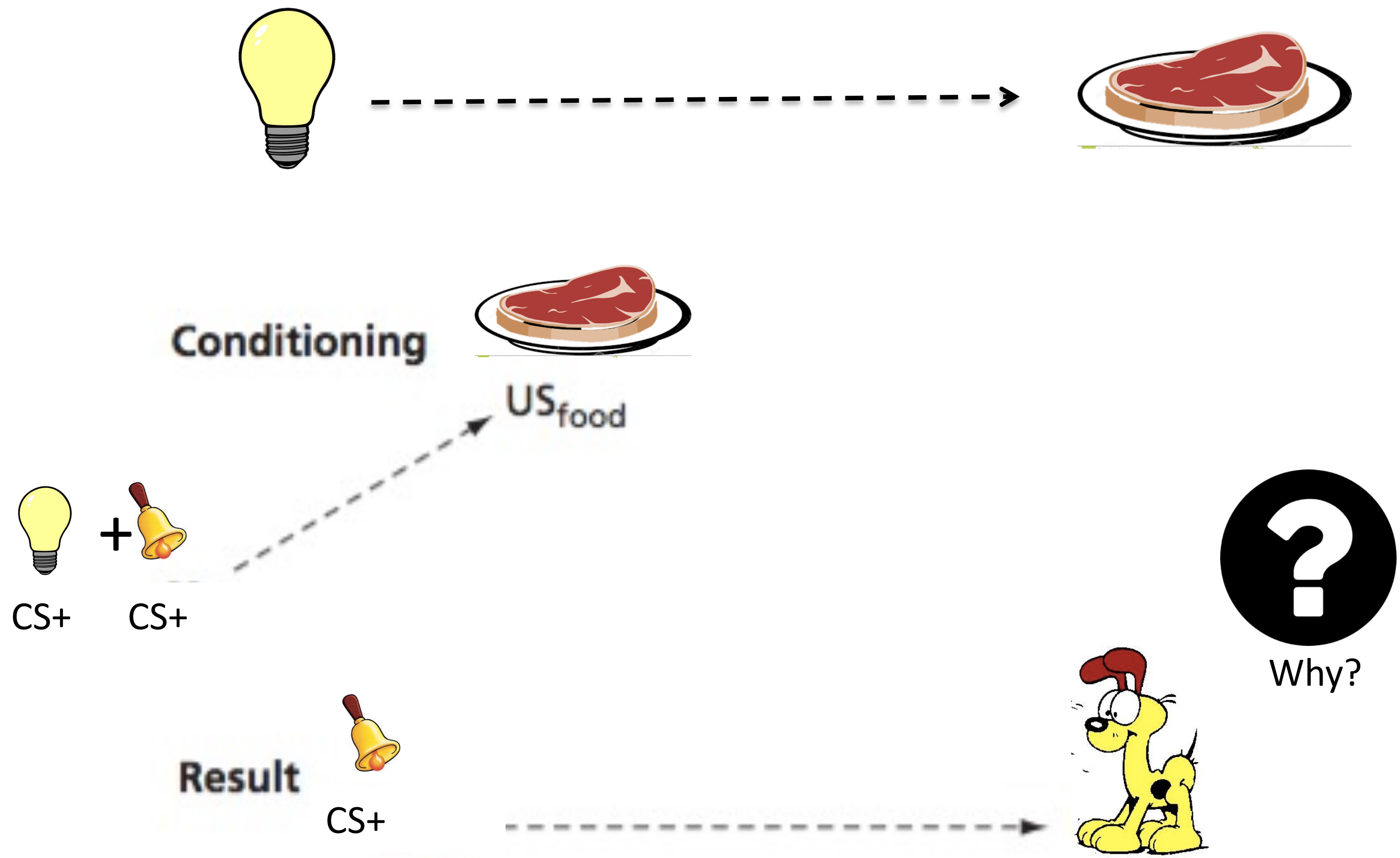
Compound conditioning + overshadowing



The more salient (loud) stimulus leads to a bigger behavioral effect

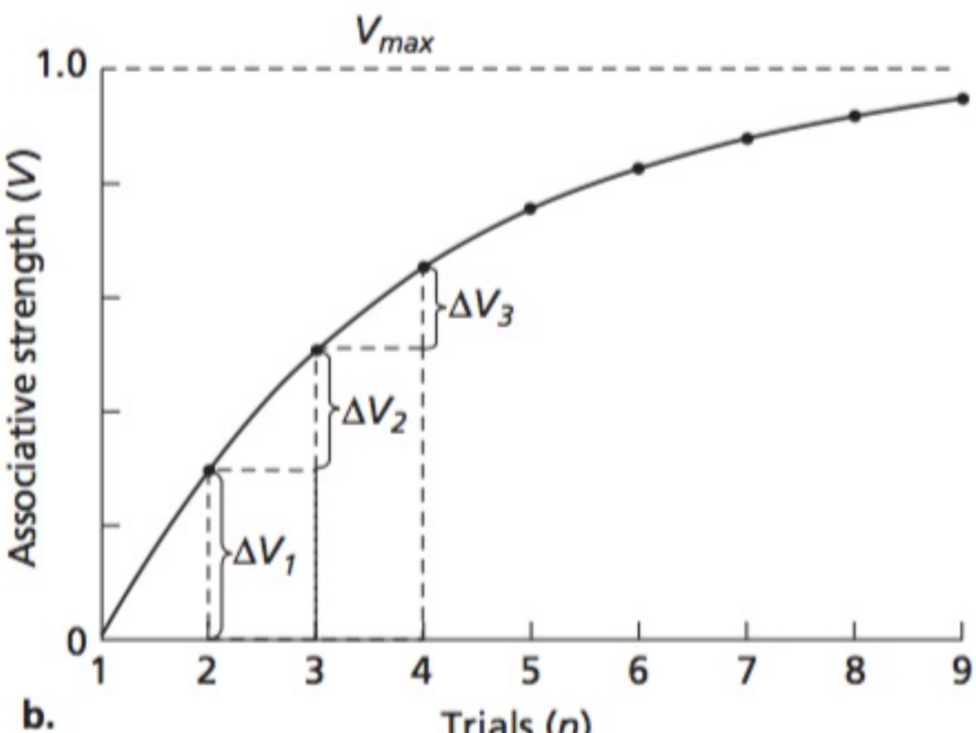
Classical Conditioning

Blocking



Rescorla Wagner

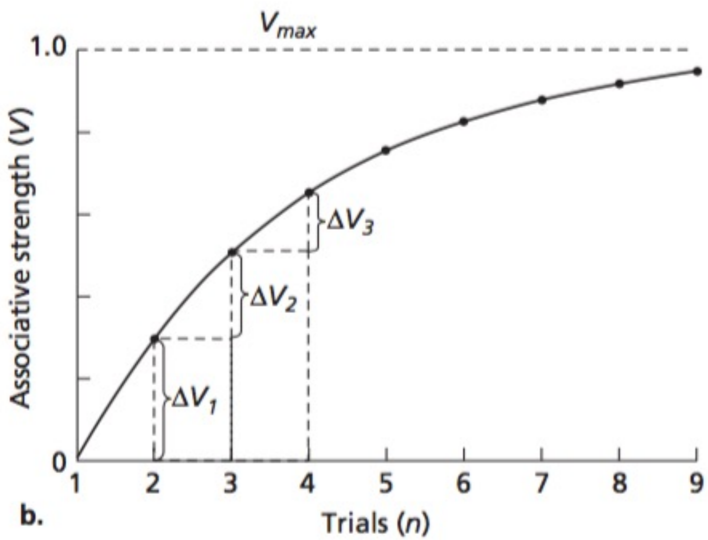
Rescorla Wagner



Surprise =
Prediction error

Larger surprise =
more learning

Rescorla Wagner



$$V_{t+1}=V_t+\Delta V_t$$
$$\Delta V_t = \alpha(V_{max} - V_t)$$

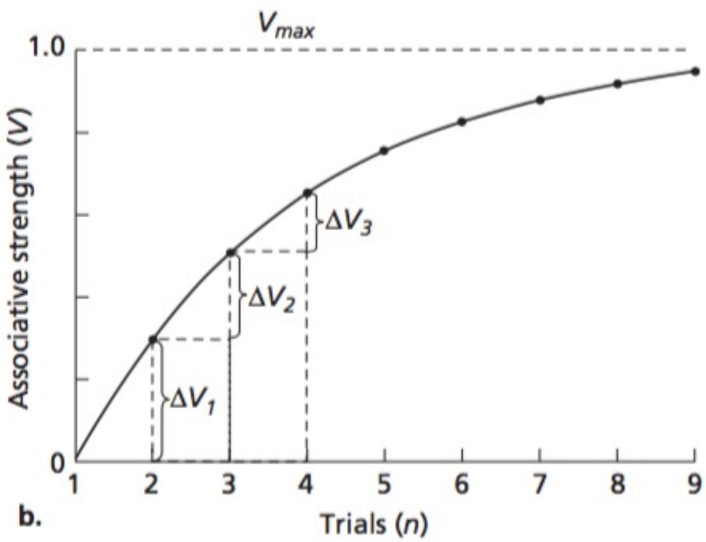
Assumption 1: conditioning on any trial would depend on the difference between the associative strength at the beginning of that trial and the maximum possible strength.

$\mathbf{V_{max}}$ represents the maximum associative value that can be conditioned to the **CS** under the conditions of the experiment (e.g., influenced by time lag).

Note that ($\mathbf{V_{max}}$- **V**) is function of expectation and hence **surprise**

When there is no association (V=0) the surprise is maximal.

Rescorla Wagner



