COGNITIVE NEUROSCIENCE
Core Knowledge

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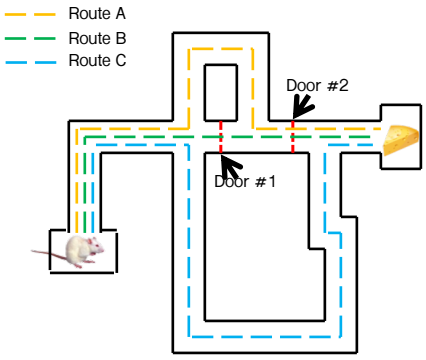
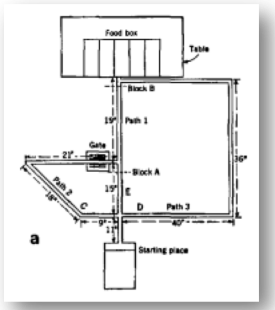
Core Knowledge

Latent learning



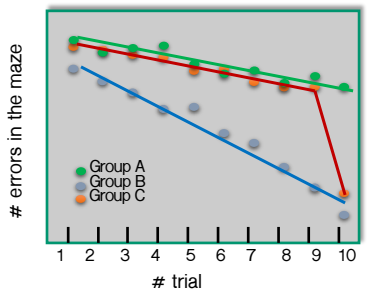
Latent learning



- Tolman & Honzik (1930)
  - 3 groups of rats were placed 10 times (one *per* day) in a maze from which they had to escape
  - Group A: no reward at the exit
  - Group B: reward every time they found the exit
  - Group C: no reward for the first 8 trials; reward at the 9th trial

Latent learning

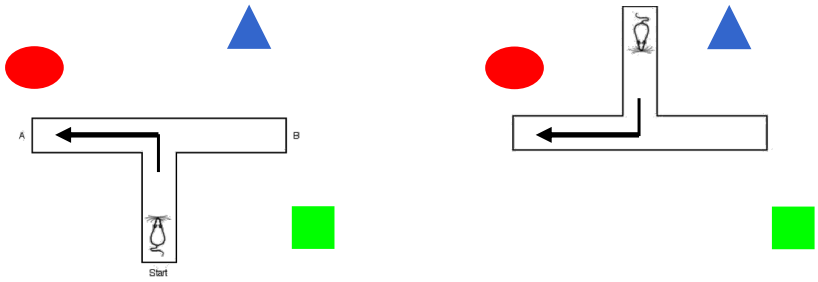
- Group A: several errors at every trial but a general improvement of the performance over time
- Group B: the n. of errors decreases faster than in group A
- Group C:
  - Trials 1 to 9 – they bahave as group A
  - At trial 10 – they behave as group B



Latent learning

- *rats of group C showed latent learning: in the days preceding the reward they created a mental map of the maze*
- rats who did not get the reward, did not use the info aquired during navigation until there was a reason to do so (e.g., the presence of the reward): the reward is important **for the learning to show up**
- Goals are fundamental: the learning is evident only when the behaviour or the action has a goal; even if the performance does not change during the trials, or it seems at chance, this does not mean that the animal is not learning properties and features of the environment

Cognitive map



Tolman *vs.* Hull

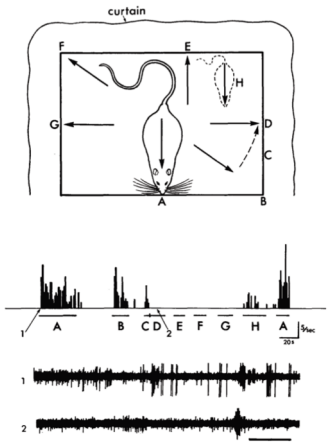
Cognitive map

- the cognitive map is a mental representation that lies in between the stimulus and the response
  - the behaviour is regulated by intentions
  - this means that the animal behaves in a certain way in order to get a specific goal or in virtue of a certain reason; it is not just or solely mechanically guided by external stimuli: there is something in between
- Such internal variable is used by the animal to anticipate the consequences of its behaviour *and to choose* how to behave in order to get to the target

