Reconstructive Memory

By Qiong Zhang for Class 85-426, CMU Spring 2018

Memory help guide our daily decisions

- Should I take a bus or walk to school at 9am?
- Have I watched this movie before?
- How much salt and pepper to put on the breakfast?
- ..

What are the problems we face in memory and their probabilistic nature

- [This class] Reconstructive memory: given blurred memory trace, how to reconstruct original memory as accurately as possible? e.g. Can you draw the Apple logo?

We can infer about it based on some of our experiences.

- [Next class] How does our brain decide whether to retain or forget a piece of memory? e.g. Why you remember better what happened yesterday than a day last week?

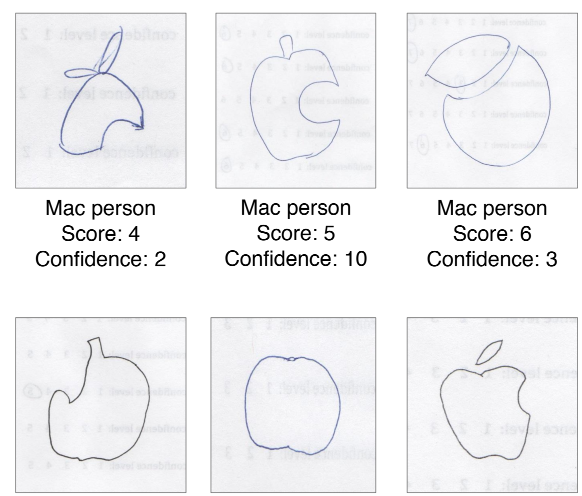
It depends on the probability that we'll need it again.

Can you draw the Apple logo?

Reconstructive memory

- Definition: assembling information from stored knowledge when a detailed memory of specific events does not exist

