MEMORY and DECISION MAKING

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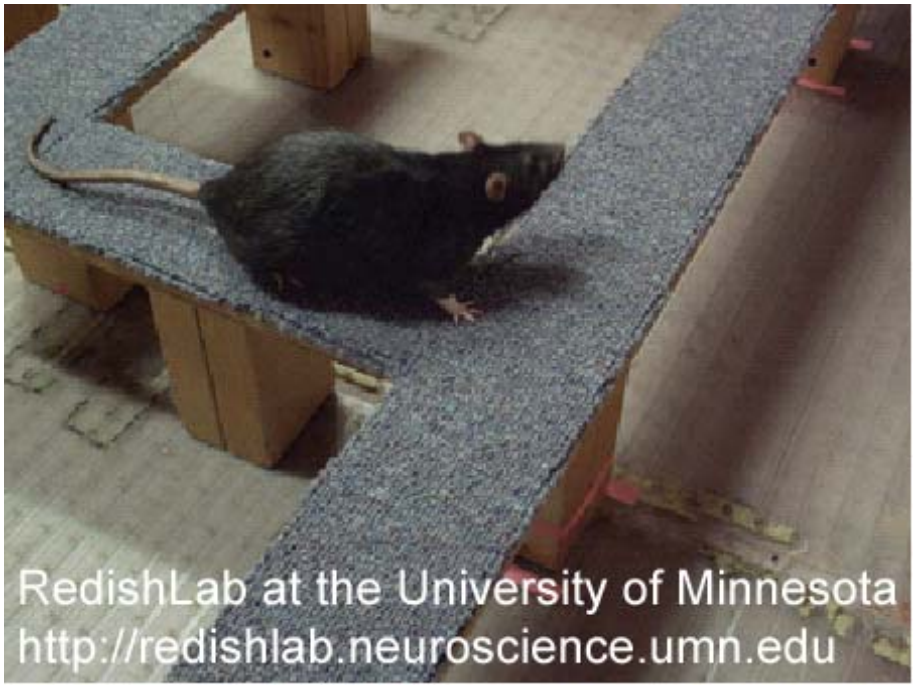
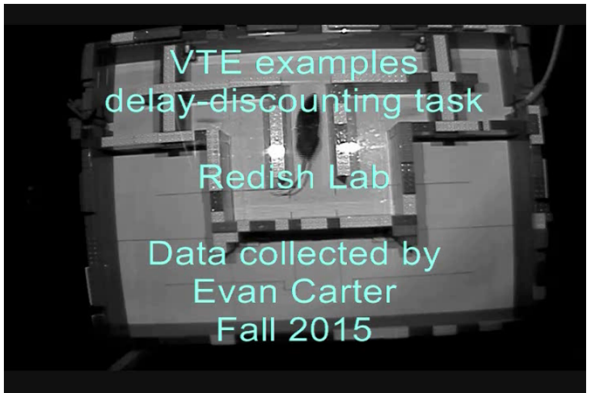


What is a decision?

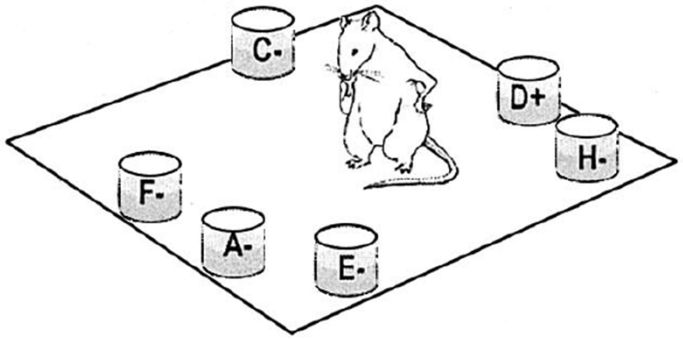
Let's define decision-making as action-selection.

Candy vending machines

Carter and Redish 2016

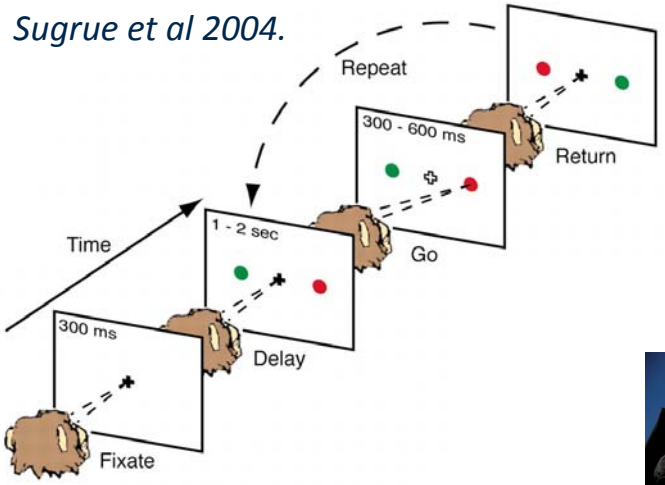


Wood et al 2004.



Gambling

Sugrue et al 2004.



Buying a house…

Taking drugs… or not…

Going to college… or not…

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Why memory?

To change our future actions.

Memory is only useful if it changes our future.

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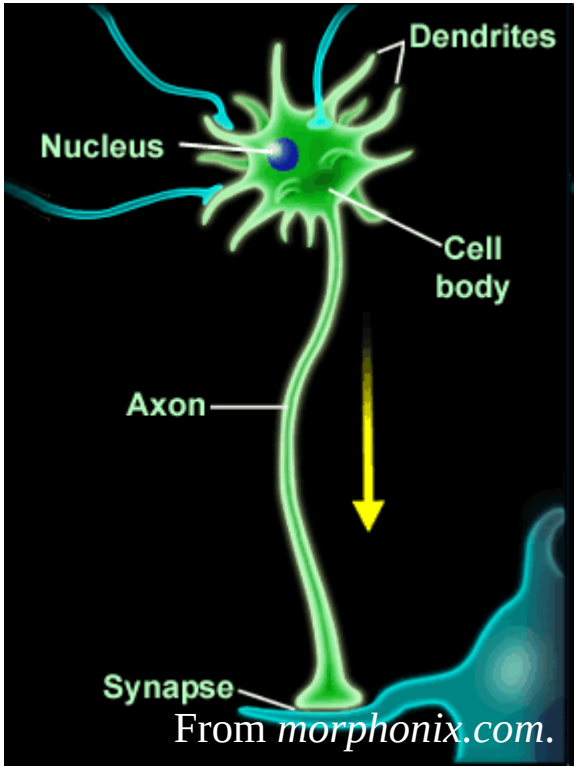
What is memory?

From *carinsurancecompanies.com.*



From *morphonix.com.*

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PART I

- CELLULAR MEMORY
  - What changes in a cell?
  - How is memory stored?
  - Is this really memory?
  - Can we read it?

PART II

- CONTENT-ADDRESSABLE MEMORY
  - How does memory in your brain differ from memory in your computer?
  - Memory as categorization
  - What are the implications of this?

PART III

- CREATIVE MEMORY
  - We don't remember our pasts.
  - We **imagine** them.

PART IV

- DECISIONS
  - Decision-making is about information processing
  - How the information is stored changes the outcome.

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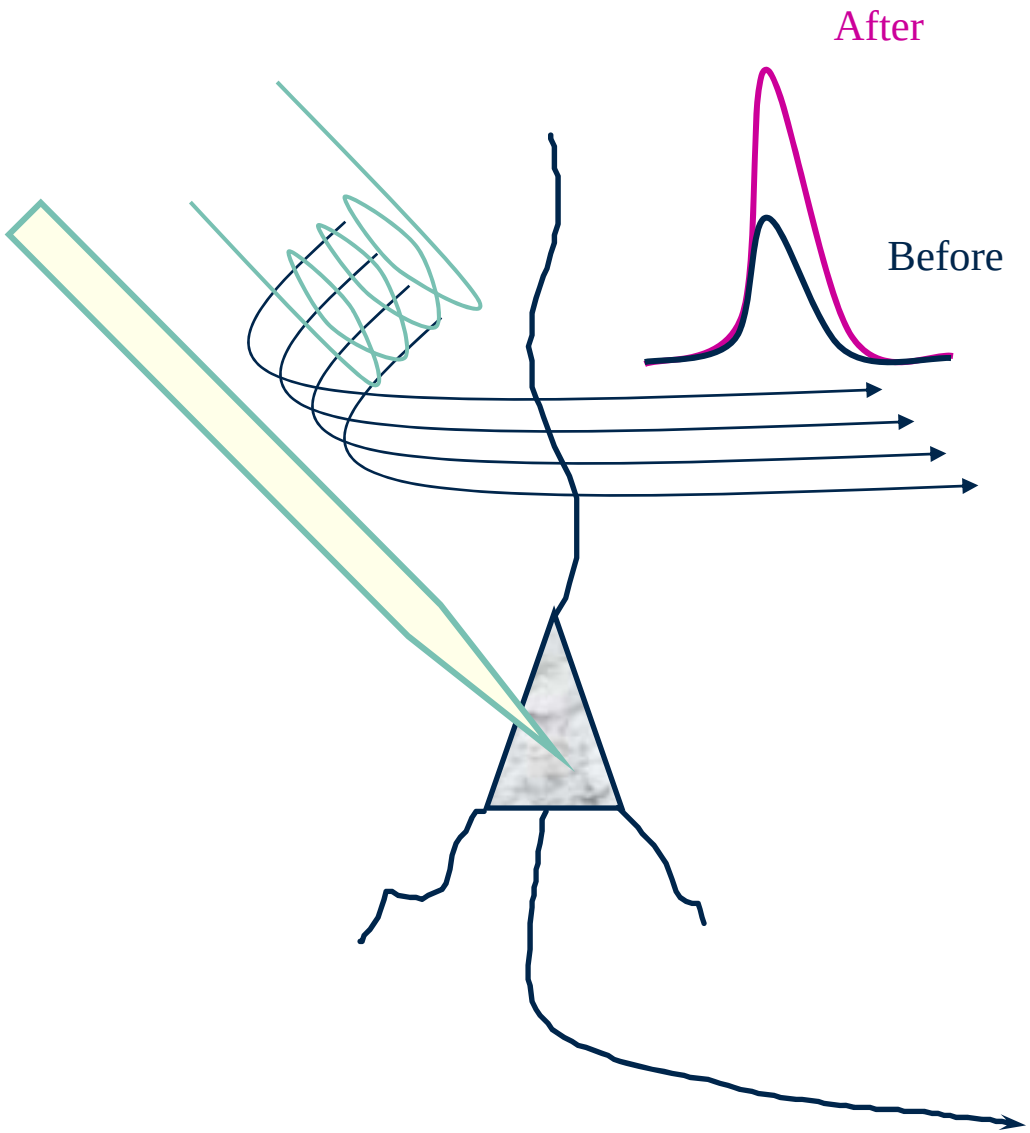
Long-term potentiation

CELLULAR MEMORY

- Found throughout the brain
  - hippocampus
  - cortex
  - nucleus accumbens
  - VTA
  - striatum
- Typically found by injecting bursts of current along pathways which depolarizes post-synaptic neurons



