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LETTERS

Evidence for grid cells in a human memory network

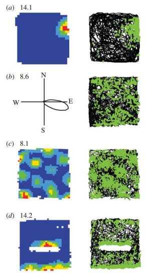
Christian F. Doeller[1,2], Caswell Barry[1,3,4] & Neil Burgess[1,2]

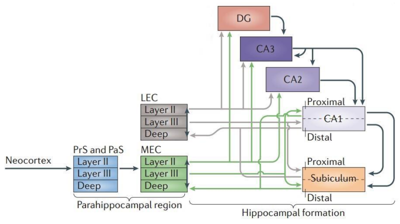
Presented by Hongbiao

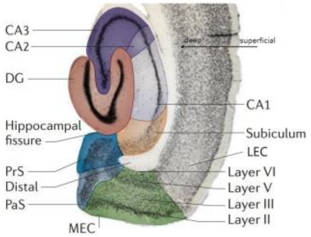
Overview

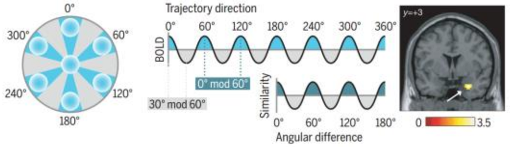
In general, the authors transfer **electrophysiological experiments** in **rats** to virtual reality **fMRI recordings** in **humans** to show that humans have **grid-cell-like representations** in a network of **entorhinal areas** which support **spatial cognition** like rats.

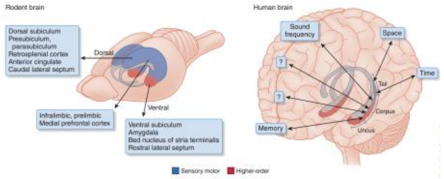
- Background
- Experiment
- Result
- Discussion



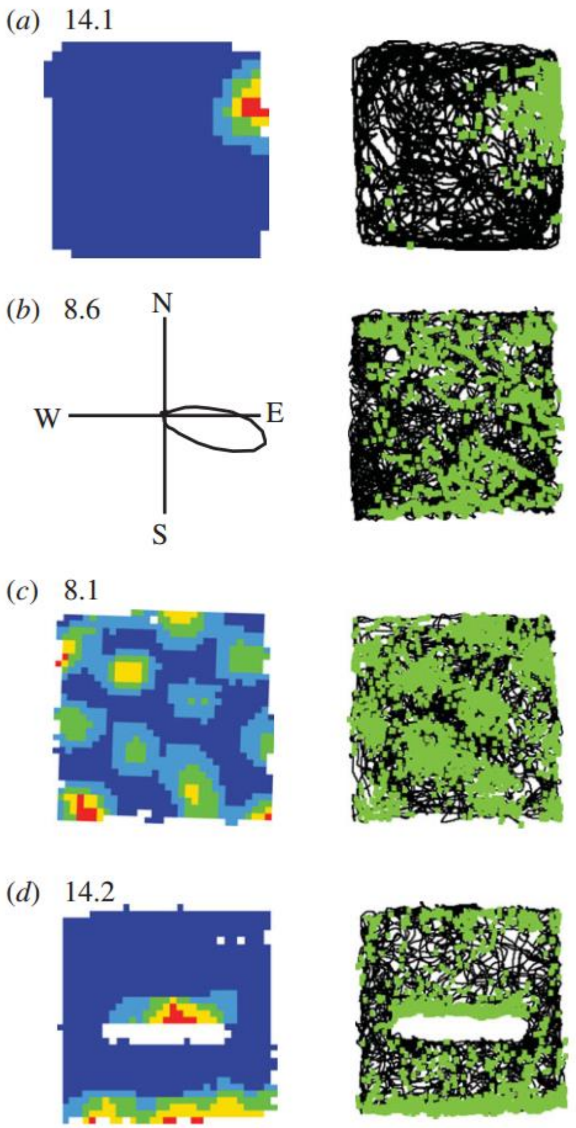


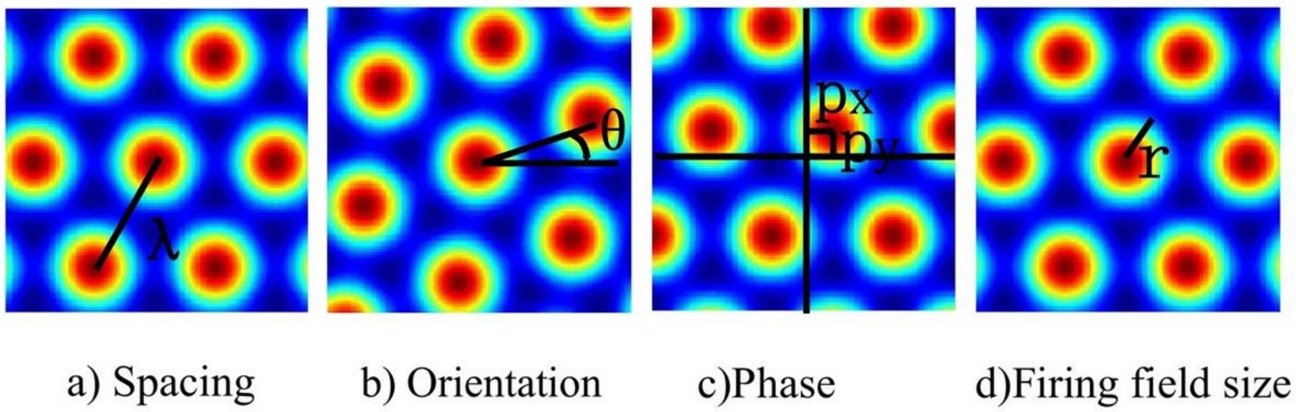






Background: Function





Grid cell: Four parameters of grid field.
(a) Spacing; (b) Orientation;
(c) Phase; (d) Firing field size.