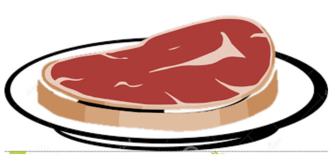
Assumption 2: Learning rates are not always similar, hence parameters to capture between context learning speeds:

α represents the relative salience of the CS/US

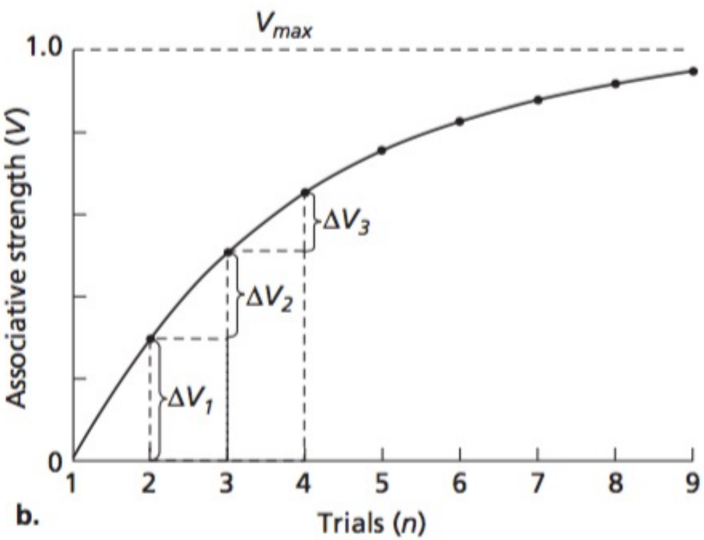
This parameter is restricted to values between 0 and 1

$$\Delta V = \alpha(V_{max} - V)$$

α

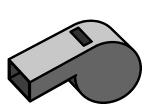


Rescorla Wagner



$$\Delta V = \alpha(V_{max} - V)$$

α_1



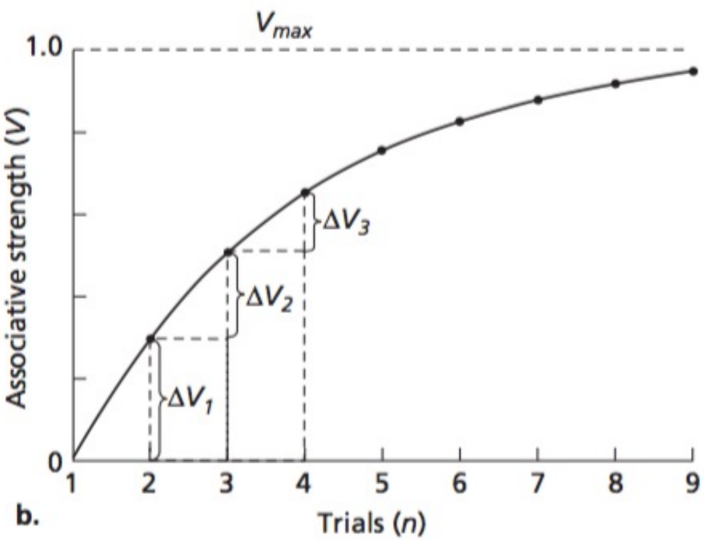
α_2

Assumption 3.1: each CS has an **associative weight**, which is a value representing the strength of association between that cue and the US.

Before any training takes place, all associative weights are 0.0

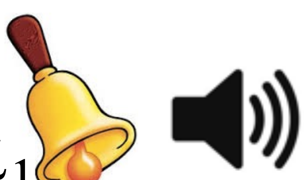
Cues compete for associative strength
$(V_1 + V_2 + ... \leq V_{max})$

Rescorla Wagner

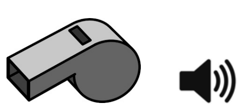


$$\Delta V = \alpha(V_{max} - V)$$

α_1



α_2



Assumption 3.2: Learning rates are not always similar, hence parameters to capture between context learning speeds:

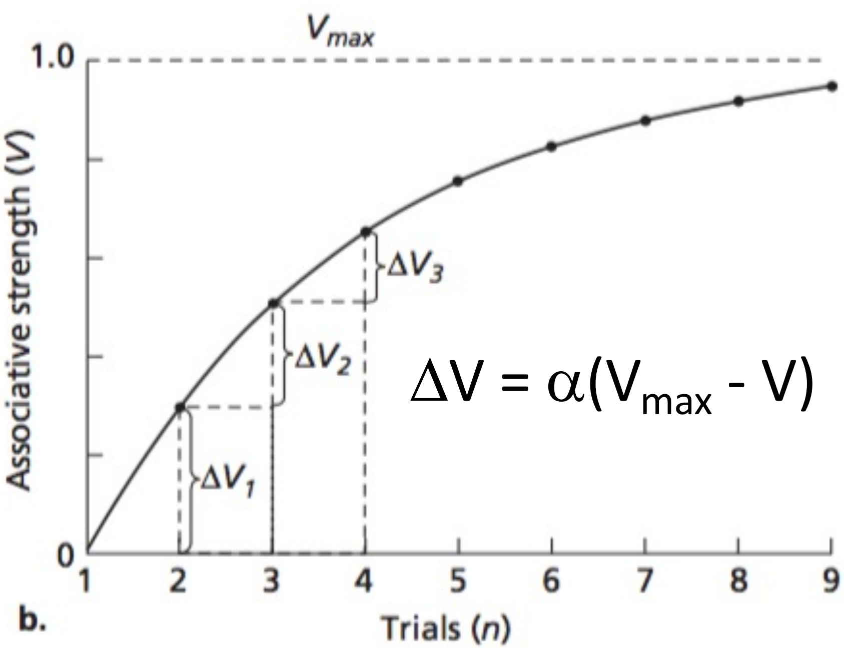
α_1 represents the relative salience of the bell
α_2 represents the relative salience of the whistle

In this example $\alpha_1 > \alpha_2$

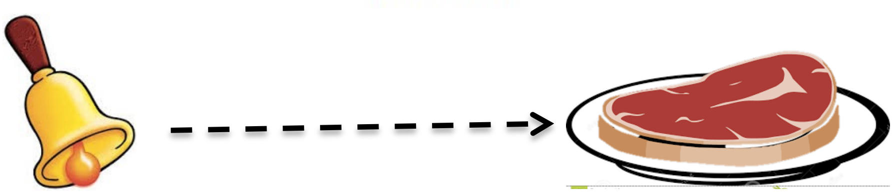
(overshadowing)

Rescorla Wagner

Example: $\alpha = .25$; $\beta = 1$*; $V_{max} = 1$; $V_{t=0}=0$



$$\Delta V = \alpha(V_{max} - V)$$



$$V_{t+1}=V_t+\Delta V_t$$

$$V_t=V_t+ \alpha(V_{max}-V_t)$$

$$V_{t+1}=0+.25(1-0)$$

$$V_{t+1}=.25$$

Next stim:

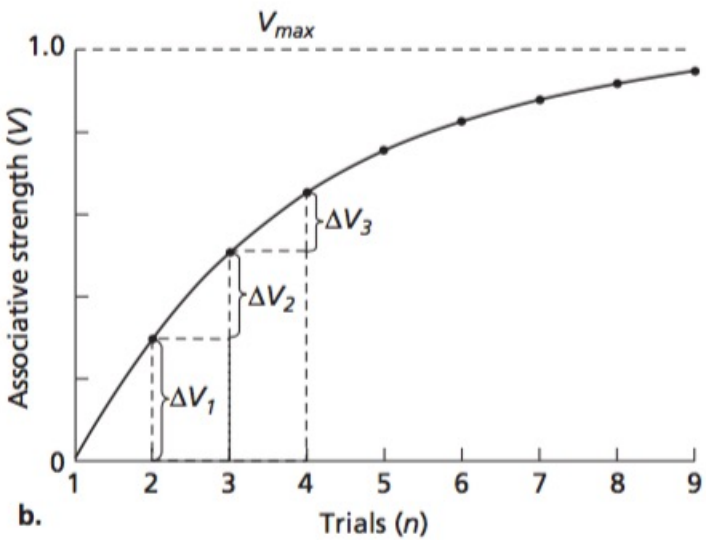
$$V_{t+1}=V_t+\Delta V$$

$$V_{t+1}=.25+.25(1-.25)$$

$$V_{t+1}=.4375$$

*We zullen β vanaf nu negeren

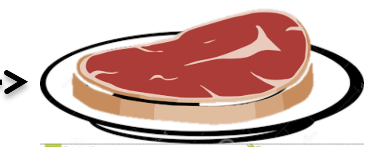
Rescorla Wagner



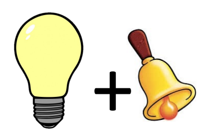
$$\Delta V = \alpha(V_{max} - V)$$

Blocking

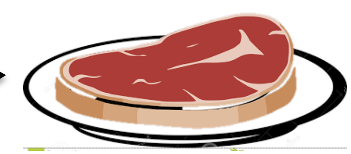
x10



$V_{bell} = V_{max}$



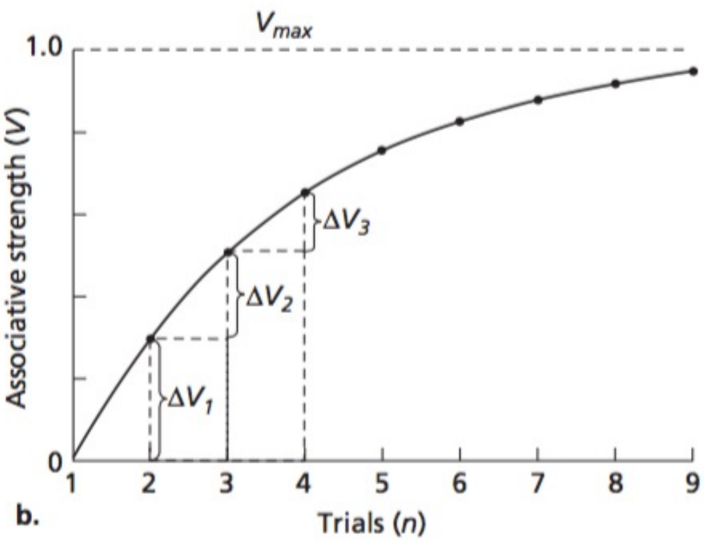
x10



$V_{bell} = ?$

$V_{light} = ?$

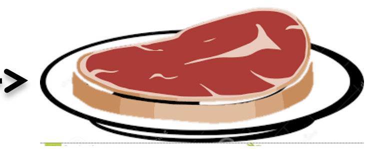
Rescorla Wagner



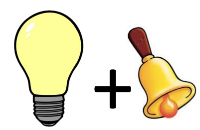
$$\Delta V = \alpha(V_{max} - V)$$

Blocking

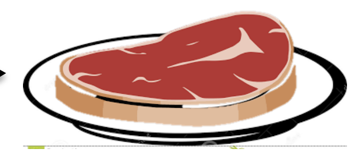
x10



$V_{bell} = V_{max}$



x10

