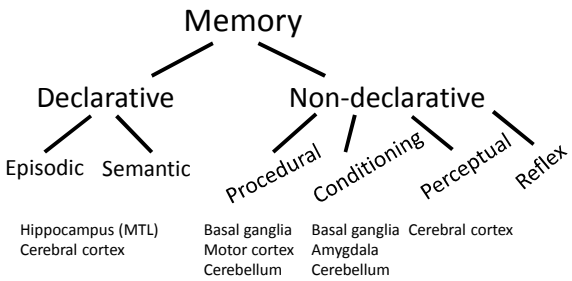
Systems Neuroscience CISC 3250

Memory

Professor Daniel Leeds
dleeds@fordham.edu
JMH 328A

Types of memory



Hippocampus (MTL)
Cerebral cortex

Basal ganglia
Motor cortex
Cerebellum

Basal ganglia
Amygdala
Cerebellum

Cerebral cortex

2

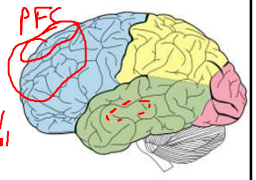
Declarative vs. non-declarative memory

- Declarative
  - "Spring break ended on March 24"
  - "Apples are edible, chairs are not edible"
- Non-declarative
  - Throwing a baseball
  - Pattern completion (seeing the dog behind the fence)

3

Short-term vs. long-term memory

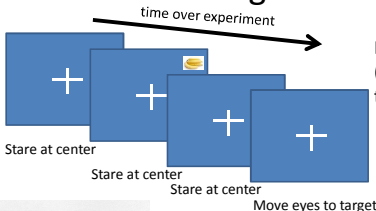
- Short-term memory – aka "working" memory
  - Hold facts in memory for 1-1,000 seconds
  - Sometimes prolonged version of perception
  - Associated with prefrontal cortex (PFC)
- Long-term memory
  - Stores facts over years
  - Associated with hippocampus (also, amygdala)



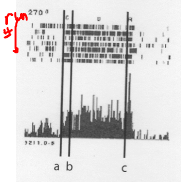
limbic-medial/ventral

4

Working memory



Delayed "saccade" (move eyes) to target task



Neural memory in dlPFC for delayed-action task
a: stimulus display onset
b: stimulus display offset
c: performance of action

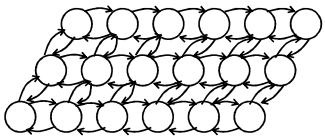
Funahashi et al. 1989

Banana picture from Fir0002/Flagstaffotos

5

Neural dynamics in "cortical sheet"

- Cortical sheet: group of neurons on same level of hierarchy interacting with lateral connections
- Balance between local cooperation and local inhibition

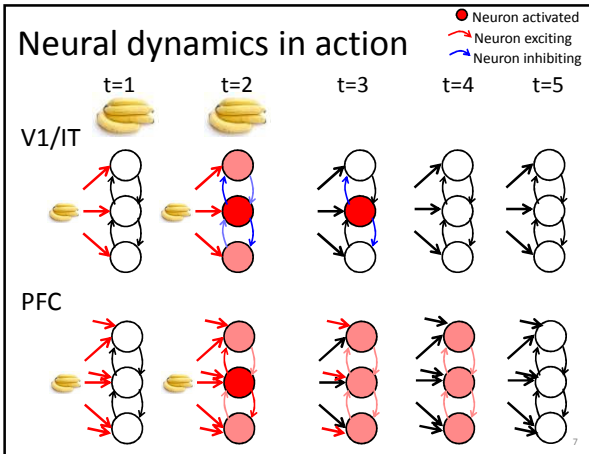


- r^{out} determined from

$$h=\left(\sum_j w_j r_j^{feedfwd}\right)+\left(\sum_k w_k r_k^{lateral}\right)+\left(\sum_m w_m r_m^{feedback}\right)$$

6

Neural dynamics in action



Neural system dynamics

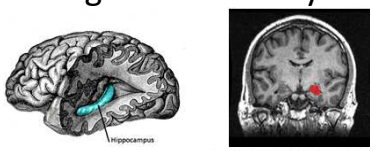
rep. in space & time

Trappenberg 7.3.2

- **Memory activity:** balance of mutual excitation and mutual inhibition produces maintained sparse distributed coding
- **Growing activity:** mutual excitation produces global, non-stop activity over time – epilepsy
- **Decaying activity:** mutual inhibition suppresses continued neural activity – V1

sparsity

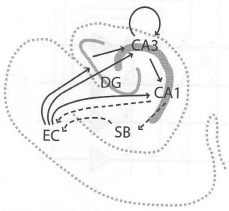
Anatomy of long term memory



Hippocampus ("sea horse")

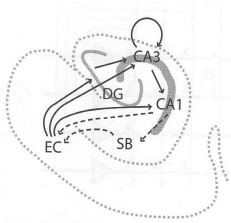
In medial temporal lobe (MTL)