Figure 1. Four types of spatial cell.
(a) Place cell; (b) Head direction cell;
(c) Grid cell; (d) Boundary cell (border cell).

Left column: Firing rate map (firing polar plot)
Right column: Animal trajectories with spike locations

Background: Algorithm

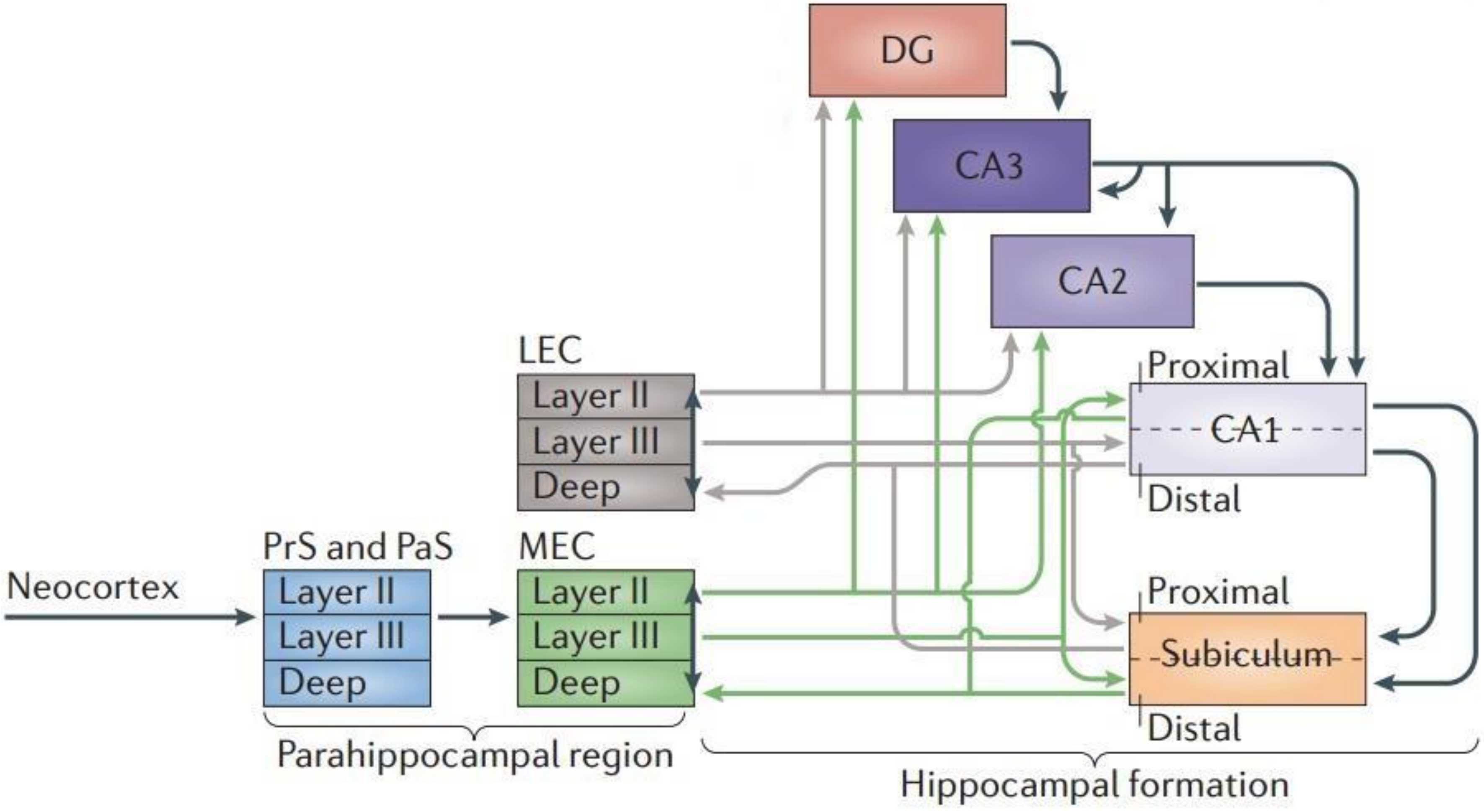
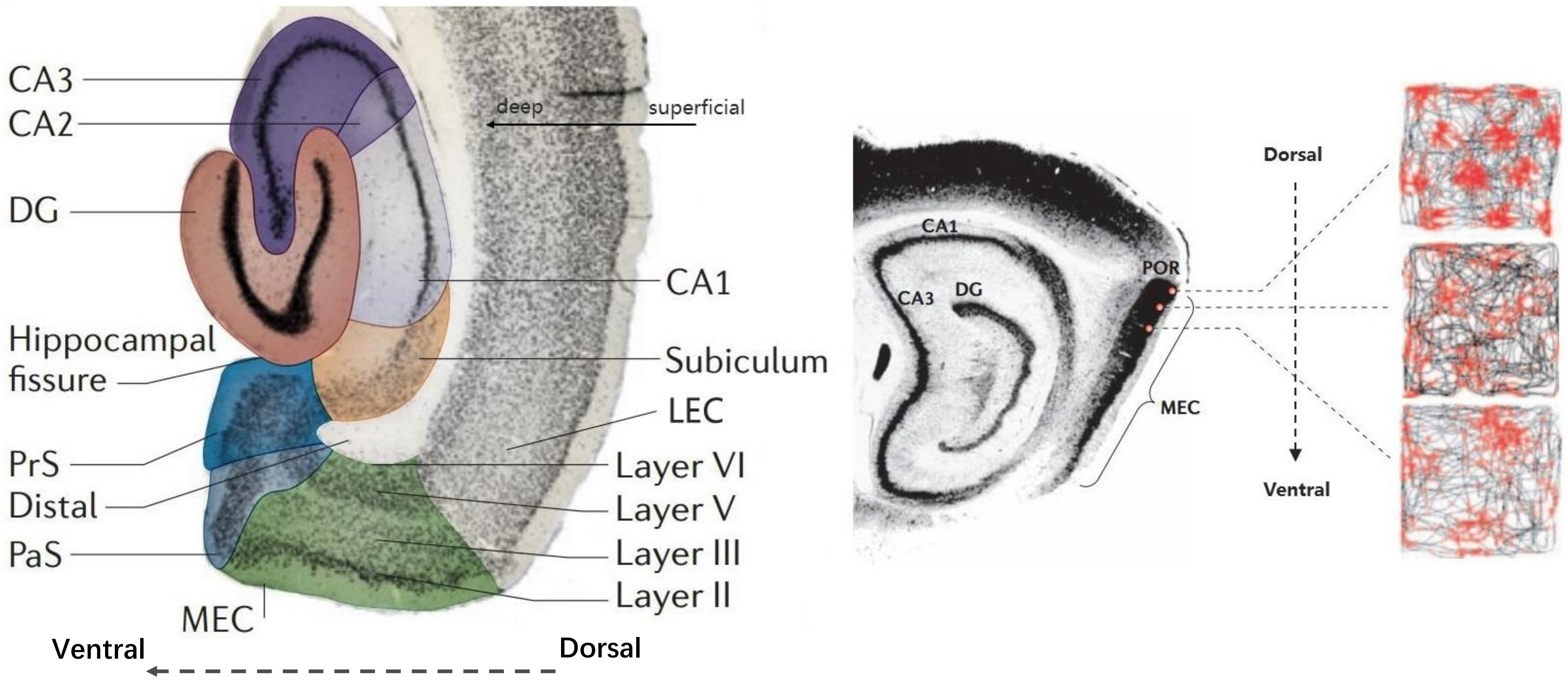


