Computational cognitive modeling - Spring 2020

NYU PSYCH-GA 3405.002 / DS-GA 1016

Instructors: Brenden Lake and Todd Gureckis

Teaching Assistants: Yanli Zhou and Graham Flick

Meeting time and location:
We have a "flipped classroom" model for lecture
Lecture is pre-recorded and available on Vimeo
Live discussion is on Mondays 1:35-2:35 PM

Lab
Tuesdays 2:40-3:30 PM
Access via the Zoom link in NYU Classes

Course numbers:
DS-GA 1016 (Data Science)
PSYCH-GA 3405.002 (Psychology)

Contact information and Piazza:
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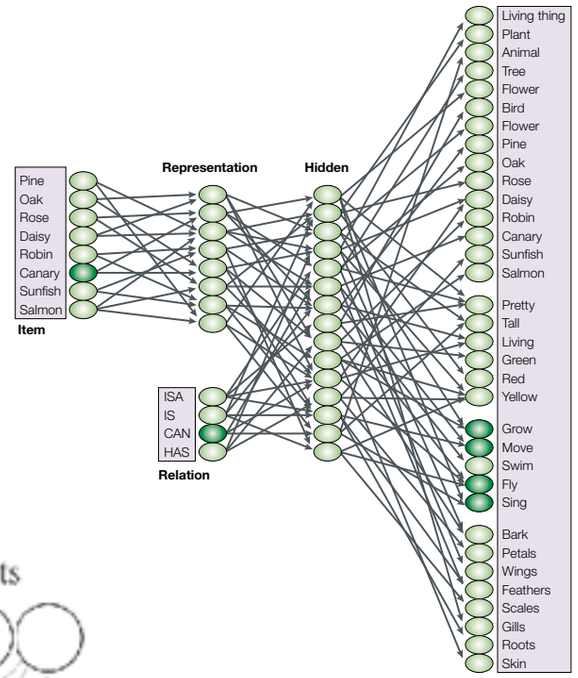
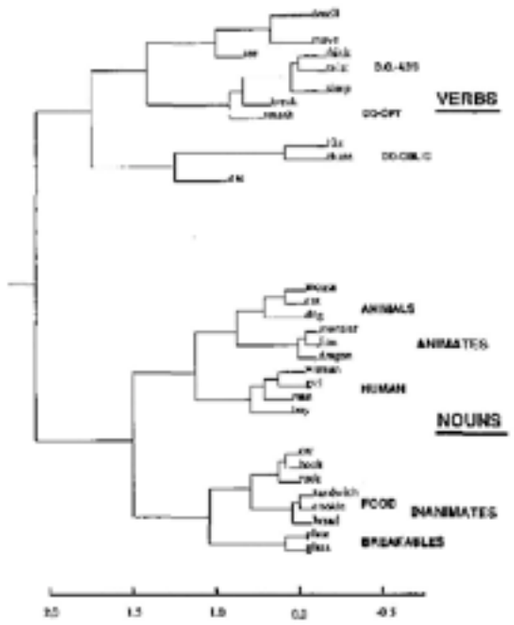
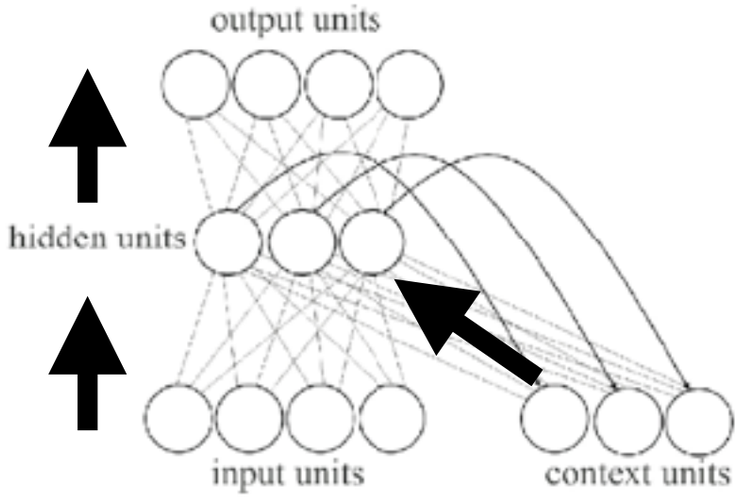
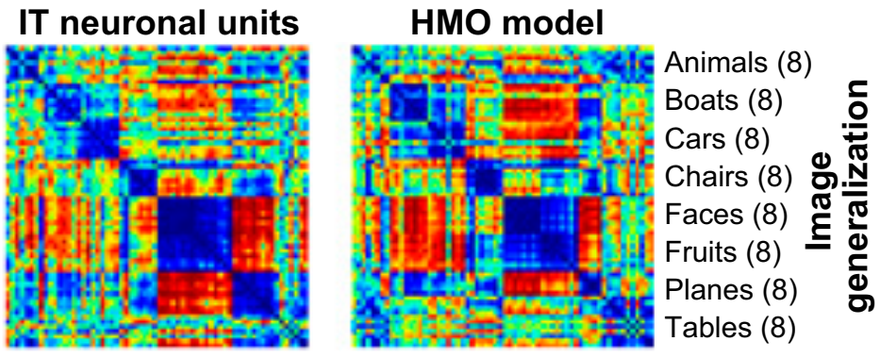
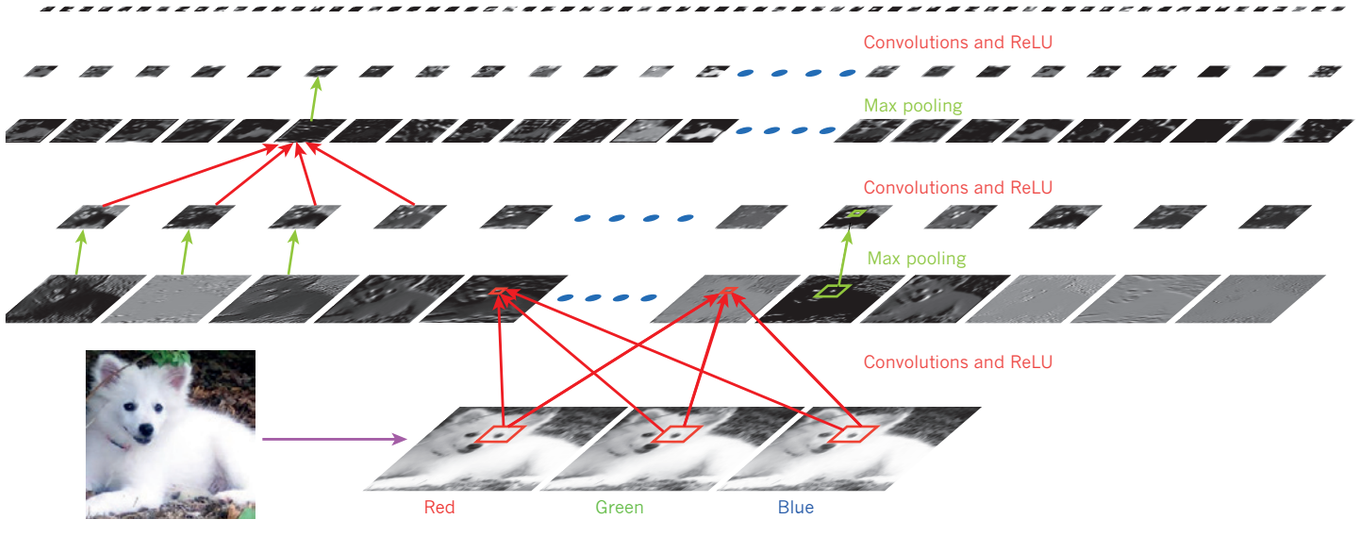
neural networks / deep learning