Cognitive map

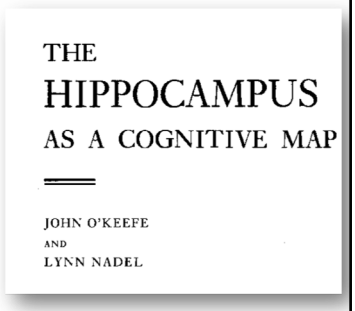
- There are several advantages in possessing such allocentric representation of the environment:
  - the organism can navigate using shortcuts – since there is an accurate memory of several reference points, they can be connected and the shorter route can be chosen (Dennet 1996)
  - the organism can reach the target position by initiating the navigation from virtually all possible starting places – since there is an accurate representation of the relations between the separate landmarks (Tolman 1948)
  - the organism can optimize the route (Menzel, 1973)

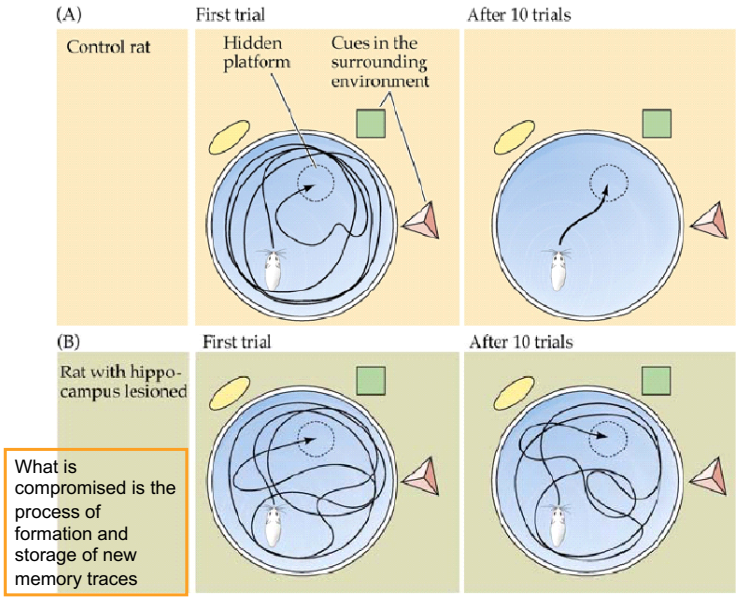
www.cognitivemap.net



"*These findings suggest that the Hippocampus provides the rest of the brain with a spatial reference map...*"

O'Keefe & Nadel



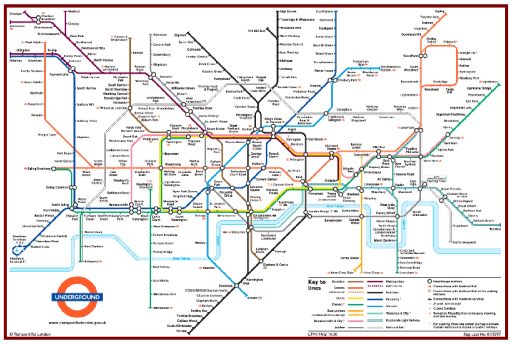


What is compromised is the process of formation and storage of new memory traces

topology

Topology, in its specific meaning within geometry, expresses the possibility of defining a place devoid of all metric attributes, but comprising the concepts of

- order
- enclosure
- adjacency



topology

- Piaget and Inhelder (1956) proposed that children initially represent space only in topological terms
  - the conception of metric, instead, would emerge only after the shift from a egocentric to an allocentric representation
- Nowadays we know that this idea is incorrect, since it has been demonstrated that even young infants, early in development, represent and respond to metric information (for a review, see Newcombe & Huttenlocher, 2000)

topography

It adds information on metric magnitudes – metric as natural instrument?

