A neural code for egocentric spatial maps in the human medial temporal lobe

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Abstract: Spatial navigation is vital for the survival of humans and animals (Kunz et al., Trends Cogn Sci, 2019). The ability to navigate relies on neural systems that encode information about places, distances, and directions relative to the external world or relative to the navigating organism (Burgess, Trends Cogn Sci, 2006). Ever since the proposal of cognitive maps (Tolman, Psychol Rev, 1948), the neuroscience of navigation has focused on allocentric (world-referenced) neural representations including place cells (O'Keefe & Dostrovsky, Brain Res, 1971), grid cells (Hafting et al., Nature, 2005), and head-direction cells (Taube et al., J Neurosci, 1990). However, little is known about the neural basis of egocentric (self-centered) representations—despite abundant evidence for egocentric navigation strategies in spatial behavior (Coughlan et al., Nat Rev Neurol, 2018). Here, using single-neuron recordings in epilepsy patients performing virtual navigation tasks (Kunz et al., Science, 2015), we identify "anchor cells" in the human brain as a neural code for egocentric spatial information: Anchor cells represent egocentric directions towards "anchor points" located in the environmental center or periphery. Anchor cells supported full vectorial representations of egocentric space by additionally encoding anchor-point distances. They were abundant in parahippocampal cortex and were integrated into a neural memory network. Neurons encoding allocentric direction complemented anchor-cell activity, potentially assisting anchor cells in transforming sensory input into allocentric representations (Bicanski & Burgess, eLife, 2018). Anchor cells may facilitate egocentric navigation strategies, may support route planning from an egocentric viewpoint, and may underlie the first-person perspective in episodic memories.

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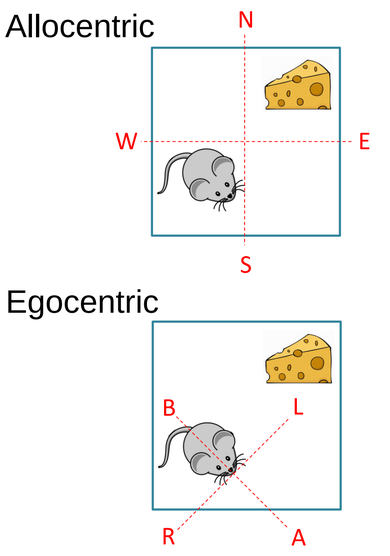
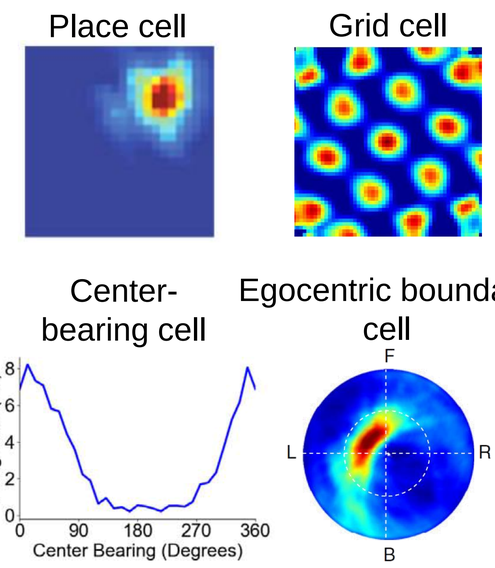
Spatial coordinate systems