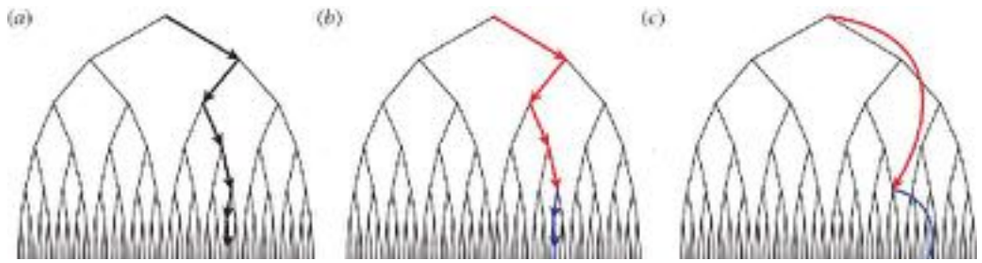


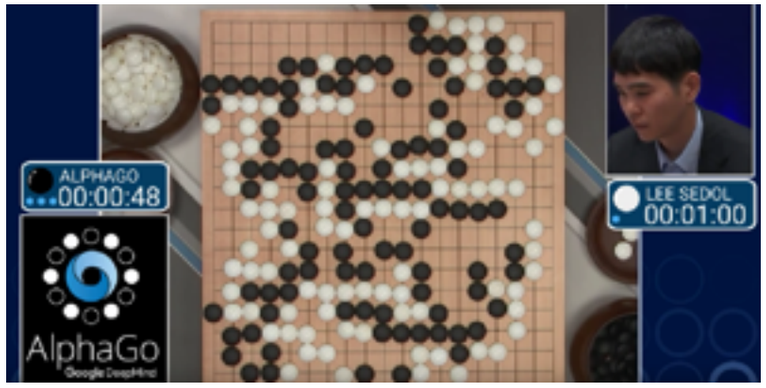


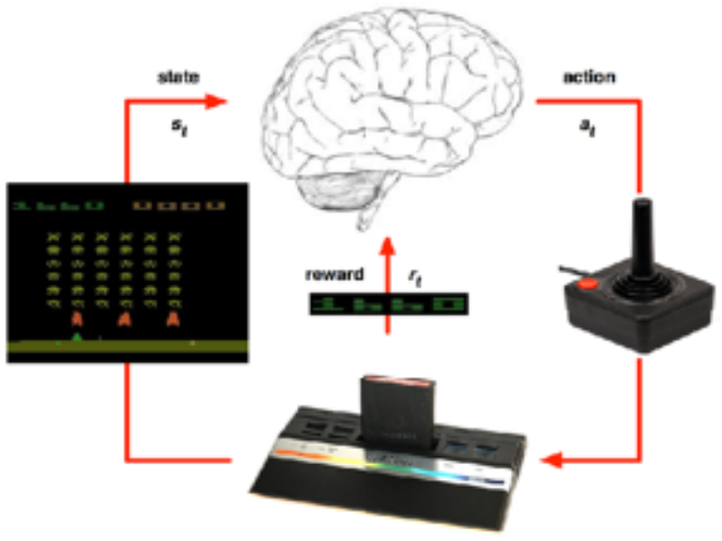


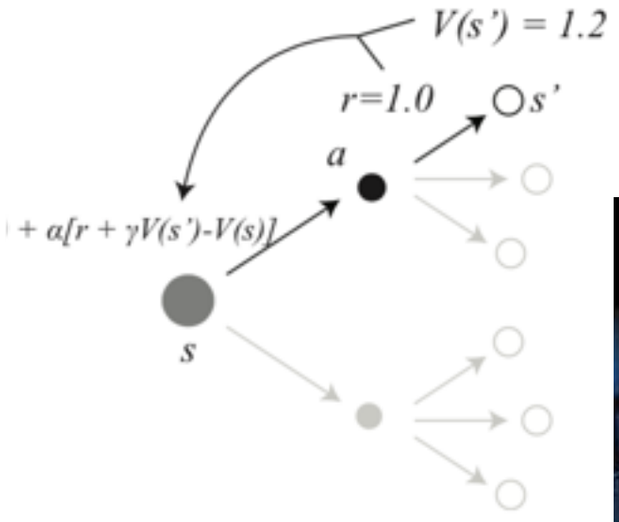


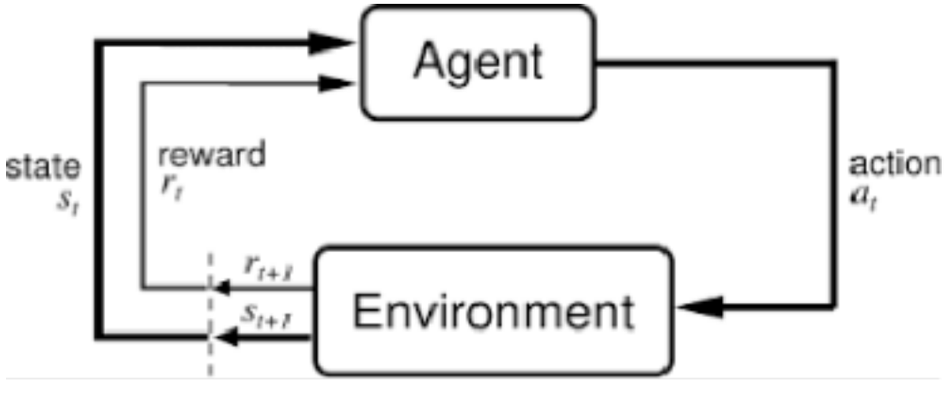
Reinforcement learning









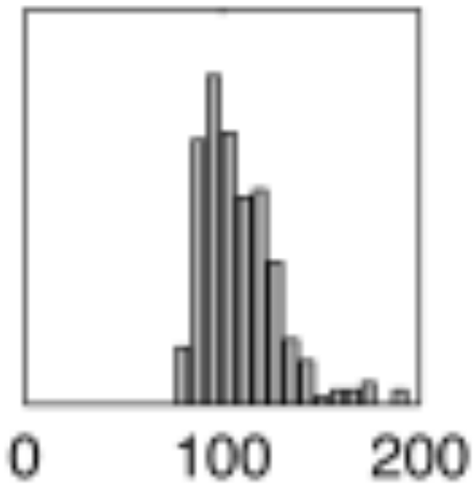


Bayesian modeling

$$P(h|D) = \frac{P(h)P(D|h)}{\sum_{h_i} P(h_i)P(D|h_i)}$$

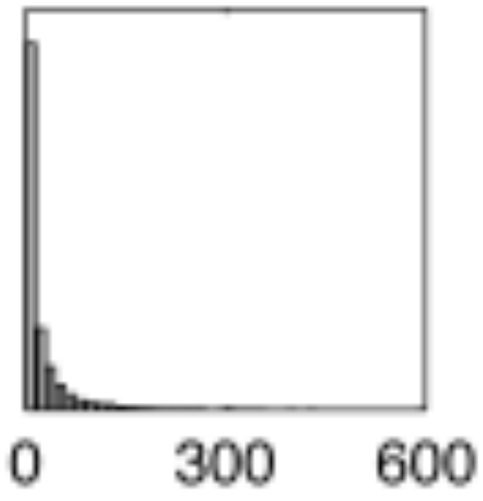
h : hypothesis D : data

Movie runtimes (Gaussian)