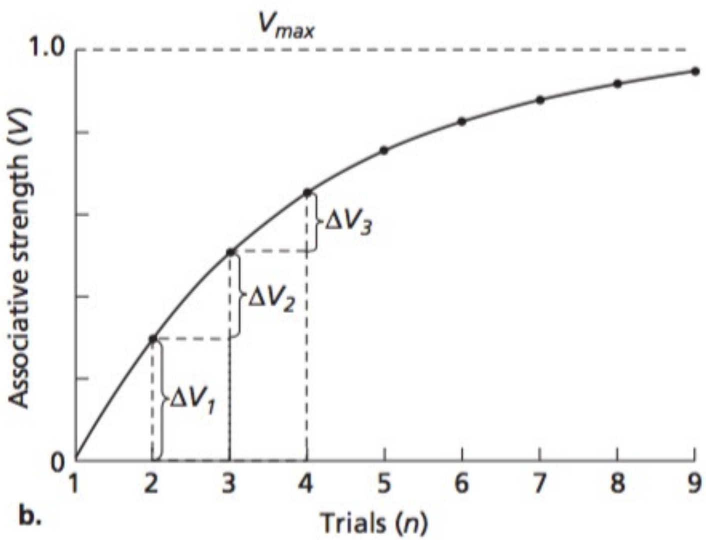


$V_{bell} = ?$

$V_{light} = ?$

Remember: $\mathbf{V_{bell} + V_{stroke} \leqq V_{max}}$

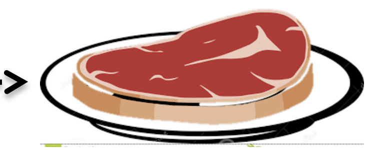
Rescorla Wagner



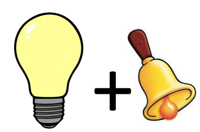
$$\Delta V = \alpha(V_{max} - V)$$

Blocking

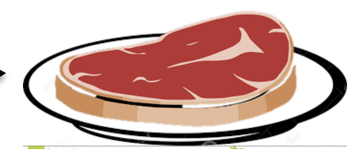
x10



$V_{bell} = V_{max}$



x10



$V_{bell} = V_{max}$
$V_{light} = 0!$

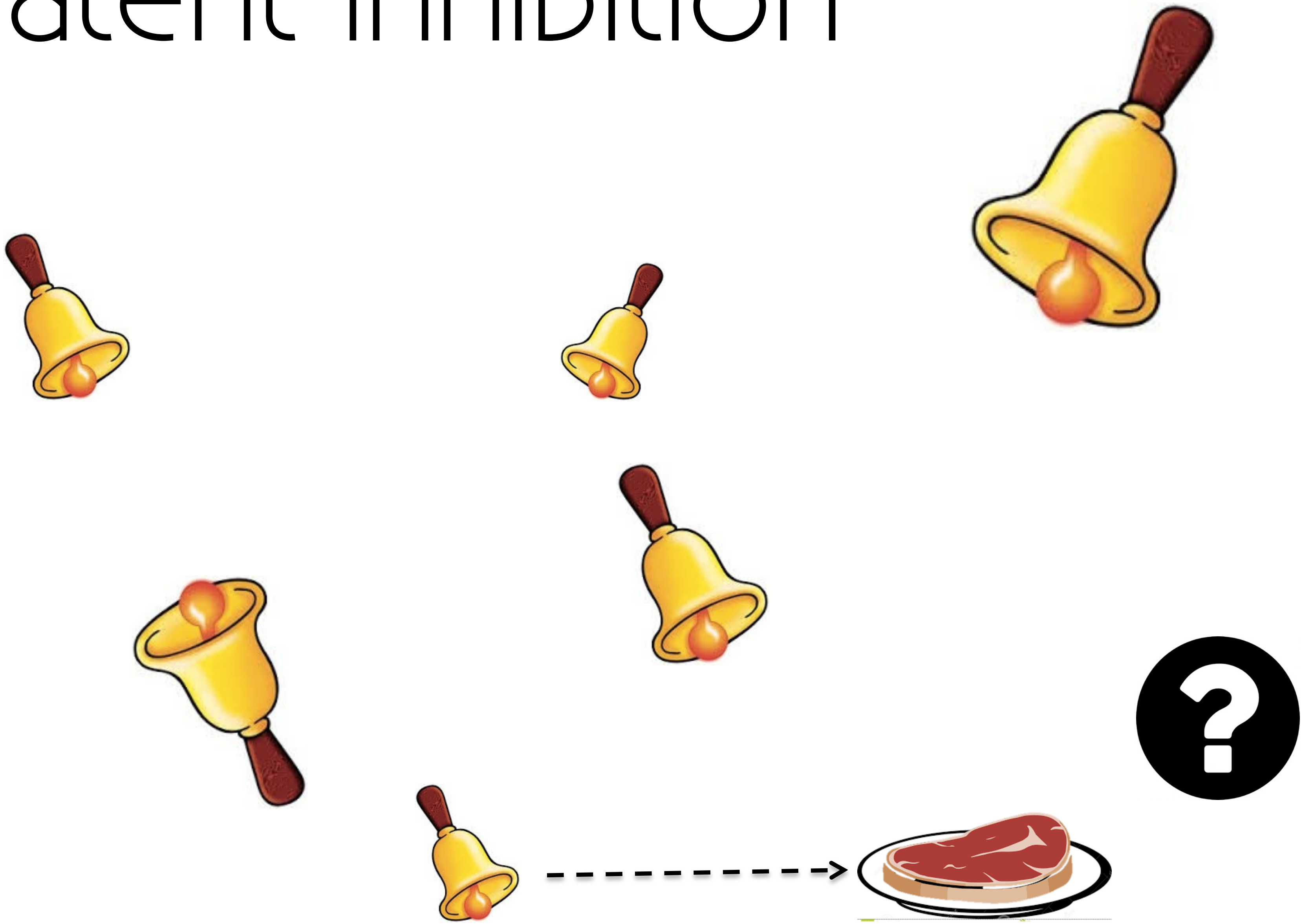
Remember: $\mathbf{V_{bell} + V_{stroke} \leqq V_{max}}$

Rescorla Wagner

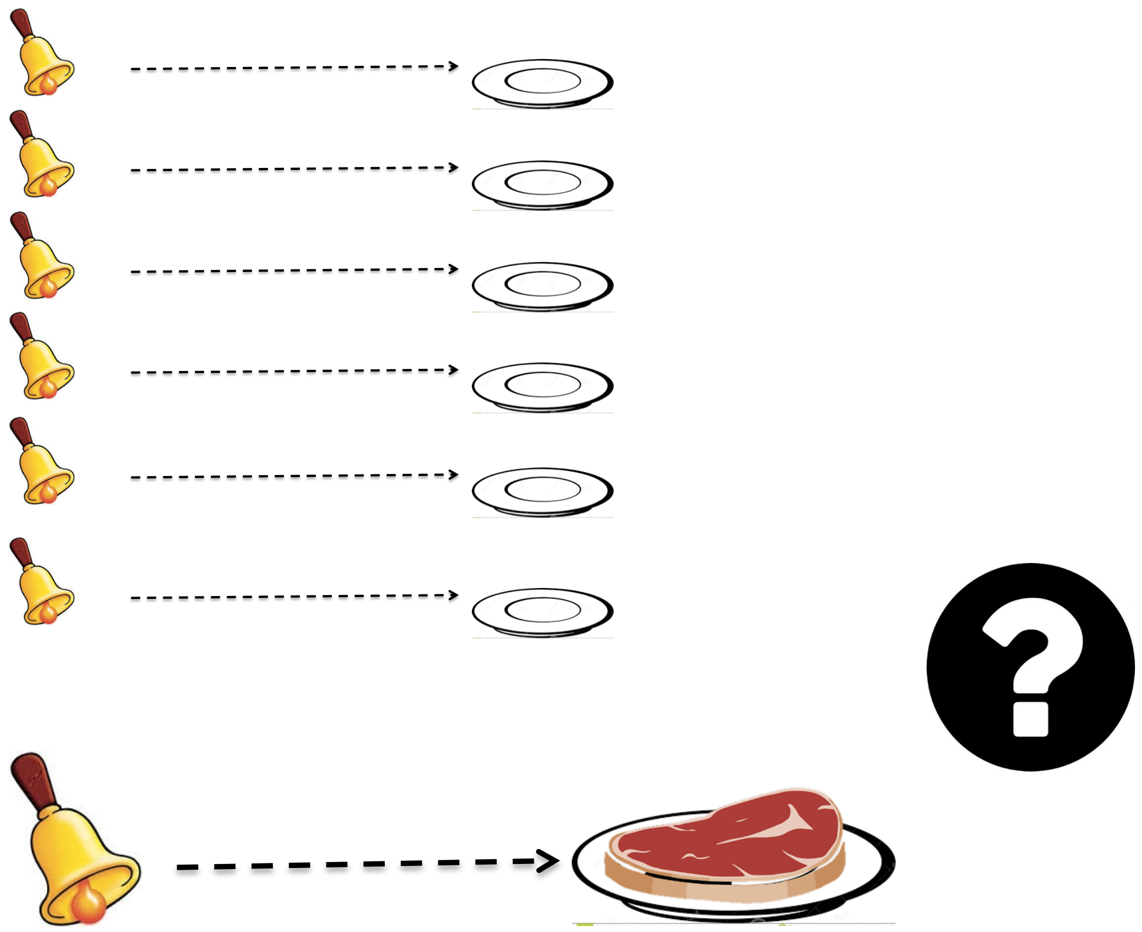
Powerful yet simple model. Generated novel and testable predictions. Also captured category learning quite well.

