

Egocentric and allocentric representations in spatial memory

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Objectives for this practical

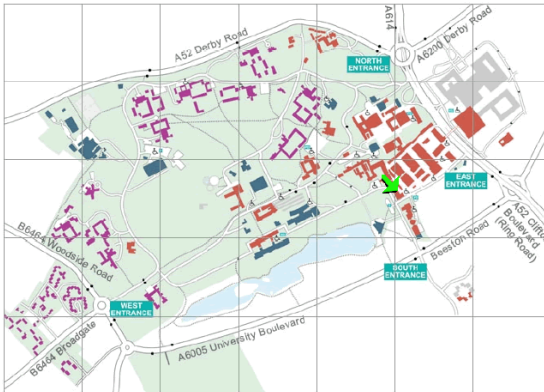
- To learn about:
 - the relevance of spatial memory and cutting-edge research on spatial memory;
 - two types of representations, egocentric and allocentric ones, that can support spatial memory and ways to study them.
 - two-factorial experimental designs and their analysis by two-factorial ANOVA
- To design and perform a two-factorial behavioural experiment that investigates properties of a specific type of spatial memory, object-location memory.
- To analyse and interpret the findings.
- To present them to the group and write them up as a research report.

Recommended reading

- Reviews giving an overview of the field:
 - Burgess, N. (2008) Spatial cognition and the brain. *Ann. N.Y. Acad. Sci.* 1124:77-97.
 - Burgess, N. (2006) Spatial memory: How egocentric and allocentric combine. *Trends Cogn. Sci.* 10:551-557.
- Key original research papers, describing key studies:
 - Wang, R. F., & Simons, D. J. (1999). Active and passive scene recognition across views. *Cognition*, 70(2), 191-210.
 - Burgess, N., Spiers, H. J., & Paleologou, E. (2004). Orientational manoeuvres in the dark: dissociating allocentric and egocentric influences on spatial memory. *Cognition*, 94(2), 149-166.
- Further reading around the topic as much as you like, depending on your interest!
- Revise lecture notes on ANOVA, factorial and repeated measures designs and read up on these topics in your Research Methods book (e.g., Fields book, chpts. 14-16).

Relevance of spatial memory

- ‘Space plays a role in all our behaviour. We live in it, move through it, explore it, defend it.’ (O’Keefe & Nadel, 1978, *The hippocampus as a cognitive map*, Chpt. 1, p. 5; <http://www.cognitivemap.net/HCMpdf/HCMChapters.html>).
- Spatial memory is critical for many every-day tasks.



Note: Many varieties of spatial memory – different spatial scales, declarative, procedural, rapidly and incrementally acquired, allocentric and egocentric, etc.

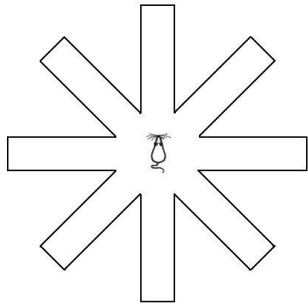
- Spatial memory can define the context of events and is a key component of episodic memory, the memory of unique personally experienced events (see Burgess et al., 2002, *Neuron* 35:625; Nadel & Hardt, 2004, *Neuropsychology* 18:473).

Cross-species studies of spatial memory – a unique window into the brain substrates of a complex cognitive process

Spatial memory can readily be studied in animals, including rats, offering a unique opportunity to characterise in detail the neurobiological substrates of a complex cognitive process (e.g., Burgess, 2008, *AnnNYAcadSci*1124:77; Nakazawa et al, 2004, *NatureRevNeurosci* 5:361).

Behavioural tests of spatial memory . . .

Radial arm maze



Olton & Samuelson (1976)
*JExpPsychol;AnimBehProc*2:97

Water maze



http://www.scholarpedia.org/article/Morris_water_maze

Also see personal account of how it was 'invented':
Morris, 2003, *PhilTransRoySocB* 358:643.

Event arena



Day et al (2003) *Nature* 424:205
Bast et al (2005) *JNeurosci* 25:5845

etc.

. . . can be combined with neurobiological analysis and manipulation of the brain