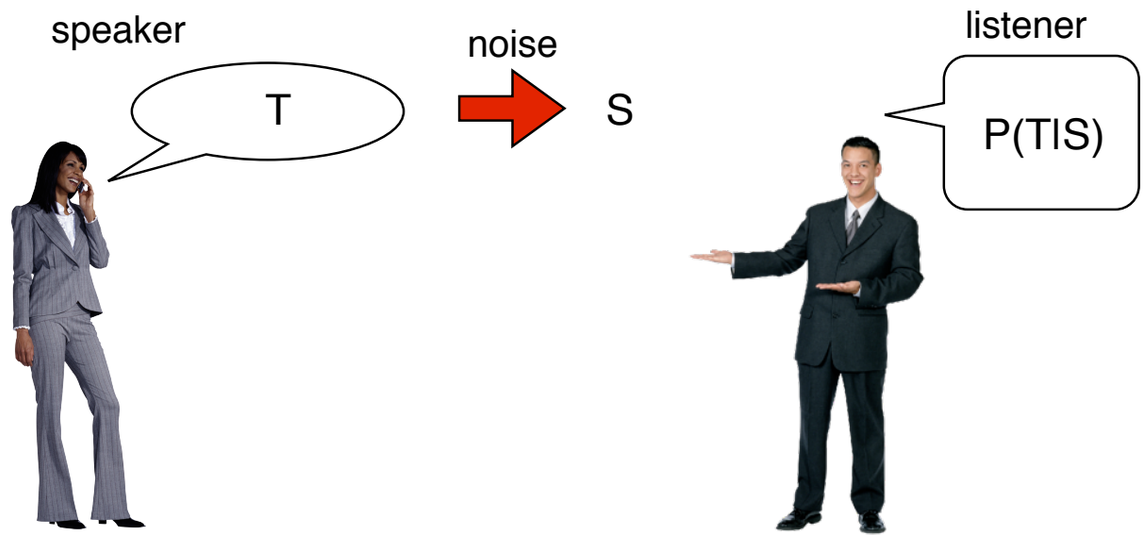


t_{total}

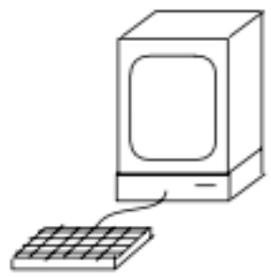
Movie grosses (Power-law)



t_{total}



1 random "yes" example:

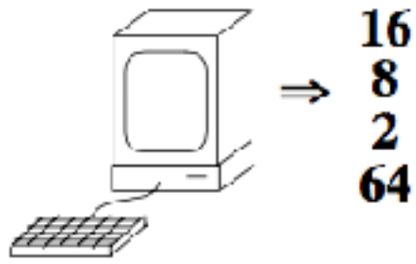


⇒ **16**

Which numbers will be accepted by the same computer program?

15? 128?

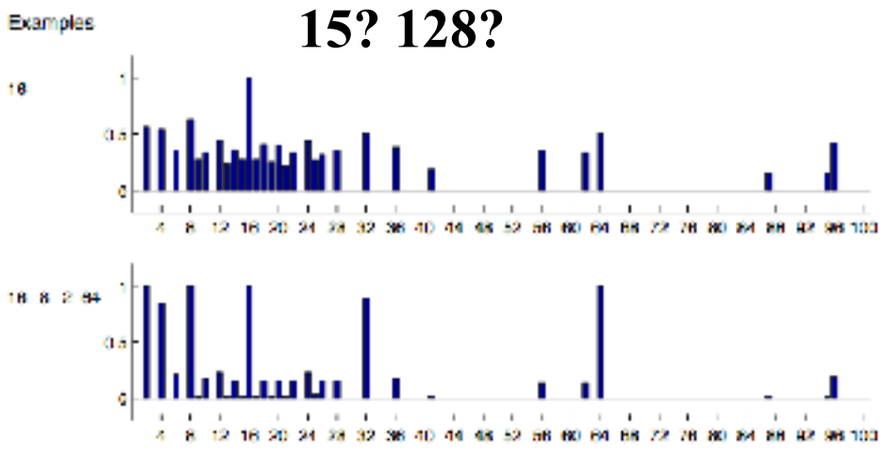
4 random "yes" examples:



16
8
2
64

Which numbers will be accepted by the same computer program?

15? 128?



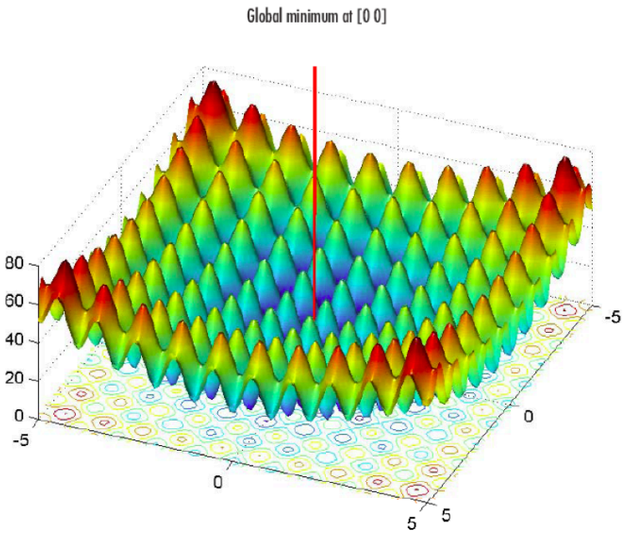
Model fitting, evaluation, and comparison

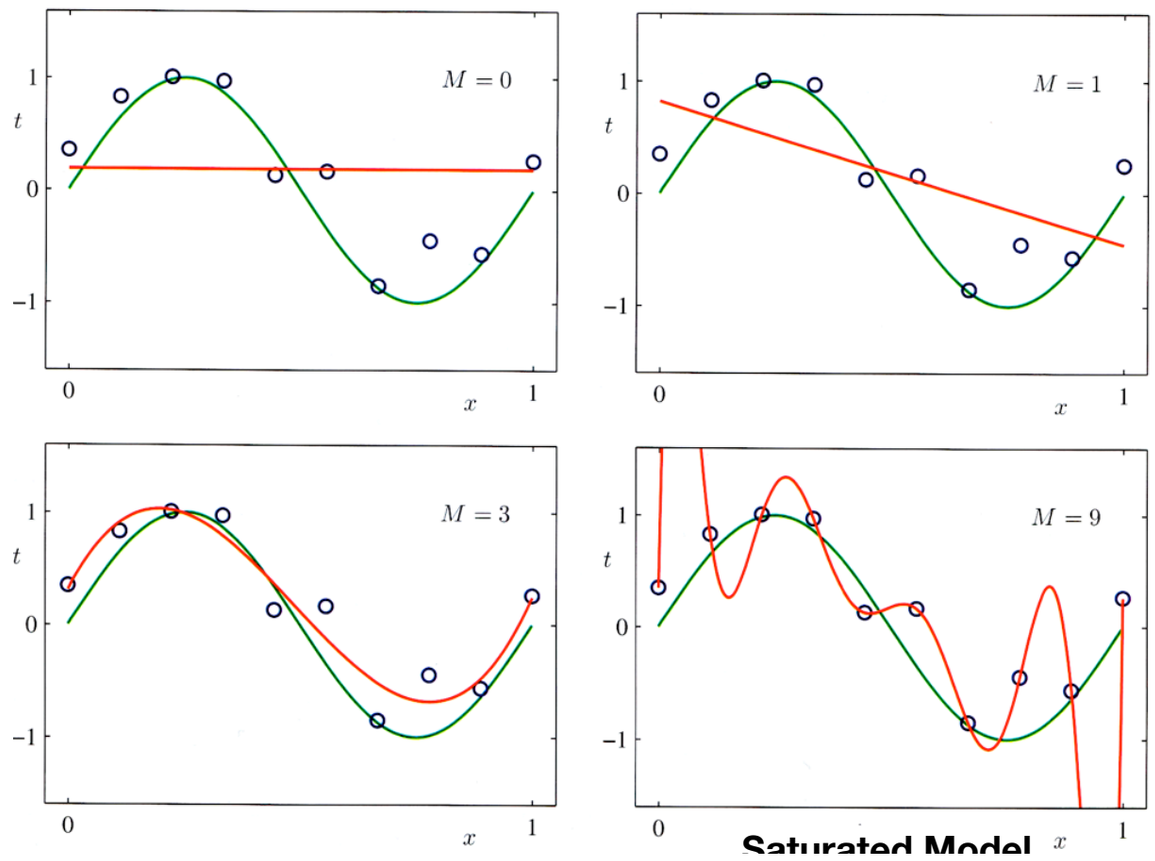
- Akaike's Information Criterion (AIC)