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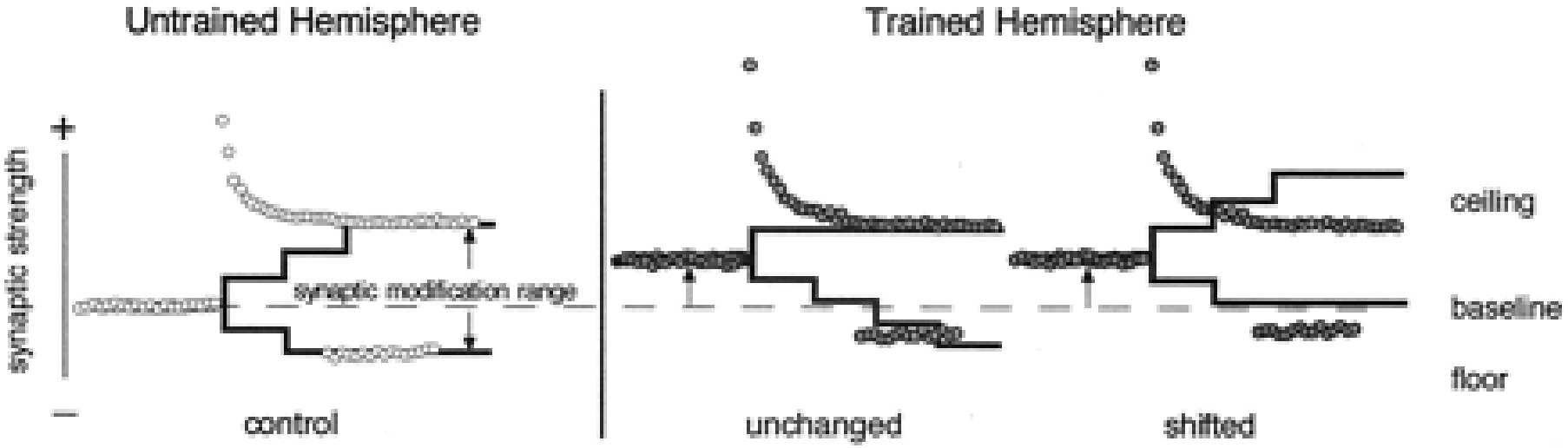
Is this really memory?

CELLULAR MEMORY

- Cellular synapses work within a specific dynamic range.
- After training, the trained areas are shifted UP.

Synapses in the trained rat motor cortex [M1] were near the ceiling of their modification range, compared with the untrained MI, but the range of synaptic modification was not affected by learning.



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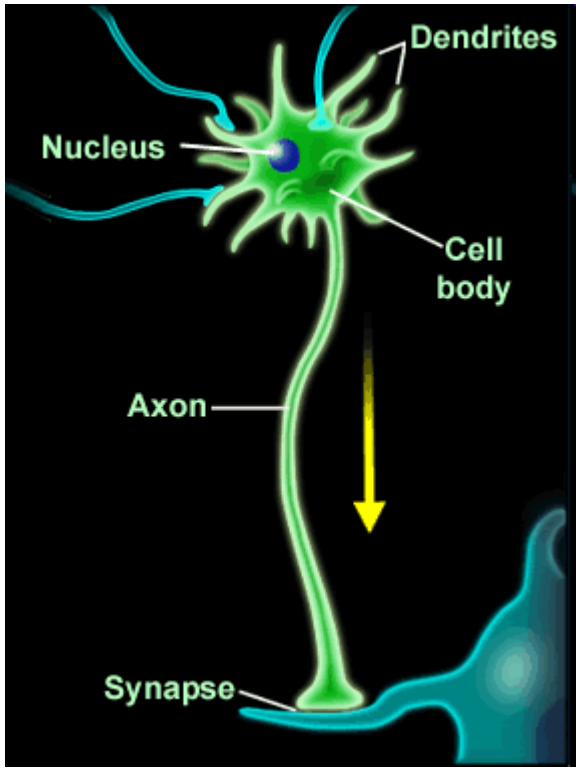
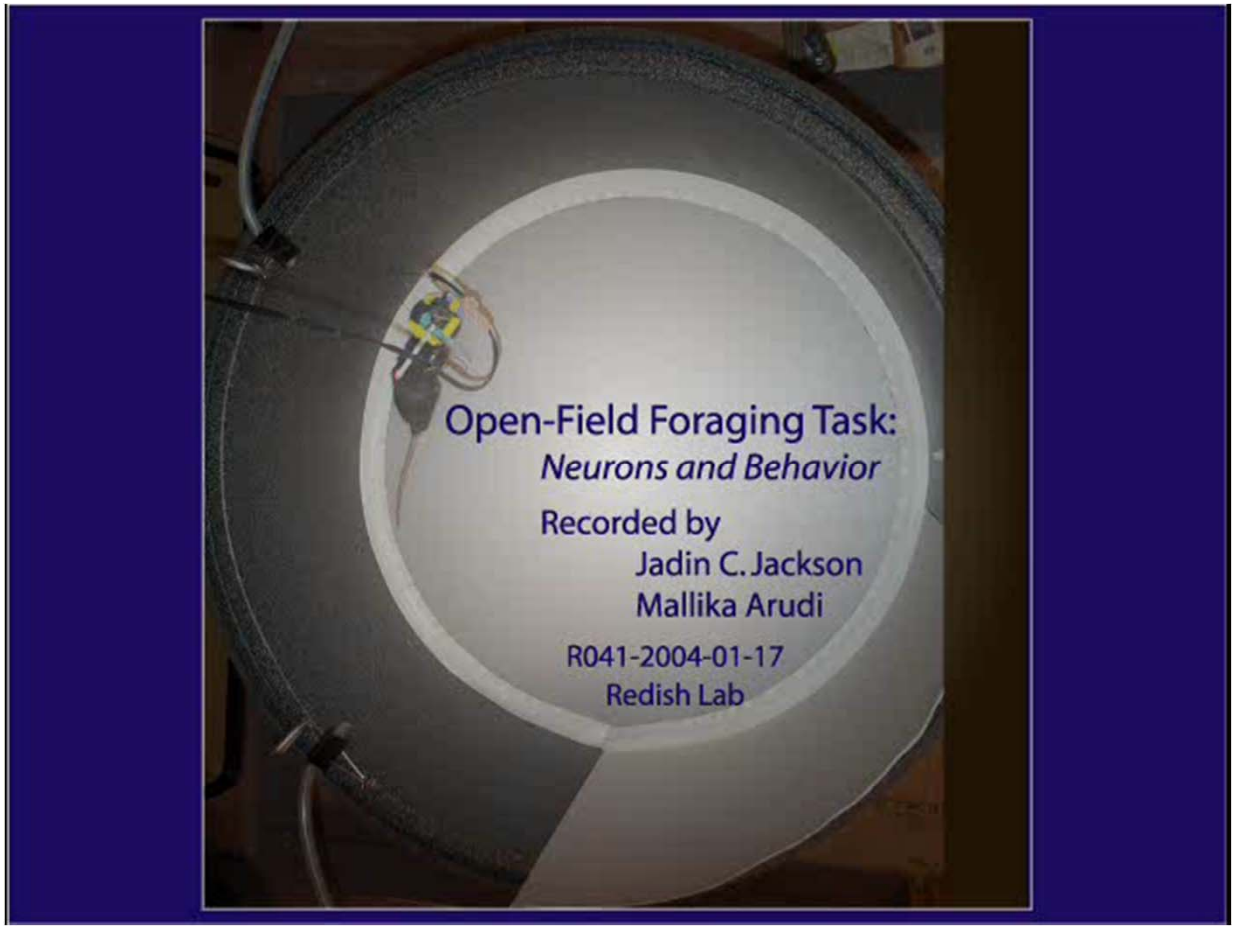
Rioult-Pedotti et al 2000

READING MEMORY



When this cell spikes,
I know where the animal is!



http://morphonix.com

Mathematical technology

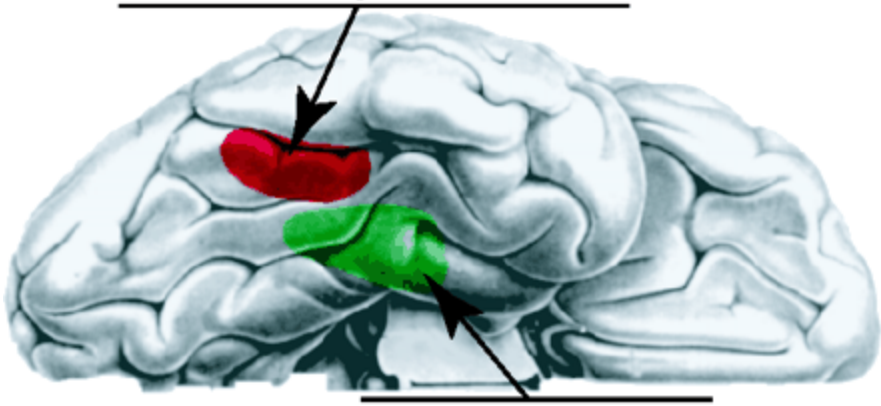
READING MEMORY

Science
AAAS

Distributed and Overlapping Representations of Faces and Objects in Ventral Temporal Cortex
James V. Haxby *et al.*
Science **293**, 2425 (2001);
DOI: 10.1126/science.1063736