original stimulus → memory trace → reconstructed stimulus



Mac person
Score: 4
Confidence: 2

Mac person
Score: 5
Confidence: 10

Mac person
Score: 6
Confidence: 3

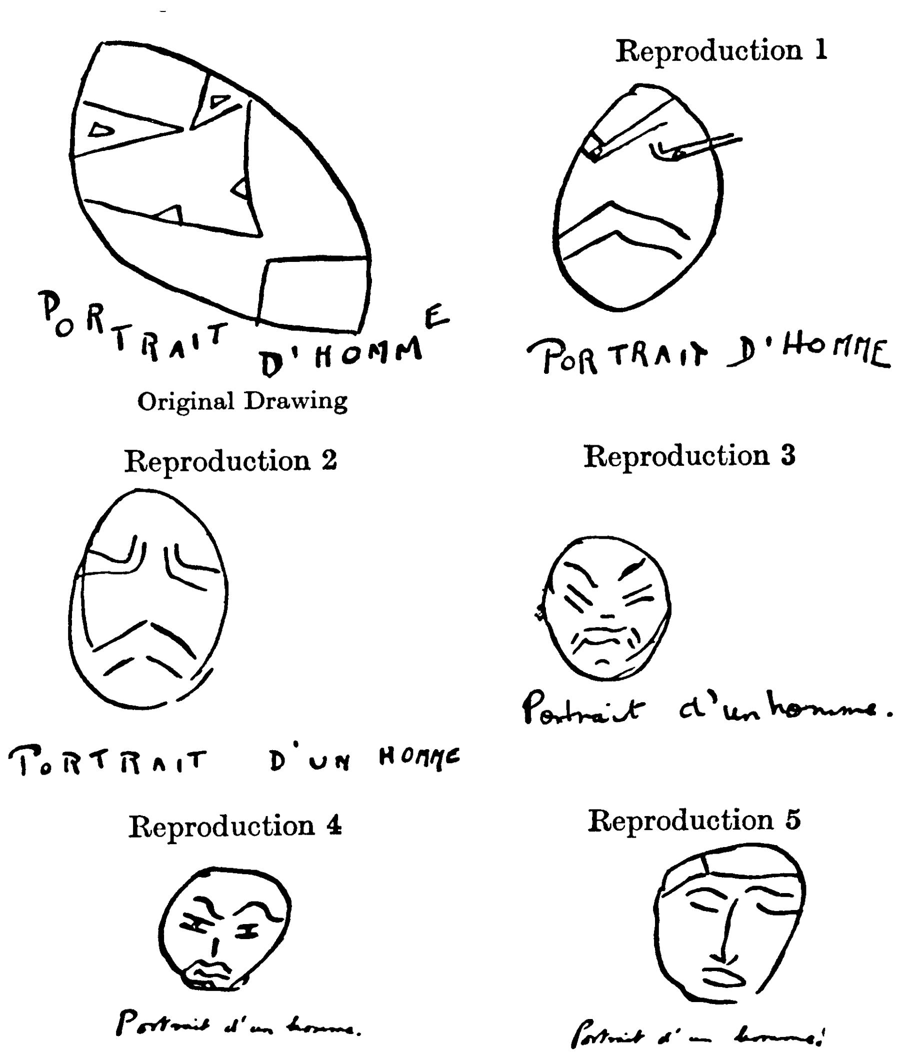
Mac person
Score: 4
Confidence: 2

Mac person
Score: 6
Confidence: 1

Mac person
Score: 14
Confidence: 7

(Blake et al., 2015)