Lesion and pharmacological manipulation of hippocampus



Single-unit recordings

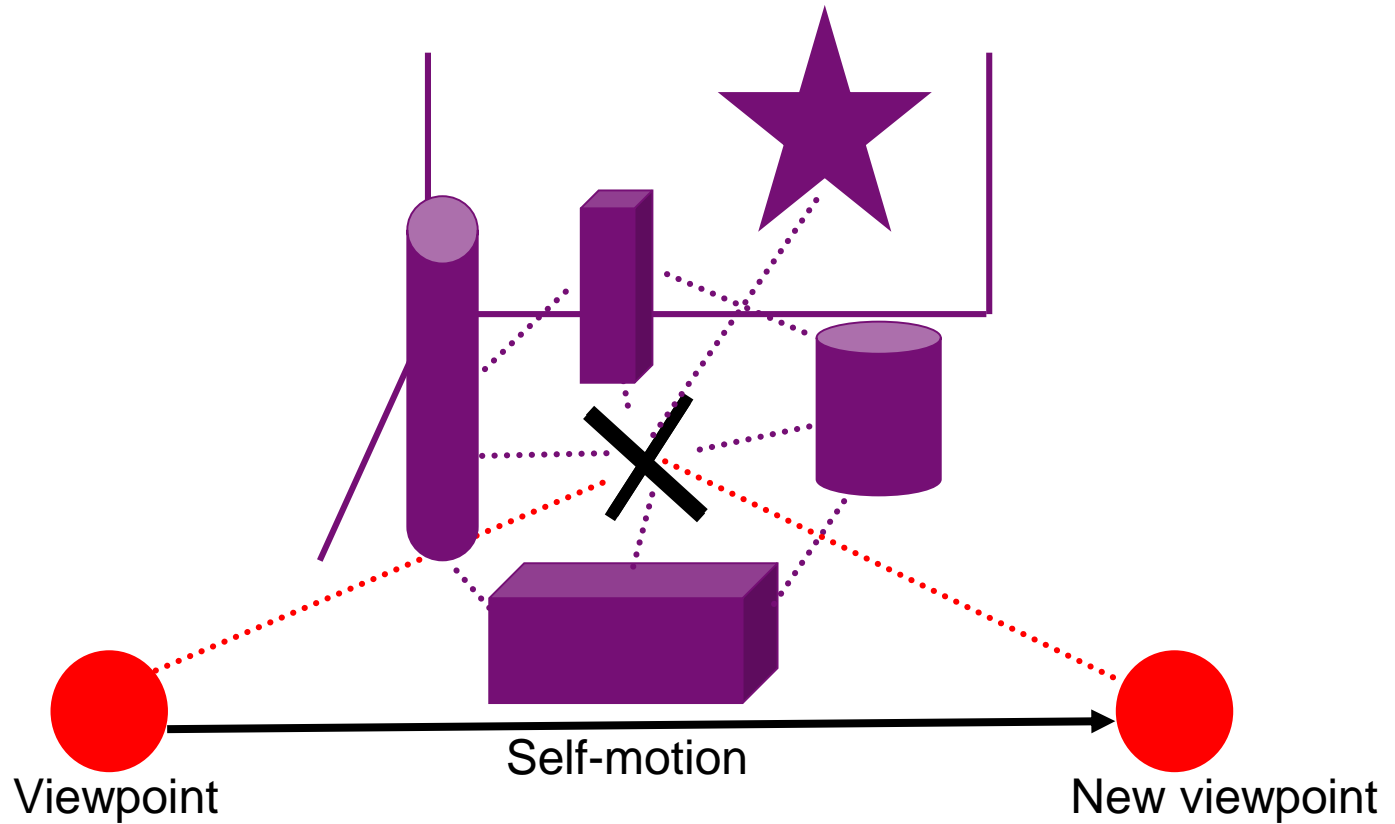
etc.

Cross-species studies of spatial memory – a unique window into the brain substrates of a cognitive dysfunction

Deficits in spatial memory (especially of the rapidly acquired, allocentric type) come with normal age-related cognitive decline (e.g., Rosenzweig & Barnes, 2003, *ProgNeurobiol* 69:143), are marked in Alzheimer's disease and its precursor state MCI (e.g., Hort et al., 2007, *PNAS* 104:4042), and are a component of the neuro-cognitive deficits in schizophrenia (e.g., Glahn et al., 2003, *BiolPsychiatry* 53:624-626; Al-Uszri et al (2006) *BrJPsychiatry* 189:132) .

Thus, spatial memory tests may serve as cross-species tools to research these conditions in humans and in relevant animal models.

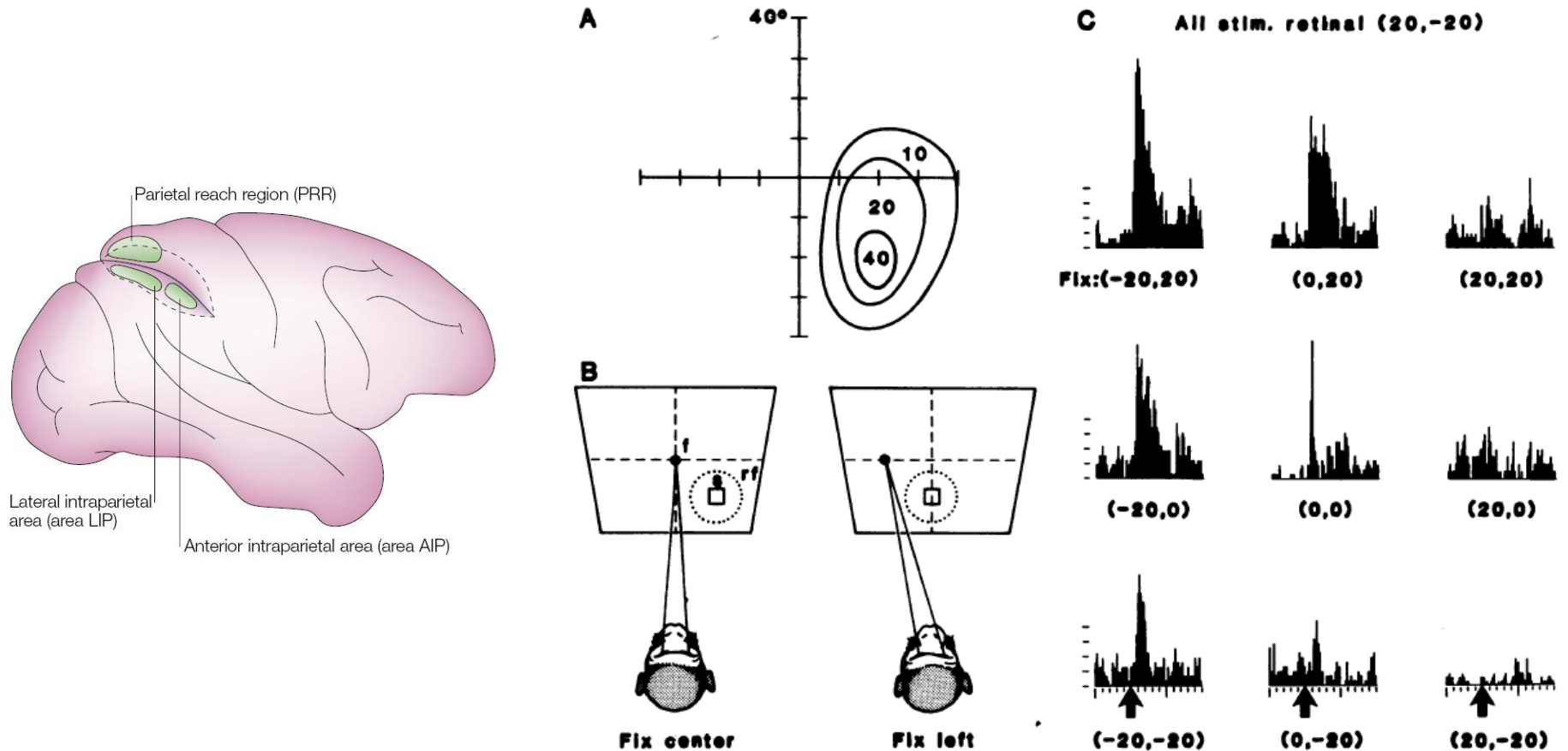
Egocentric and allocentric representations in spatial memory



