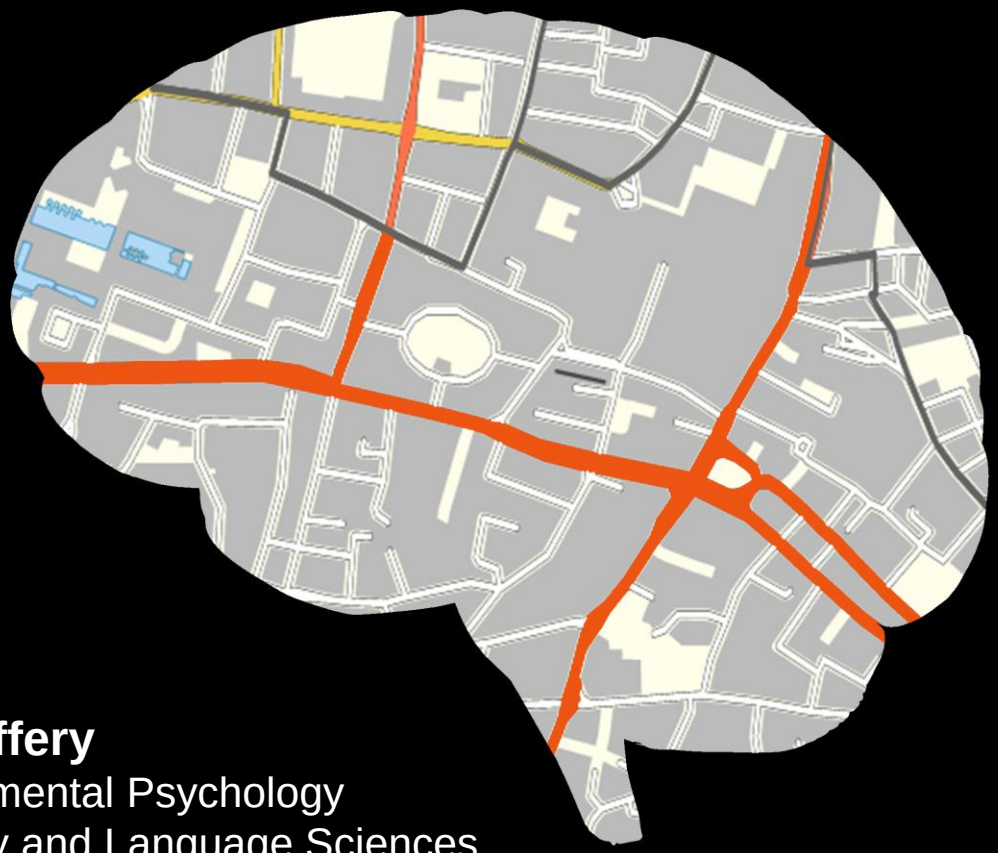
How the brain makes a map of space



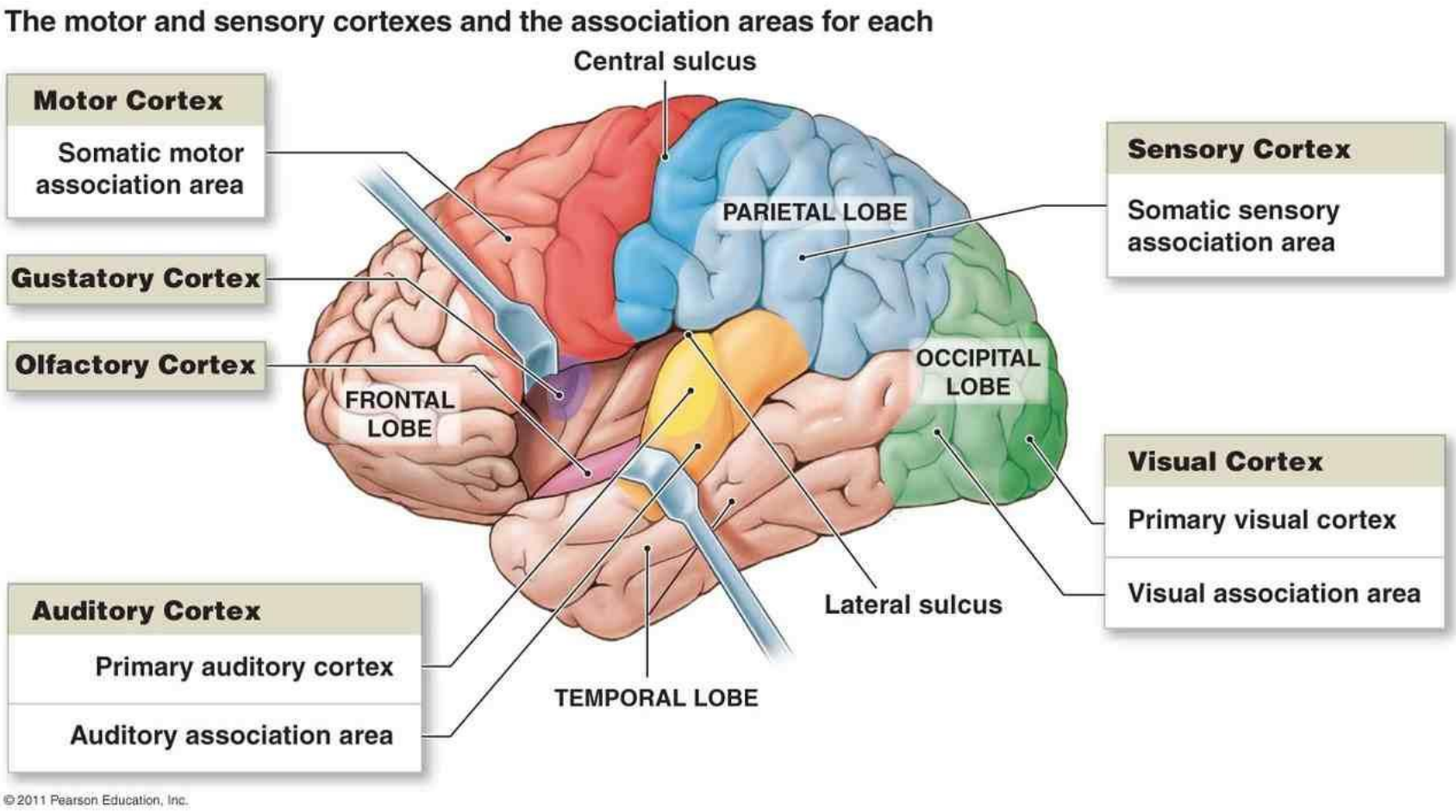
Professor Kate Jeffery
Department of Experimental Psychology
Division of Psychology and Language Sciences