HOWEVER, does not explain everything:
<u>Latent inhibition</u>

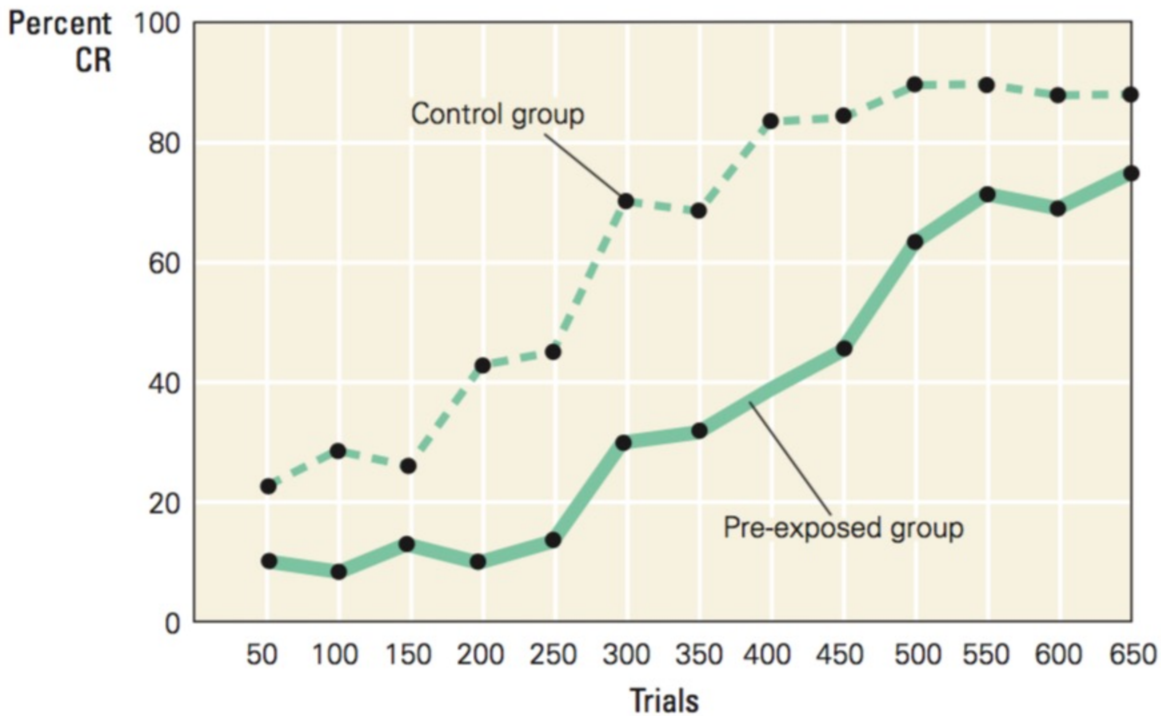
Latent inhibition



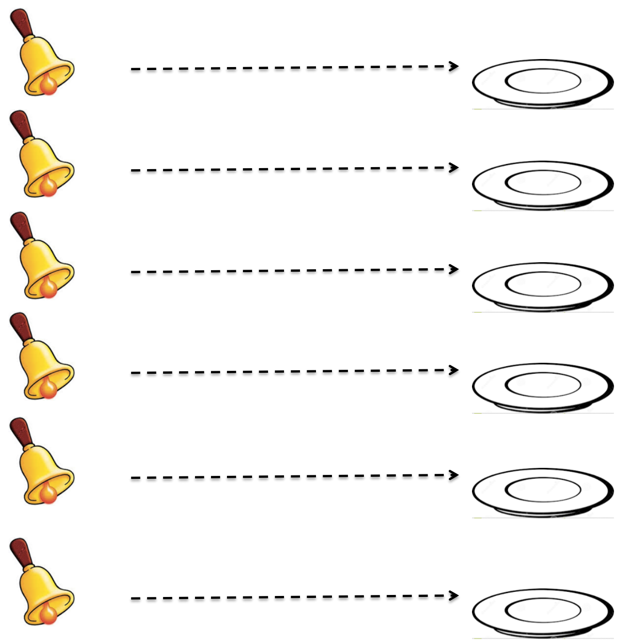
Latent inhibition



Latent inhibition



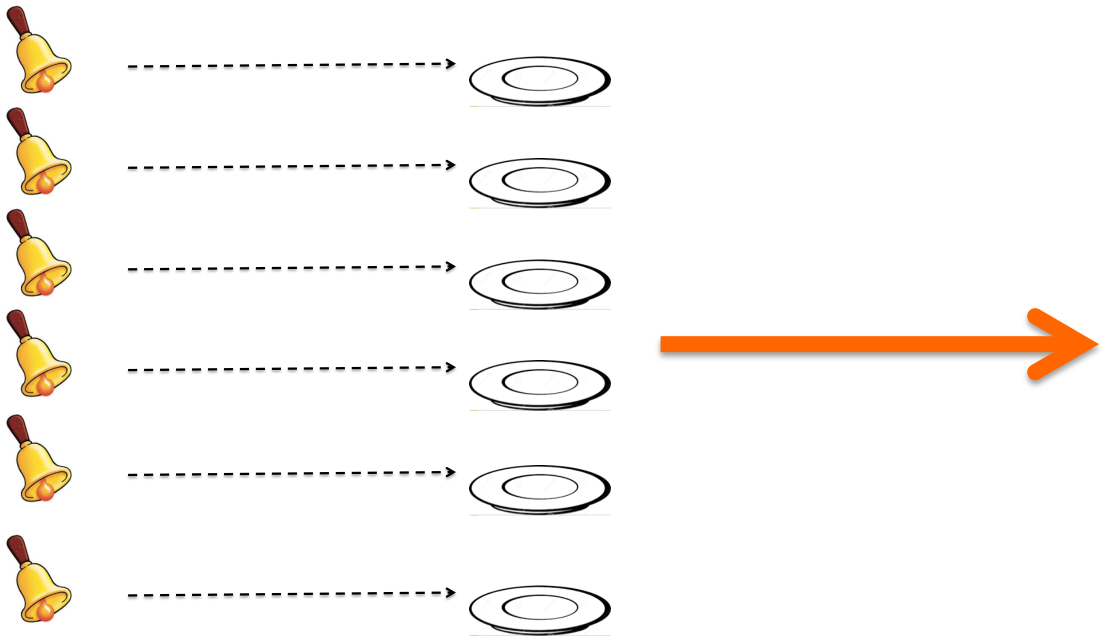
Latent inhibition



$V_{bell} = ?$

Mackintosh

CS modulation models

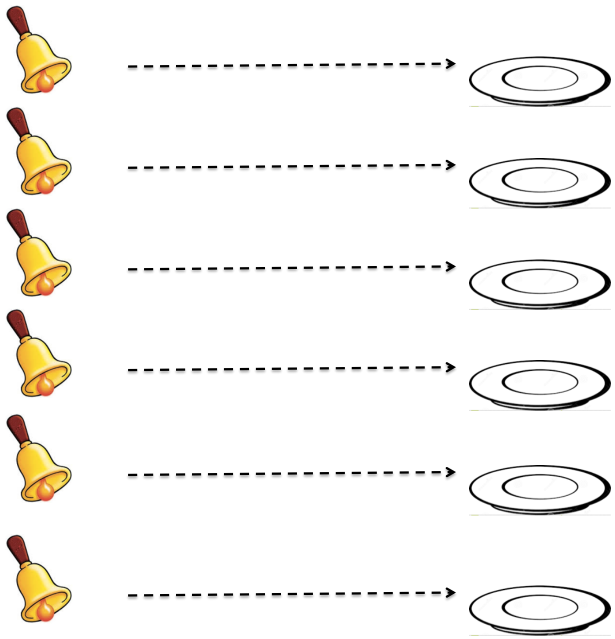


$S \downarrow$ Habituation to CS

$$\Delta V = S \,.\, \alpha(V_{max} - V)$$

Pearce-Hall

CS modulation models



Volatility in the environment determines the learning rate (cf. Kalman Filter)