cc

cc



commons.wikimedia.org

Imagination

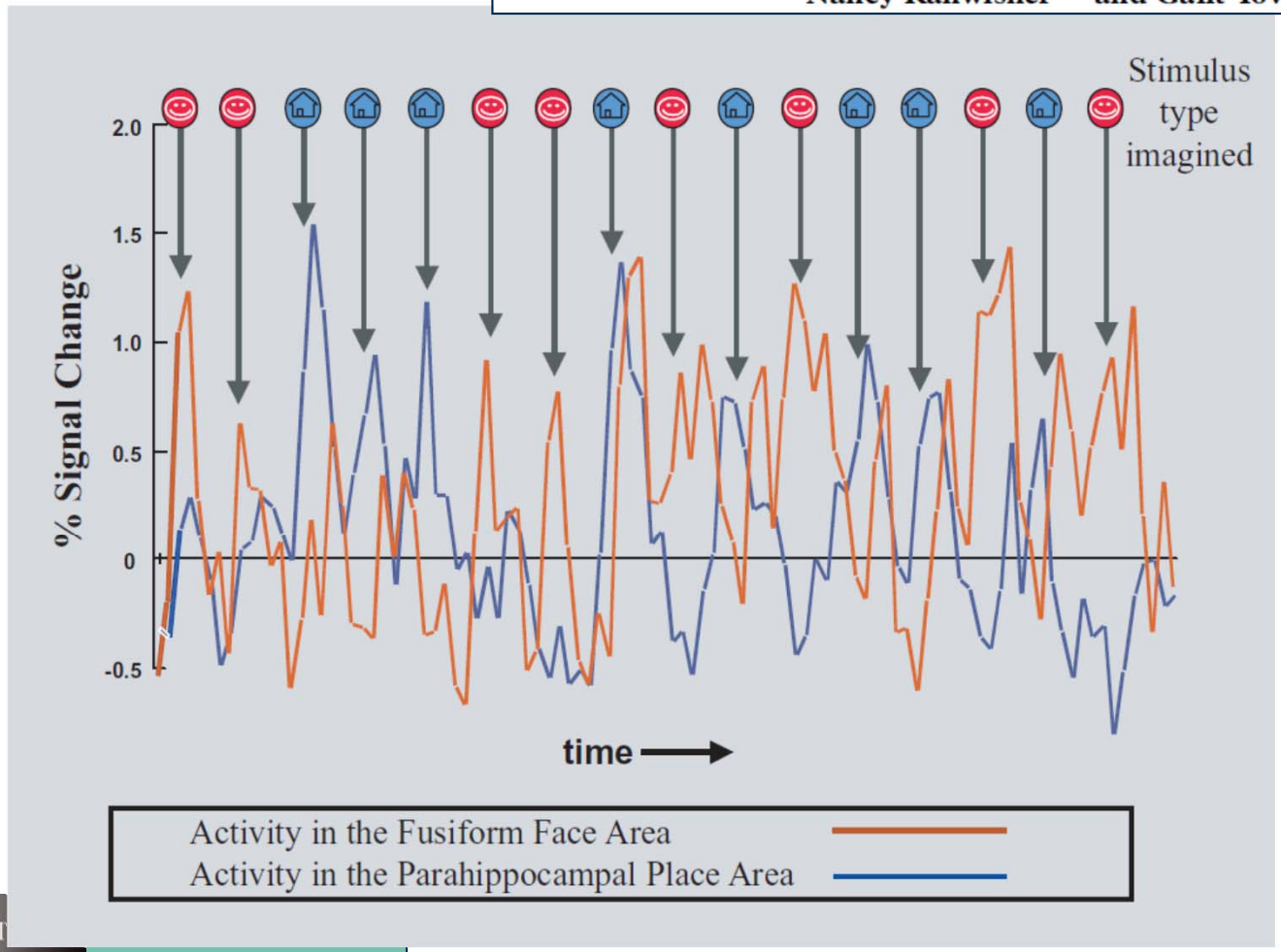
READING MEMORY

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B

Phil. Trans. R. Soc. B (2006) **361**, 2109–2128
doi:10.1098/rstb.2006.1934
Published online 8 November 2006

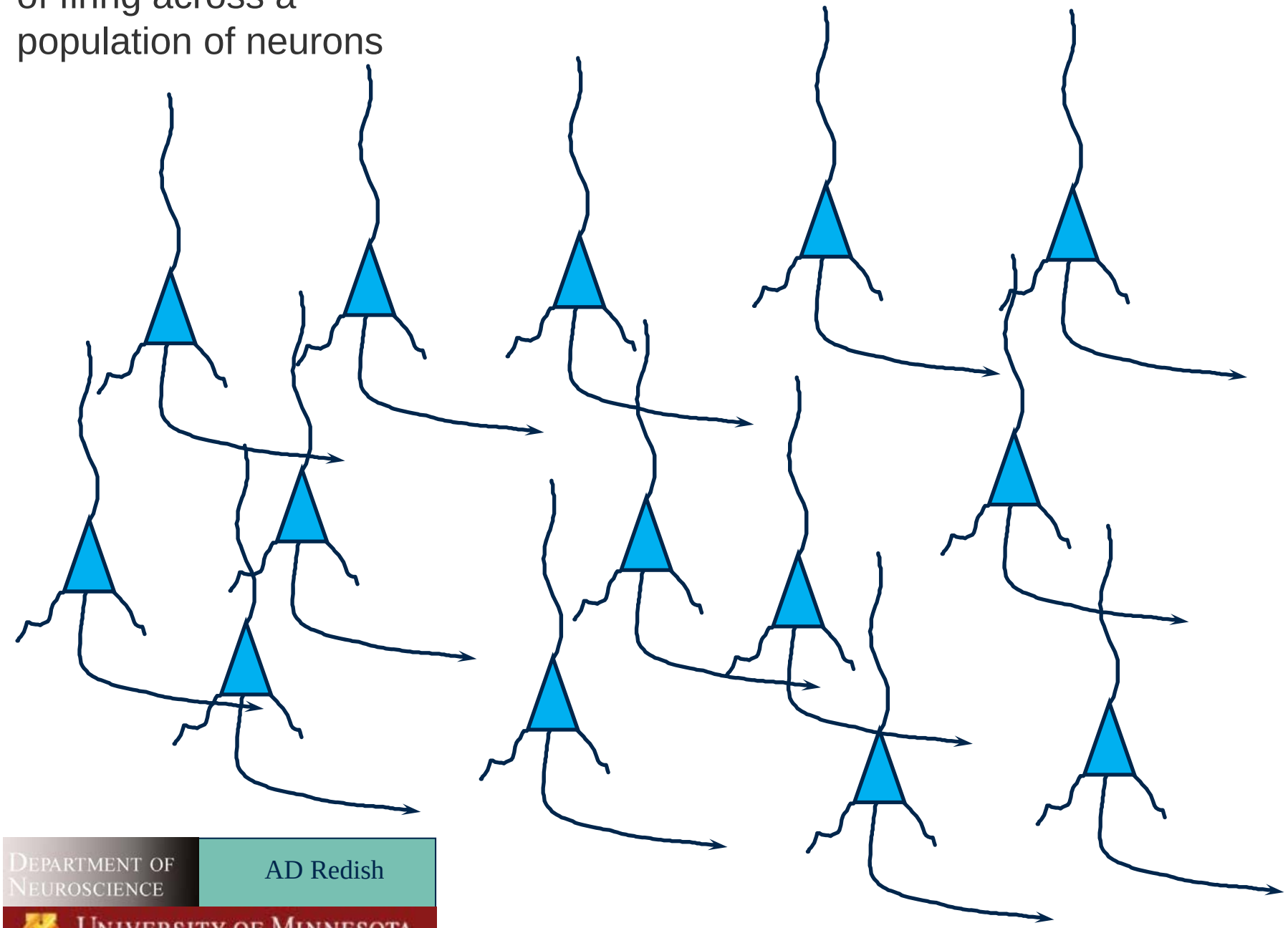
The fusiform face area: a cortical region specialized for the perception of faces

Nancy Kanwisher[1,*] and Galit Yovel[2]



A memory is a pattern of firing across a population of neurons

CONTENT-ADDRESSABLE MEMORY



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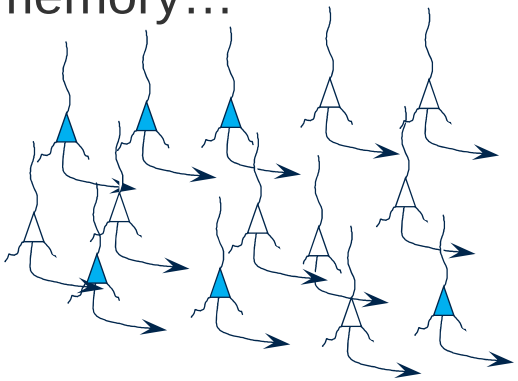
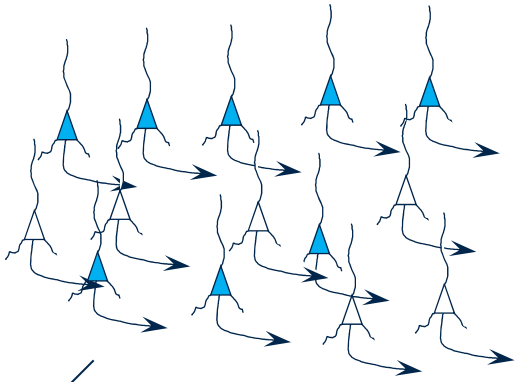
CONTENT-ADDRESSABLE MEMORY

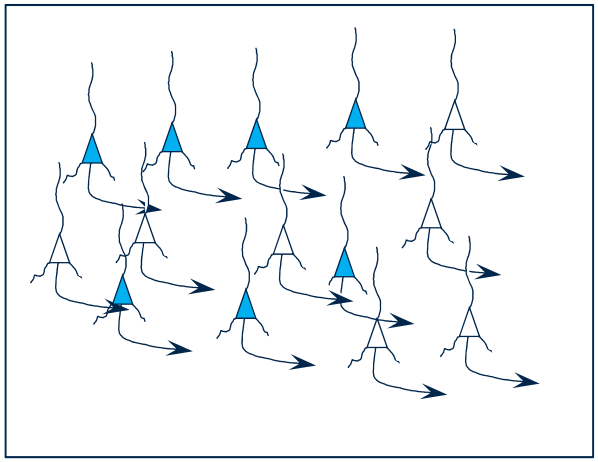
Let's define a "distance" from the memory…



3 cells changed

1 cell changed





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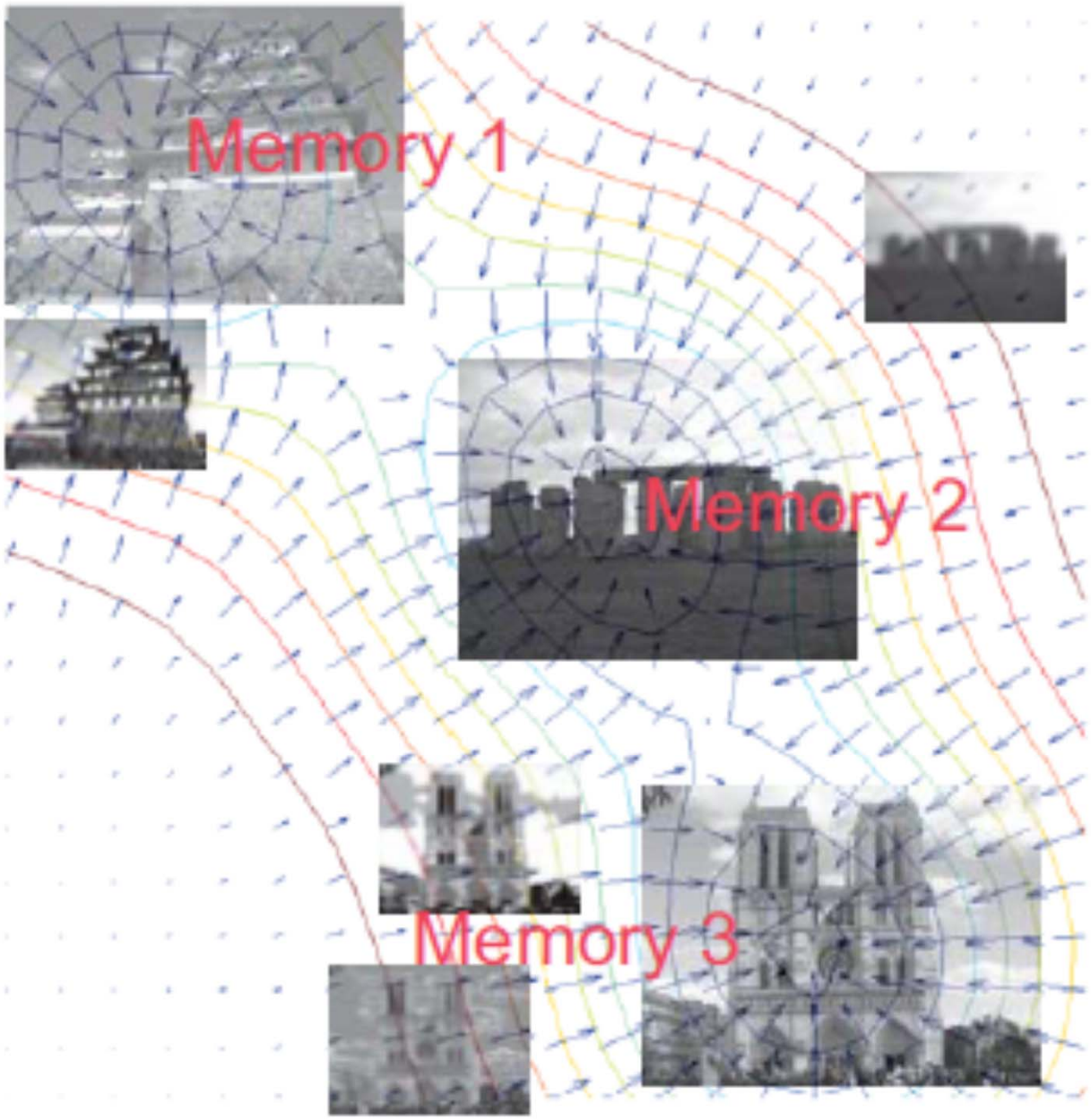
Memory as a “Basin of attraction”