How does the brain make an internal model of complex space?

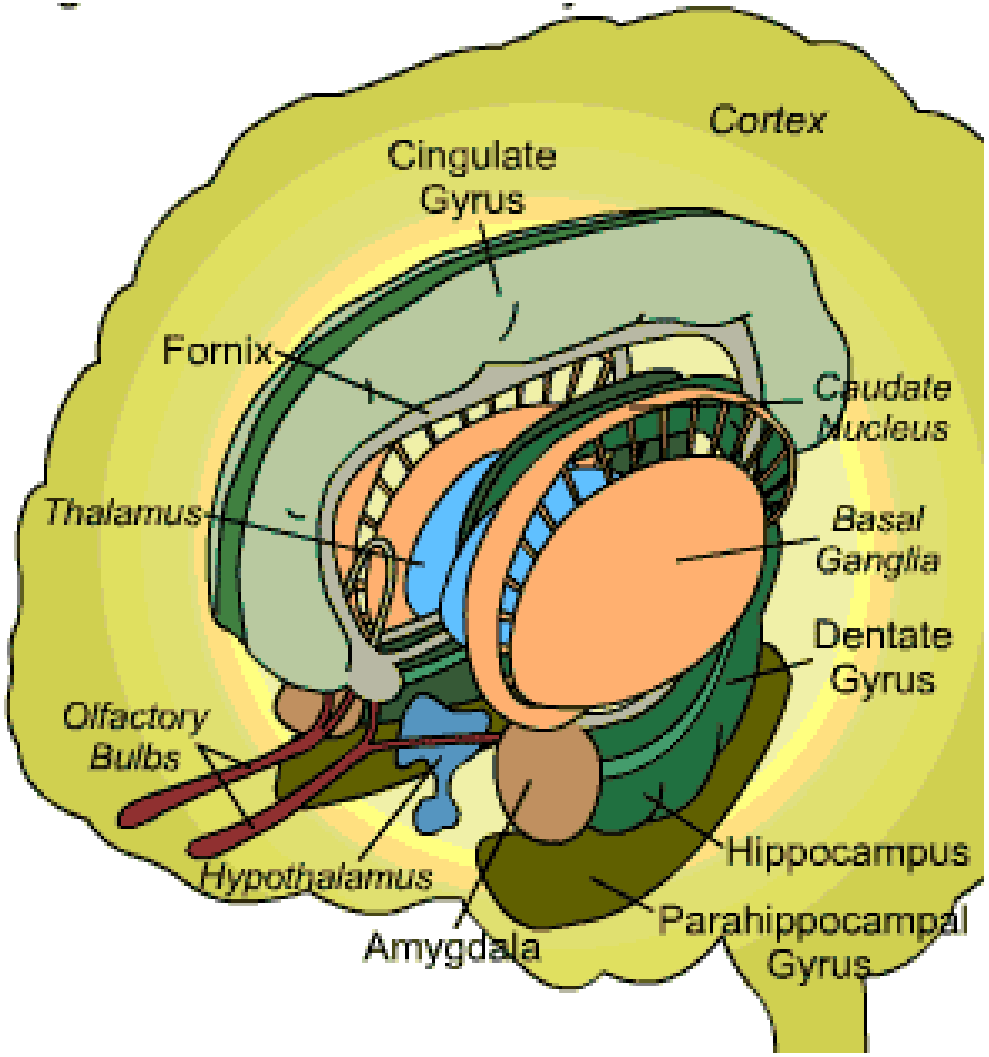
This is important for:

- **Navigation**
- **Memory**
- **Language**

Major cortical brain systems

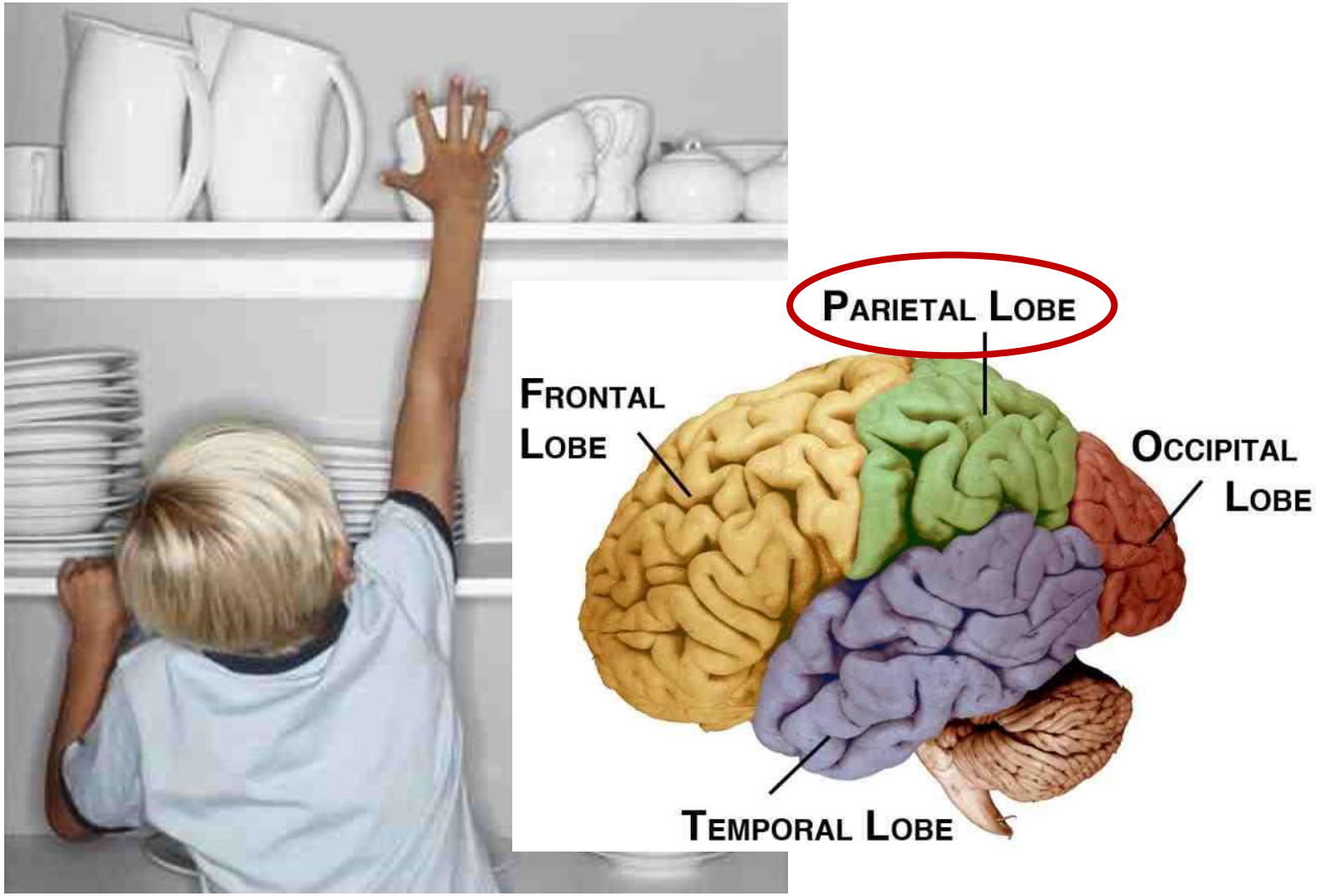


Major subcortical brain systems

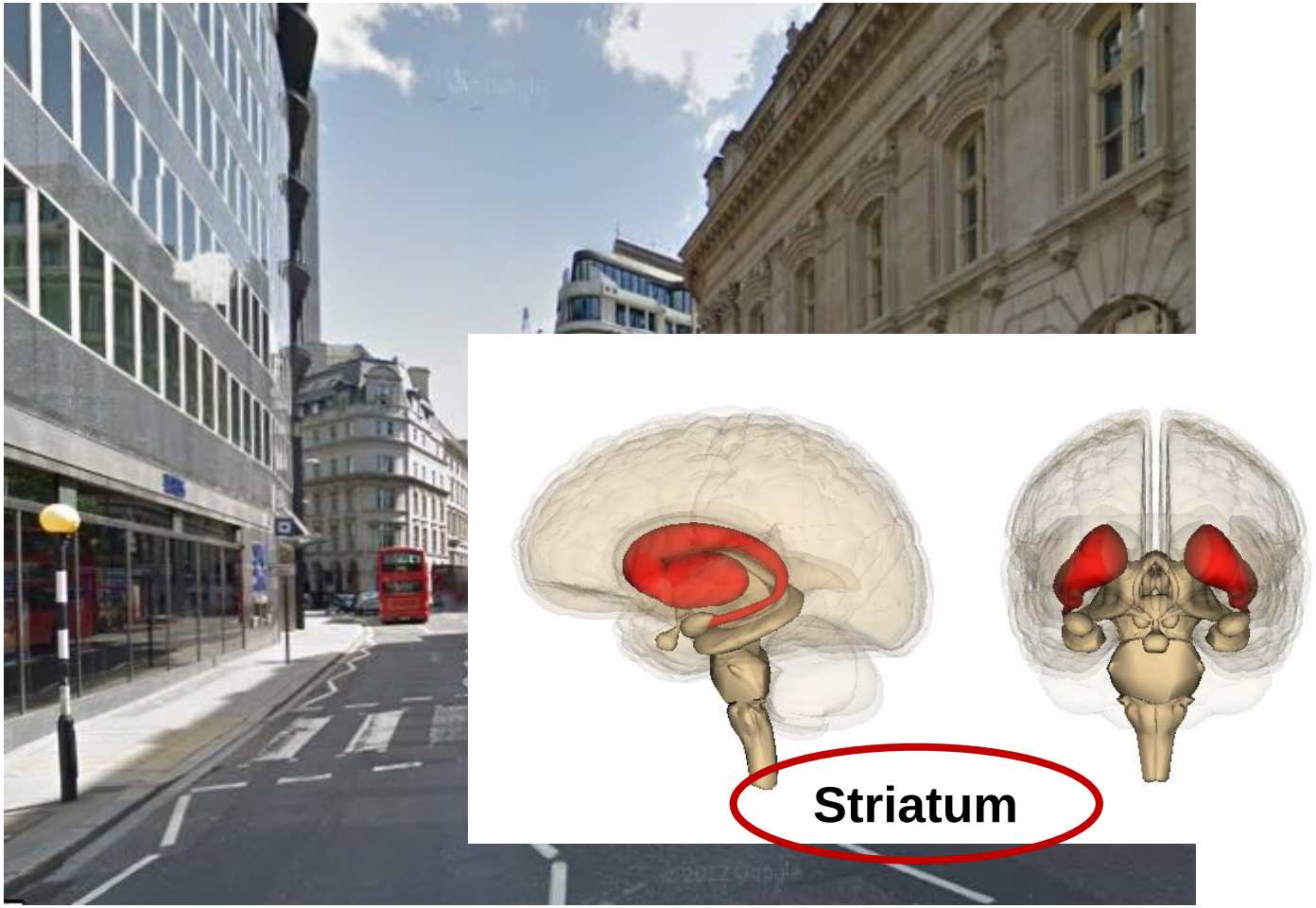


Different kinds of spatial behaviour