- direction
- distance
- elevation
- size
- …

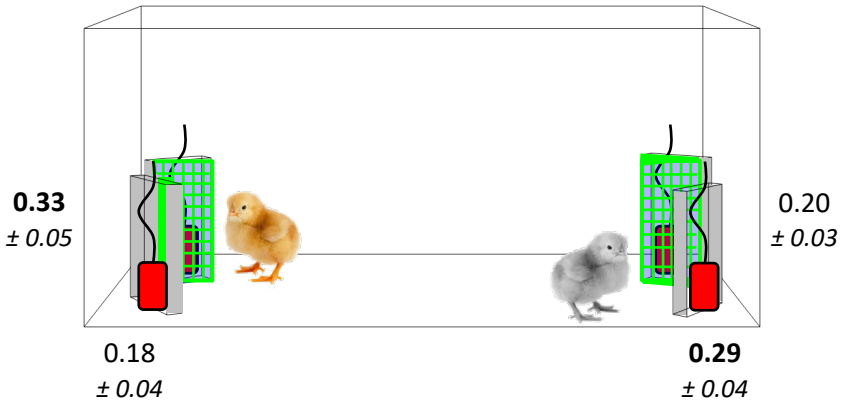
- are used to move from and towards important places (see for examples Gallistel, 1990)
- while moving and approaching a target, an animal has to perceive the distance and the direction of its own position with respect to the landmark, to remember the distance between the landmark and the goal and the intervening direction between those points, and then to implicitly calculate the distance and direction from its position to the goal

Munduruku

- Isolated villages
- Lack of rulers, compass, maps, ...
- Lack formal education
- A few words or phrases to refer to geometrical or spatial concepts

In all tests, peformance was comparable between young and adult munduruku and between mumduruku and american children-

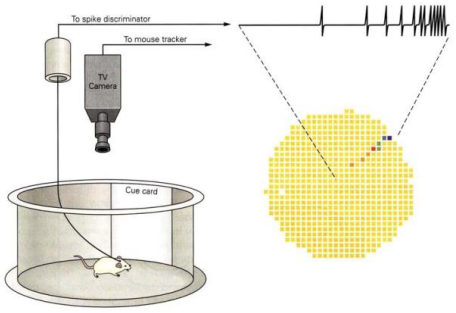
Geometric module task



Chiandetti Spelke Vallortigara, 2015

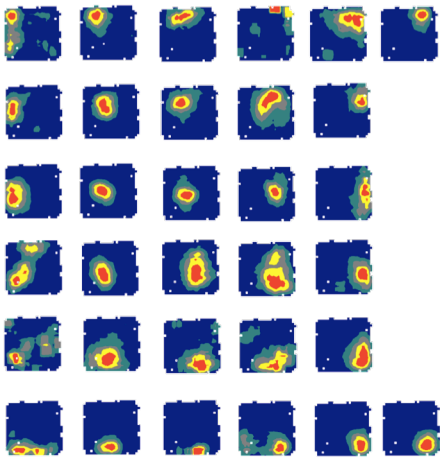
Place cells

- the rat moves around freely in an open arena
- some neurons become active as the rat reaches a specific place in the arena
- different place cells are activated in different places
- their combination creates a map of a specific environment