CONTENT-ADDRESSABLE MEMORY

- Memory is a process of moving the pattern of neurons to a previously stored pattern.
- The means that memory is **constructed**.



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Memory is accessed by content

CREATIVE MEMORY

Ratatouille

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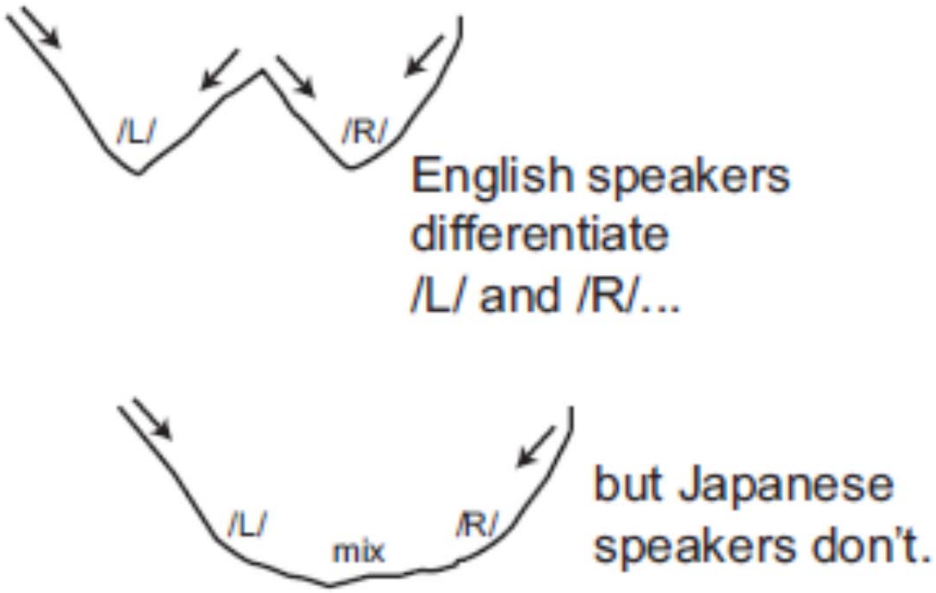
Perception as categorization (and memory)

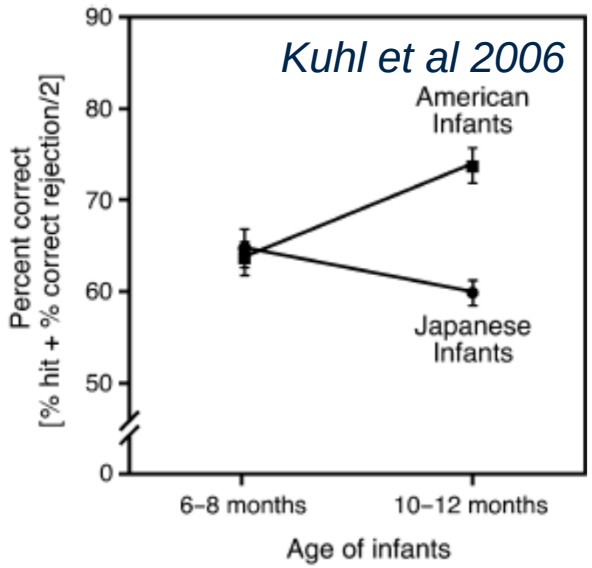
CONTENT-ADDRESSABLE MEMORY

How is this memory?

- This means that perception is a form of categorization.



/l/ vs /r/



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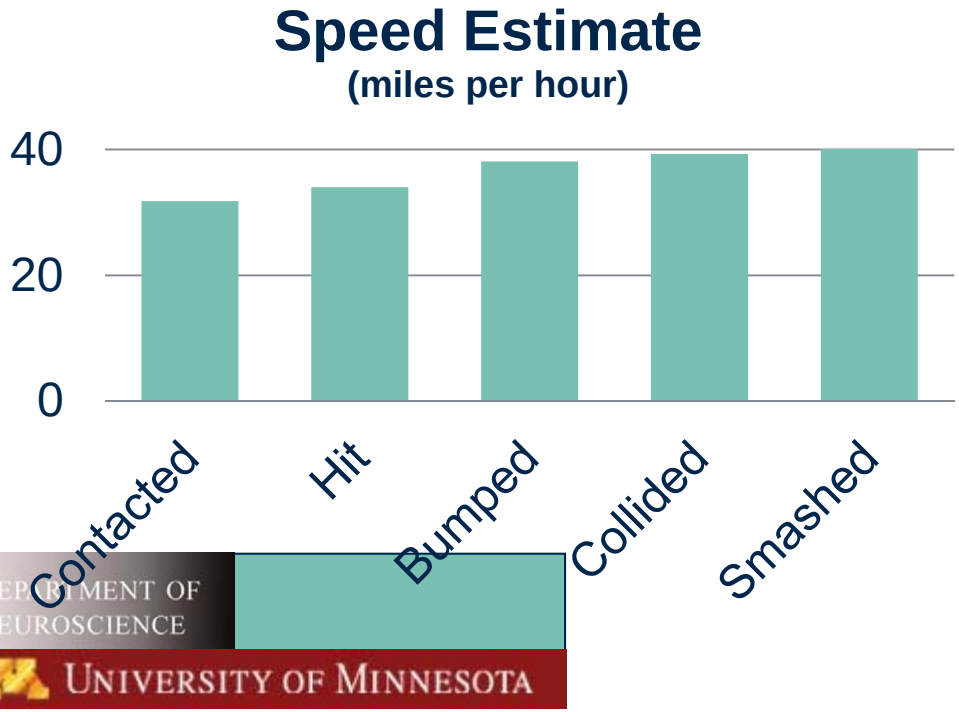
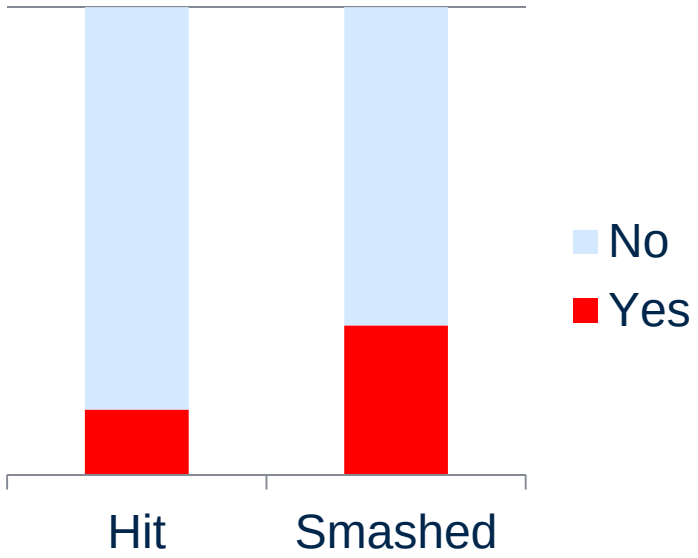
Memory is fragile,
and suggestible.

- In 1974, Elizabeth Loftus and John Palmer found that the way a question was asked could change the memory.

How fast were the cars going when they _____ each other?



Was there broken glass?



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Why memory?

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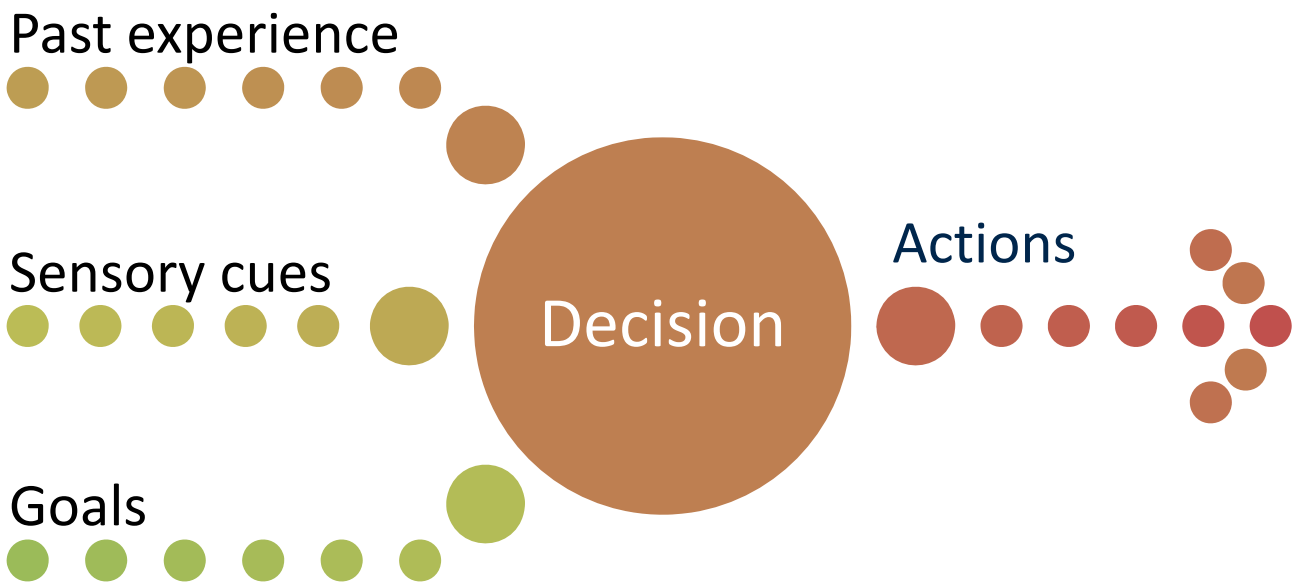
DECISION MAKING

How is information processed so as to select the action?