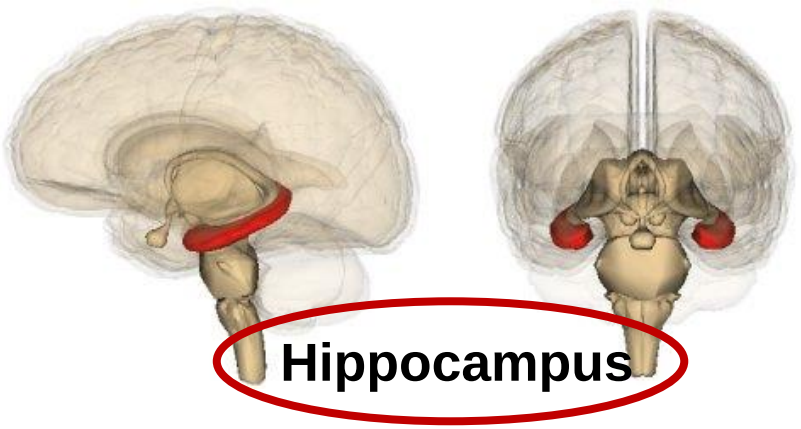
Local behaviour referenced to the body



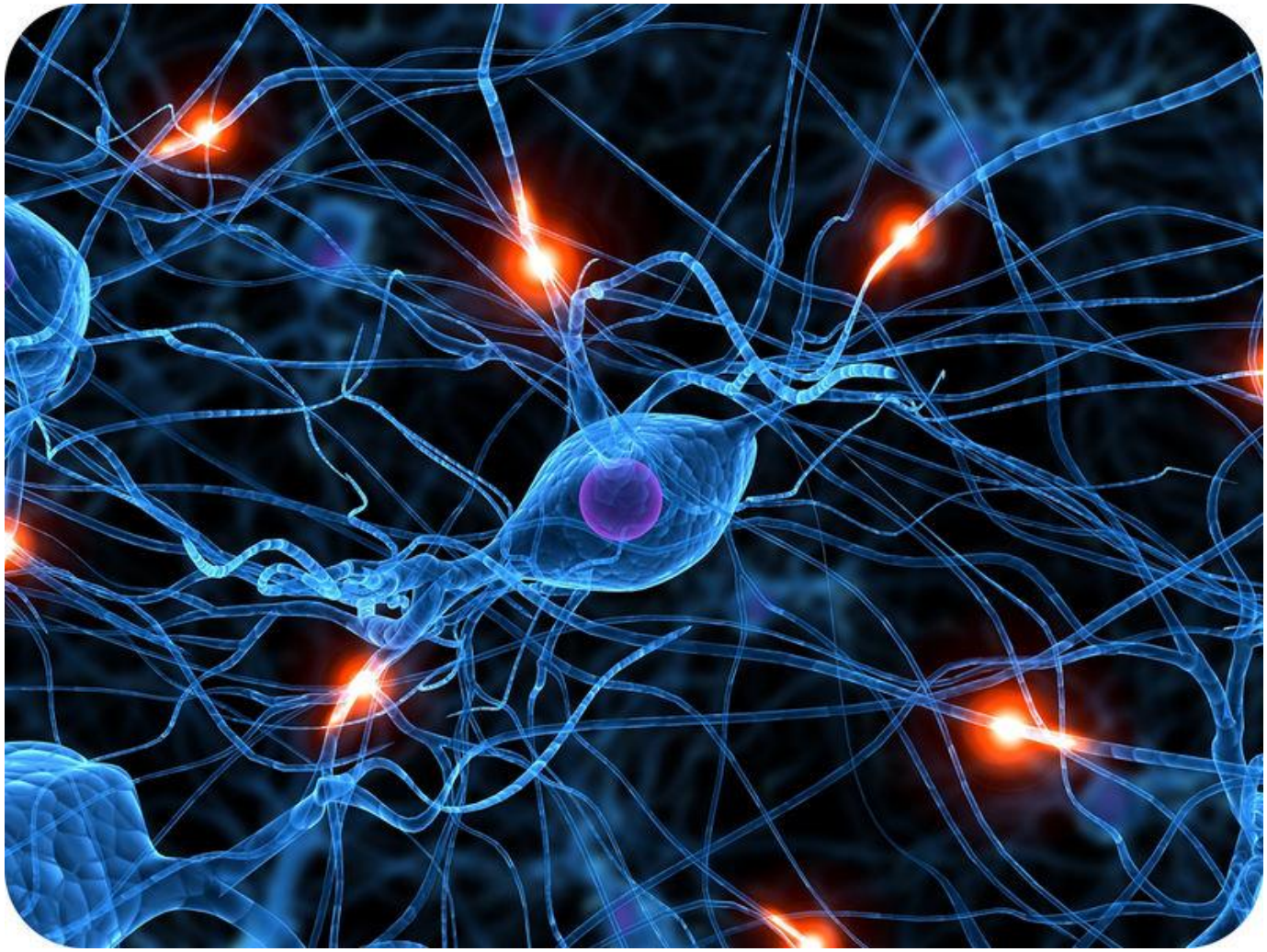
Habit-based behaviour controlled by the structure of the environment