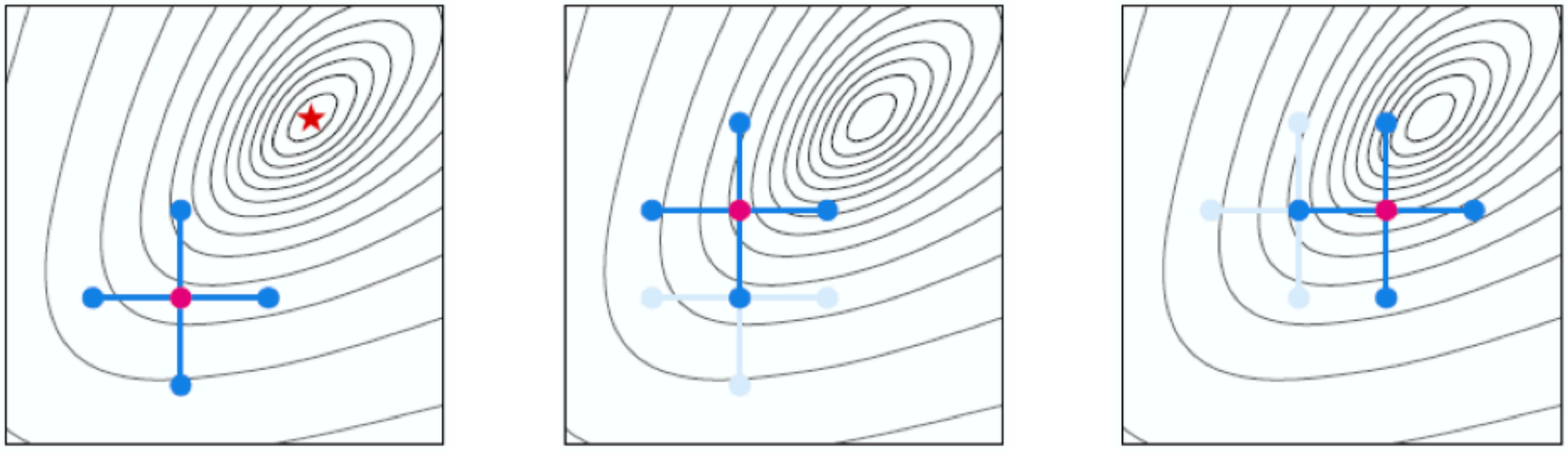
$$AIC = -2lnL(\theta|u, M) + 2K$$

- Bayesian Information Criterion (BIC)

$$BIC = -2lnL(\theta|u, M) + KlnN$$







(a) Initial pattern (b) Move North (c) Move West

classification and category learning

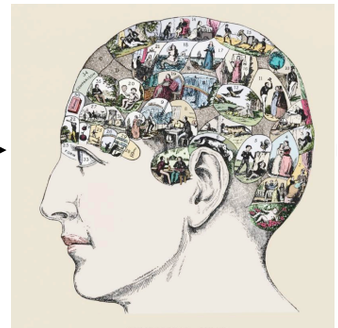
the human cognition framework

What is the function y = f(x) that best characterizes how people make categorization decisions?

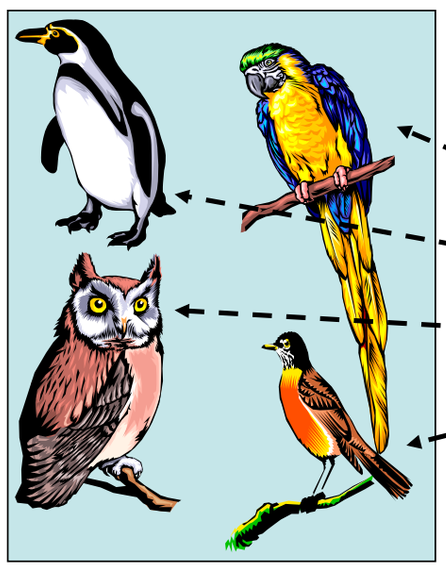
$$y = f(\mathbf{x})$$

output — prediction function — Image feature

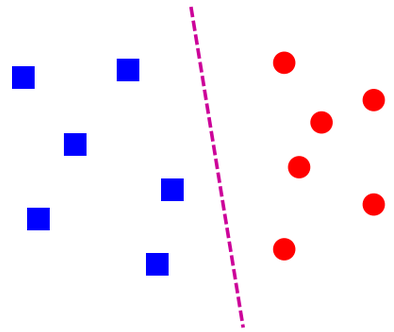
x_0	x_2	x_3	x_4	x_5	x_6	x_7
0	0	0	1	0	0	0
0	1	0	0	1	0	1
1	0	0	1	0	0	0
1	1	1	1	0	1	1