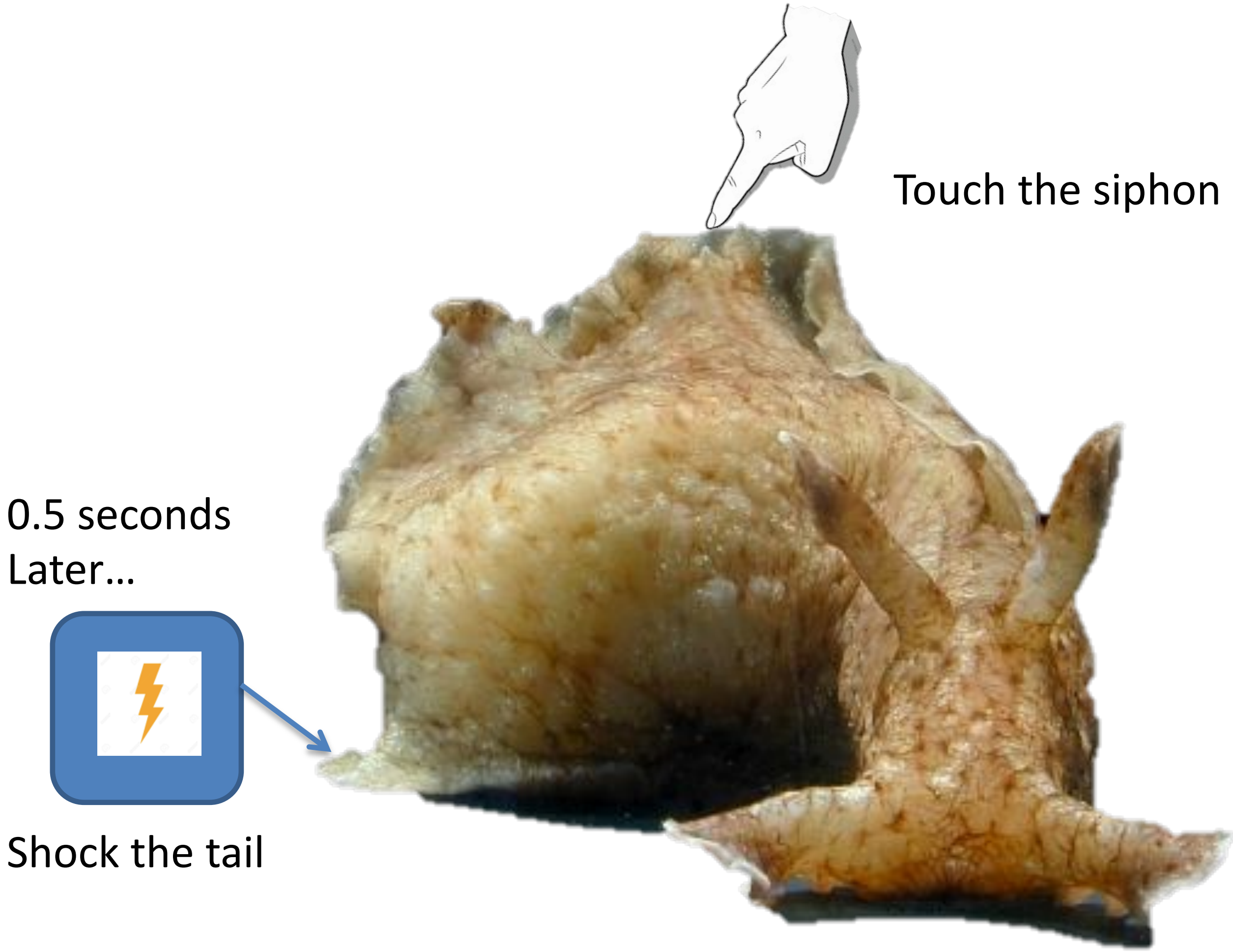
$$\alpha \downarrow$$

$$\Delta V = S \,.\, \alpha \,.\, V_{max}$$

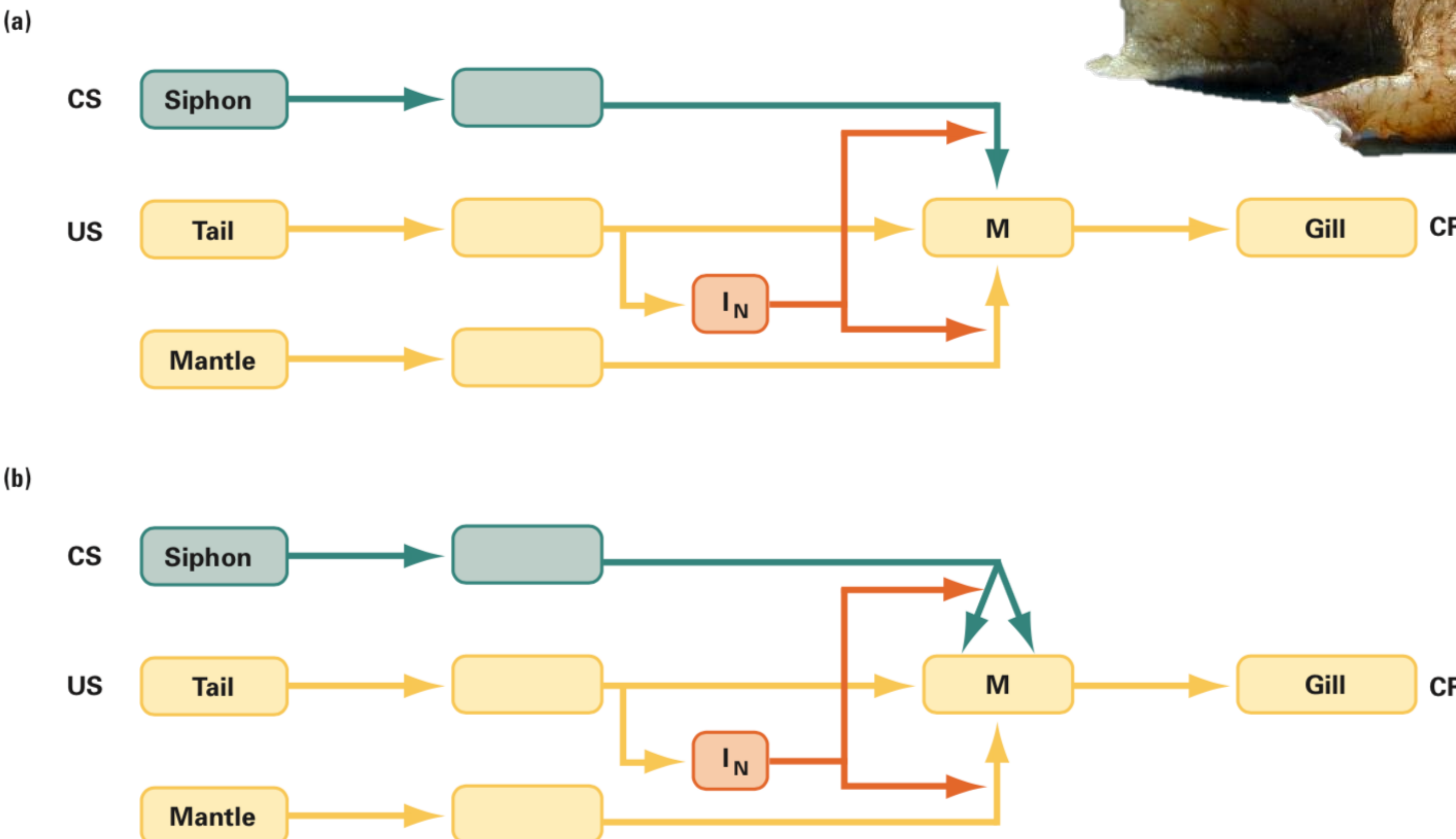
$$\alpha_t = |V_{max} - V_{t-1}|$$

Surprise on previous trial

Neural Principles



Neural Principles

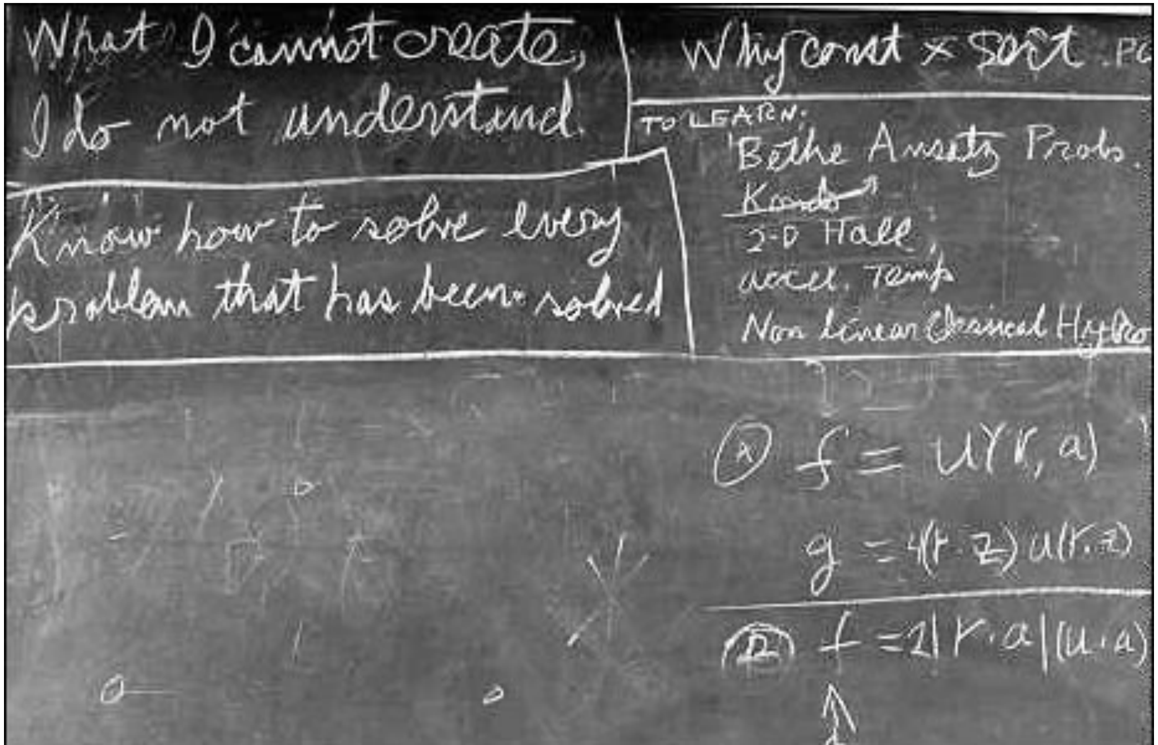


Neural Principles

Table 4.9 Varieties of learning in *Aplysia*

Type of learning	Associative	Stimulus specific	Mechanism(s)	Locus of effect
Habituation	No	Yes	Decrease in glutamate	Cellular process
Sensitization	No	No	Serotonin-induced increase in glutamate	Cellular process
Classical conditioning	Yes	Yes	1. Presynaptic activity–dependent enhancement of glutamate release from sensory neuron	Cellular process
			2. Postsynaptic change in receptors of motor neuron	Structural change
			3. A cascade of intracellular molecular events that activate genes in the neuron's nucleus, causing an increase in the number of sensory-motor synapses	Structural change

Laptop College 1



"What I cannot create I do not understand"