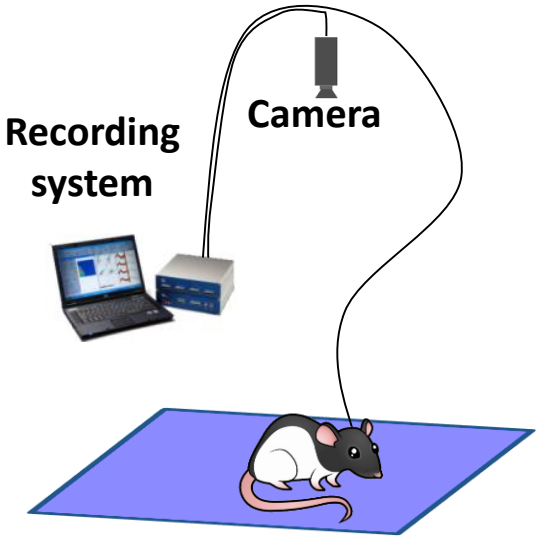
Long-range navigation based on an internal map



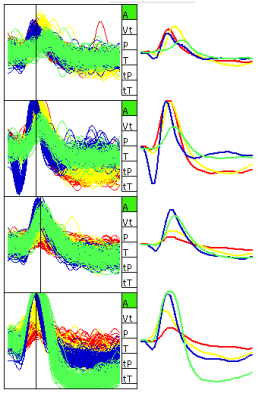
How is all this done by neurons?

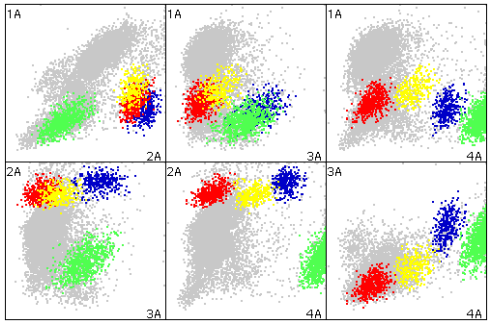


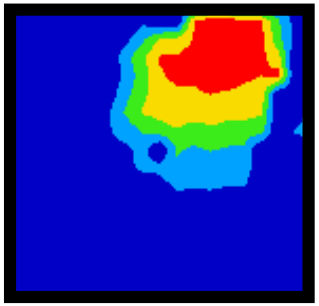
Studying knowledge formation at the single neuron level