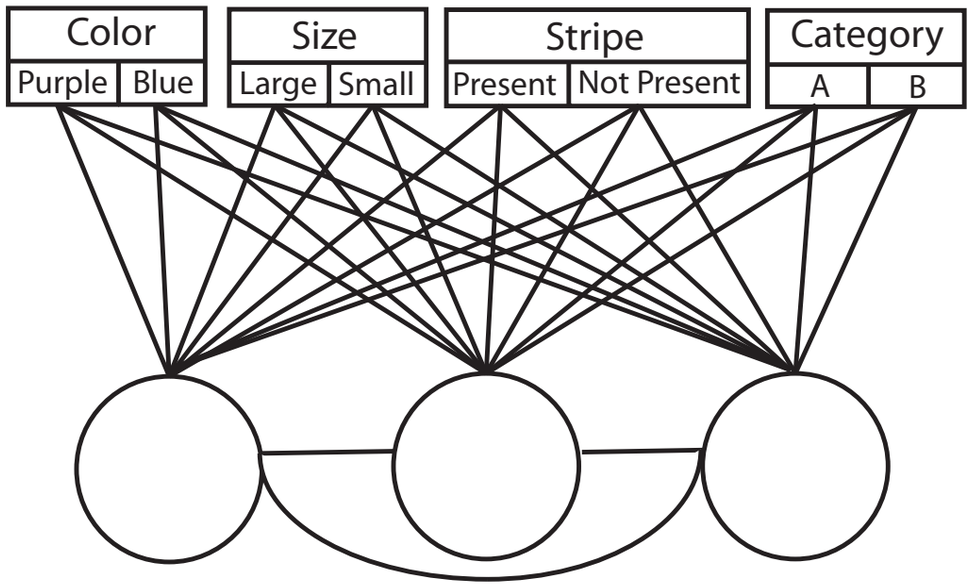
y
0
0
1
1

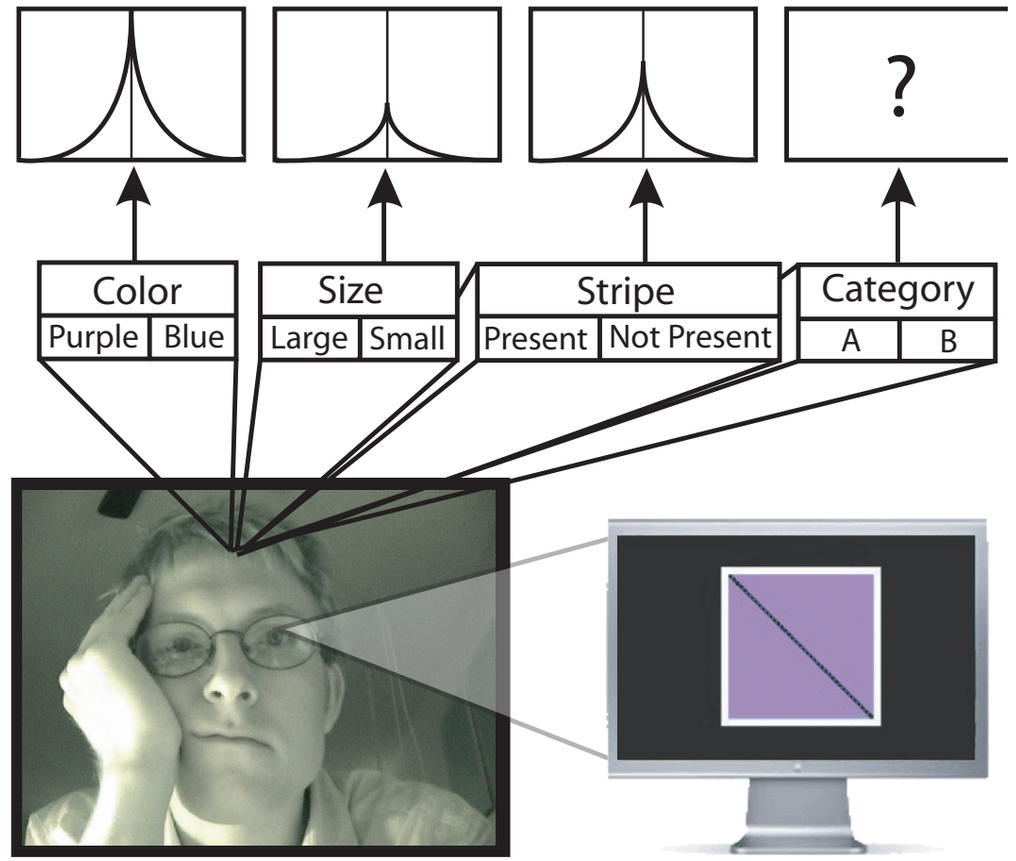


Birds
You've Seen

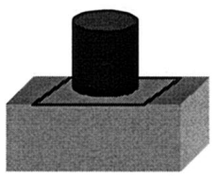


Bird?

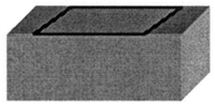




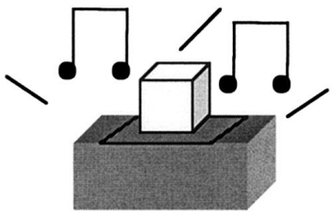
Probabilistic graphical models



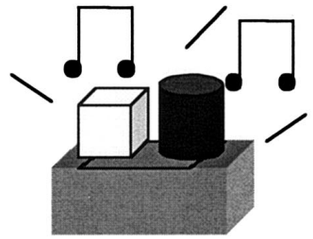
Object B is placed on the detector and nothing happens