Figure 2. Information flow model of entorhinal-hippocampal region.
Parahippocampal region: presubiculum (**PrS**), parasubiculum (**PaS**)
Entorhinal cortex: lateral entorhinal cortex (**LEC**), medial entorhinal cortex (**MEC**)
Hippocampus: dentate gyrus (**DG**), Cornu Ammonis (**CA**)

Background: Implement



<u>Figure 3.</u> Anatomy of entorhinal-hippocampal region.
Left: the right hemisphere of a rat brain, with a focus on the hippocampal formation.
Right: the sagittal section shows the properties of grid field along the dorsoventral axis.

Background: Hypothesis

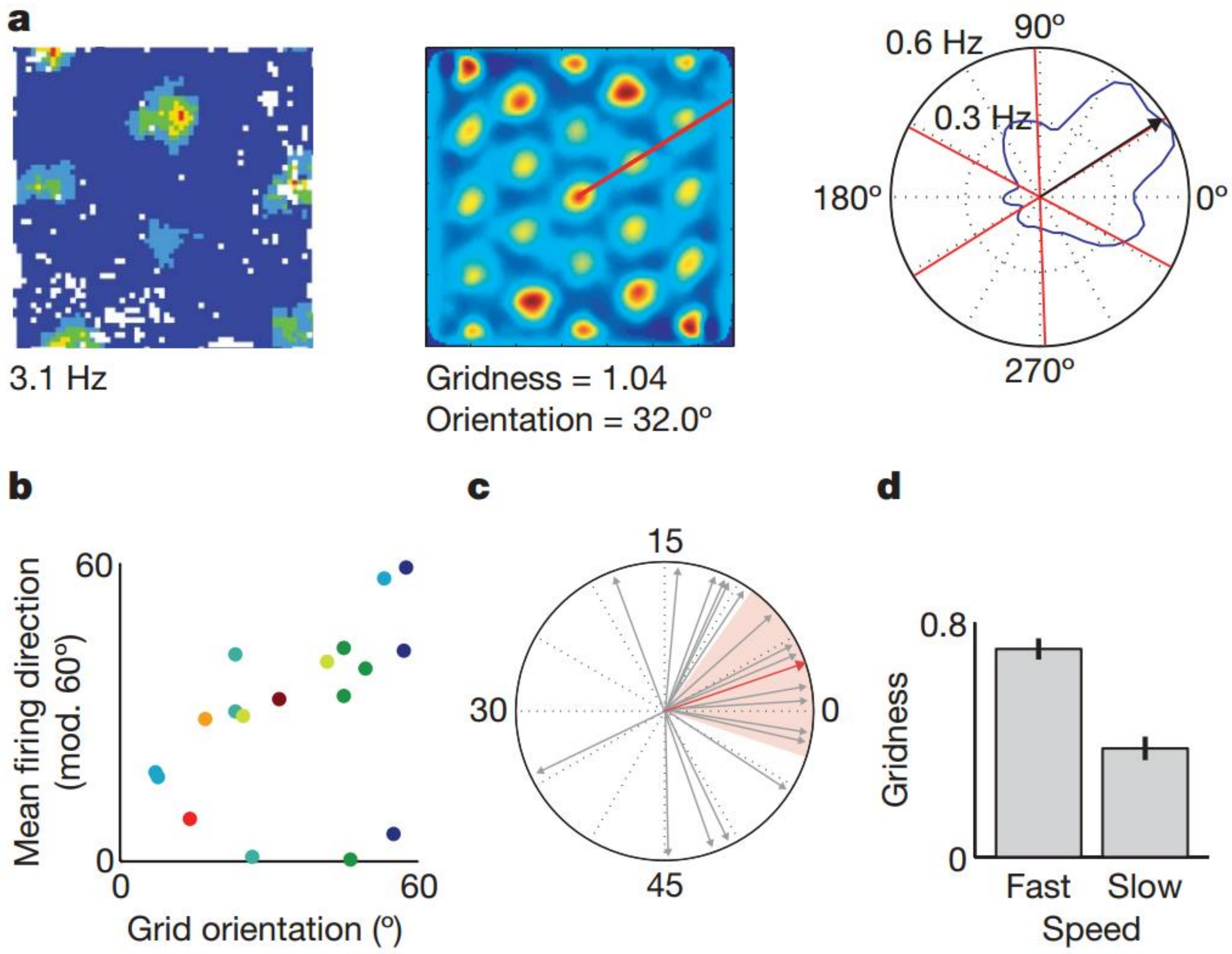


Figure 4. Three factors of grid field allow fMRI to detect grid cells in humans

1) **Orientation** of grid fields are the same;

2) Preferred direction of **mixing grid cells** are always **aligned with** the axes of the grids;

3) The gird cell firing rate and grid field score, are increasing with animal **running speed**.

Experiment: fMRI with virtual reality

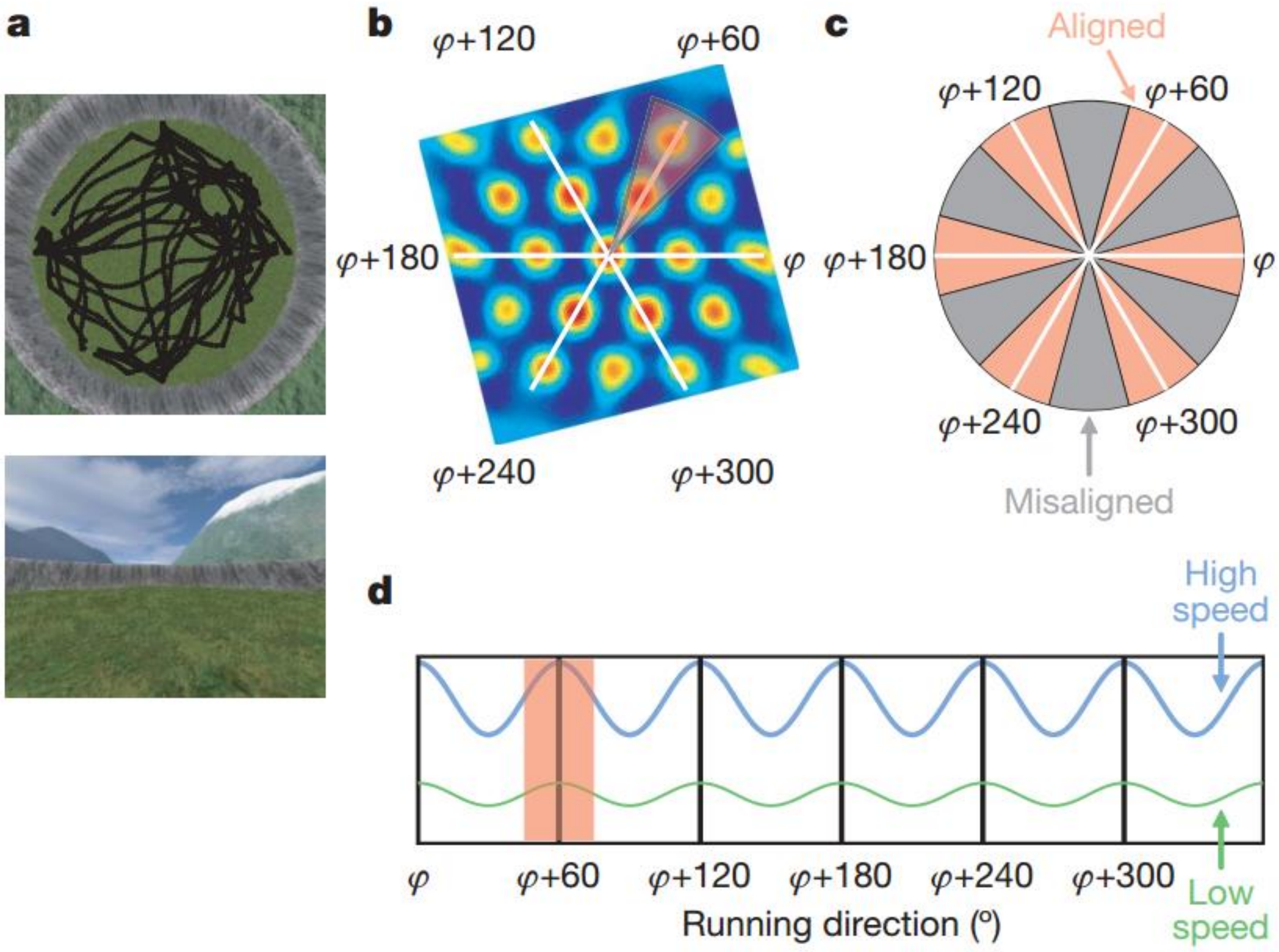


Figure 5. Experimental logic.