Rat on arena

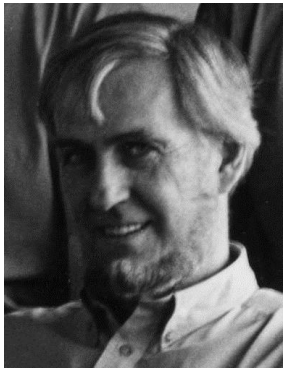






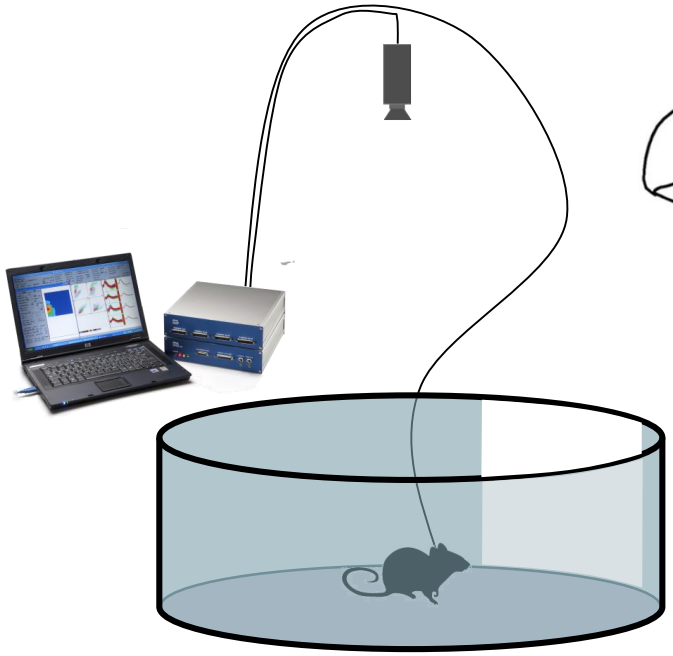
20 40 60 80 100 %

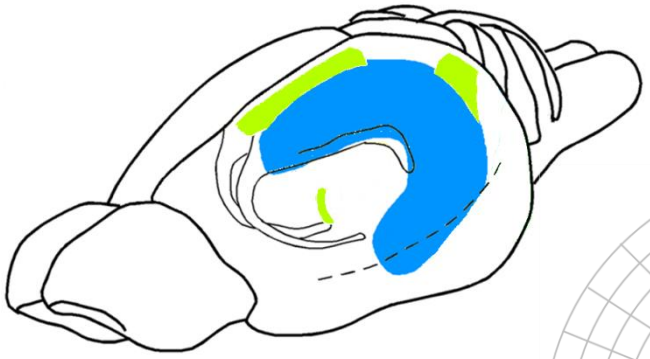
Place field

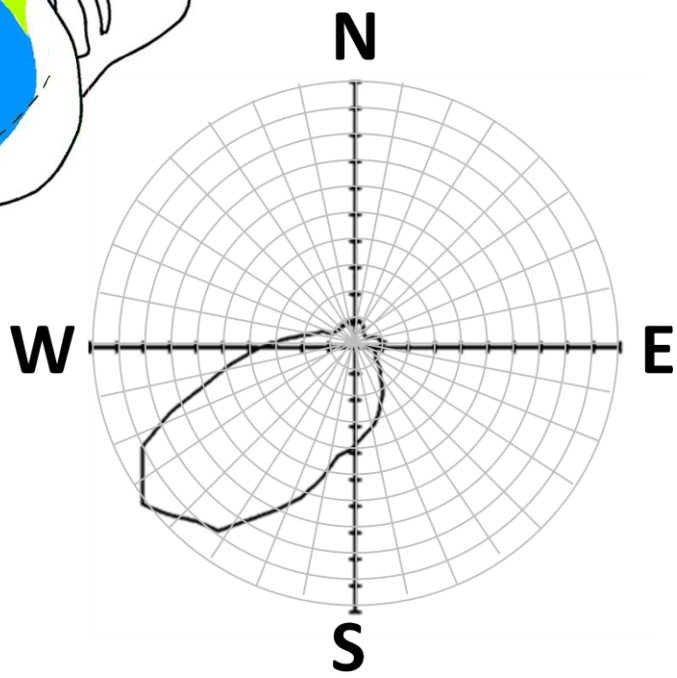


John O'Keefe

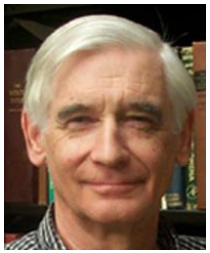
A compass in the brain: The head direction cells







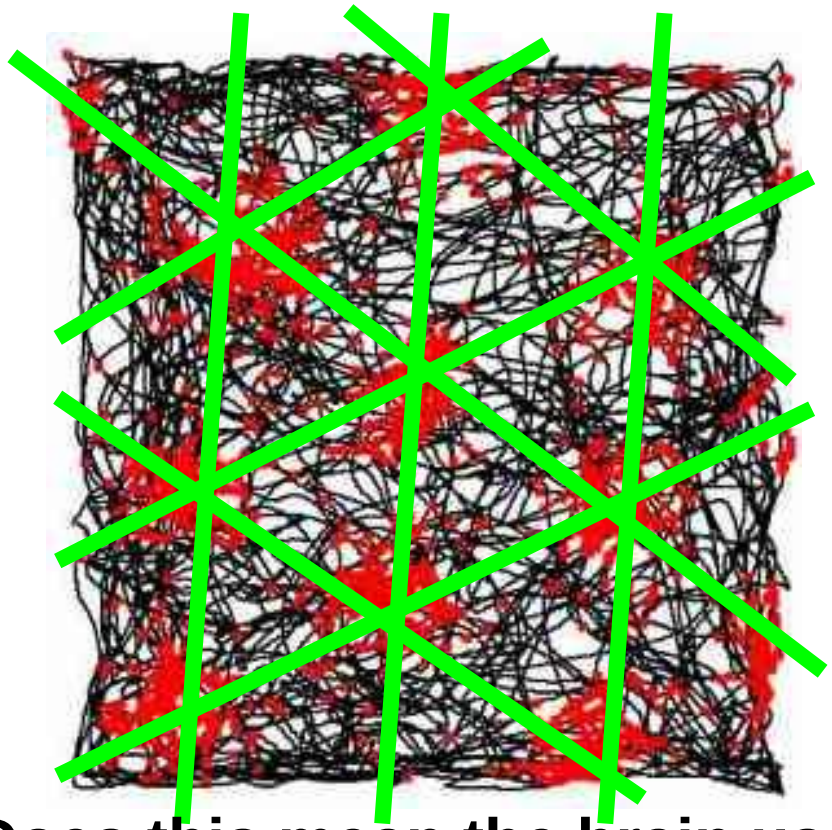
Note that this “compass” is not tied to magnetic North

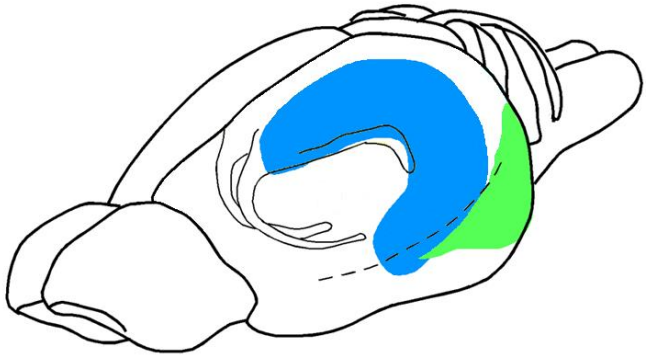


James Ranck

Jeff Taube

A odometer in the brain: The grid cells





Edvard & May-Britt Moser

Does this mean the brain uses a hexagonal grid reference?