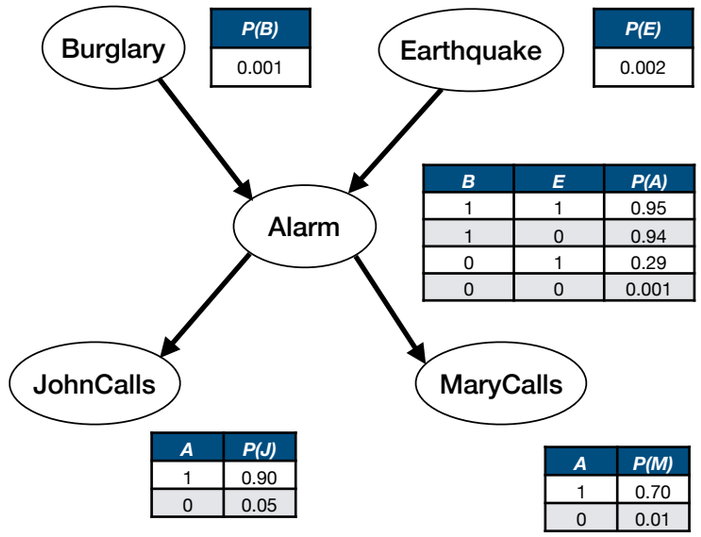
Object B is removed

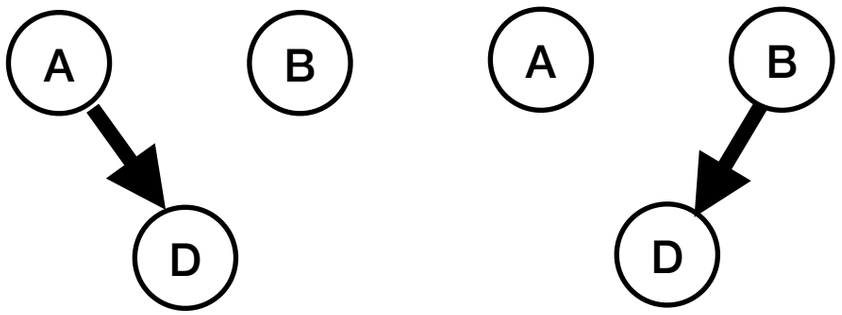


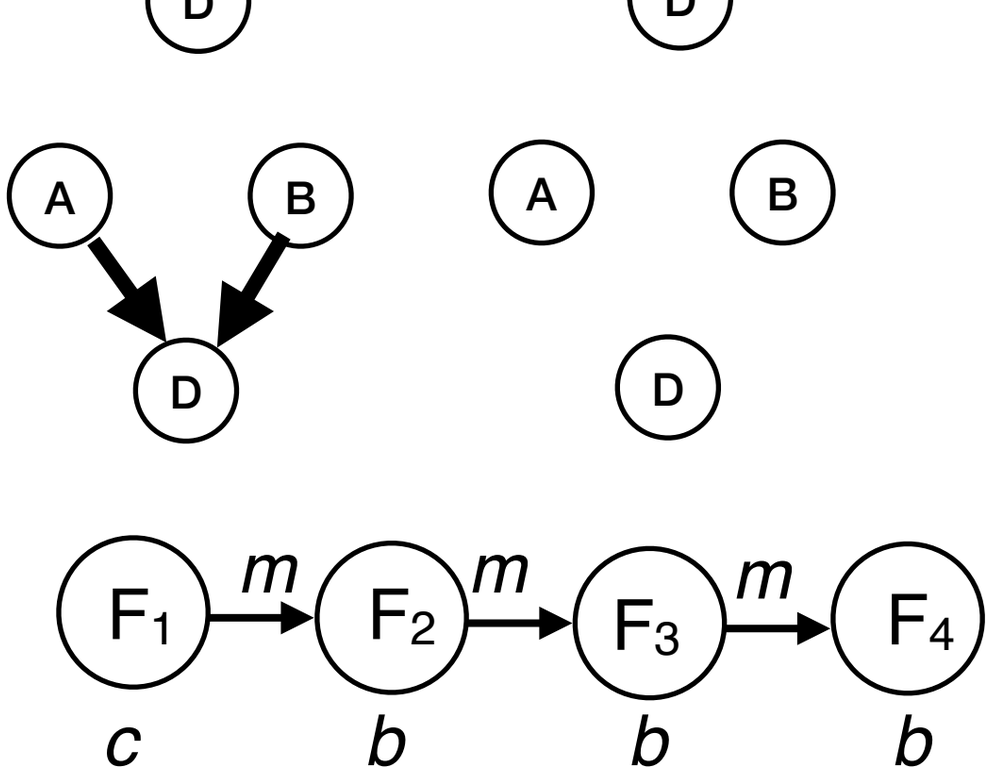
Object A is placed on the detector by itself and the detector activates

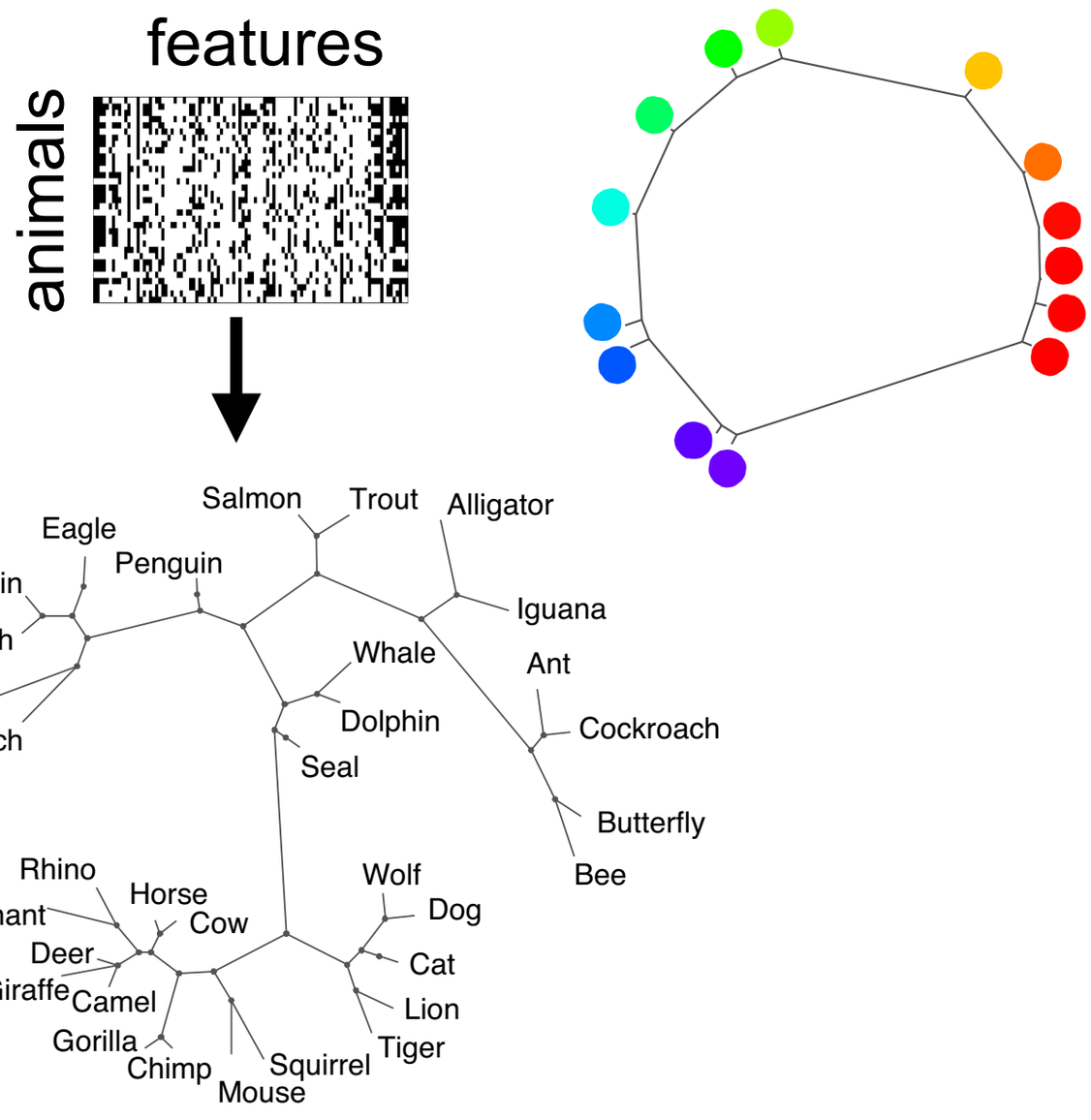


Object B is added to the detector with Object A. The detector continues to activate. Children are asked to make it stop