Bias in visual memory: a repeated reproduction task

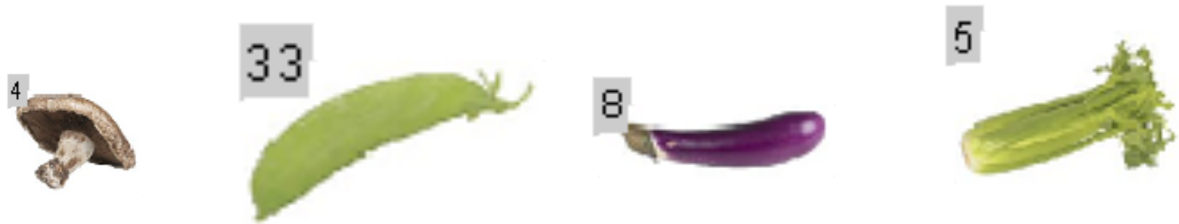


[1] Cf. Philippe, *Rev. Phil.* XLIV, 524.

Adopted from slides from 85426 , 2017

Recall of vegetable size

Study phase



...

P(size|observation) α p(observation|size) p(size)

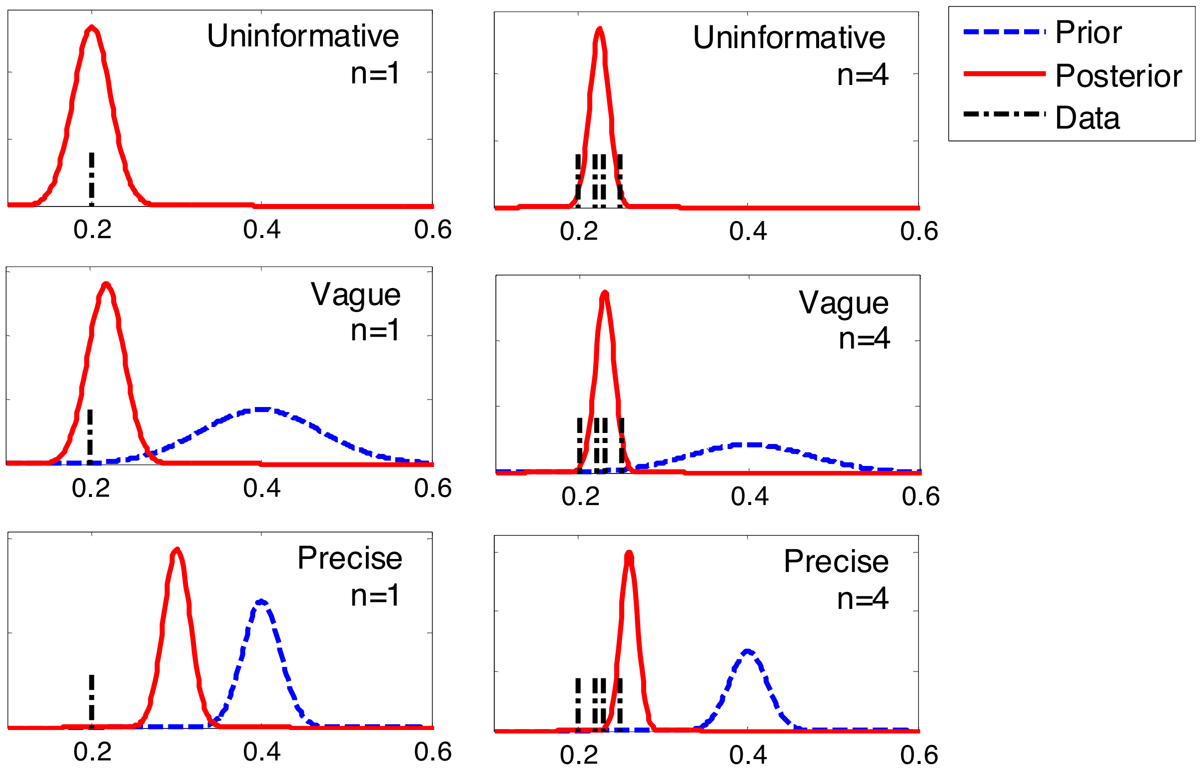
Test phase: what is the size of this vegetable at study?