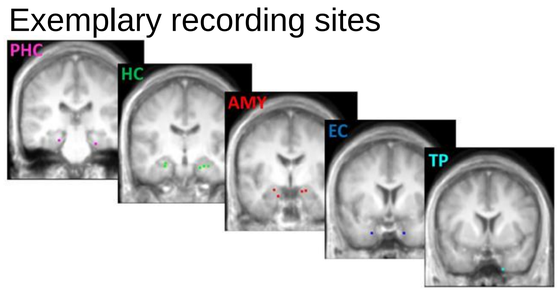


Example neural representations



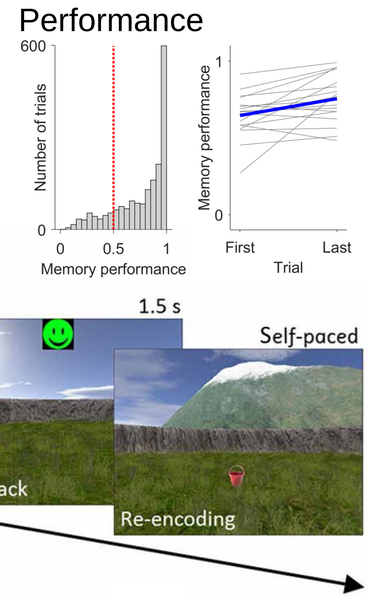
O'Keefe & Dostrovsky, Brain Res, 1971; Hafting et al., Nature, 2005; LaChance et al., Science, 2019; Hinman et al., Nat Commun, 2019

Human single-neuron recordings



Subjects and virtual spatial navigation task

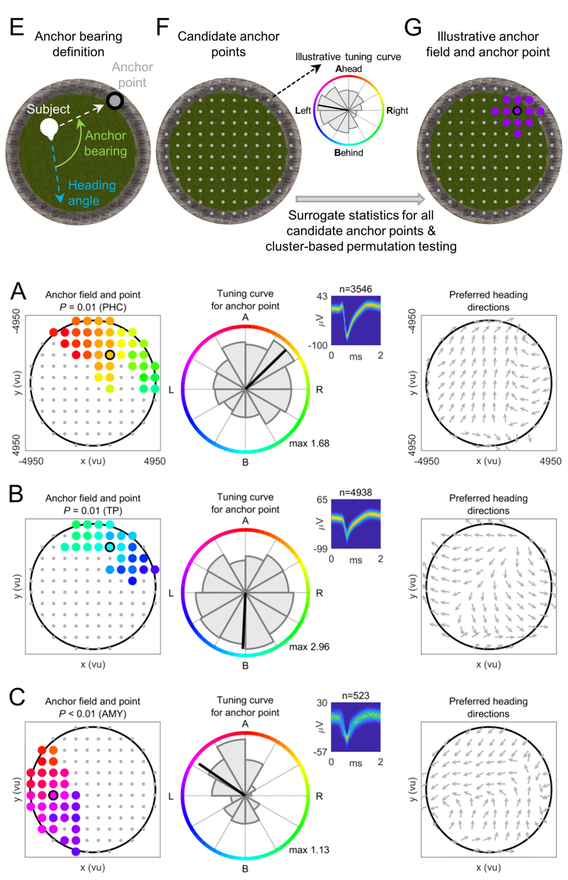
N = 14 epilepsy patients
N = 18 sessions
N = 729 neurons



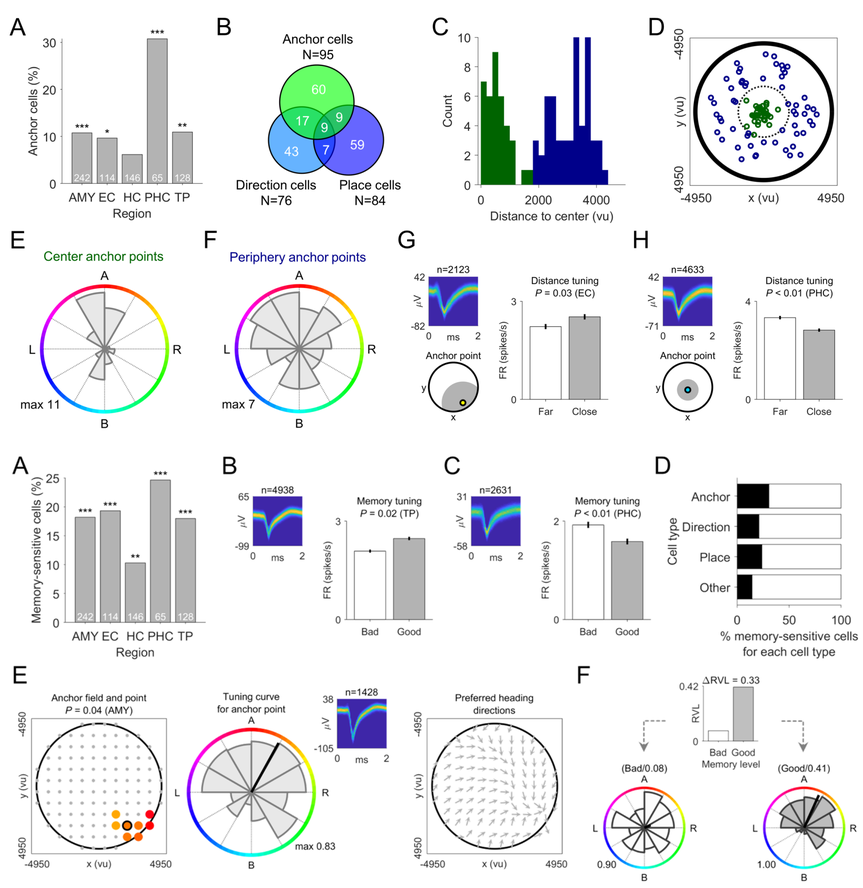
Kunz et al., Science, 2015; Kunz et al., Science Advances, 2019; Kunz et al., in prep; Rutishauser, TiCS, 2019