Egocentric spatial representation: location is encoded in relation to own body; egocentric representations may be updated from one viewpoint to another based on information of the observer's self motion.

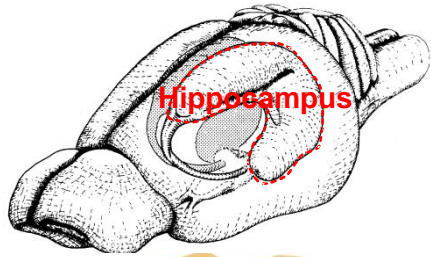
Allocentric (or geocentric) spatial representation: location is encoded in relation to the external world; viewpoint independent.

Egocentric spatial representations – gain-field responses of neurons in posterior parietal cortex

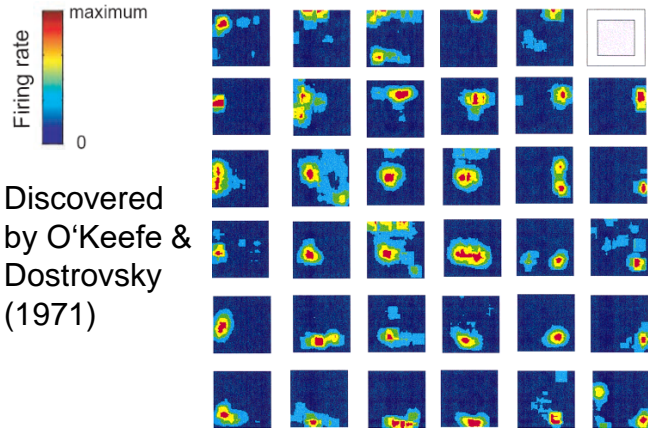


- Eye-position dependent modulation of neuronal firing to stimuli in the neuron's receptive field.
- Neuronal firing codes for a specific location relative to the animal's head.

Allocentric spatial representations – place cells, grid cells, boundary cells



Place cells in hippocampus

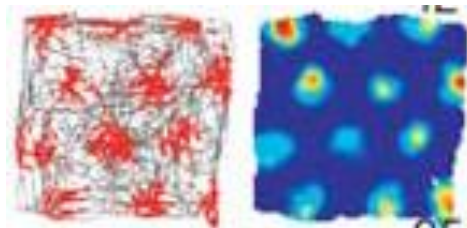


Discovered by O'Keefe & Dostrovsky (1971)

O'Keefe et al (1998) *PhilTransRSocLondB* 335:1333

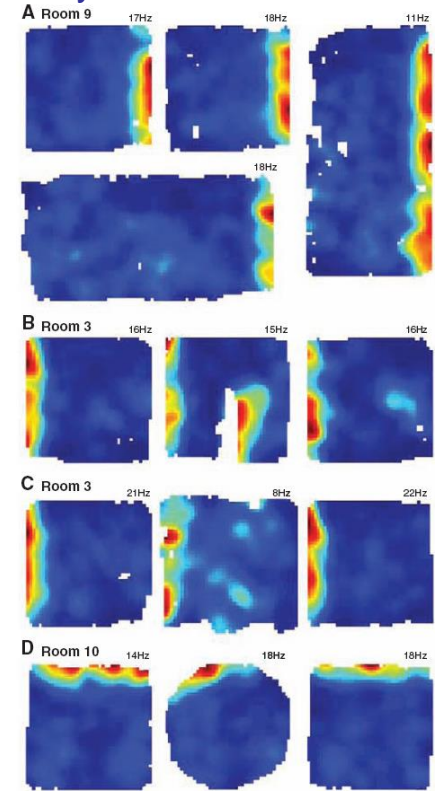
Place cells have also been found in human hippocampus Ekstrom et al. (2003) *Nature* 424:124.