P(estimated size|actual size) α p(intuitive size| actual size) pi(intuitive size) ,
Pi(intuitive size) is probability of observing a fish that size according to distribution of shown fish sizes

p(size|memory trace) α p(memory trace | size) p(size)

(Hemmer & Steyvers, 2008)

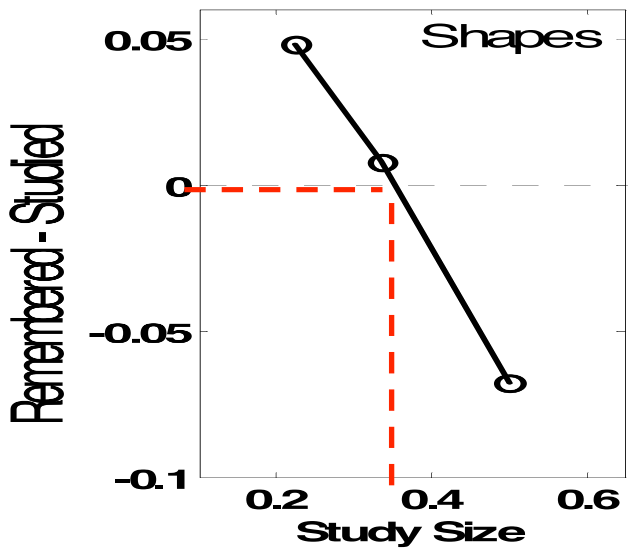
Recall of vegetable size



p(size|memory trace) α p(memory trace | size) p(size)

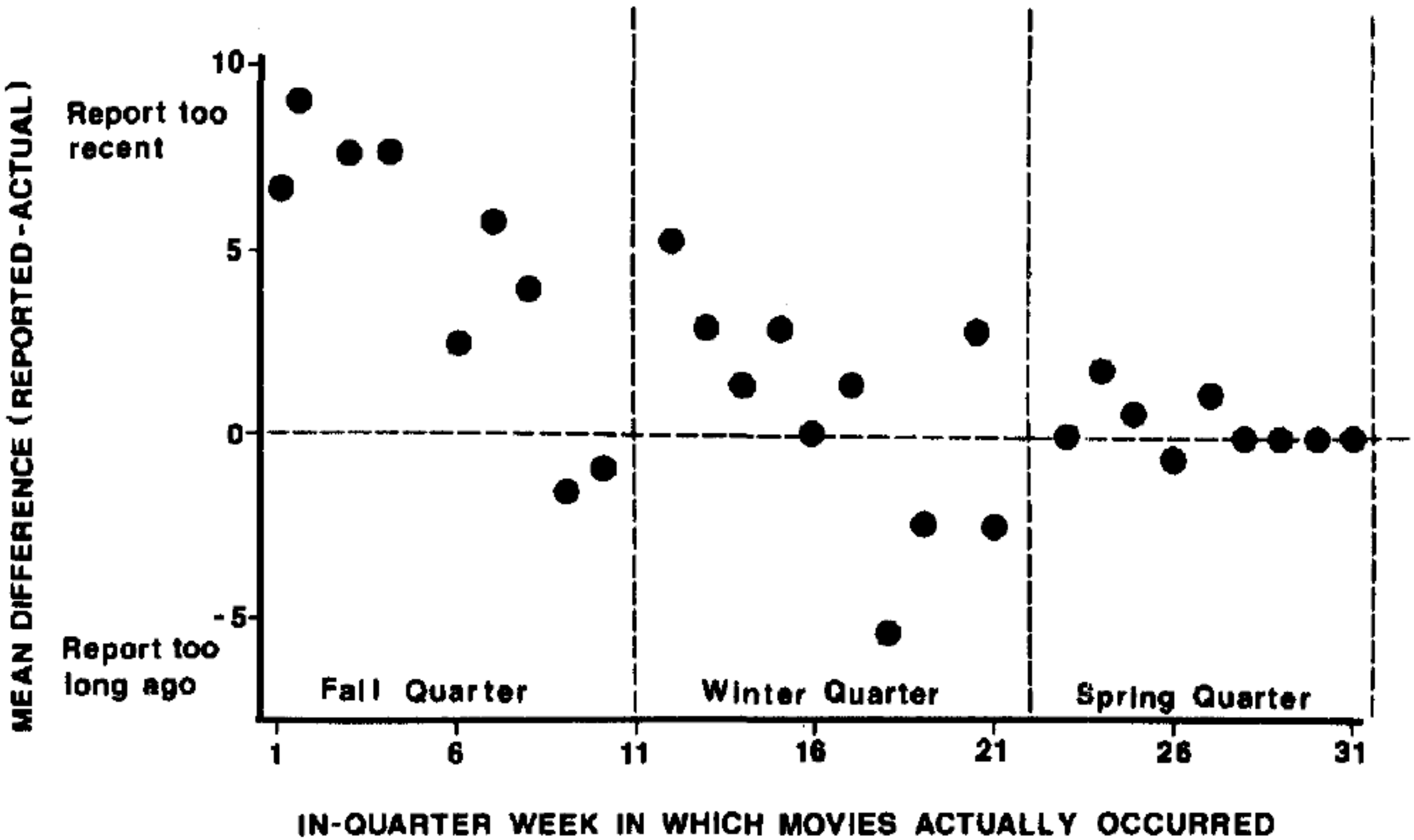
(Hemmer & Steyvers, 2008)