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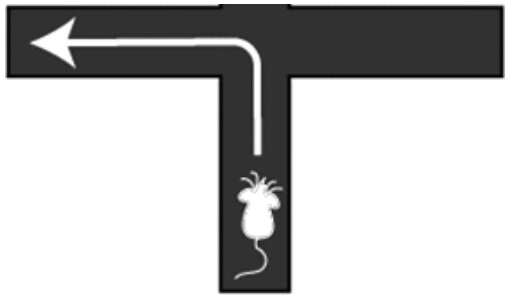
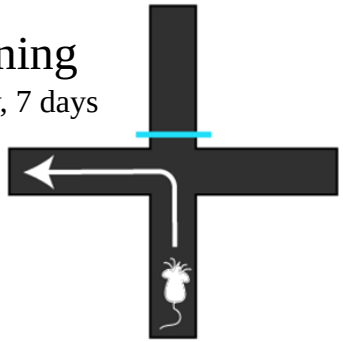
How you represent the data changes the calculation

Multiple decision-making systems

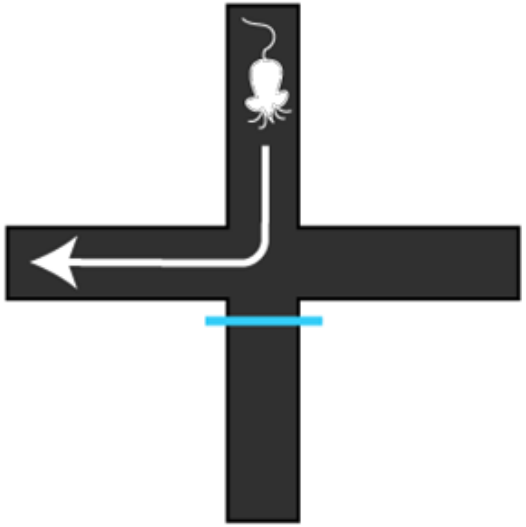
Designing probe trials right reveals decision processes.



Training
4x/day, 7 days

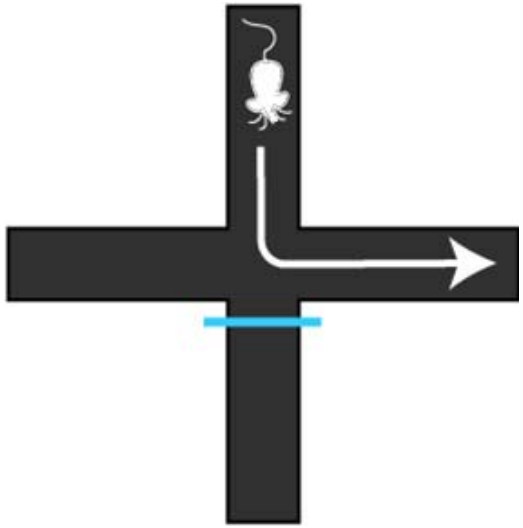


Probe trials



Place-strategy
(return to same location by taking a different action)

Dependent on hippocampal function



Response-strategy
(turn in same direction but reach a different goal)

Dependent on dorsolateral striatal function

Kinds of decisions

Decision-making

Reflexes

- Not learned
- Evolutionary

- "pre-wired"

Spinal cord

Deliberative

- Planning
- Constructed!

- Imagination

Hippocampus

Procedural

- Skills
- Habits

- Action-chains

Striatum
Cerebellum

Emotional

- Fear
- Joy

- Survival circuits

Amygdala

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Kinds of memory

Memory

Episodic	*Procedural*	*Emotional*
- Events - Constructed!	- Skills - Habits	- Fear - Joy
- Basins of attraction	- Associations	- Associations
Hippocampus	*Striatum* *Cerebellum*	*Amygdala*

Semantic

- Facts
- Causality

- Basins of attraction

NEOCORTEX

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The decision-making machinery

Reflexes

- Inflexible
- Simple
- Does not learn

$S \xrightarrow{a}$

Goals and stimulus-action pairs are learned over an *evolutionary timescale*.

Learning within the lifespan is limited to habituation, sensitization, and other simple threshold adjustments.

Downward Parachute Reflex

(Protective Extension Reaction Downward)

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The decision-making machine

- The goals and stimulus-action pairs in reflexes are learned over an evolutionary timescale.
- Learning within the lifespan is limited to habituation, sensitization, and other simple threshold adjustments.

Reflexes

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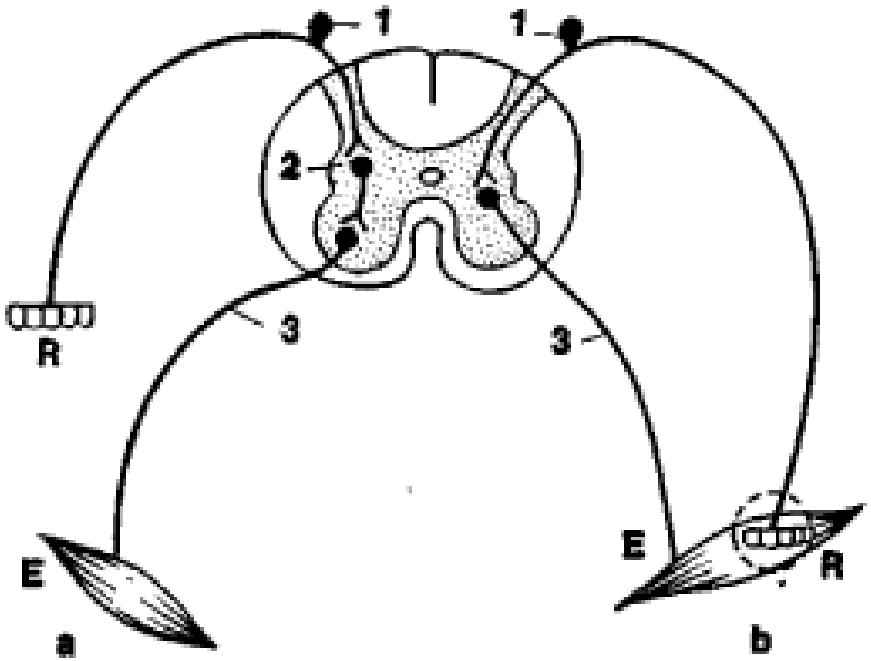
$S \xrightarrow{a}$



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The decision-making machinery

Reflexes: prewired responses to stimuli.

Pavlovian (emotional): learning the situation to release prewired actions.

Deliberation: search and evaluate potential consequences.

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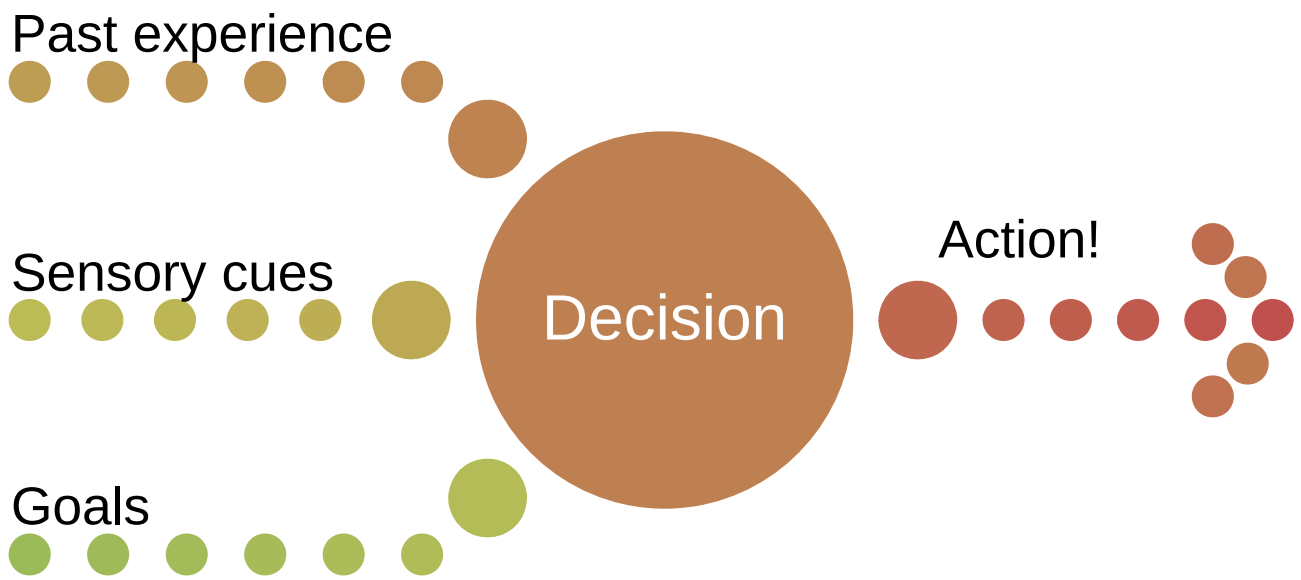
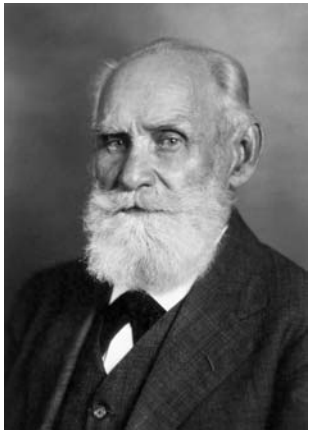


The decision-making machine

- By associating stimuli with outcomes, observation of a stimulus will leading to the *expectation of an outcome*, leading to the release of *pre-wired actions.*



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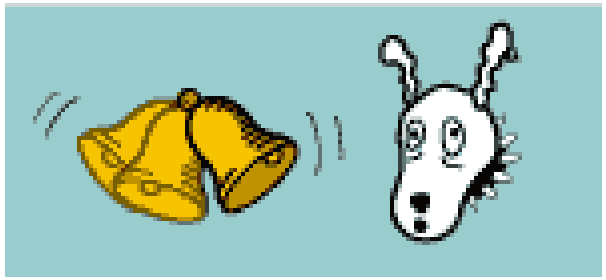
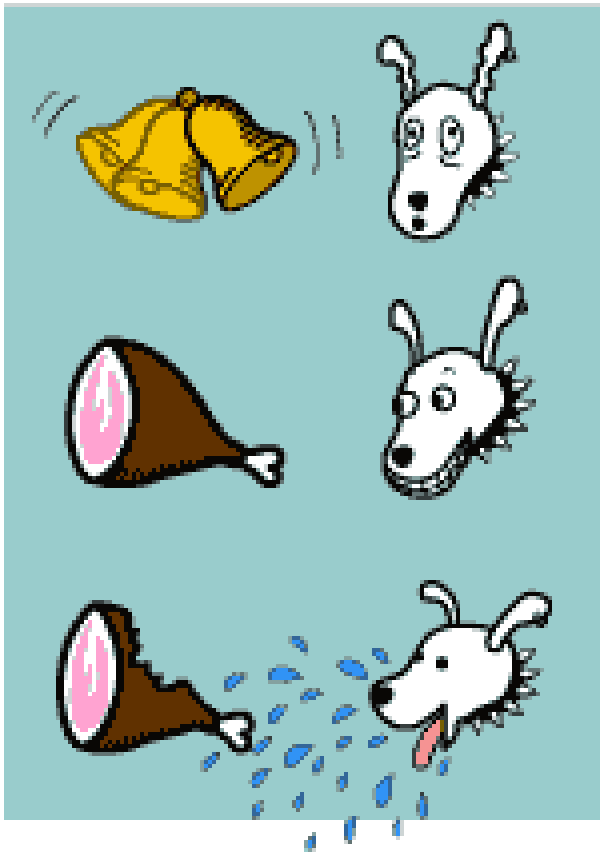
Pavlovian

- Inflexible
- Simple

$$S \longrightarrow E(O) \xrightarrow{a}$$





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- Inflexible
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- By associating stimuli with outcomes, observation of a stimulus will leading to the *expectation of an outcome*, leading to the release of *pre-wired actions.*

- Pavlovian action-selection is sometimes referred to as *survival circuits* and may be related to emotional decision-making.