- Input: Entorhinal cortex – EC
- Dentate gyrus – DG
- Cornus ammonis – CA1, CA3
- Perforant pathway: EC -> CA3

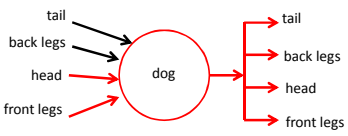


Recurrent networks

- Extensive collateral connections in CA3
- Broader loop: EC -> CA3 -> CA1->EC



Memory through associator network

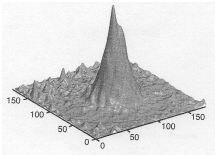


Learning locations

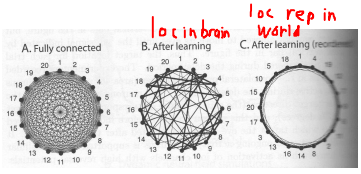
- Rats learn neural representations of locations within a maze
- Hippocampal place cells in CA1, CA3

cells for 1 place distributed around hippocampus

loc in brain loc rep in world



Samsonowich, J Neurosci 1997
Neurons organized in 2D based on similarity of tuning curves

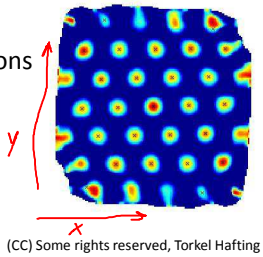


Connections between hippocampal neurons before (A) and after (B,C) learning

Further hippocampal representations

Grid cells

- In dorsocaudal medial EC
- Represent multiple locations



13

Learning/remembering

- Learning: neurogenesis in DG
- Retrieval: pattern completion in CA3

- Alternate between learning and retrieval phases
  - DG granule cells enable learning
  - Perforant pathway probes memory

Potential model

15

Modeling limits of working memory

- How much can we hold in working memory?
  - 7±2 things
  - Things can be simple A Q R L G
  - Things can be complex

- Why is our working memory limited?
  - Binding hypothesis: distributed code with synchronous spiking – errors with spurious synchronization

16

Binding problem p267

Green
Blue
Person
Dog

can have several objects competing for spike timings

also, spurious spikes

hard to determine spur. synchronization

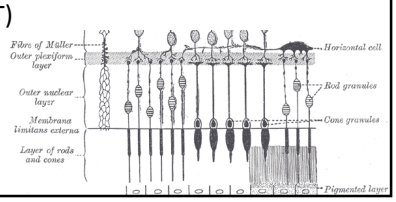
17

On an earlier note…

Horizontal cells – lateral inhibition in the retina

- Photoreceptor (rod/cone granule) activates horizontal cell
- Horizontal cell inhibits nearby photoreceptors (with GABA NT)

On-center, off- surround retinal neuron response



Memory review

- Long term memory
- Short term memory

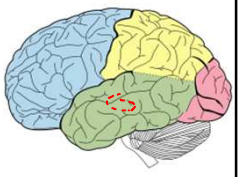
19

Declarative memory: long-term

Remembering (over years):

- Your childhood house
- Your high school friends
- Your family

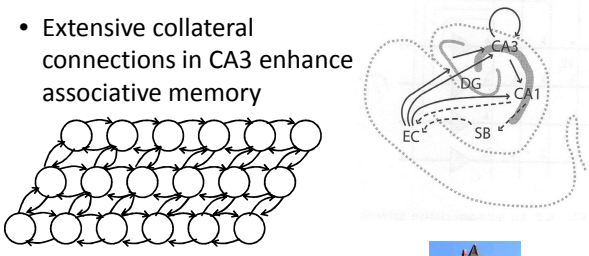
hippocampus

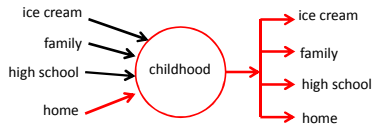


20

Recurrent networks

- Extensive collateral connections in CA3 enhance associative memory





21

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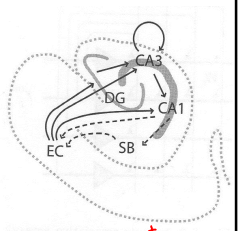


Hebb

$$\Delta w_{ij} = r_i r_j - r_i w_{ij}$$

not control

Willshaw

Cells that fire together, wire together
Loop repeatedly increases weight – increasingly encourage simultaneous firing

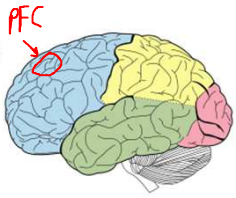
22

Declarative memory: short-term

Remembering (over 10-200 s):