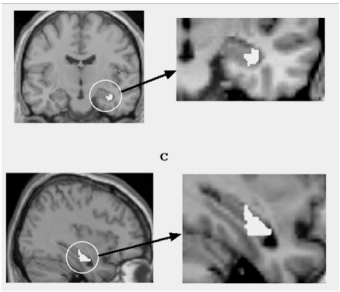


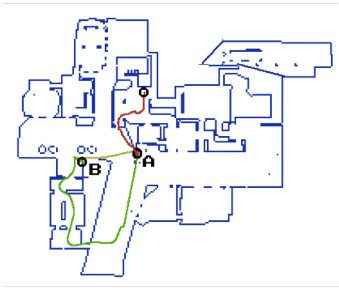
Place cells

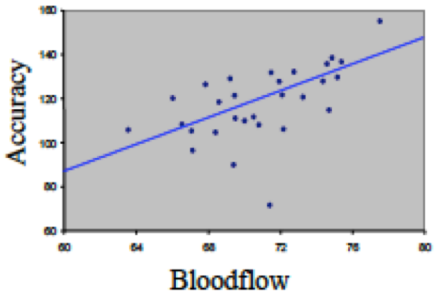
- Piramidal cells in CA1
- place fields are established within minutes
- cells tend to be stable over repeated exposures to the same environment
- there is always an active cell in a certain position: the whole environemnt is "mapped"



Place cells – the virtual town







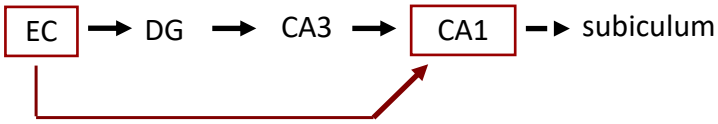
Place cells

- In order to understand whether the activity is hippocampus-dependent, the Mosers started considering the connectivity of CA1: they recorded from CA1 after lesioning the areas sending input to the CA1.

1. PCs' activity could show relational properties that are encoded during the spatial learning and not necessarily spatial information *per se*
2. PCs's acitivity could depend on processing of other areas than the hyppocampus (or could depend also by other external areas' activity)

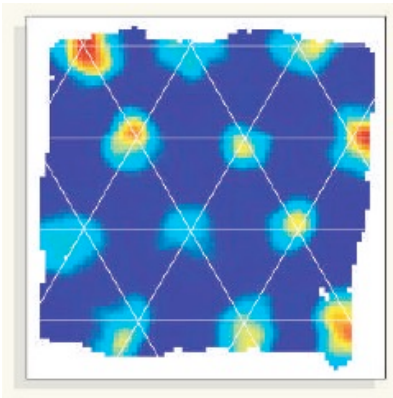
Place cells

- neurons in CA1 show their typical "place field" even after the lesion, suggesting that the source for the signal is external, is outside the CA1



Grid cells

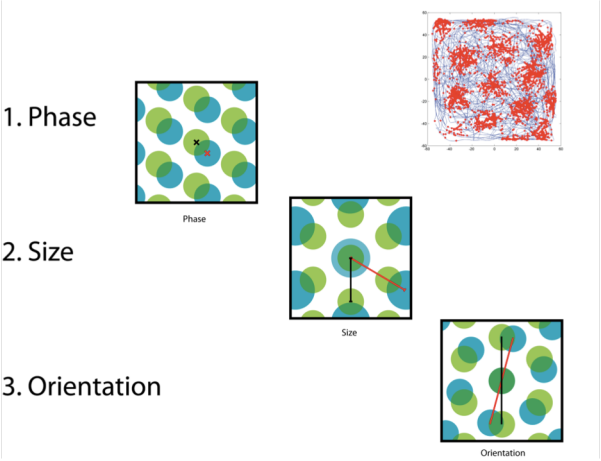
- Enthorinal cells show multiple spatial fields that exhibit a regular pattern
- The fields are organized at a regular hexagonal distance, like a grid, covering the entire space around
- The fields create a sort of grid, a metric map



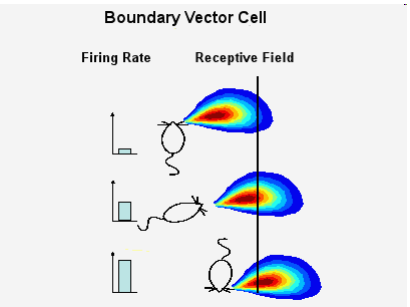
Grid cells

- Grid patterns
  - appear on the first entrance of an animal into a novel environment, and usually remain stable thereafter
  - do not require visual input
    - remain unchanged when all the lights in an environment are turned off
  - when visual cues are available, they exert strong control over the alignment of the grids
    - rotating a cue card on the wall of a cylinder causes grid patterns to rotate by the same amount (rotational remapping)
  - when an animal is moved into a completely different environment, grid cells maintain their "grid spacing"
  - the regularity in grid spacing does not derive from any regularity in the environment or in the sensory input available to an animal