1) Human participants (N = 42) do VR collect-and-replace **spatial memory task**, mimicking the foraging task in rodents.

2) fMRI **input** and fMRI **output** expectation. If grid cell firing pattern does exist in humans, there should be **differences** in fMRI signals for running **aligned**/**misaligned** to grid axes.

- **Aligned:** mixing grid*HD cell + grid cell.
- **Misaligned:** grid cell misaligned activation.

Result: fMRI activation

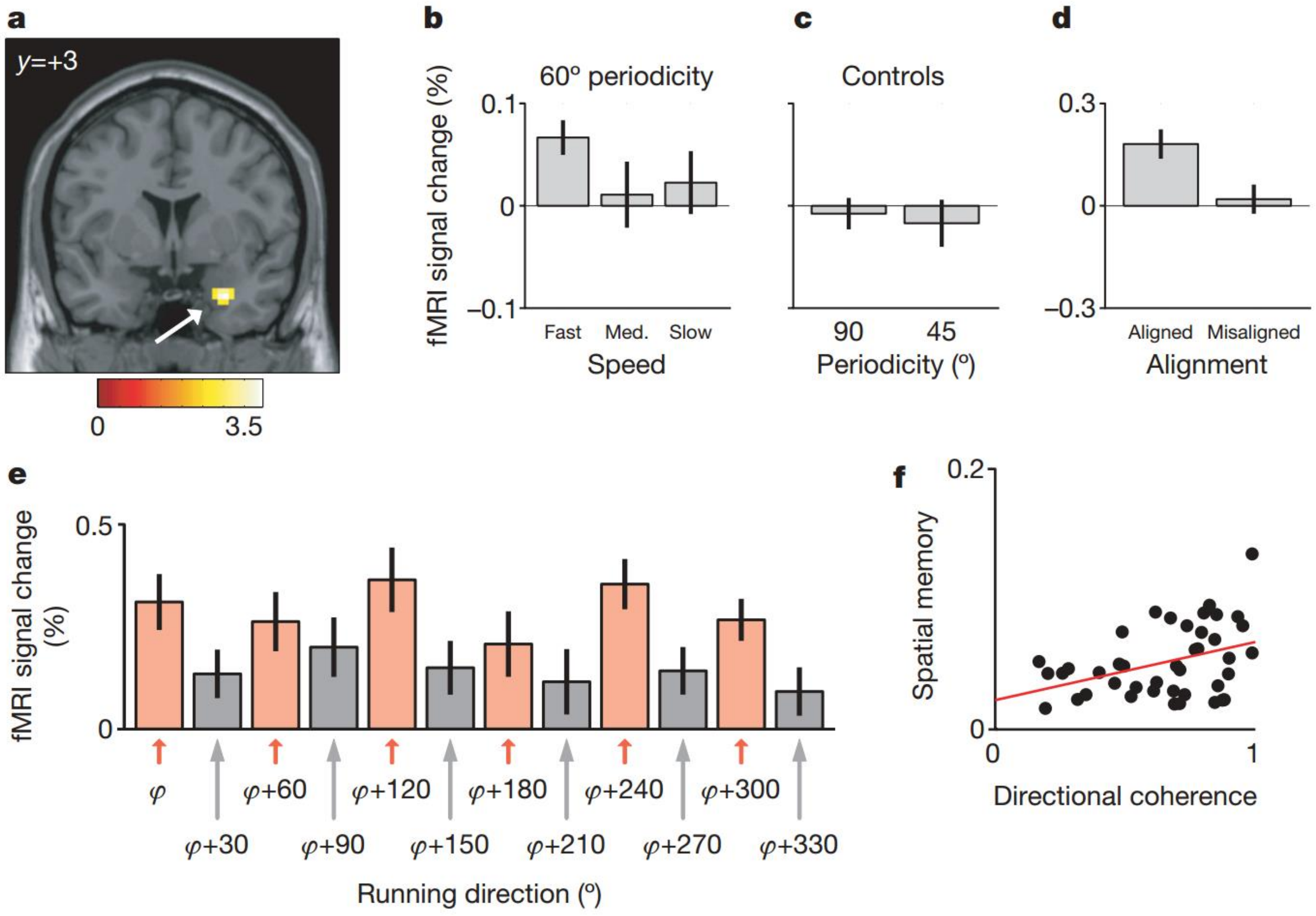
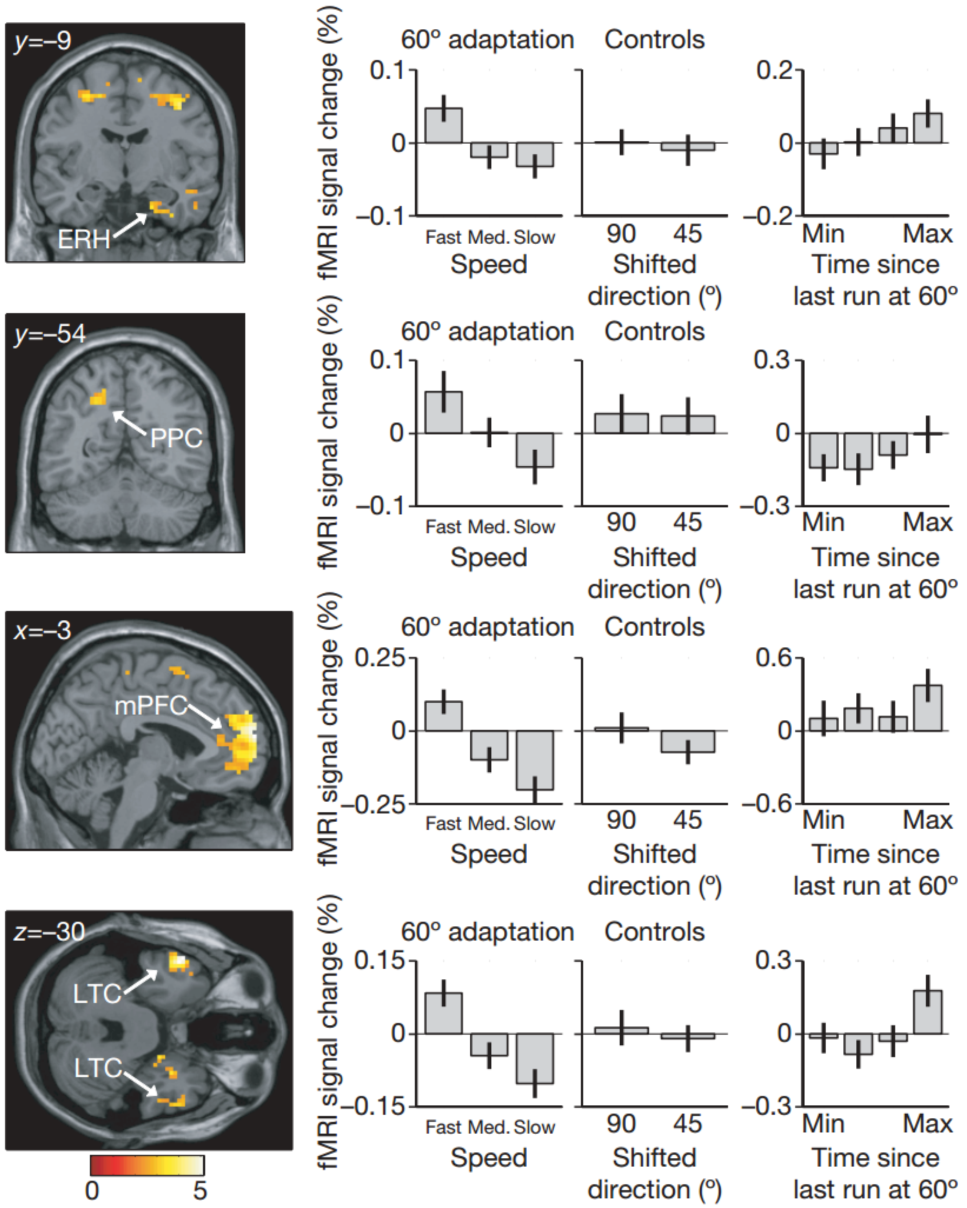