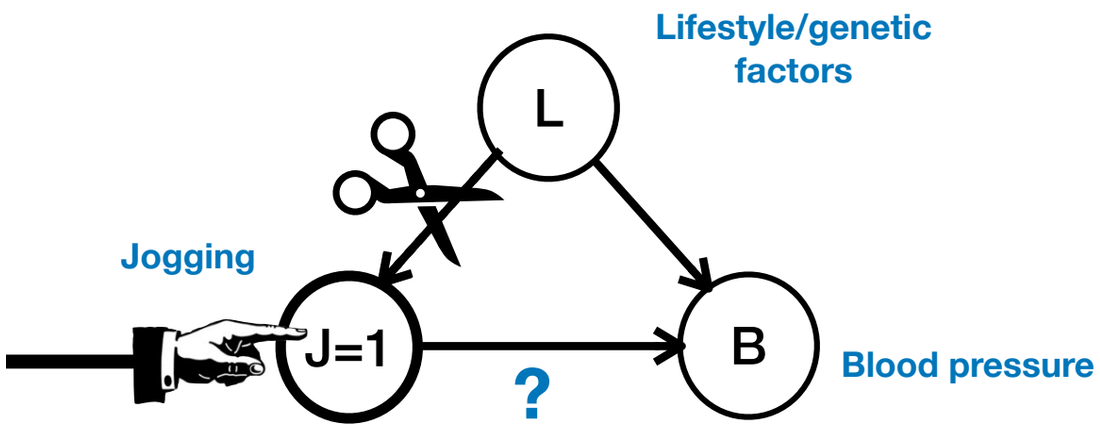




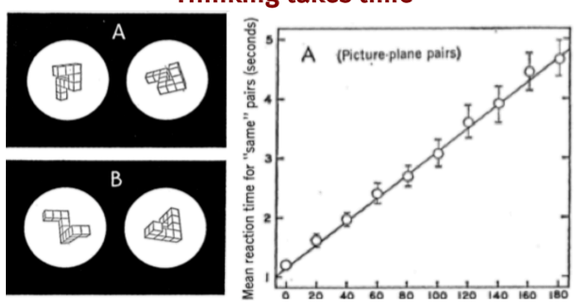




Information sampling and active learning

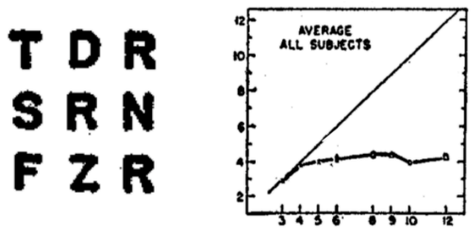


Thinking takes time



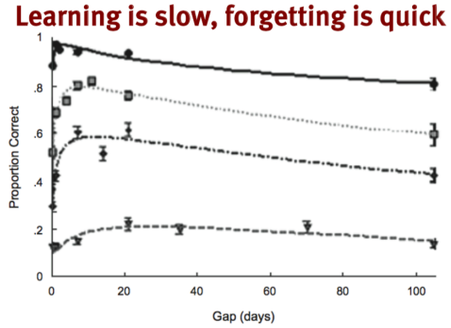
Shepard & Metzler (1971)

Memory stores are limited



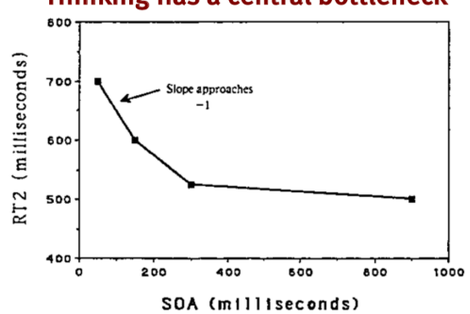
Sperling (1960)

Learning is slow, forgetting is quick

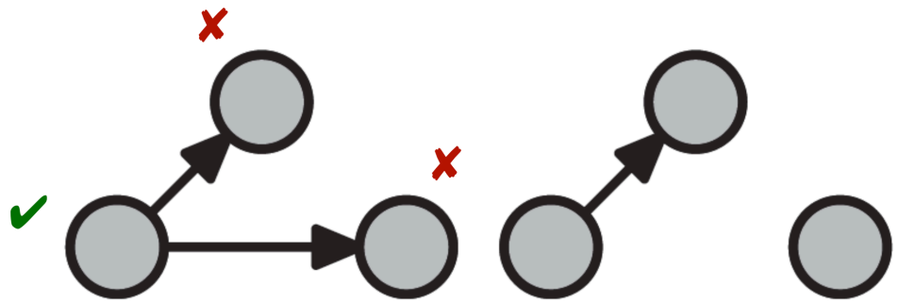


Cepeda, Vul, Rohrer, Wixted, Pahler, 2008

Thinking has a central bottleneck

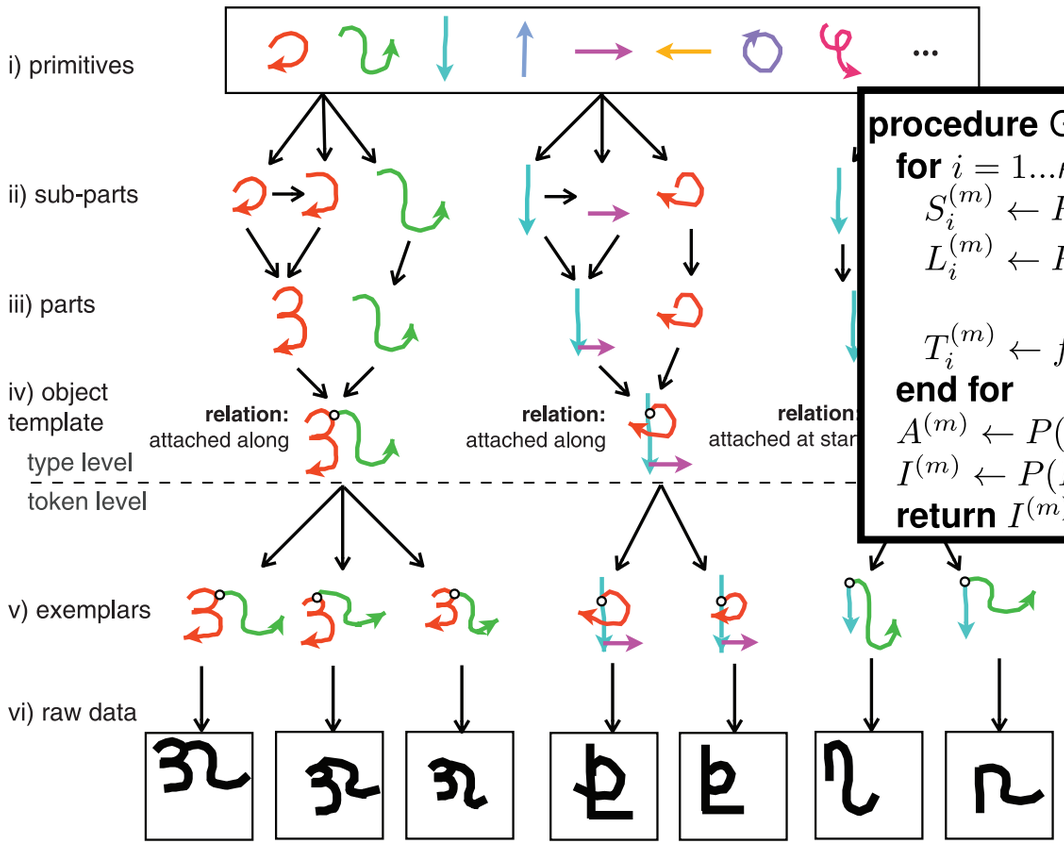


Pashler (1994)

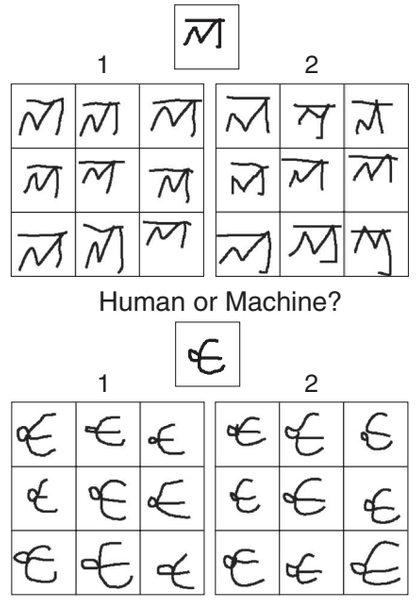


Which would you intervene on?