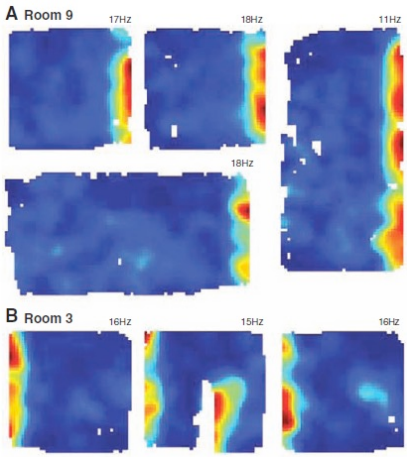
Grid cells dimensions



Other cells: mathematical model



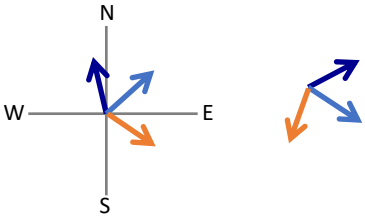
the model anticipated the real data

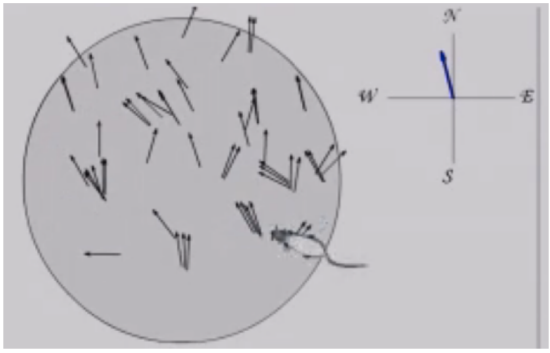


- Border cells
  - whenever the animal is at a certain distance from a landmark, a border, a wall
  - recorded in the subiculum and the EC

Other cells

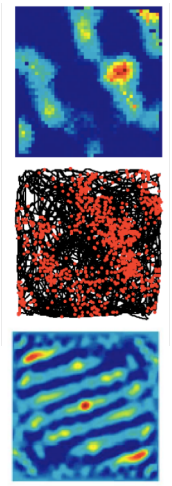
- Head direction cells
  - between EC and Hp
  - independently from where the animal is
  - connected one with the other



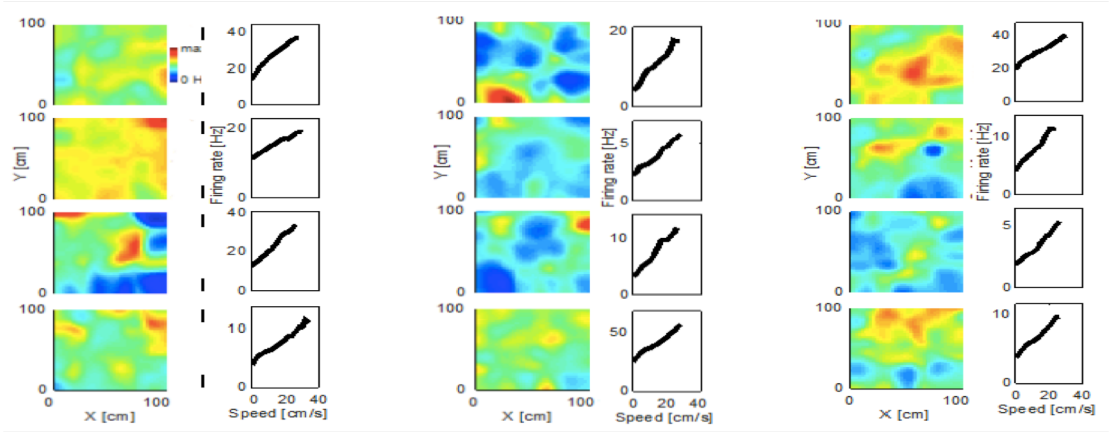


Other cells

- Band-like cells
  - parasubiculum
  - probably they support the creation of place cells