Schuyler Shepherd, WikiMedia Commons

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The decision-making machine

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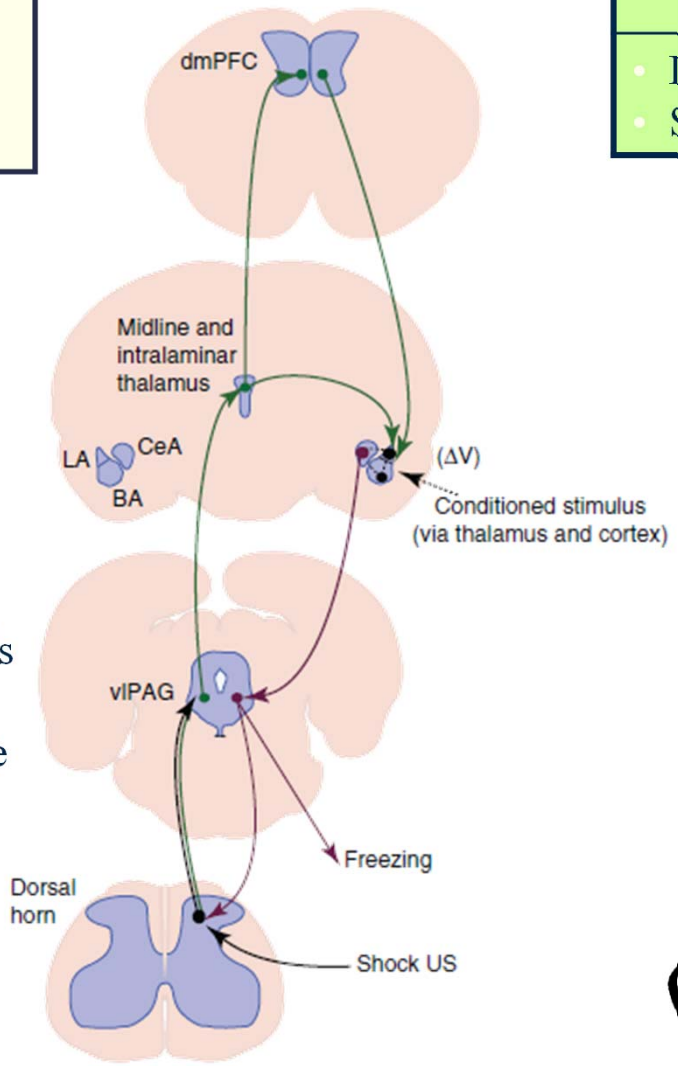

McNally, Johansen, Blair 2011

Pavlovian

- Inflexible
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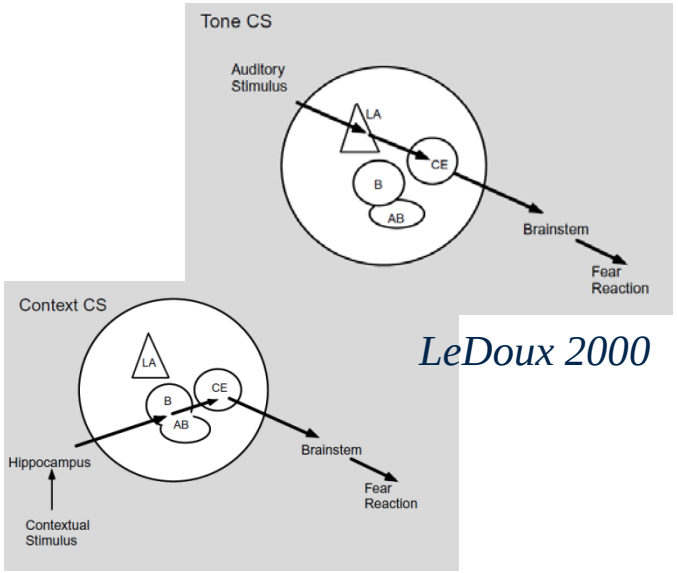
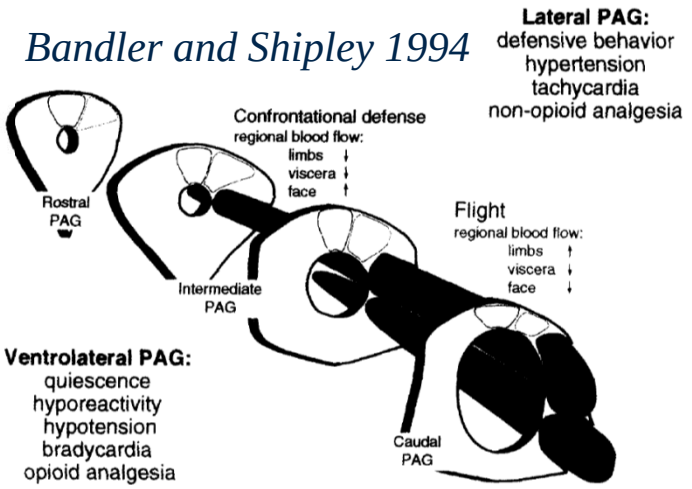
$$S \longrightarrow E(O) \xrightarrow{a}$$



LeDoux 2000

Bandler and Shipley 1994



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Human social interactions

Pavlovian

- Inflexible
- Simple

$$S \longrightarrow E(O) \xrightarrow{a}$$

People with motor cortical damage cannot laugh when told to, but they laugh normally with friends…

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Being watched

Pavlovian

- Inflexible
- Simple

$$S \longrightarrow E(O) \xrightarrow{a}$$

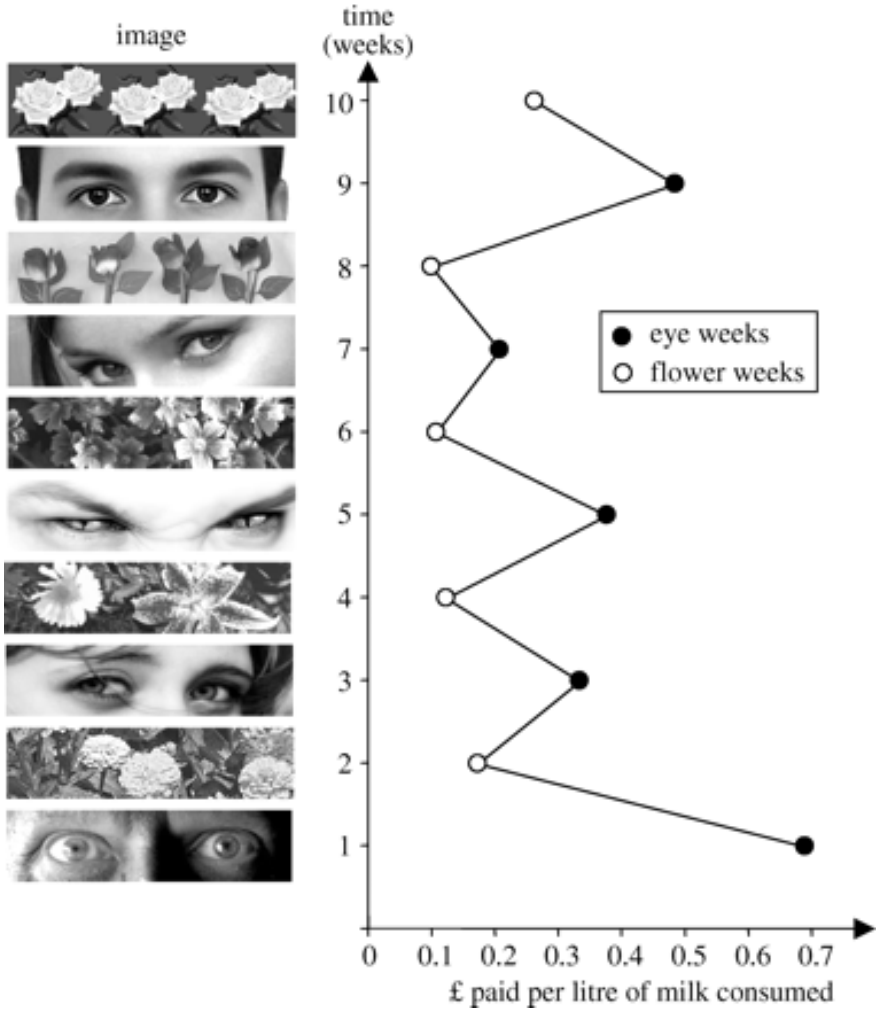
COFFEE CLUB

Prices:

Coffee (with or without milk): 50p
Tea (with or without milk): 30p
Milk only (in your own coffee or tea): 10p
Full cup of milk: 30p

Please put your money in the blue tin.

Thanks, Melissa.