- List of numbers
- Set of pictures

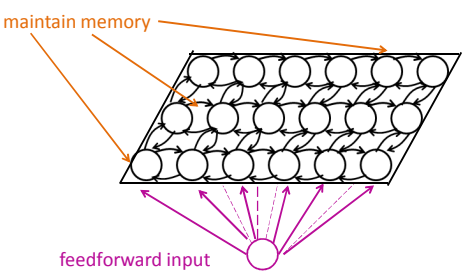
PFC



23

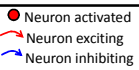
Neural system dynamics

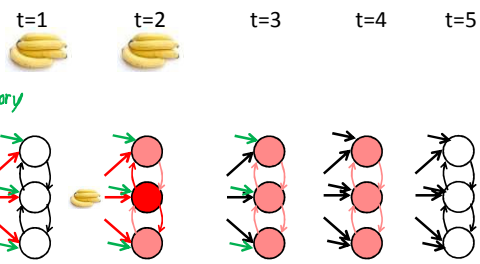
- In an interconnected cortical sheet, neural activity can continue after feedforward input is gone



24

Neural dynamics in action

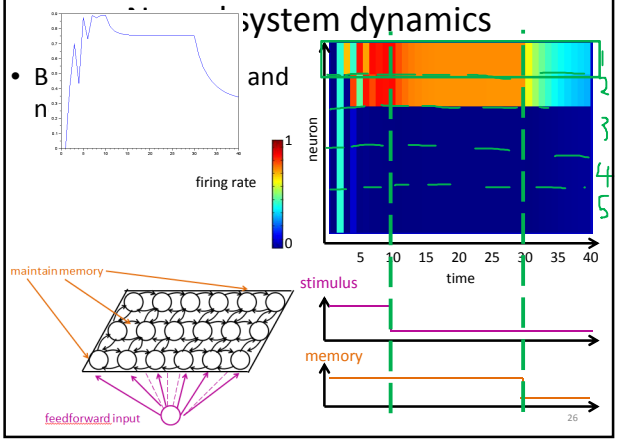




25

system dynamics

- B and n

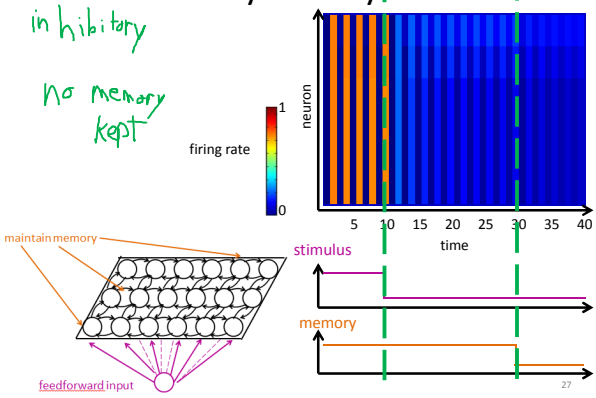


26

Neural system dynamics

inhibitory

no memory kept

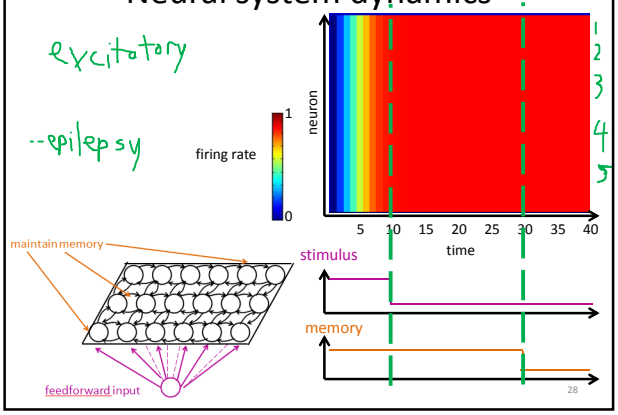


27

Neural system dynamics

excitatory

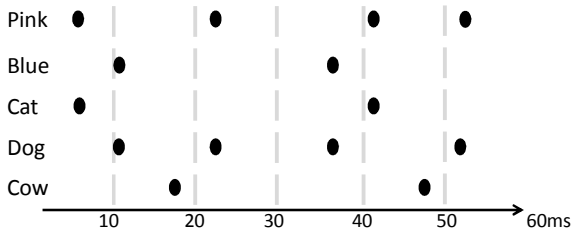
--epilepsy



28

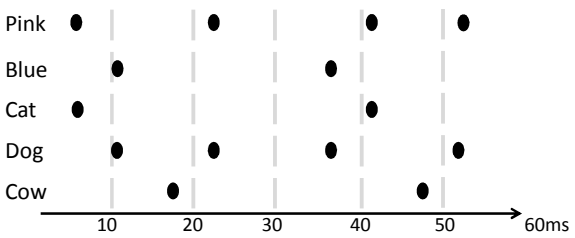
Binding problem

Neurons firing at "same time" represent same thing



"Cow"

Spurious synchronization



If spikes occurring within 1 ms of each other are considered synchronous, hard to incorporate increasing number of spikes in fixed time

30