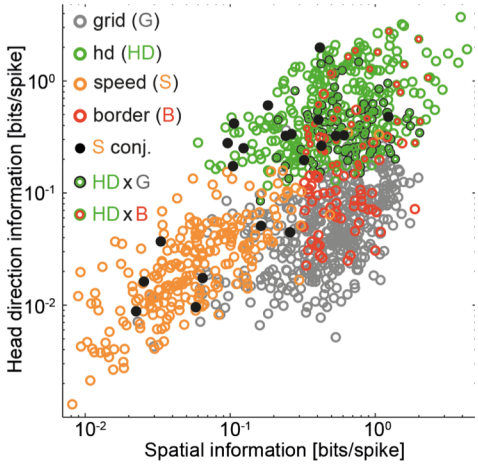


Other cells – speed



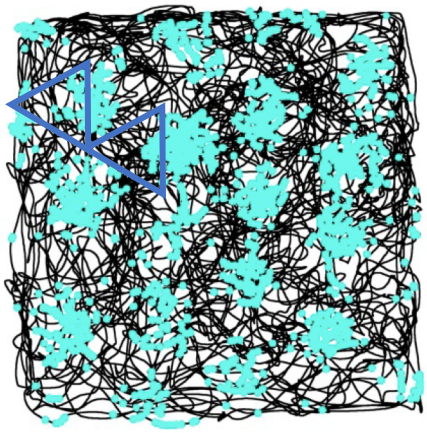
Speed cells

- Within the EC there are also the speed cells
- they update the grid pattern on the basis of the movement of the animal (distance=speed*time)
- discharging frequency follows the running velocity



Other cells

- By the integration of speed and head direction inputs, grid cells can be activated in specific positions



GPS in the brain

- grid and band-like cells support the creation of a cerebral map that gives the animal a "sense" of space and allows it to direct navigation within the environment following its metric
- head-direction cells act as a compass, by pointing toward a certain direction
- border cells are activated whenever the borders are encountered
- **TOGETHER** they create a complex network working as a positional system

Imaginary navigation

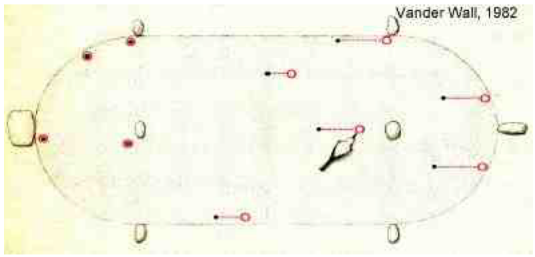
- the same grid cell-like activity has been recently visualized (fMRI) during imaginary navigation, providing the first evidence that that this activity occurs in the absence of actual movements
  - 26 participants had to imagine while navigating a virtual mountainous environment and memorizing the location of a few objects within it
  - and also while just imagining that they were moving through it to retrieve those objects

Imaginary navigation

- a signal that is consistent with grid cell-like activity in the entorhinal cortex was observed
  - during the navigational task
  - but also during periods when the participants merely imagined navigating through the environment to retrieve what they had seen earlier
- This suggests that grid cells not only track our movements during spatial navigation, but also contribute to route planning, perhaps by moving the viewpoint of the imagined environment

Hippocampus

- Food storers memorize the hiding positions using *landmarks* (salient visual features)
- thousands of memory traces
- are they geniuses or do they posses a specific advantage? ➜ comparison between food storers and non-storers