Bias in Recall of mushroom size



(Hemmer & Steyvers, 2008)

Bias in temporal memory



Episodic memory and Semantic memory

- Episodic memory: Personally experienced events (e.g. size of a specific vegetable stimulus studied in an experiment)
- Semantic memory: Facts, data, general information, or world knowledge (e.g. general knowledge of vegetable size)

We just showed that reconstructing episodic memory is biased/influenced by semantic memory:

$p(\text{size}|\text{memory trace}) \propto p(\text{memory trace} \mid \text{size})\, p(\text{size})$

Free recall task: can you remember as many objects as you can in the next picture

By Citobun - BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=61540634

lights

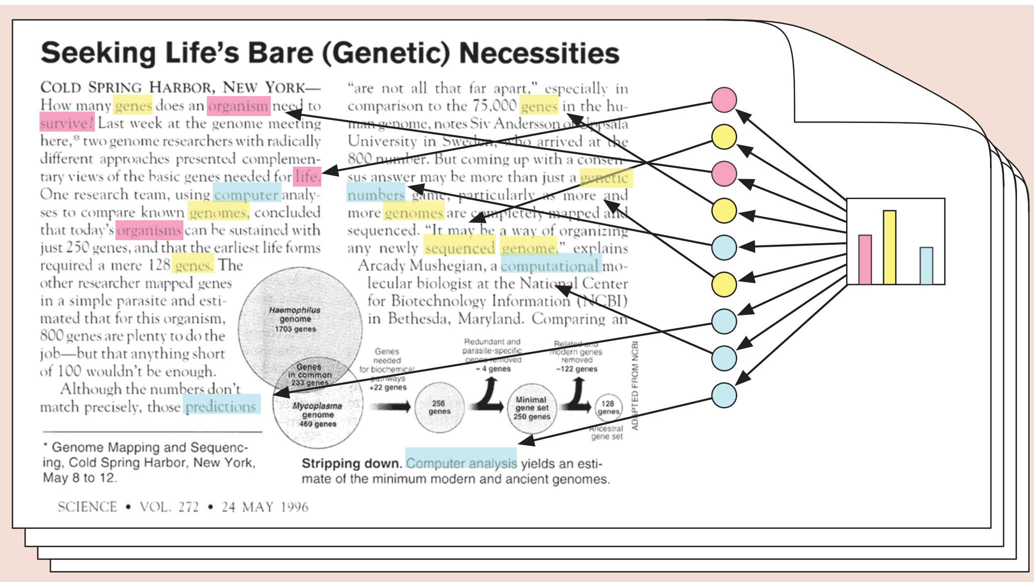
shelf

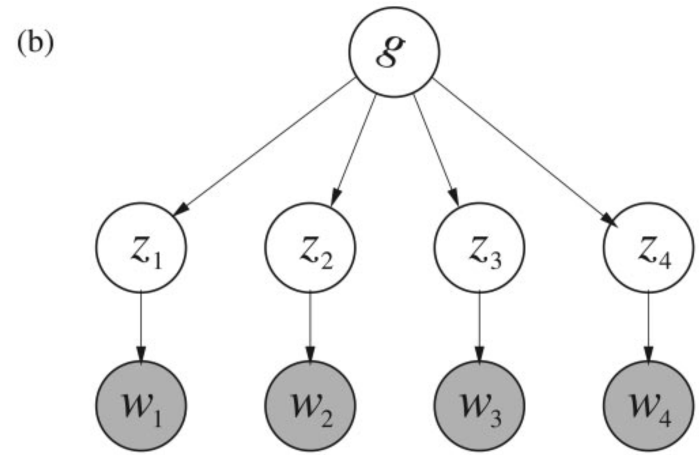
table

stove

sink

Topic model - documents

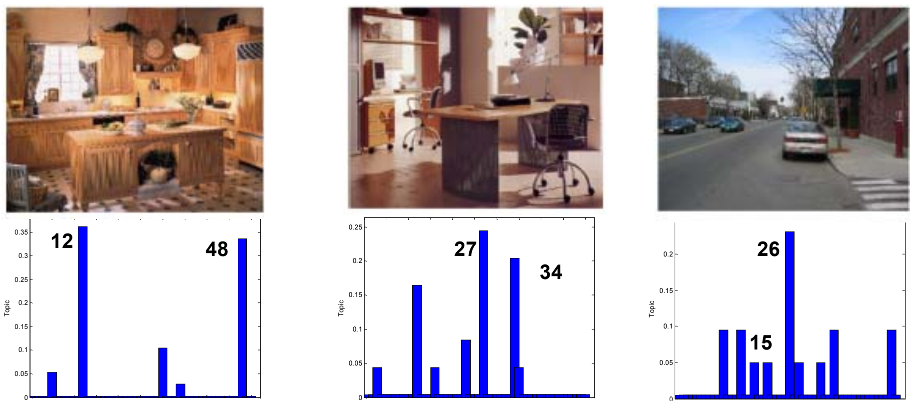




$$P(w_i|g) = \sum_{z_i=1}^{T} P(w_i|z_i)P(z_i|g),$$

(Blei, 2012)

Topic model –scenes



Topic 12	Topic 48	Topic 27	Topic 34	Topic 26	Topic 15
cabinet	***chair***	screen	***lamp***	person	***tree***
stove	box	***keyboard***	***wall***	***building***	grass
table	book	mouse	bed	***sign***	***sky***
sink	***plant***	***table***	***table***	***car***	bench
fridge	***picture***	mug	***floor***	streetlight	***plant***
wall	lamp	mousepad	phone	***window***	person
floor	***basket***	***cpu***	curtain	***road***	path
faucet	bookshelf	speaker	pillow	***sky***	***building***
dishwasher	painting	phone	***chair***	flag	curb
coffeemachine	***cabinet***	***chair***	painting	***sidewalk***	streetlight

Previous:

$$P(w_i|g) = \sum_{z_i=1}^{T} P(w_i|z_i)P(z_i|g),$$

Now:

$$P(o \mid s) = \sum_{t=1}^{T} P(o \mid z = t) P(z = t \mid s)$$

(Hemmer & Steyvers, 2009)

Why P(o|s) ≈ P(recall o| study s)

$$P(o \mid s) = \sum_{t=1}^{T} P(o \mid z = t) P(z = t \mid s)$$

- Utilizing the gist/topics of a list of items has a slower memory decay (Toglia, 2010)
- Items that are consistent with people's prior knowledge are easier to remember (Alba and Hasher, 1983; Tse et al., 2007)