Torkel Hafting & Marianne Fyhn

The Nobel Prize in Physiology or Medicine 2014

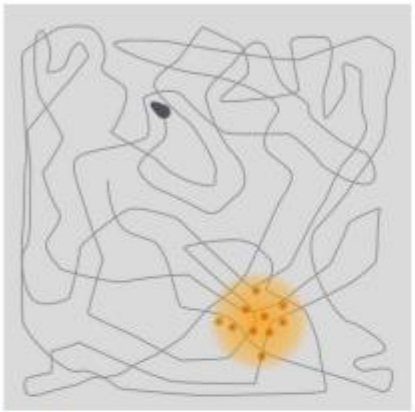


Fig. 1

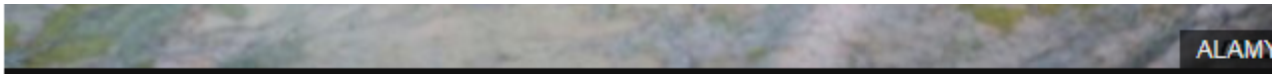
John O'Keefe

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.

May-Britt Moser and Edvard I. Moser

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.

Fig. 2



A man looks at a giant Ordnance Survey map of Wales

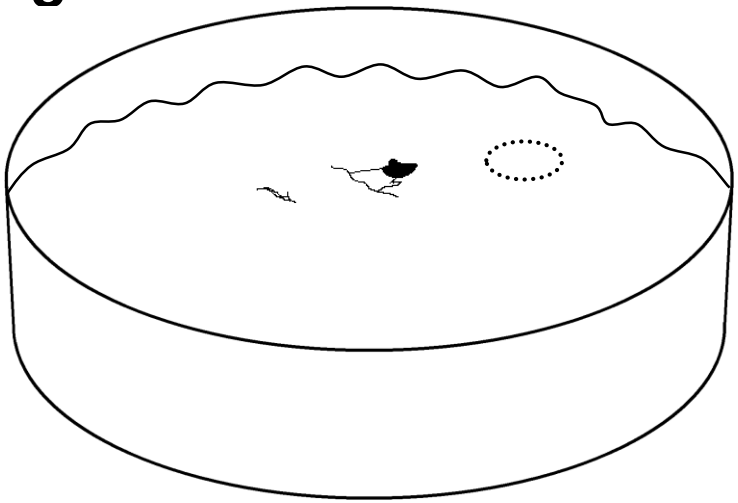
US-born neuroscientist John O'Keefe has jointly won the 2014 Nobel Prize for medicine for discovering the brain's navigation system. Is it any surprise then that he loves Ordnance Survey maps, writes Luke Jones.

O'Keefe came to the UK from the US in the late 1960s. He was supposed to stay for only two years as part of post-doctoral study. He decided to relocate for good.

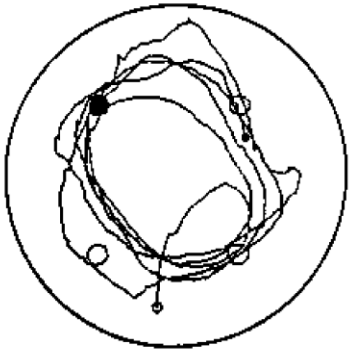
The 74-year-old told BBC Radio 4's Today programme that he was "very attracted to many aspects of British culture".

Two aspects that he named were the NHS and the Ordnance Survey map. "I like

Morris showed that rats need their hippocampus to navigate across featureless terrain



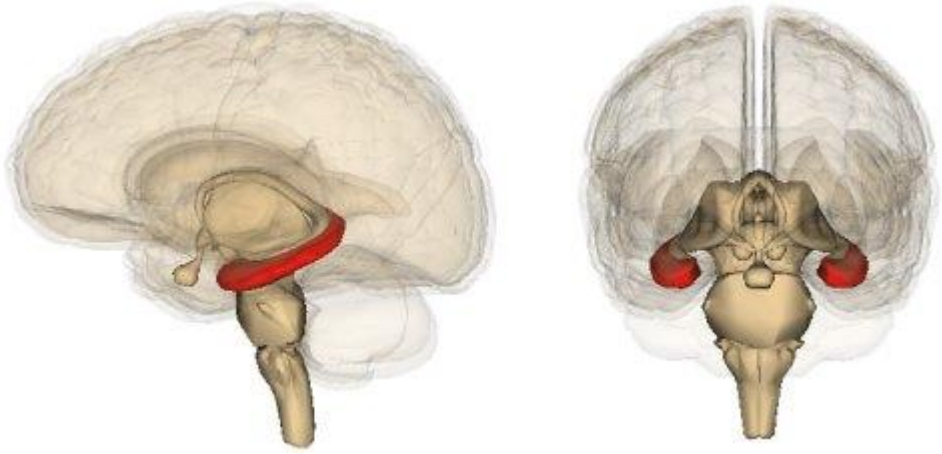
Richard Morris



Search path of normal rat

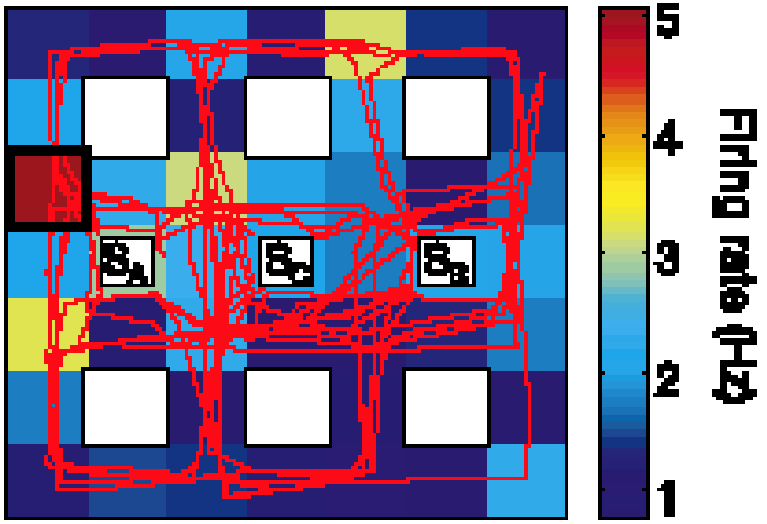
Search path of rat with hippocampal damage

