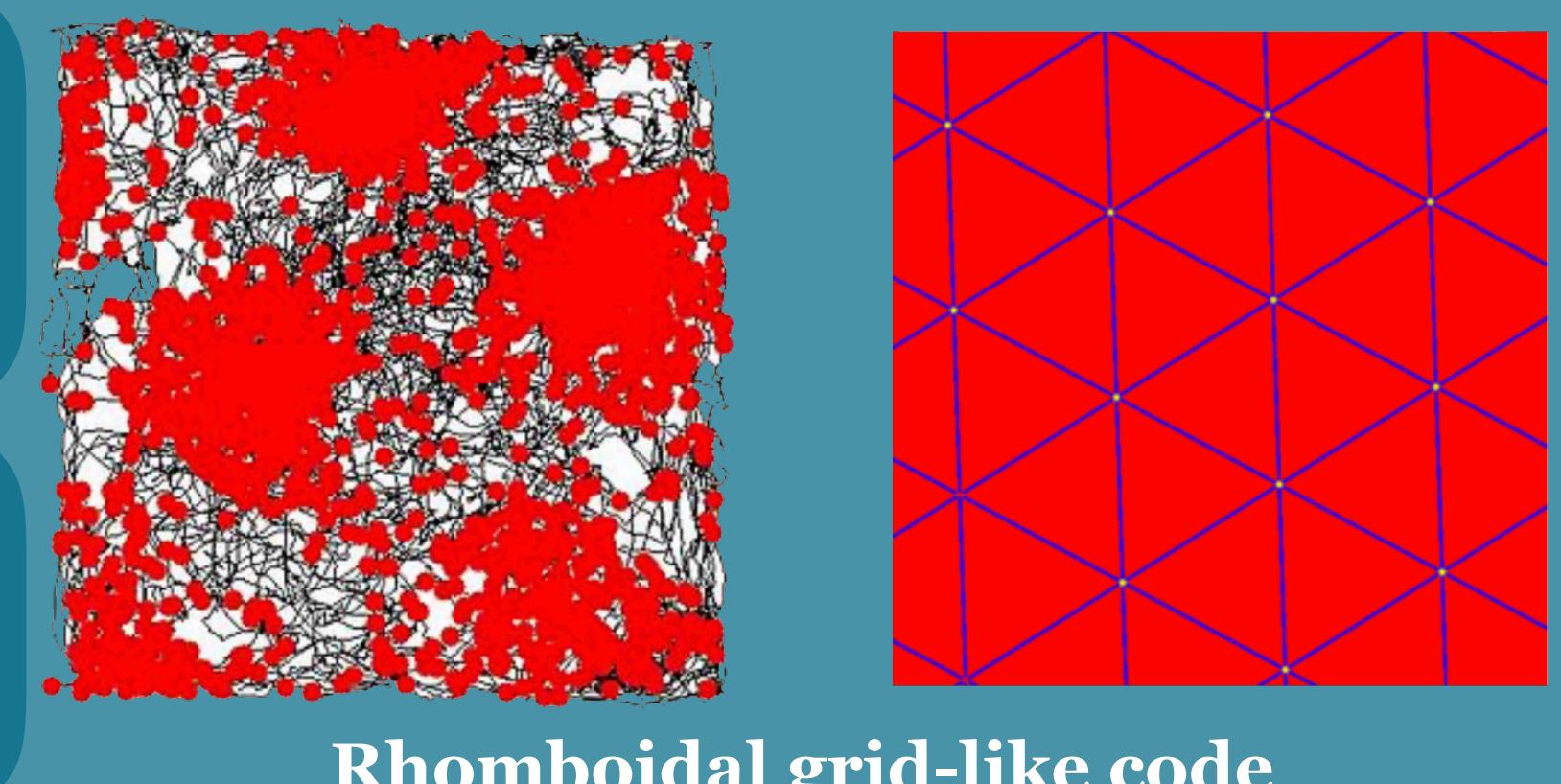


# Cognitive Maps: Grid like coding for improved efficiency

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## Introduction

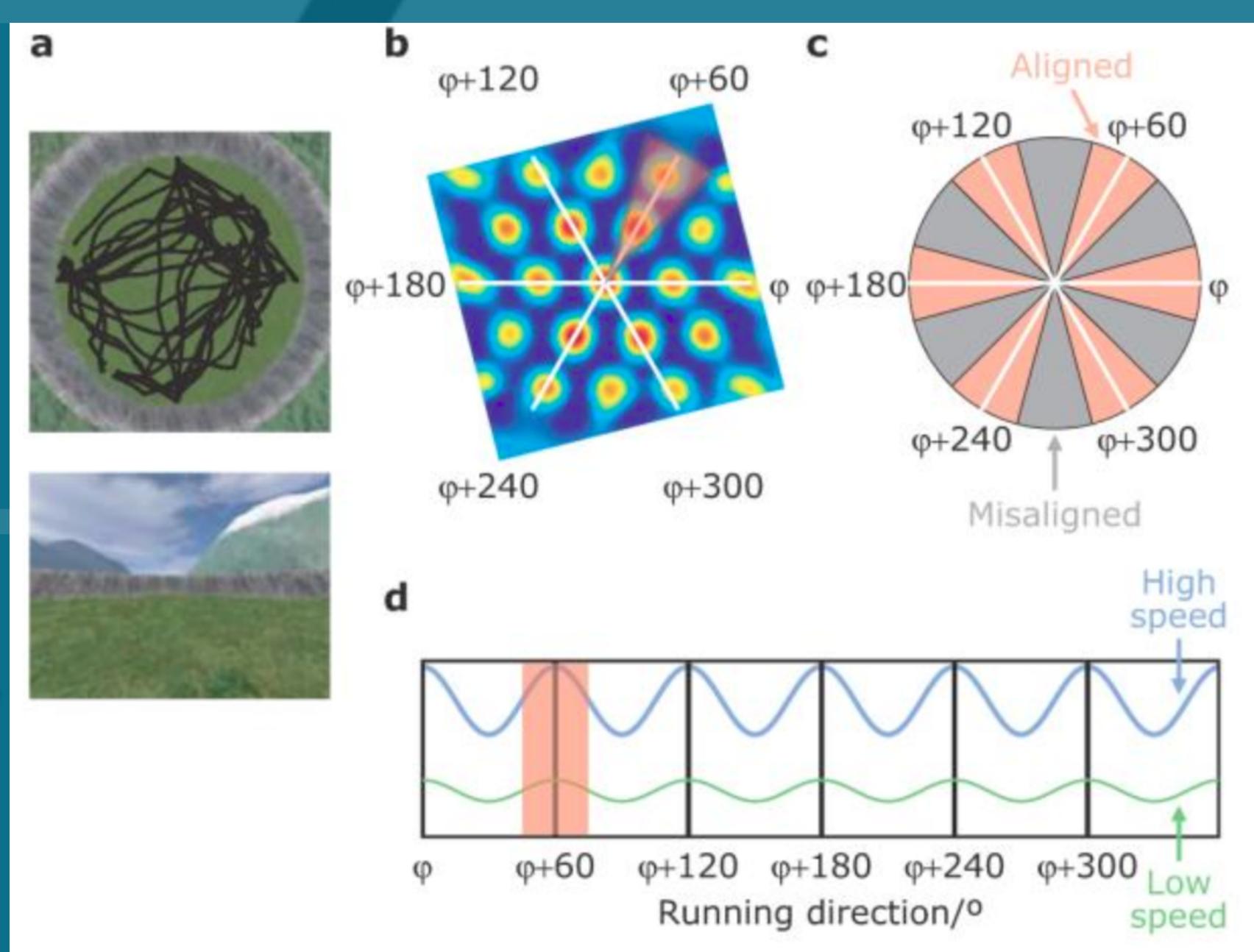
- A **cognitive map** is described as a mental representation of one's physical environment and was introduced by Edward Tolman in 1948. The mapping system is a type of memory responsible for the encoding of spatial information. The space can be both real or metaphorical.
- In the hippocampus, **place cells** (a type of pyramidal neurons), so called as they fire action potential when an animal is located in a distinct region of space (the place field of the cell), are thought to generate cognitive maps [1].
- In 2005, Moser et al. discovered the existence of **grid cells** in the medial entorhinal cortex (MEC) [2]. They represent a **rhomboidal grid-like structure** of location fields that repeat at regular intervals. The rhombus composing the grid have internal angles of 60 and 120 degrees.