Hippocampus

SPATIAL TASK

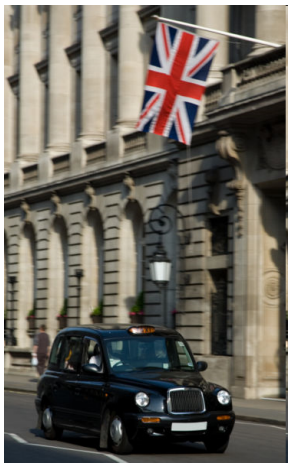
- find a reward on the basis of the position
  - two identical boxes, you have to learn if it is hidden in the one on the right or on the left

NON-SPATIAL TASK

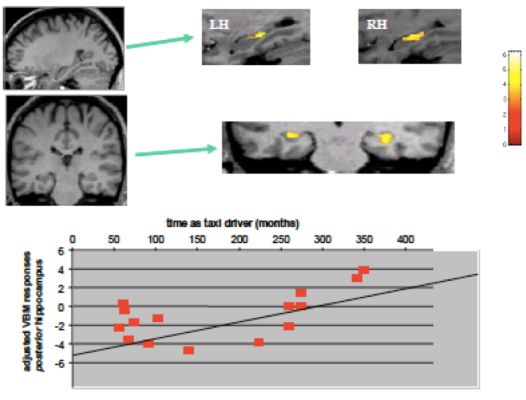
- find a reward on the basis of a visual feature
  - two identical boxes that differ in colour, you have to learn if it is hidden in the green or the yellow box

Hippocampus

- There is a human job requiring the very same ability that food storers have...
- guess...



Hippocampus



Maguire 2000

Hippocampus

- Taxists' brains were compared to those of participants of similar age, gender, socio-economical position…just doing other jobs
  - expansion of the posterior part of the Hp (involved in the fomation of the cognitive map of the environment)
  - with a reduction of the anterior part (this has not been observed in the birds' brain)

Hippocampus

- Control group?
  - Comparable for

✓ experience of driving

✓ stress levels

⌦ fixed routes

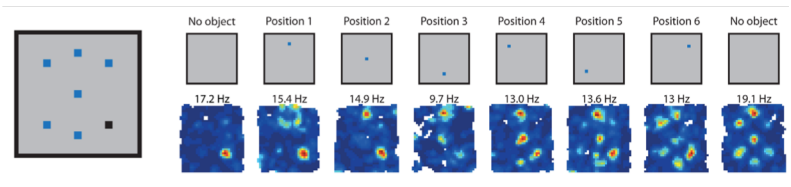
The Hp does not show the same incremement

Hippocampus

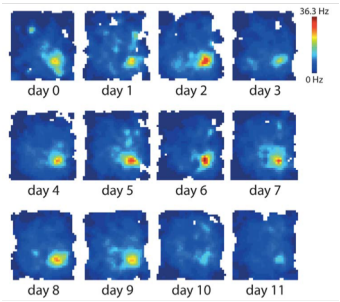
- Let's go back to the storing behaviour of food storers
  - if the Hp is selectively lesioned, the storing itself is not compromised
  - what is compromised instead is the retrieving capability
- This means that motor skills and motivation, are independent from the Hp functionality which is crucial for spatial memory only

Entorhinal cortex (Medial and Lateral)

- By changing the position of an object, it leaves a memory-trace field in lateral entorhinal cells
- In every position, a trace field emerges one trial after the object presentation
- The trace fields accumulate in the following trials



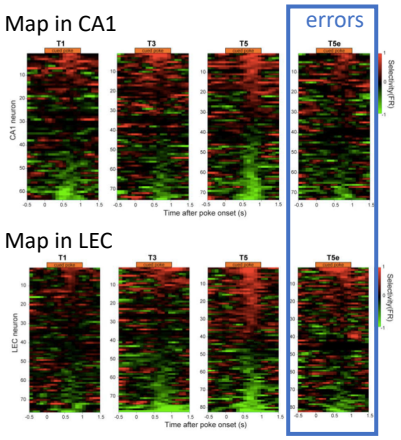
Entorhinal cortex (Medial and Lateral)



- When the training is prolonged, the trace field becomes persistent, it may last weeks after the first presentation
- the trace cell activity is not a mismatch response to the absence of the object