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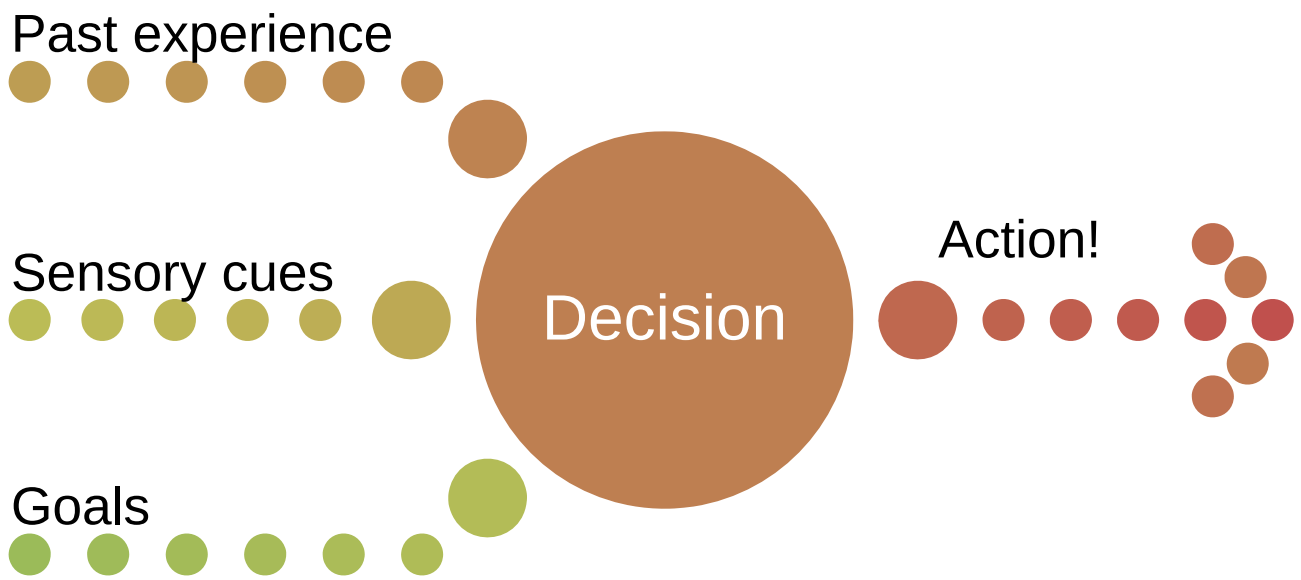


The decision-making machine

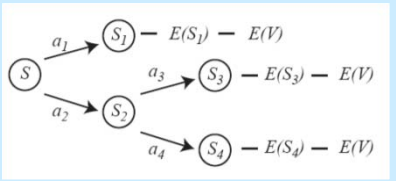
- Deliberative decision-making entails the search through potential future outcomes.

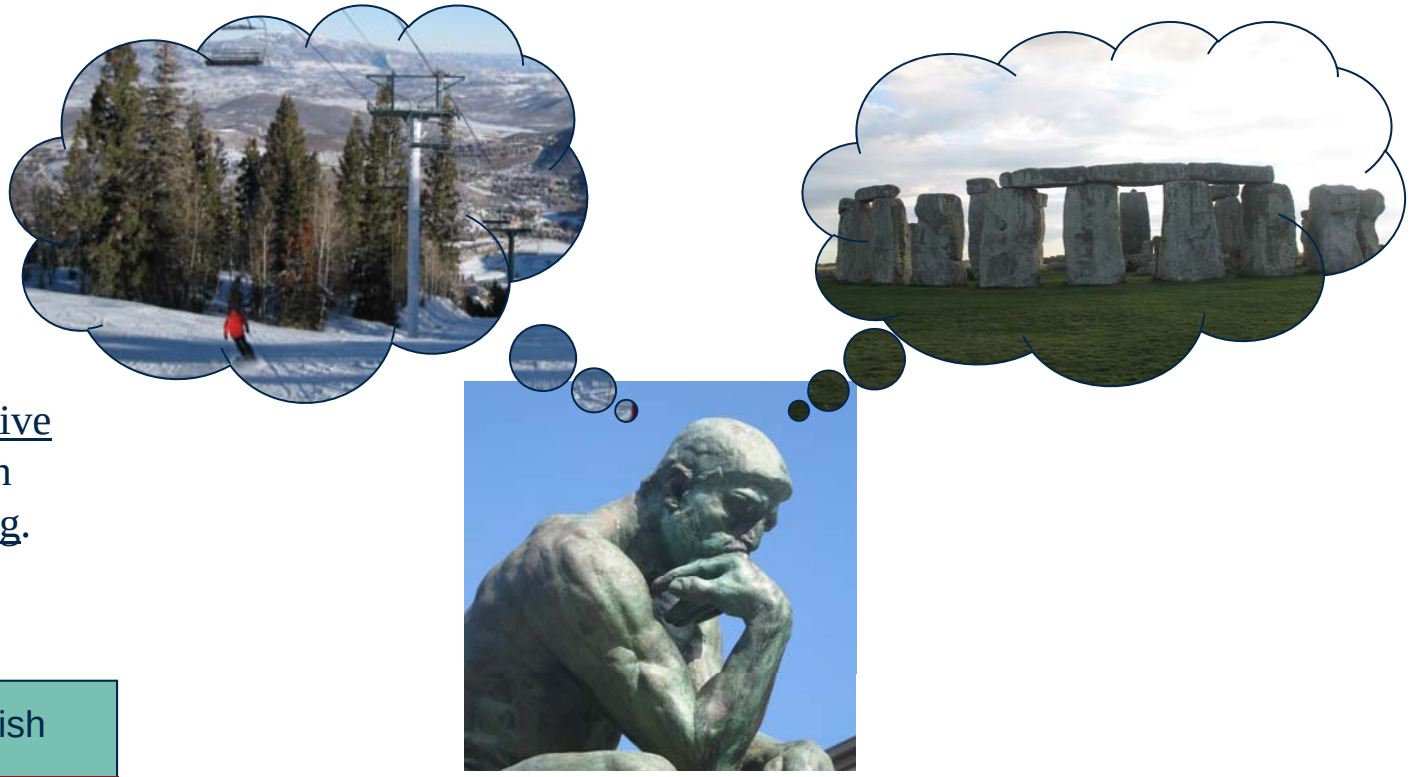
- This is a cognitive, computationally-intensive process that depends on episodic-future-thinking.

Deliberative

Calculated by a search process, that creates expectancies, and evaluates them on-line

- Flexible
- Slow to execute





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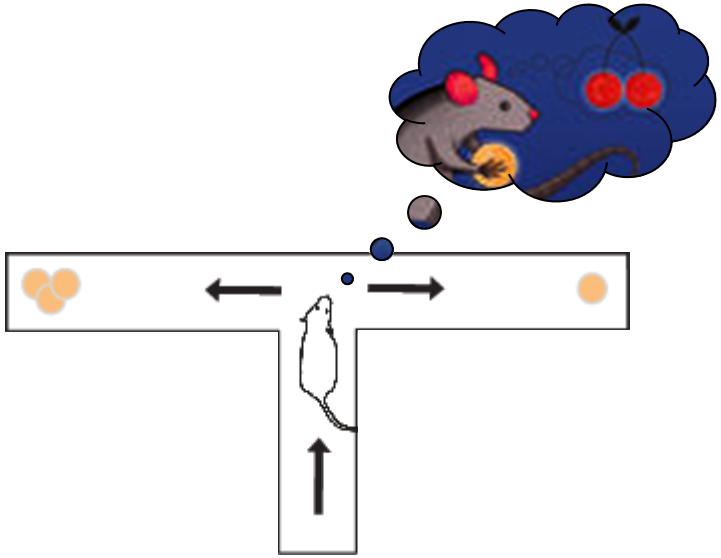
VTE and deliberation

Planning and deliberation

Redish (2016) Nature Reviews Neuroscience

VTE is creation of an imagined scenario that is passed to evaluation structures.

VTE reflects indecision.



Prefrontal Cortex

Hippocampus

World Model, search process

Ventral Striatum

Model evaluator

Computational processes of deliberation

Deliberation is a creation of a simulated world that is then evaluated by normal motivational systems.

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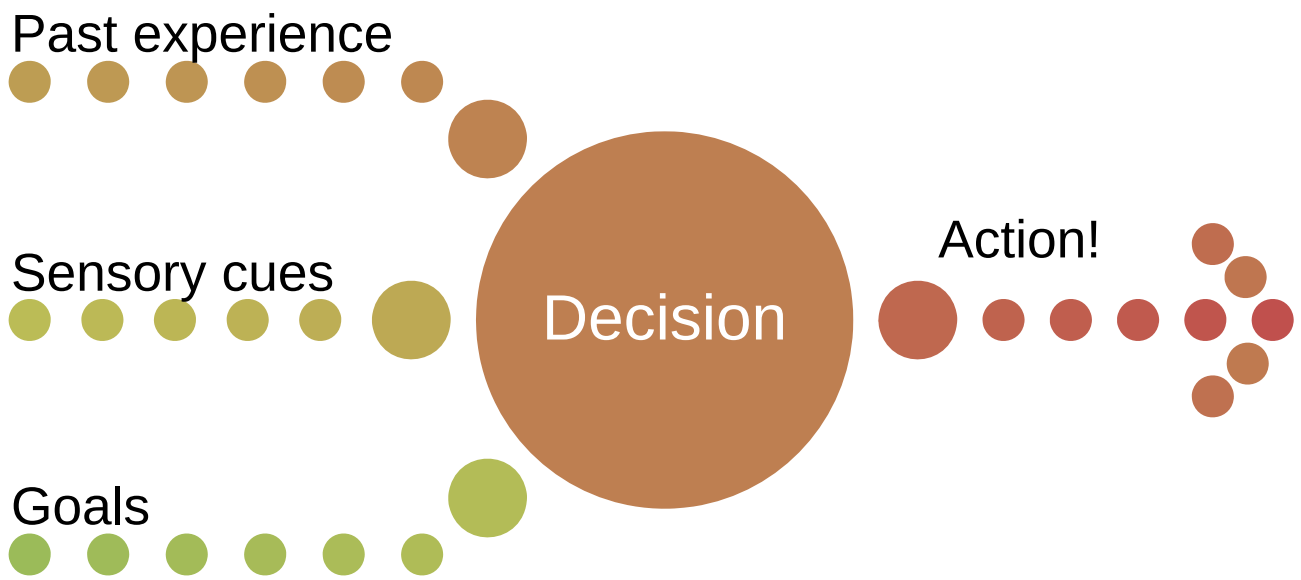


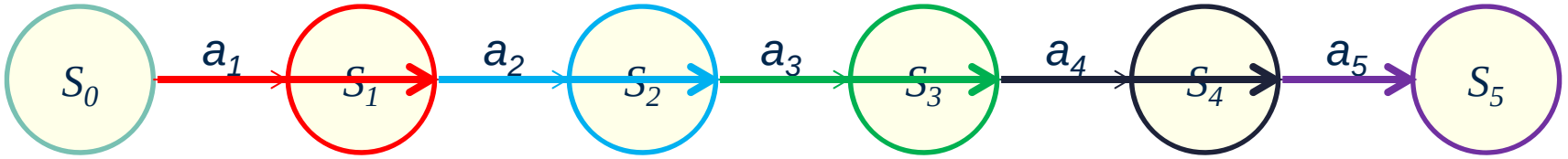
Procedural actions learn to release an action sequence in a given situation.

The decision-making machine

Procedural

Associates action-sequences with situations

- Inflexible
- Fast to execute
- Learned slowly



Mao Asada performing a triple axle jump

- One can associate a value with each *situation* (thus caching the value)
- Or one can associate an action with each *situation* (thus caching the action)

- Procedural learning puts all of the work into the recognition of the situation.