Rhomboïdal grid-like code

## Evidence for grid cells in a human memory network

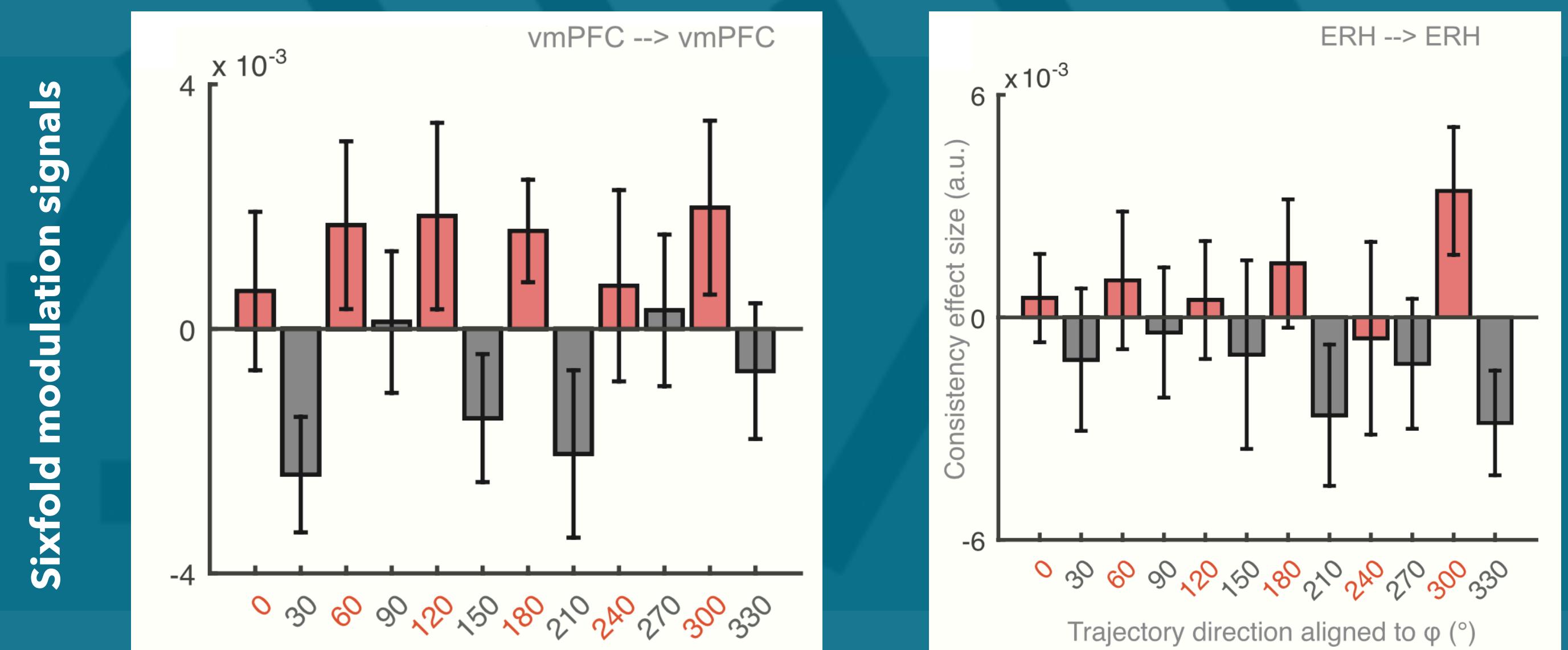
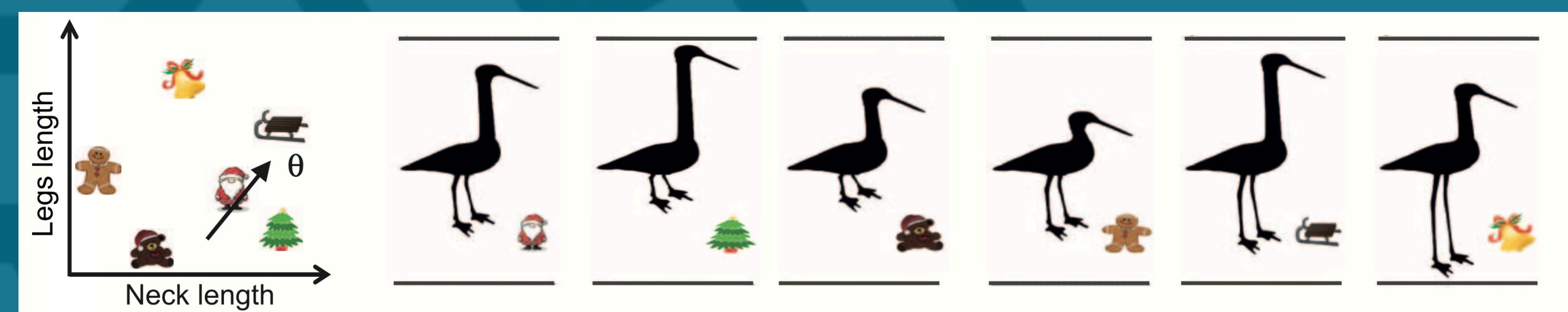
- Methods: Experiment carried out on male rats using tetrodes and mimicked in humans using fMRI and Virtual reality.
- The arena and how it was assayed and aligned in sync to the proposed grid-cell cell activations. Doeller et al. [3] looked for significantly active areas in sync to **six-fold periodicity** to represent a **six-fold rotation orientation**.