Grid cells in entorhinal cortex



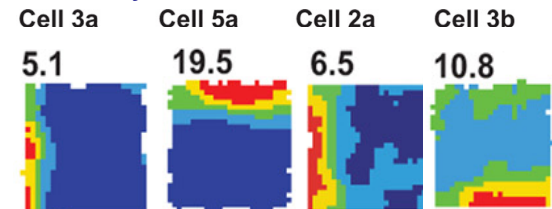
Hafting et al (2005) *Nature* 436:801

Boundary cells in entorhinal cortex



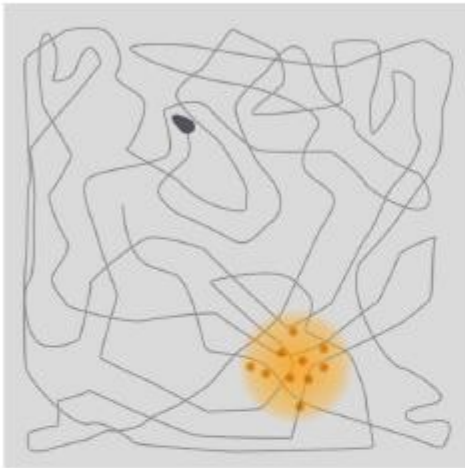
Solstad et al (2008) *Science* 322:1865

Boundary vector cells in subiculum



Lever et al (2009) *JNeurosci* 29:9771

The Nobel Prize in Physiology or Medicine 2014



John O'Keefe

John O'Keefe discovered, in 1971, that certain nerve cells in the brain were activated when a rat assumed a particular place in the environment. Other nerve cells were activated at other places. He proposed that these "place cells" build up an inner map of the environment. Place cells are located in a part of the brain called the hippocampus.

Fig. 1

May-Britt Moser and
Edvard I. Moser

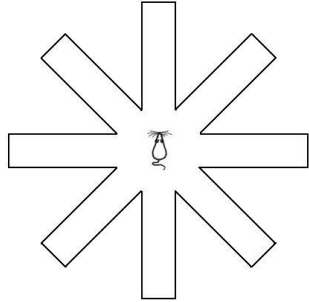


Fig. 2

May-Britt och Edvard I. Moser discovered in 2005 that other nerve cells in a nearby part of the brain, the entorhinal cortex, were activated when the rat passed certain locations. Together, these locations formed a hexagonal grid, each "grid cell" reacting in a unique spatial pattern. Collectively, these grid cells form a coordinate system that allows for spatial navigation.

Rat paradigms to study spatial memory

Radial arm maze



Olton & Samuelson (1976)
*JExpPsychol;AnimBehavProc*2:97

Water maze



[http://www.scholarpedia.org/
article/Morris_water_maze](http://www.scholarpedia.org/article/Morris_water_maze)

Event arena

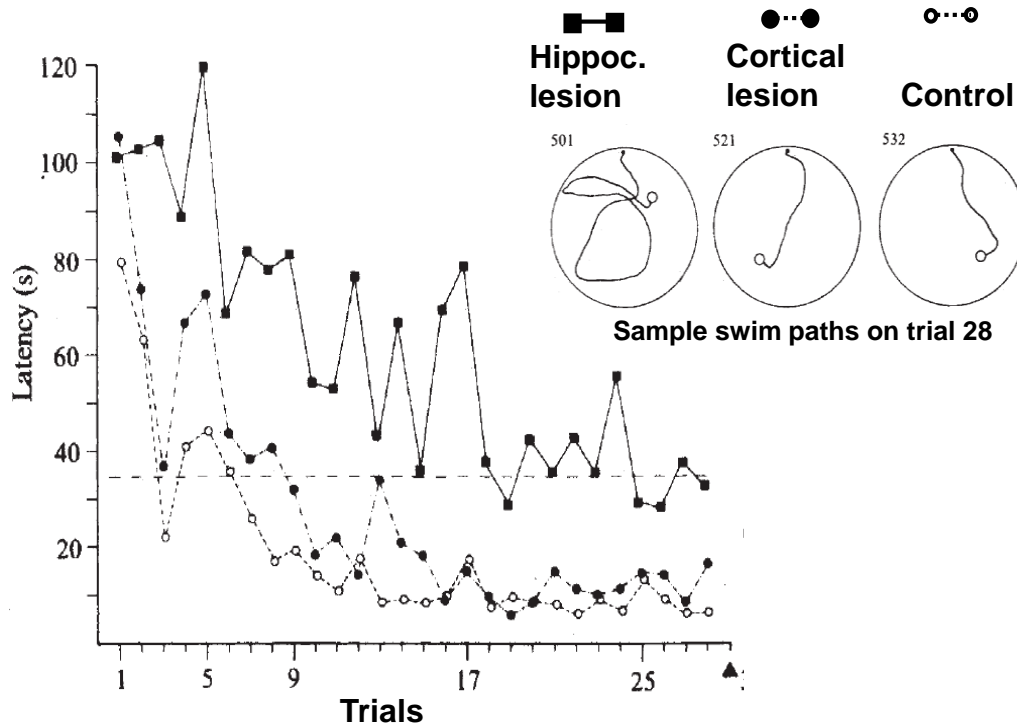


Day et al (2003) *Nature* 424:205
Bast et al (2005) *JNeurosci* 25:5845

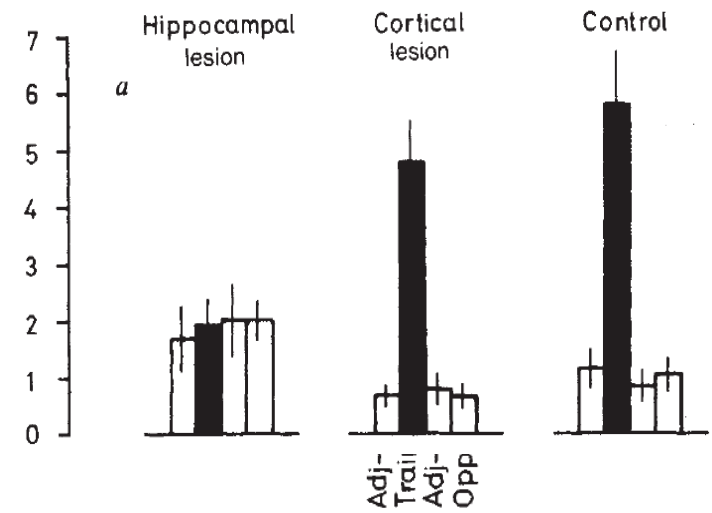
etc.