Entorhinal cortex (Medial and Lateral)

- The rat is trained to feed from container A when it recognizes "banana" and from B when it recognizes "chocolate"
- The number of odor-selective LEC neurons during the sampling of the cue increases during learning
- Selectivity for odors is lost in error trials
- This suggests that the expression of an olfactory map during cue sampling is predictive (maybe necessary) to recall the info

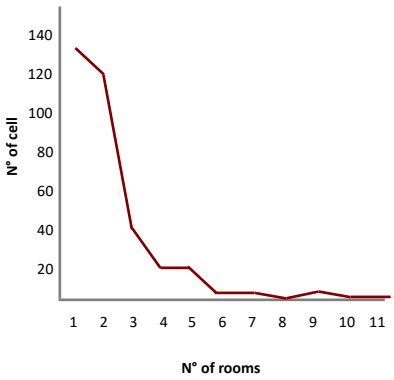


Episodic memory

- The association between places and odors could get established thanks to coherent oscillations of Hp and LEC neurons
- The development of coherent activity in dCA1 or LEC could create unions of functional cells during learning, e.g. by making it possible synaptic plasticity. Such "unions" could be at the basis of odor memories

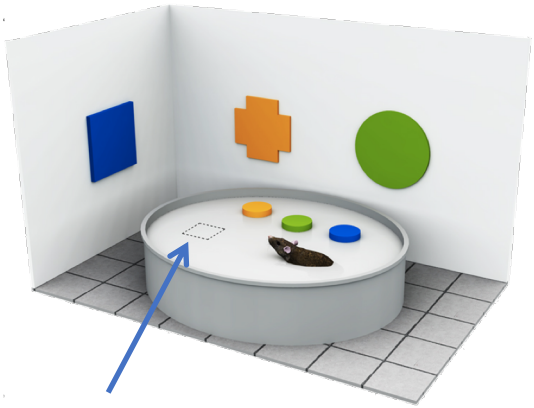
Episodic memory

- Each place cell is active in one or two rooms
- If active in more than one rooms, it has different coordinates in different rooms
- One trial is sufficient to encode the map
- The space is a cue to recall the memory and the memories associated to each space are kept separate



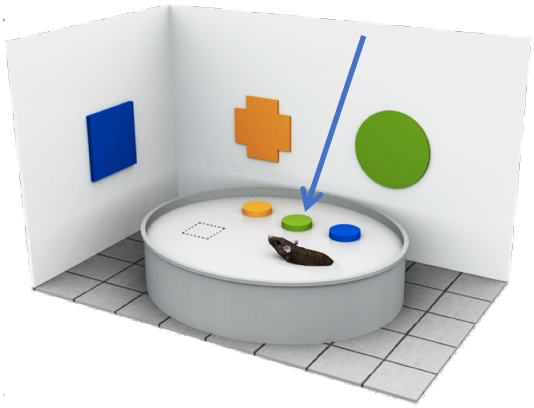
Different memories

- if the platform is not visible (dotted square), the rat uses the configuration of external objects to orient and find the safer position
  - spatial memory



Different memories

- if the platforms are visible (coloured cylinders), and only one floates (the others sink) the rat has to learn to associate a response to a feature
  - proceural memory



Place cells and episodic memory

- The place cells
  - seem to encode declarative aspects
  - allowing to discriminate between different contexts in which specific facts may take place
- The Hp, it is not a mere spatial processor, rather it seems a relational processor of declarative memories (referred to facts and events)
- "Episodic memories can be formed by linking successive event representations and episodic trajectories into ensemble patterns stored in hippocampal networks for subsequent retrieval" Bellmund et al., 2018

Core knowledge

The criteria hypothesized by Spelke (2000) seem to be satisfied also for the system of knowledge that support our navigation and orientation (in terms of metric):

- Given at birth
- Independent from experience and formal culture/acculturation
- Largely shared between species
- At the basis of learning processes