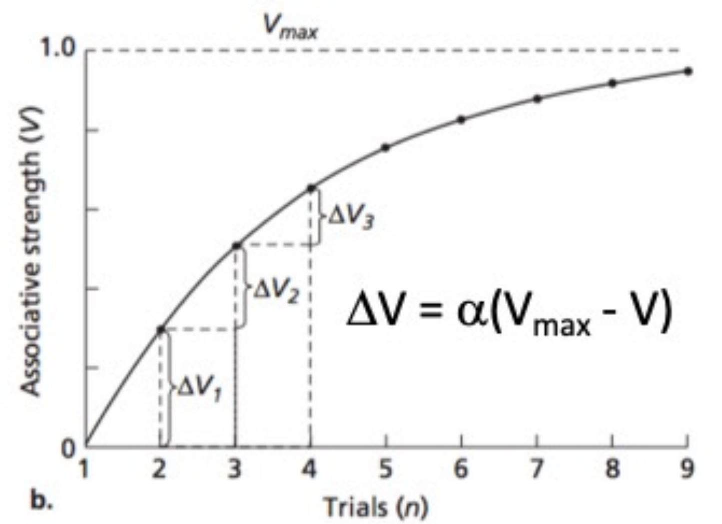
-Richard Feynman

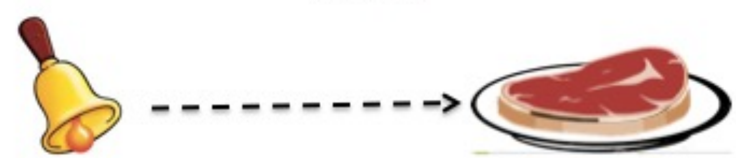
LC 1 – building the model

```python
def rescorla_wagner(alpha, v_start, v_max, trials):
    v_list = [] # empty list for Vs
    delta_list = [] # empty list for ΔVs

    for i in range(trials):
        #1 store current V in list Vs
        #2 calucalte ΔVs
        #3 store current ΔV in list dVs
        #4 update V with new ΔV

    return (v_list, delta_list)
```



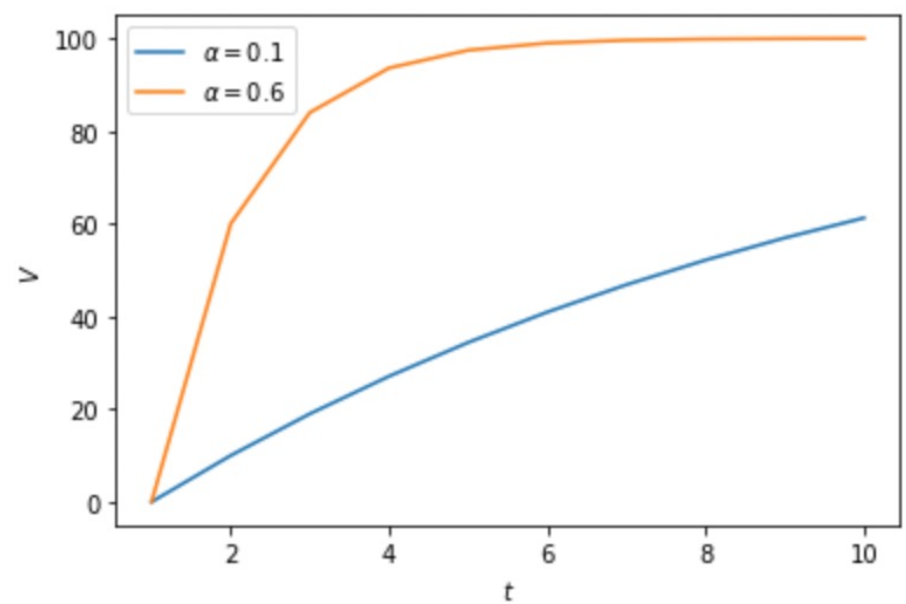


LC 1 – parameter settings

```
def rescorla_wagner(alpha, v_start, v_max, trials):
    v_list = [] # empty list for Vs
    delta_list = [] # empty list for ΔVs

    for i in range(trials):
        #1 store current V in list Vs
        #2 calucalte ΔVs
        #3 store current ΔV in list dVs
        #4 update V with new ΔV

    return (v_list, delta_list)
```

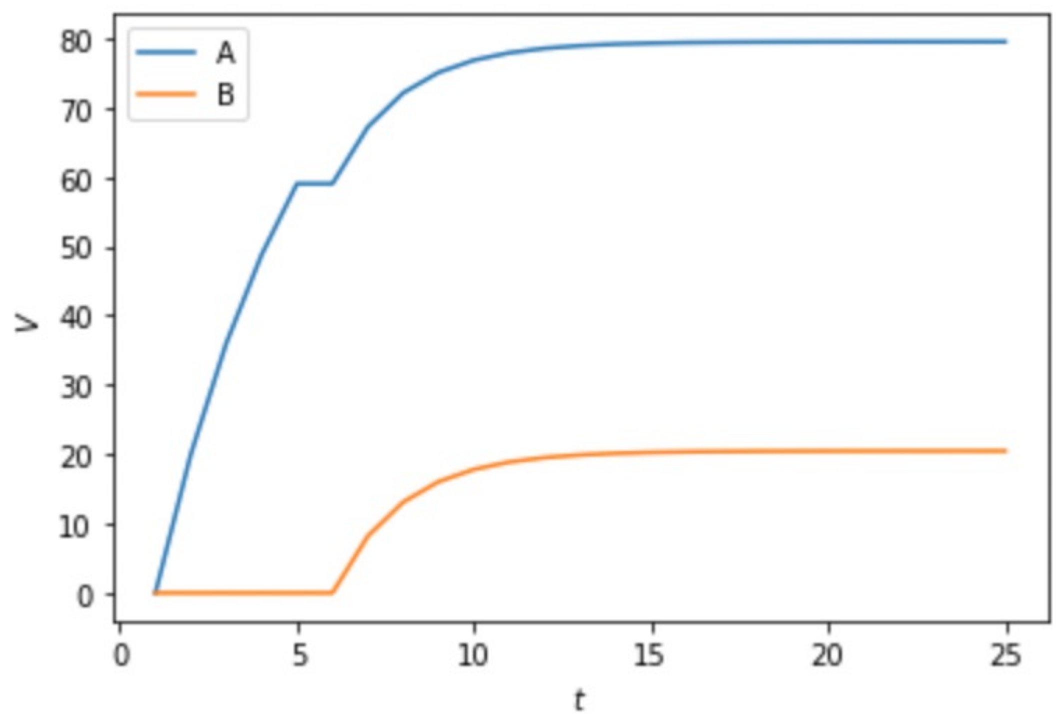


LC 1 — compound stimuli

```
def rescorla_wagner(alpha, v_start, v_max, trials):
    v_list = [] # empty list for Vs
    delta_list = [] # empty list for ΔVs

    for i in range(trials):
        #1 store current V in list Vs
        #2 calucalte ΔVs
        #3 store current ΔV
        #4 update V with ne

    return (v_list, delta_l
```



LC 1 — Pearce-Hall

def pearce_hall() ?

```
def rescorla_wagner(alpha, v_start, v_max, trials):
    v_list = [] # empty list for Vs
    delta_list = [] # empty list for ΔVs

    for i in range(trials):
        #1 store current V in list Vs
        #2 calucalte ΔVs
        #3 store current ΔV in list dVs
        #4 update V with new ΔV

    return (v_list, delta_list)
```

Fin