Figure 6. Modulation of **right entorhinal cortex activity** by **running direction** with six-fold rotational symmetry, and correlation with **spatial memory**.

1) Activation for **aligned** and **misaligned** in fast runs confirms the sinusoidal modulation effect. It has **60° directional periodicity**, not 90° or 45° .

2) **Grid score** and **spatial memory score** are correlated. Thus, Grid cell representations are useful to guide behavior in humans.

Result: fMRI adaptation



<u>Figure 7</u>. fMRI **adaptation** to **all running directions** and to **60° direction** in **fast runs**.

1) fMRI activities in **para-hippocampal** region, **retrosplenial** and **visual cortices** show adaptation to **360°** running direction.

I.e., fMRI signals will **decrease** when activation happens at this direction again.

2) fMRI adaptation to **60° direction** in a network of **entorhinal cortex**, extending to subiculum (**ERH**), posterior parietal (**PPC**), medial prefrontal (**mPFC**), lateral temporal cortices (**LTC**) and motor cortex.

I.e., they show **more signal reductions** when activation happens at 60° direction again.

Discussion: Direct evidence

nature
neuroscience

Direct recordings of grid-like neuronal activity in human spatial navigation

Joshua Jacobs[1], Christoph T Weidemann[2], Jonathan F Miller[1], Alec Solway[3], John F Burke[4], Xue-Xin Wei[4], Nanthia Suthana[5], Michael R Sperling[6], Ashwini D Sharan[7], Itzhak Fried[5,8,9] & Michael J Kahana[4,9]