- Often explicitly designed to require **allocentric representations** as much as possible (in order to study hippocampal function):
 - Spatial relations that define locations are **large scale** (in relation to rat body)
 - Salient **distal cues** define location
 - Rat's '**viewpoint**', i.e. **starting point**, is **moved** between learning trials or between learning and testing (however note: even in the radial arm maze where rats always start from centre, i.e. same position, they seem to rely on allocentric representations).
- Have been used extensively to study role of the hippocampus and local synaptic plasticity to allocentric spatial memory.

'Standard' water maze paradigm – learning of a constant platform location across several trials with a changing start position

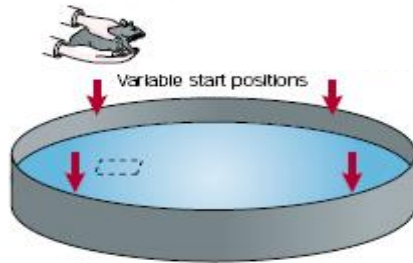


Annulus crossing on probe trials (▲) without platform

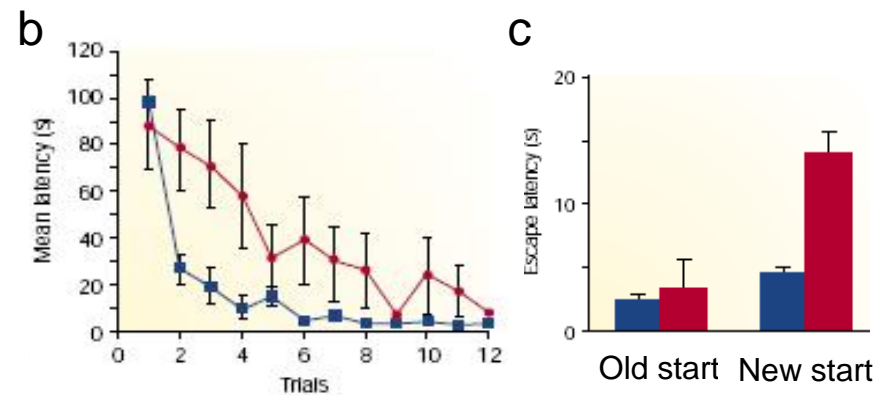
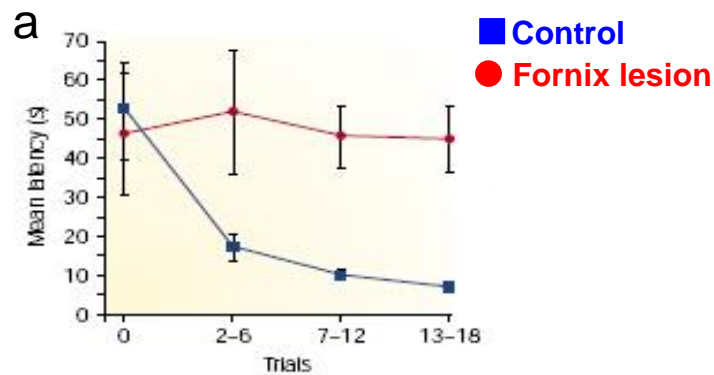
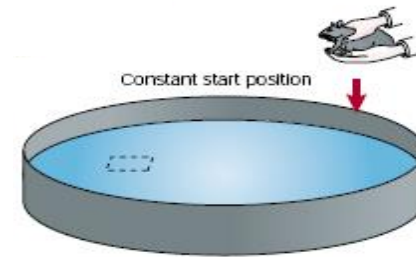


Allocentric and egocentric spatial representations in the water maze

Variable start positions



Constant start position



- Allocentric representations are necessary
- Hippocampus is required (a)



Allocentric, but not egocentric, spatial memory requires the hippocampus.

- Egocentric representations can be used
- Hippocampus is not required (b)



- Intact rats 'automatically' encode an allocentric representation which they can use if required (c)

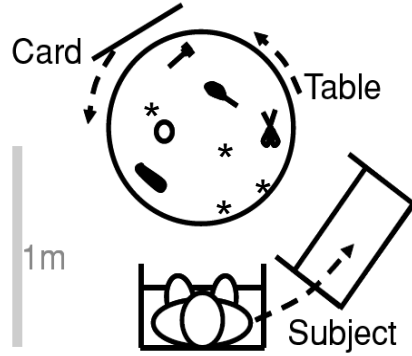
Studying spatial memory in humans

Object-place memory test, paper & pen



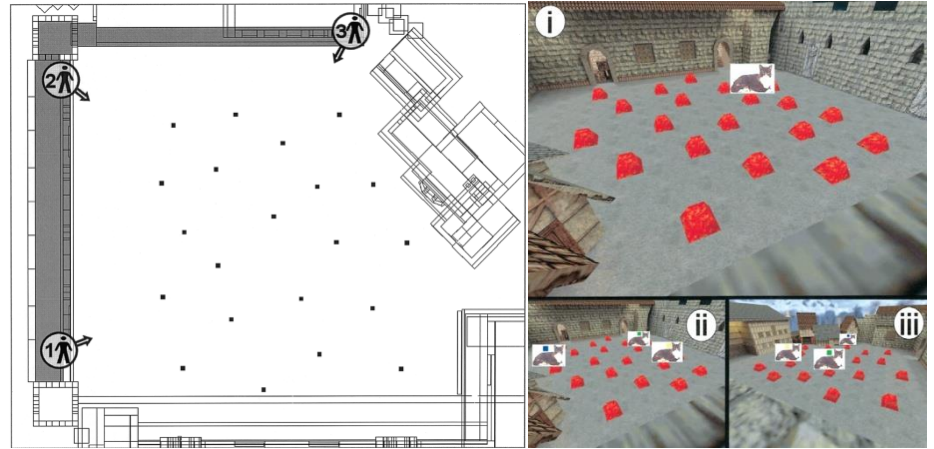
James & Kimura (1997)
EvolHumBehav 18:155