- Key results: (Left) **Right entorhinal cortex** significantly active with six-fold periodicity with arena navigation. (Middle) Average fMRI activity of ROI was increased when aligned to a six-fold rotation symmetrical representation of the arena. (Right) The ROI was more active for **faster speeds**. fMRI detected no area in sync with other periodicity - other rotation symmetries.
- Conclusion: fMRI activation significantly tuned to a six-fold periodicity when the external world was represented with six-fold symmetrical directions, in the right entorhinal cortex.
- The activation, dependent on the external world, of the internal representations suggests that the grid-like effect is an encoding, responsive recognition mechanism.

## Organizing conceptual knowledge in humans with a gridlike code

- Constantinescu et al. [4] confirmed the relationship between the **hexagonally symmetric code** used by grid cells and the **organisation of spatial representations** even for navigating conceptual relationships in a 2D knowledge space.
- In particular, they found that subjects with a **wider hexagonal modulation performed better** at the task of navigating a two-dimensional knowledge space in order to associate specific symbols or images with specific states of this concept space.



- Global relational codes, they suggested, may be used to **organise non spatial conceptual representations**, and when conceptual knowledge is represented in two continuous dimensions, these codes may produce a **hexagonal grid-like pattern**.



## Argument for grid cells as a non-essential, performance enhancing mechanism

- Banino et al. trained **artificial agents** to perform path-integration with **grid-like coded** representation. Before grid-like coding, artificial intelligence would perform worse than humans. In this experiment it **outperformed humans**, forming a better map based on cues and finding shortcuts. [5]
- Hexagonal** grid-like representation lattice outperformed square lattices as the **most efficient representation** when measuring for spatial feature content per required point-field in **two dimensions**. [6]
- Rat pups** with immature grid-cells had significant **place cell activation** at fixed distance intervals. This represents evidence against an essential role of grid cells in path-integration dependent place-cell firing to navigate through space using internal cognitive maps. [7]

## Conclusion

- Doeller et al. and Constantinescu et al. inferred the existence of **grid-like coding in humans** based on the unique characteristic of the **six-fold periodicity** in two dimensions, using fMRI signals from the right entorhinal cortex.
- Grid-like coding** through grid-cells is suggested to have a **non-essential, performance enhancing** role in forming cognitive maps.

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