Anchor cells in the human MTL encode egocentric directions towards local reference points

Analysis and anchor-cell examples

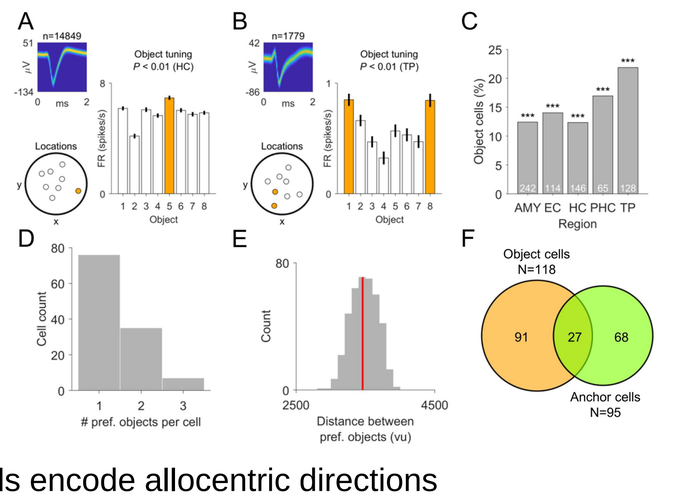


Characterization of anchor cells

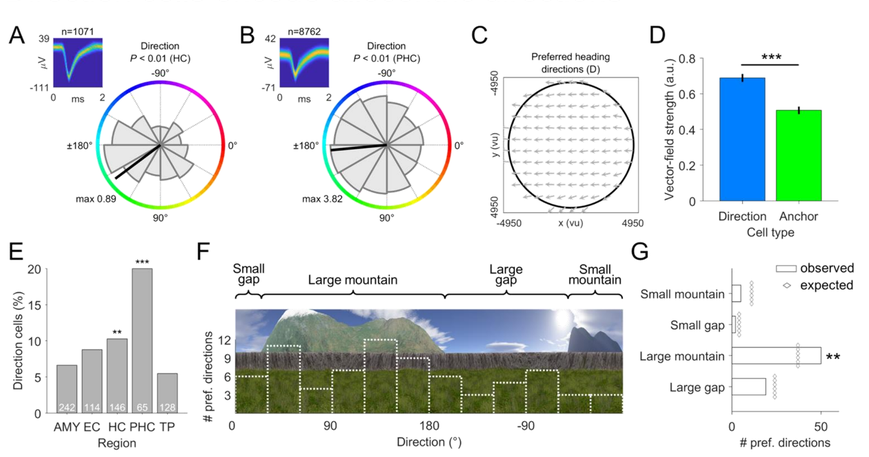


Single-neuron codes of objects and global direction

Object cells



Direction cells encode allocentric directions



Highlights:

- Anchor cells in the human MTL encode egocentric directions towards local reference points (anchor points)
- Anchor points are located both in the center and the periphery of the environment
- Anchor cells additionally encode the distance towards the anchor point, providing full vectorial representations of egocentric space
- Anchor cells are integrated into a neural memory network