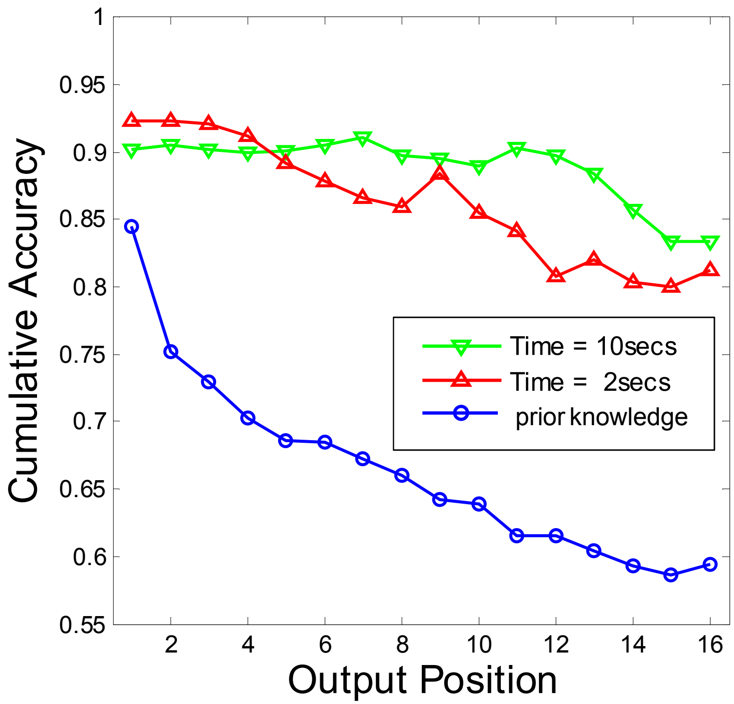
(Brewer & Treyens,1981)

$$p(o \mid s) = p(x = 1 \mid s)\sum_{t=1}^{T} p(o \mid z = t)p(z = t \mid s) + p(x = 0 \mid s)p'(o \mid s)$$