Detection of change in object location



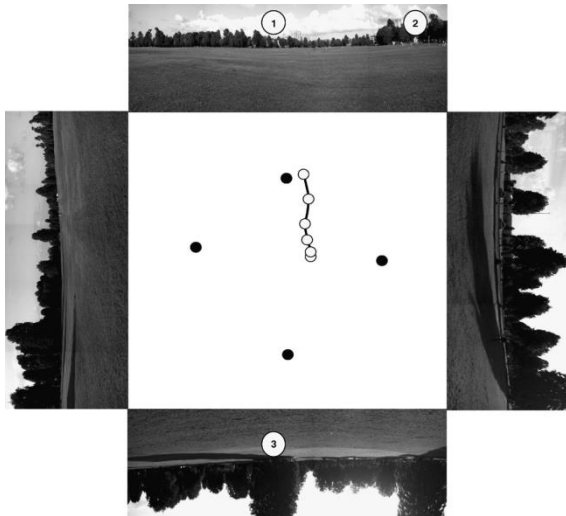
Burgess et al (2004) *Cognition* 94:149

Object-place memory test in virtual town



King et al (2002) *Hippocampus* 12:811

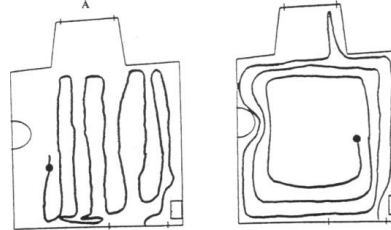
Object-place memory test in natural large-scale environment



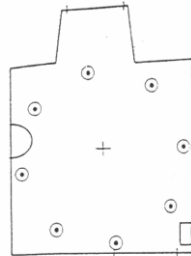
Smith et al (2008) *Cognition* 107:1102

Tests based on rat paradigms

Invisible-sensor task (water maze analogue)



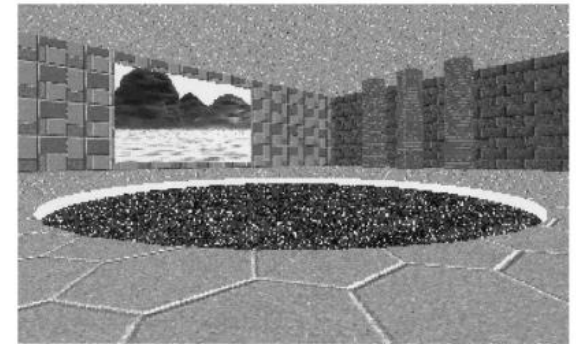
8-arm radial maze



1 m

Bohbot et al. (2002)
PhysiolRes 51 (Suppl. 1):S49

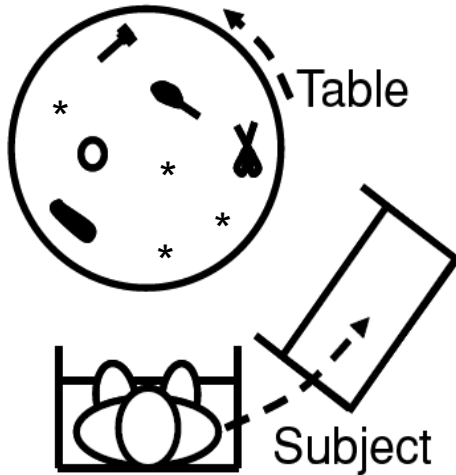
Water maze analogues (virtual)



Astur et al. (1998) *BehavBrainRes* 93:185
Buckley & Bast, 2018, *Hippocampus*: in press

Allocentric and egocentric representations in spatial memory

Detection-of-a-change-in-object-location experiment

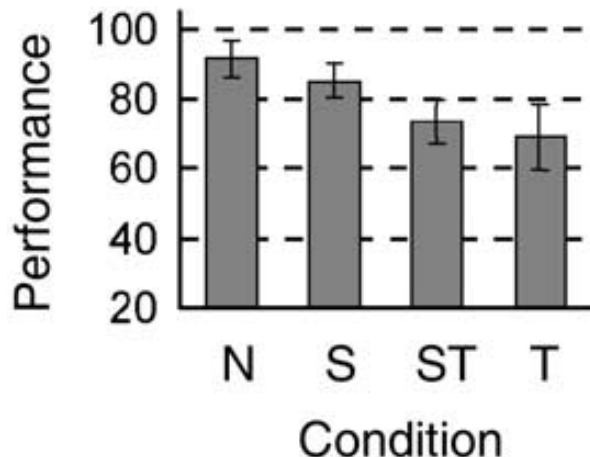


Learning phase: Subject studies object array for a few seconds.

Test: After retention delay of a few seconds, during which the subject is blindfolded and one object location is changed, subject is asked which one has moved.

To examine the contribution of allocentric or egocentric representations, the effects of subject movement (S) or table rotation (T) between Learning and Test can be examined.