Probilistic programs and program induction

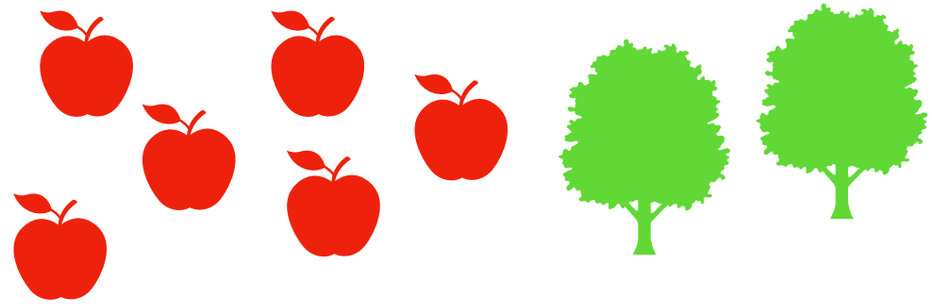


procedure GENERATETOKEN(ψ)
  for $i = 1...\kappa$ **do**
    $S_i^{(m)} \leftarrow P(S_i^{(m)}|S_i)$ ▷ Add motor variance
    $L_i^{(m)} \leftarrow P(L_i^{(m)}|R_i, T_1^{(m)}, ..., T_{i-1}^{(m)})$
      ▷ Sample part's start location
    $T_i^{(m)} \leftarrow f(L_i^{(m)}, S_i^{(m)})$ ▷ Compose a part's trajectory
  end for
  $A^{(m)} \leftarrow P(A^{(m)})$ ▷ Sample affine transform
  $I^{(m)} \leftarrow P(I^{(m)}|T^{(m)}, A^{(m)})$ ▷ Sample image
  return $I^{(m)}$

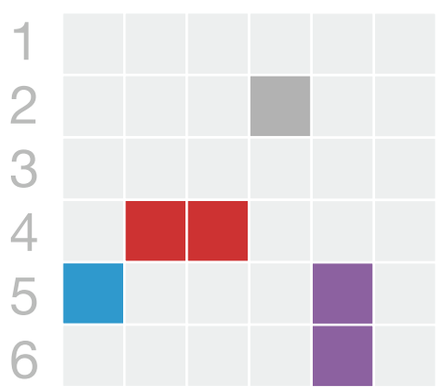


“six”

“two”



$$\lambda\, S\, .\, (if\ (singleton?\ S)$$
$$\text{“one”}$$
$$(if\ (doubleton?\ S)$$
$$\text{“two”}$$
$$undef))$$



What is the top left of all the ship tiles?

```
(topleft (setDifference (set 1A ... 6F) (coloredTiles Water)))
```

Are all the ships horizontal?

```
(all (map (lambda x (== H (orient x))) (set Blue Red Purple)))
```

Are blue and purple ships touching and red and purple not touching (or vice versa)?

```
(== (touch Blue Purple) (not (touch Red Purple)))
```

Open questions

- How does a computationally limited, time constrained, noisy/wet/squishy brain perform sophisticated (probabilistic) inferences?

- How do these noisy/wet/squishy neurons hook up in neural networks and maintain stability and function, even under damage or disease?

- How does the mind and brain learn, represent and reason with rich structural representations (graphs, trees, programs, etc.)? These representations sometimes seems as antithetical to brain processes (e.g., neural networks) but we are on a verge of seeing convergence in approaches.

More open questions

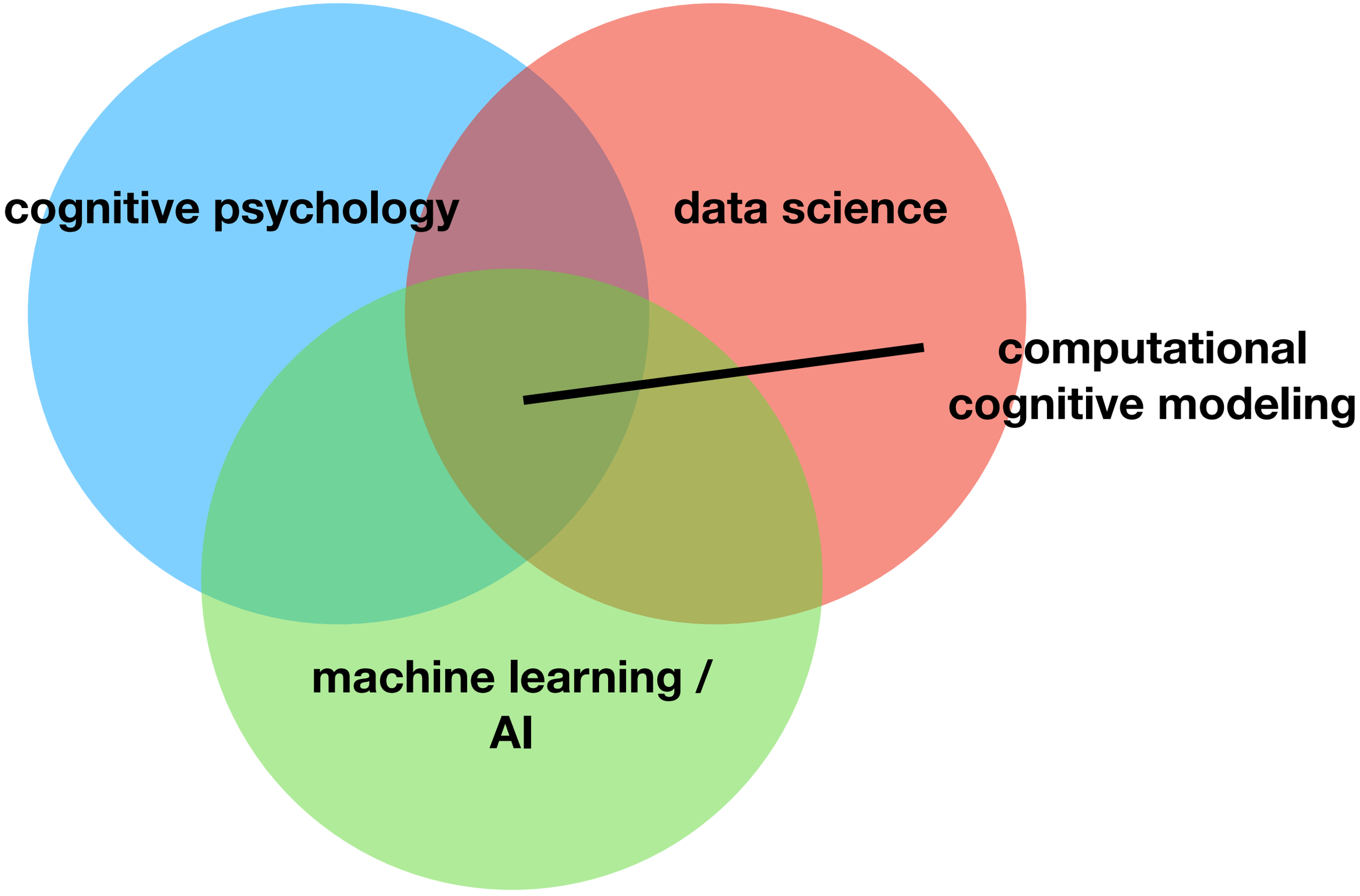
- How can recent advances in AI best advance computational cognitive modeling? How can recent advances in computational cognitive modeling best advance AI?

- Many human abilities lack compelling computational models:

- scene understanding
- language understanding
- creativity
- general purpose problem solving
- learning new video games
- commonsense reasoning, etc.

- How do deep learning, reinforcement learning, Bayesian modeling, graphical models, and probabilistic programming fit together? Is there a unifying computational framework for understanding human intelligence?

- How can understanding the structure of the cognitive system (e.g., the algorithmic or computational level) help us interpret the function and organization of the human brain?


cognitive psychology
data science
computational
cognitive modeling
machine learning /
AI