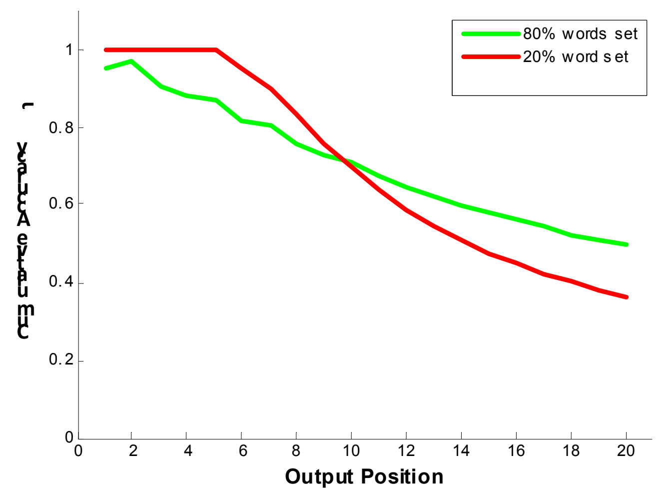
Semantic path

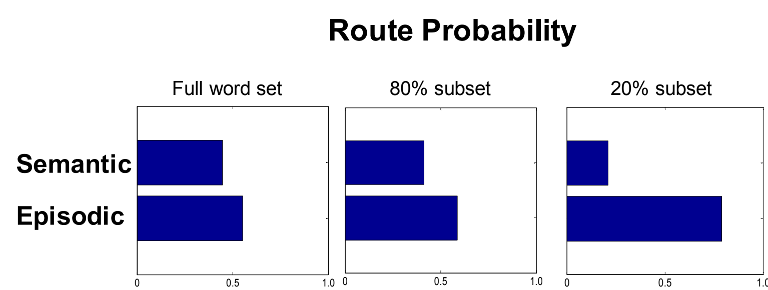
Episodic path

Experiment



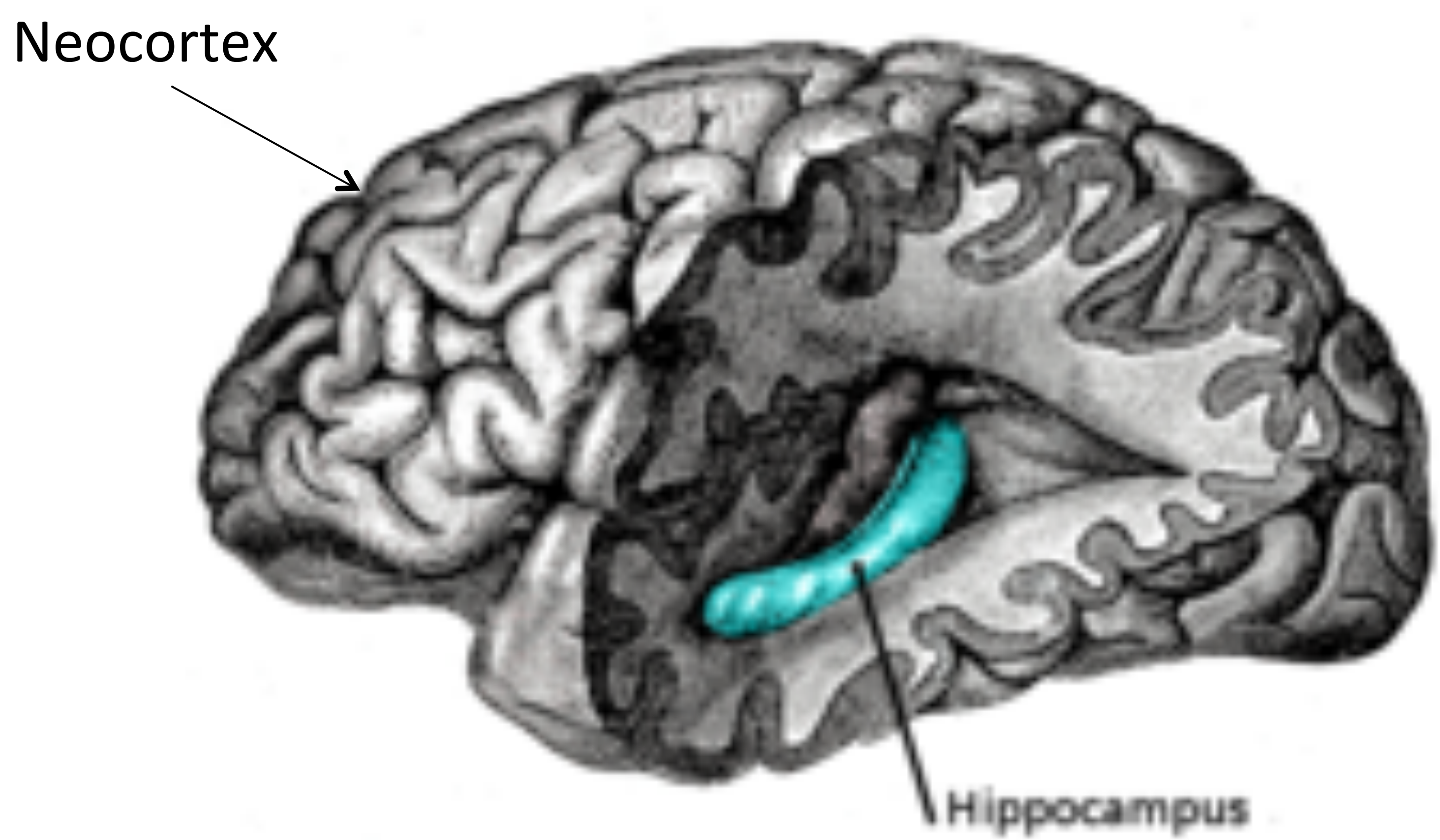
Model





Is there neural evidence of distinct episodic path and semantic path?

Memory & The Brain



Complementary Learning System

New information

e.g. Penguin cannot fly.

Hippocampus

Neocortex

e.g. Birds can fly;
Penguin is a kind of bird.

Outside world

Our brain

(Kumaran, 2016; McClelland, 1995)

An Update to the Complementary Learning System

e.g. Doves can fly.

New information

Neocortex

e.g. Penguin cannot fly.

Hippocampus

e.g. Birds can fly;
Penguin is a kind of bird.

Outside world

Our brain

Medial prefrontal cortex (mPFC) is responsible for detecting whether the new information is consistent with prior knowledge. (van Kesteren, 2012)

(Tse, 2007)

Episodic path and semantic path in free recall task

e.g. Stove in the kitchen

New information

e.g. Skull in the office

Hippocampus

Neocortex

e.g. knowledge of what objects are usually in a kitchen

Outside world

Our brain

Recap

- What is reconstructive memory
- Two ways to model the effect of prior knowledge in reconstructive memory
- Neural evidence of episodic/semantic paths