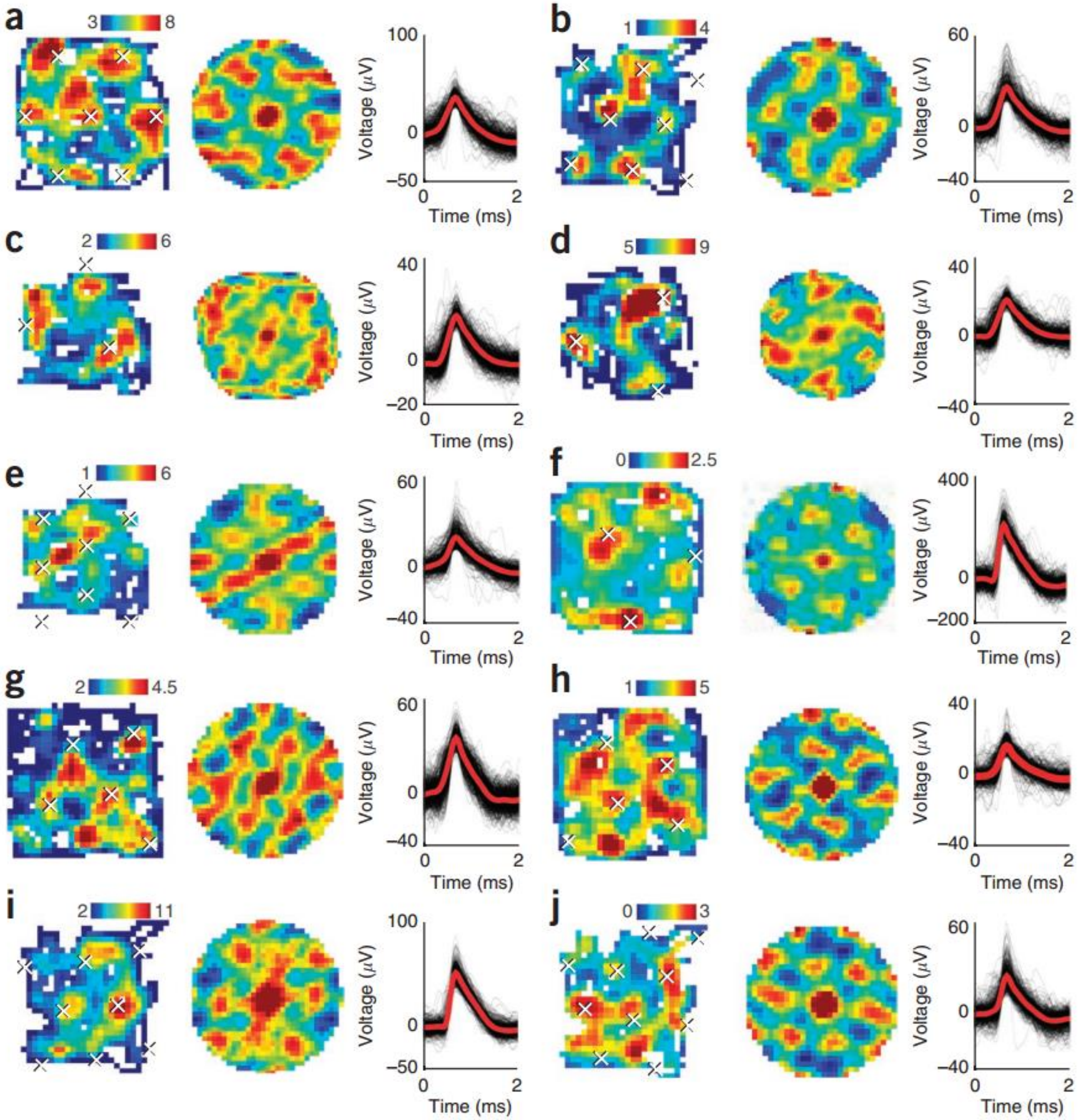


Figure 8. Examples of grid-like spatial firing in humans.

Discussion: Generalized function

CellPress

Current Biology
Report

Grid-like Processing of Imagined Navigation

Aidan J. Horner,[1,2,*] James A. Bisby,[1,2] Ewa Zotow,[1] Daniel Bush,[1,2] and Neil Burgess[1,2,*]
[1]UCL Institute of Cognitive Neuroscience, 17 Queen Square, London WC1N 3AZ, UK
[2]UCL Institute of Neurology, Queen Square, London WC1 3BG, UK
*Correspondence: aidan.horner@york.ac.uk (A.J.H.), n.burgess@ucl.ac.uk (N.B.)
http://dx.doi.org/10.1016/j.cub.2016.01.042