Effects of S, T or their combination (ST)

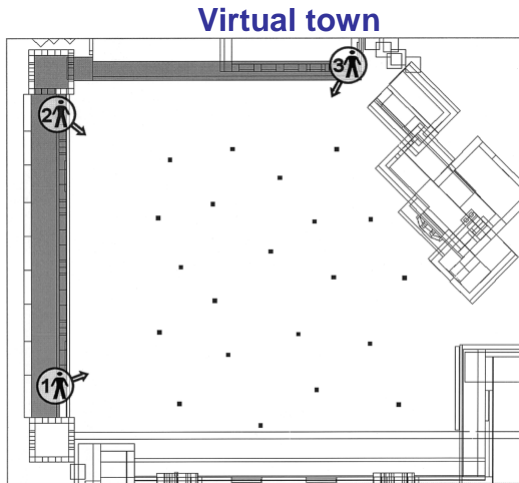


Data from Wang & Simons (1999), Experiment 1, shown in Fig. 2, as redrawn by Burgess et al. (2004), Fig. 2c.

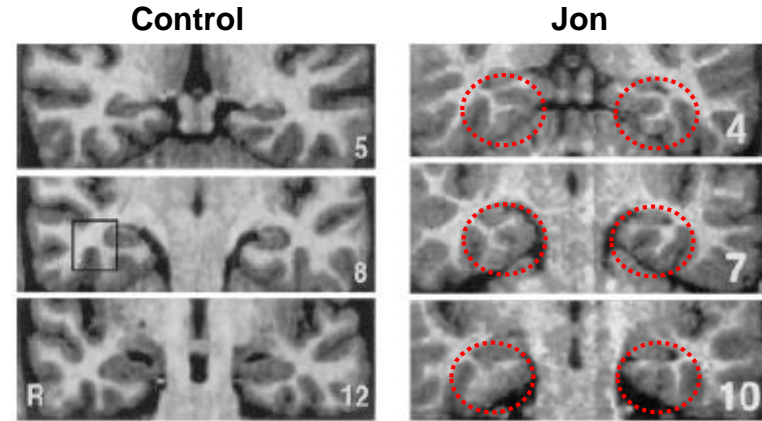
Conclusions

- Both allocentric and egocentric representations contribute to spatial memory in this paradigm.
- Egocentric memory can be updated based on self-motion (idiothetic) cues.

Egocentric and allocentric spatial memory in patients with hippocampal damage



Hippocampal atrophy due to perinatal anoxia



Presentation phase (encoding)



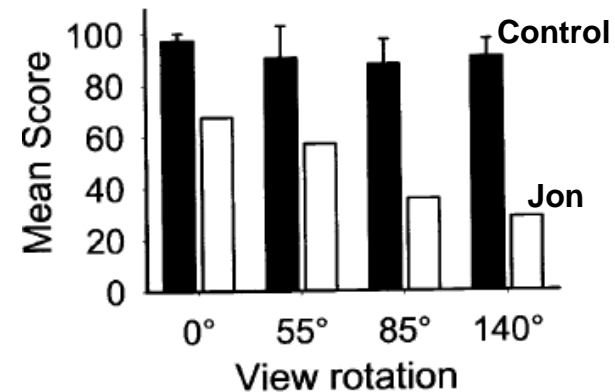
Test phase



Same view

Alternative view
(note: no self-motion cues)

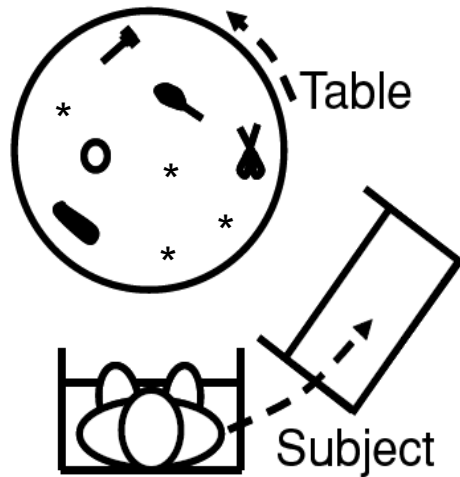
Jon's performance is especially impaired if allocentric representations are required



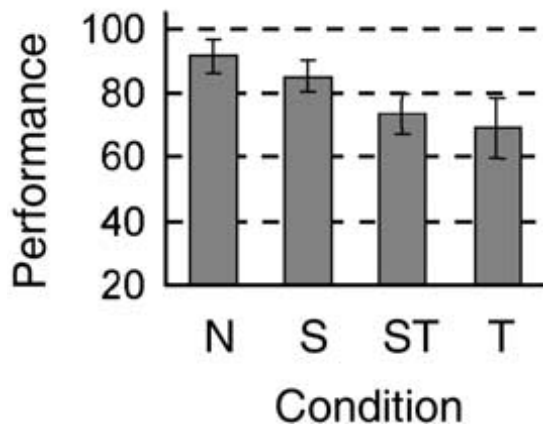
Conclusion

Hippocampus is especially important for allocentric representations (see also Holdstock et al., 2000, *Neuropsychologia* 38:410).

Experiment using the detection-of-a-change-in-object-location paradigm



- Use the 'simple' version without cue card and involving only S, T, and S+T rotations (Wang and Simons, 1999, *Cognition*).
- Can the rotation effects indicating spatial updating based on self-motion cues be replicated (compare Motes et al., 2006, *Perception*; Banta Lavenex et al., 2011, *Behav Brain Res*)?