Maguire showed that the hippocampus is needed for navigation in humans too



Eleanor Maguire

Fried and colleagues have found place cells in humans



What we know

How spatial neurons form a perceptual representation of immediate space

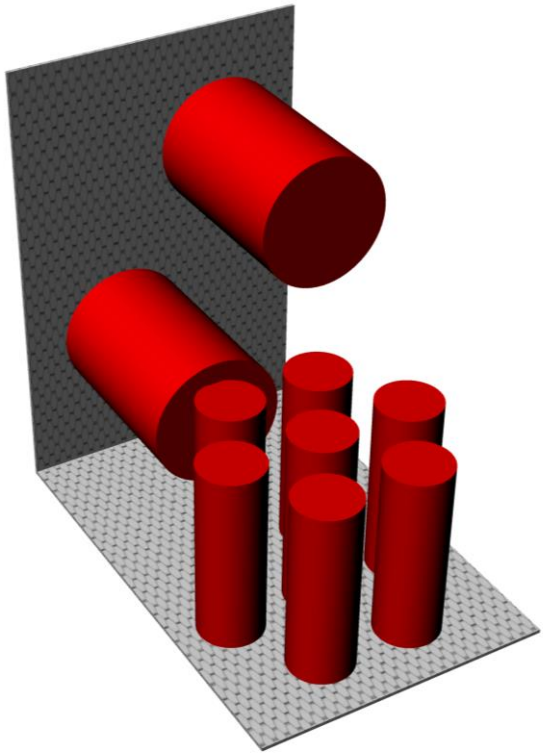
What we don't know

How these local representations are, themselves, related

↓

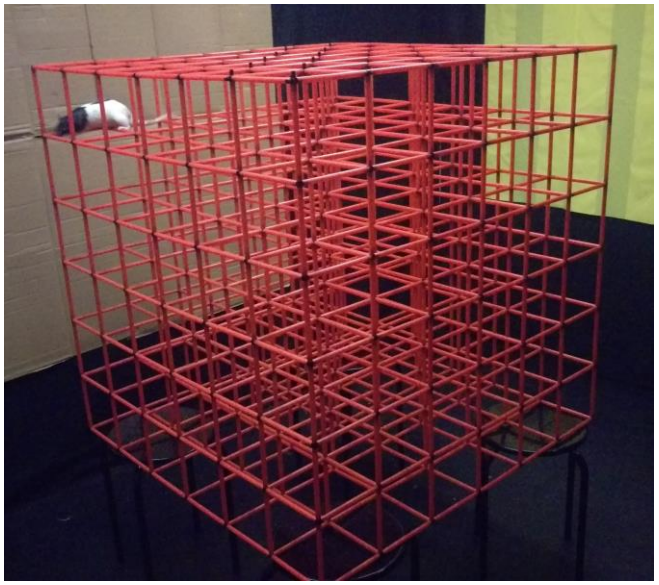
The foundation of complex cognition

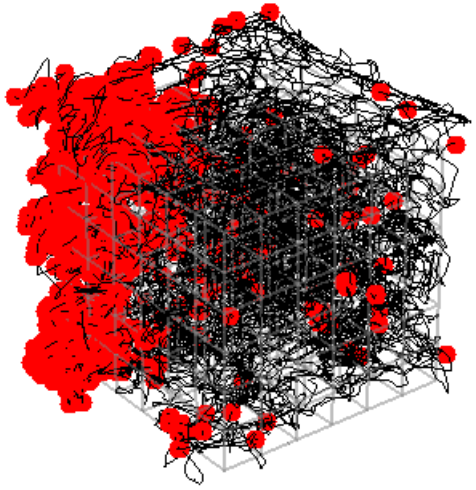
We think the grid cell map may be ‘multi-planar’ in 3D



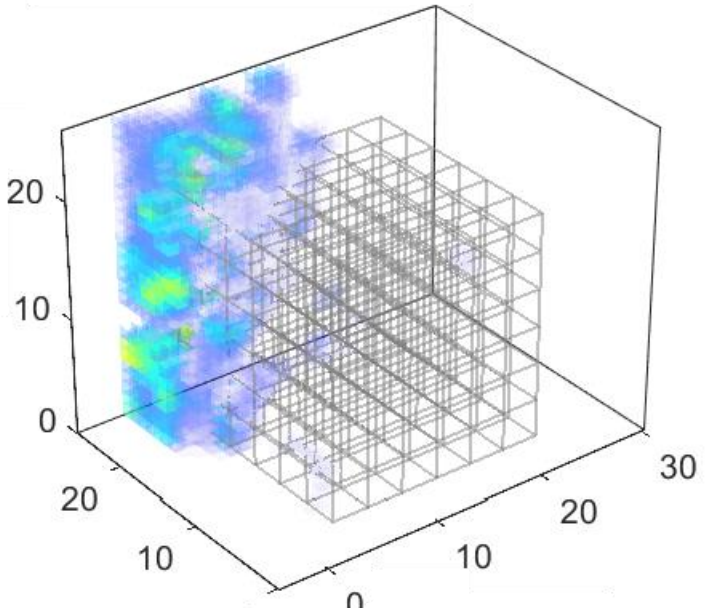
Giulio Casali

What happens in a volumetric space?





Roddy Grieves



What is the future for the cognitive neuroscience of navigation?


Building spaces we can comprehend
DC Convention Center

Building navigable cities

Integrated technology

Multidimensional spaces

COGNAV (Cognitive navigation)