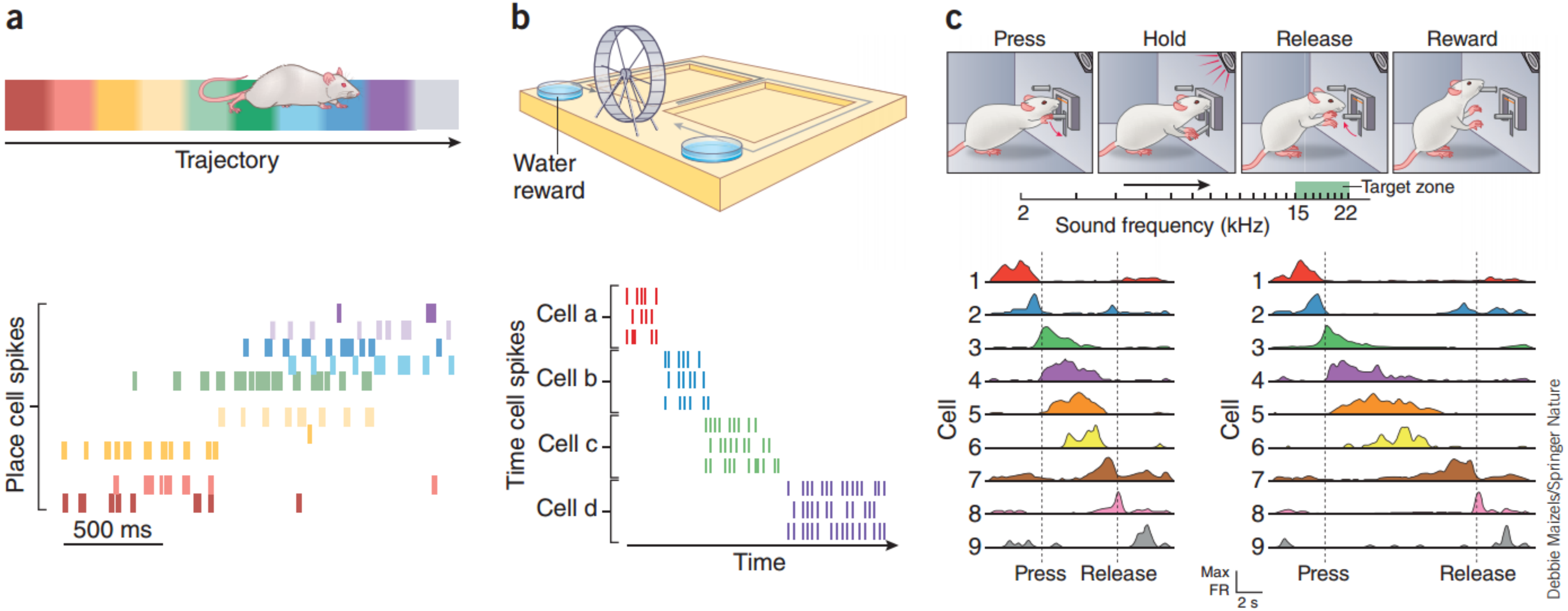


Figure 9 Cells in the hippocampal formation (**place cells, grid cells**) have capacity to support **flexible cognition and behavior**, like they do in the **spatial representation**.

Discussion: To human thinking

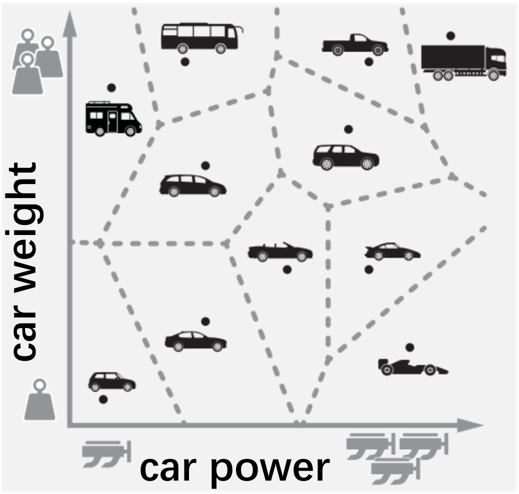
REVIEW

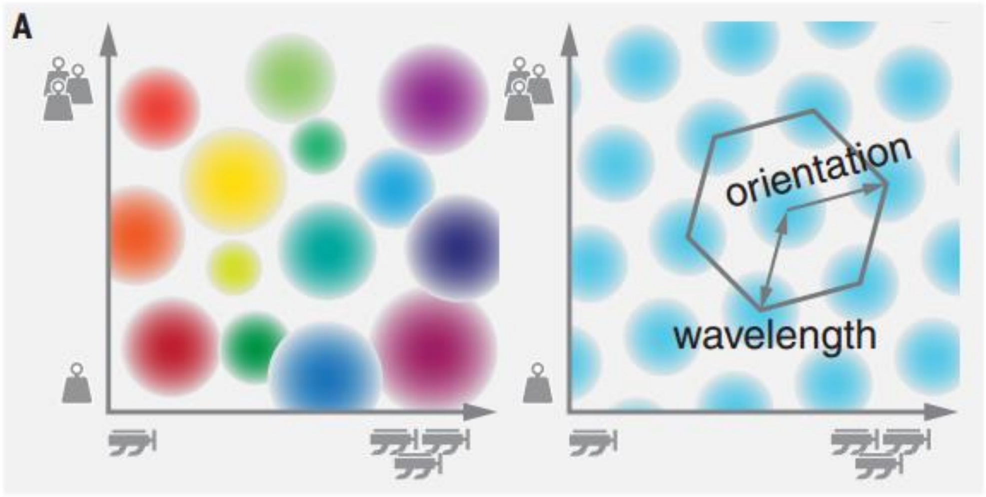
NEUROSCIENCE

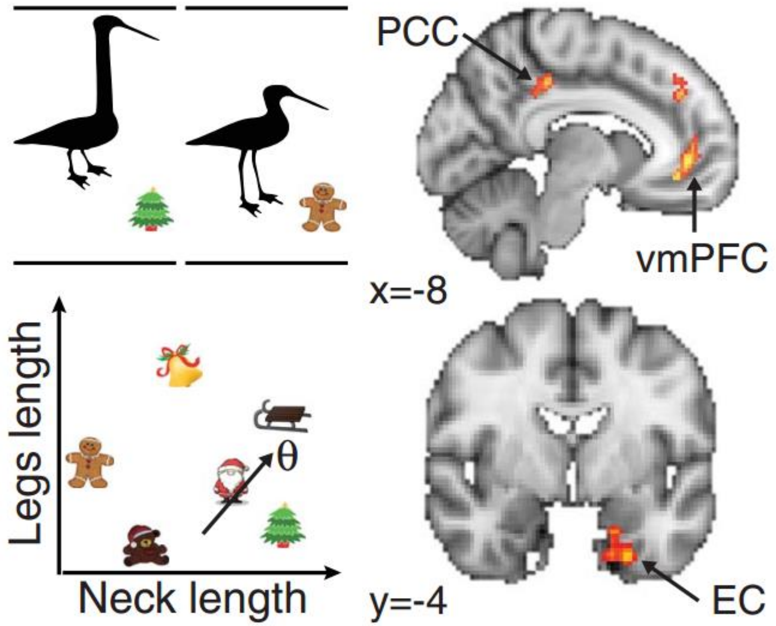
Navigating cognition: Spatial codes for human thinking

Jacob L. S. Bellmund[1,2,3]*, Peter Gärdenfors[4,5], Edvard I. Moser[1], Christian F. Doeller[1,3]*

Figure 10
Two-dimensional **cognitive space**.
Concepts organized in a mental map.
Feature distances help us to do pattern **completion**, pattern **separation** and similarity **inference**.







Thank you
Q&A