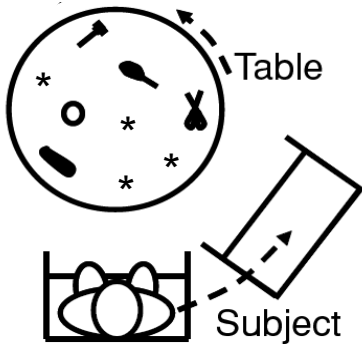


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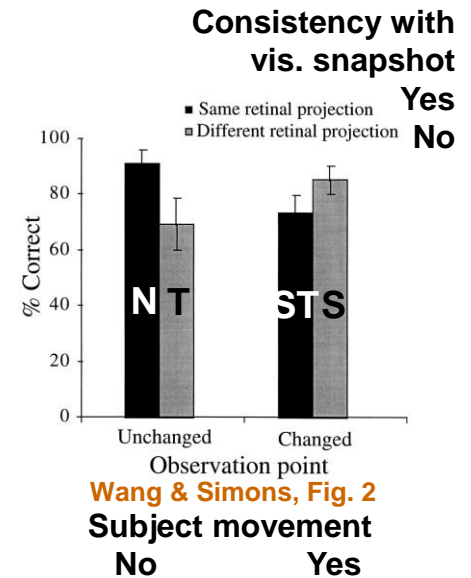
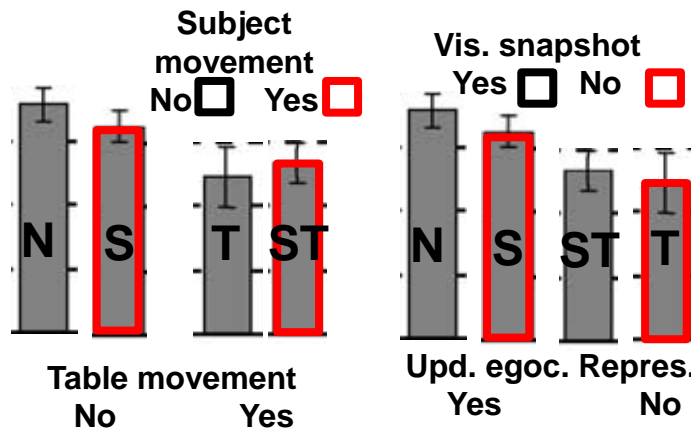
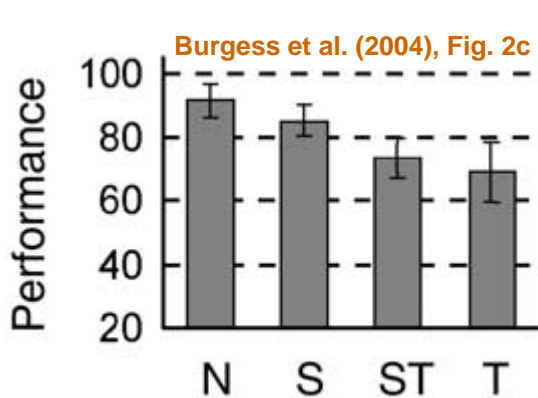
Detection-of-a-change-in-object-location experiment

A two-factorial (2X2) design – IVs and levels?

- Table rotation and subject movement, 2 levels each (yes, no) (compare Wang & Simons, 1999, *Cognition*)
- Consistency with updateable egocentric representation and consistency with visual snapshot, 2 levels each (yes, no) (Burgess et al., 2004)
- Subject movement and consistency with visual snapshot, 2 levels each (yes, no) (Wang & Simons, 1999)
- Alternatively, this may be considered a one-factorial design, with one IV (combination of S and T movements) that has 4 levels.



Analysis and interpretation of data?



Subj. movement	No	Yes	Yes	No
Table rotation	No	No	Yes	Yes
Upd. egoc. repres.	Yes	Yes	No	No
Vis. snapshot	Yes	No	Yes	No

2X2 repeated measures ANOVA

(<https://statistics.laerd.com/spss-tutorials/two-way-repeated-measures-anova-using-spss-statistics.php>)

Key points to consider in planning your experiments

- Clearly defined performance measures.
- Clearly defined testing procedures: instruction of the participants, presentation times, what happens between presentation and study phases, constant and reproducible spatial cue arrangements, etc.
- Counterbalancing, i.e. control for the effects of a confounding variable by ensuring these effects are equal or comparable in all experimental conditions. Important confounding variables include: testing order, object location, object array.
- Any ethical issues?
Please see:
<https://workspace.nottingham.ac.uk/display/PsychTeach/Ethics+Review+Process>

Next steps

Today (5 November)

- Form groups of 6 students.
- We'll go around to take names of members in the different groups.
- Perhaps, arrange a meeting before next Monday to do a bit of pre-planning.

Next Monday (12 November)

- Everybody should have read carefully the key papers on the detection-of-a-change-in-object-location paradigm and understand how the experiment is run.
- Work on experimental procedures and design of your experiment and check with us.

Drop in: Wed, 14 Nov, 2-4 pm, Chloe's office (B13)

Monday, 19 November

- We will be available to discuss problems, but you will not need to attend session if you feel comfortable with your experiment.

Monday, 26 November

- By then you should have collected your data!
- Each group to prepare a plot of their data that can be presented to the class.
- We will discuss the analysis of the experimental data.
- In preparation of the session, please have a look here:

<https://statistics.laerd.com/spss-tutorials/two-way-repeated-measures-anova-using-spss-statistics.php>

Drop in: Wed, 28 Nov, 2-4 pm, Chloe's office (B13)

Monday, 3 December

- Oral presentations (10-15 min plus 2 min discussion) by each group.

All meetings Monday, 9-11 AM, in Room A20.

Reports due Wed, 12 December (please double check on Moodle).