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The decision-making machinery

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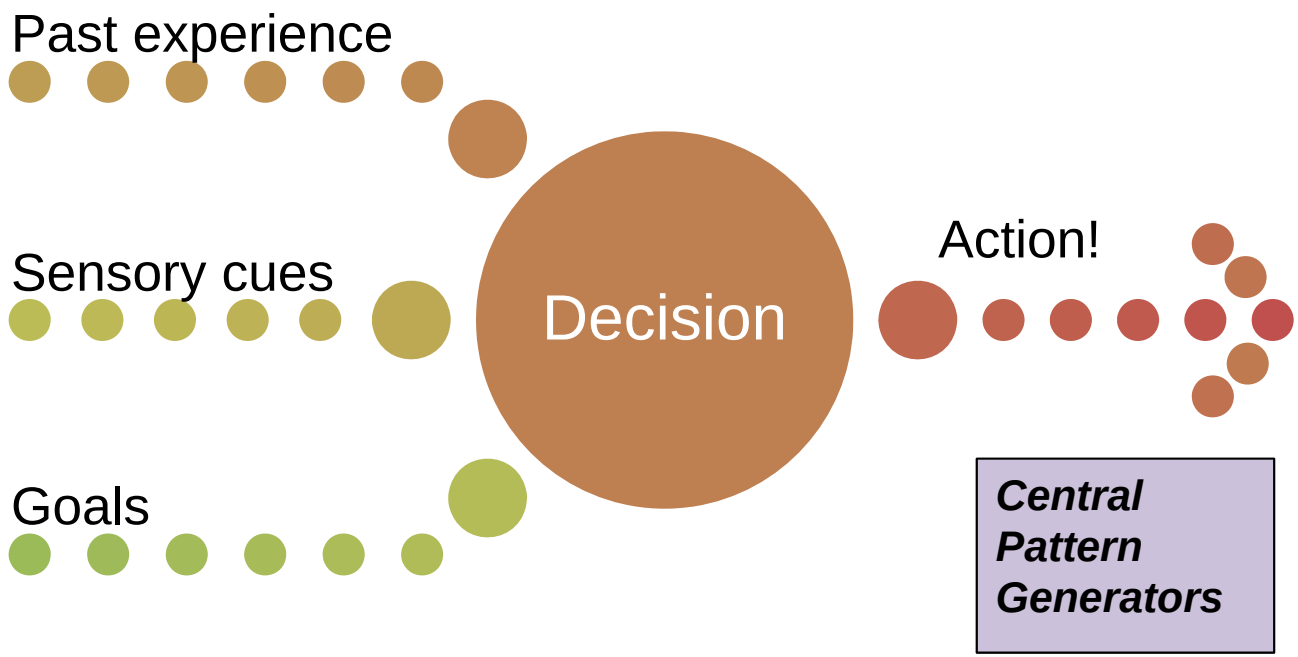
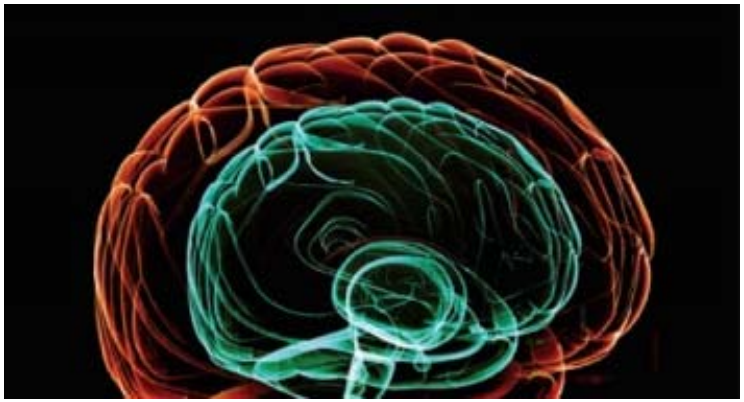
Procedural (habits): cached action-chain sequences.

Situation-recognition and schemas



We are many



Do I contradict myself?
Very well then I contradict myself,
(I am large, I contain multitudes.)

- Walt Whitman (Song of Myself)

Reflexes

Pavlovian action-selection systems

Deliberative action-selection

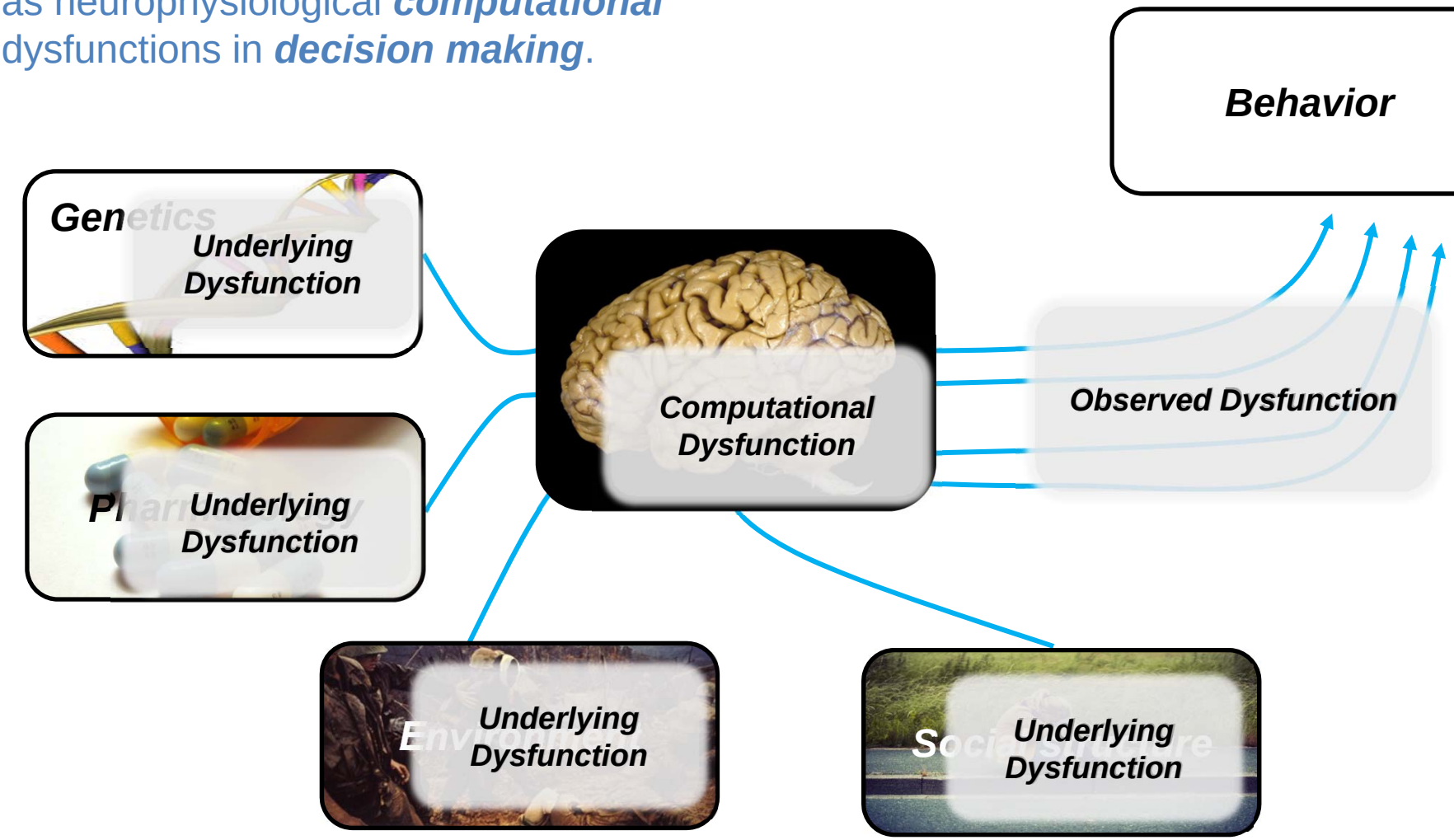
Procedural action selection

This means we will do better if we select the right system at the right time.

Why neurophysiology matters

We need to understand **how** decision-making works to begin to understand how it can go wrong.

This suggests a new view on psychiatry as neurophysiological ***computational*** dysfunctions in ***decision making***.



Questions to think about

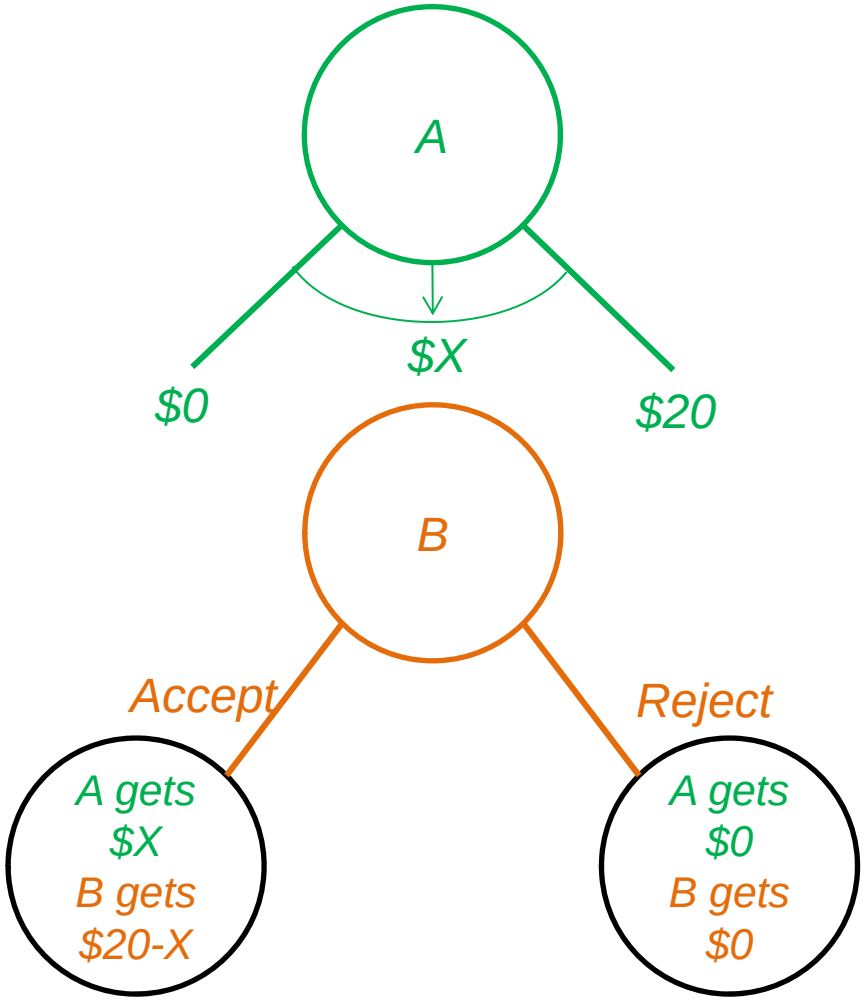
We don't think about our actions… until our actions change.

The ultimatum game

- Two players: A + B
- Person A has $20 to distribute between person A and B.
- Person B can take it or leave it.

How much do you offer as person A?

How much will you take as person B?



Questions to think about

Why is morality Pavlovian?

SMBC (Zach Weiner)

Questions to think about

How does a quarterback decide to throw a pass?

Ben Rothlisberger, Pittsburgh Steelers

Why memory?

To change our future actions.

Memory is only useful if it changes our future.

The decision-making machinery

Reflexes: prewired responses to stimuli.

Pavlovian (emotional): learning the situation to release prewired actions.

Deliberation: search and evaluate potential consequences.

Procedural (habits): cached action-chain sequences.

Situation-recognition and schemas