Concept cells in the temporal pole and the posterior cingulate cortex: testing memory systems at the neuronal level

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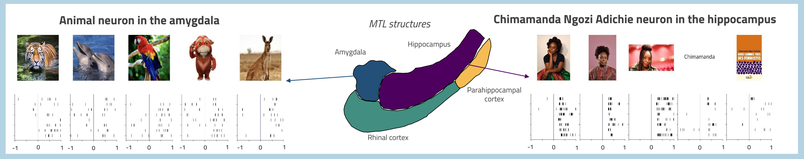
Introduction

Extracellular recordings have identified selective neurons that respond to one particular concept, called *concept cells* (Quiroga et al., 2005; Quiroga, 2016). These concept cells have been recorded in the hippocampus and adjacent medial temporal lobe (MTL) structures (Mormann et al., 2008). These cells demonstrate strong semantic properties (Reber et al., 2019 ; Karkowski et al., 2025). These cells are seen as the building blocks of semantic memory underlying episodic memory (Quiroga, 2012). This is intriguing given that the semantic network includes various regions from the **temporal pole** (Lambon-Ralph et al., 2017 ; Jonin et al., 2018) to the **posterior cingulate cortex** (Renoult et al., 2019).

We thus made the hypothesis that concept cells should also exist beyond the MTL, and in particular in the neocortical areas underlying the semantic memory network.



Do concept cells also exist beyond the MTL?
What is the link between these cells and those in the MTL?

Methods

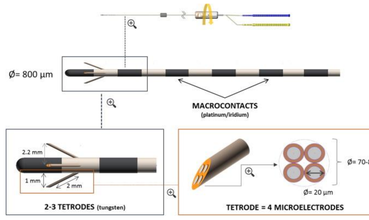
Patients. 27 patients with drug-resistant epilepsy, 14 of them with at least one electrode in the temporal pole (defined in this study as the region anterior to the limen insulae) and 3 of them had electrodes in the posterior cingulate cortex

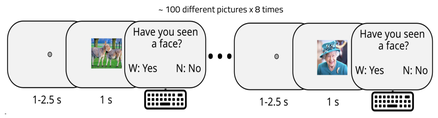
Electrodes. Hybrid electrodes (Dixi Medical, France) consisted of standard macroelectrodes fitted with two or three tetrodes extending from the shaft between the 2 deepest contacts (Despouy et al., 2020) or between the 2 most lateral contacts (for 2 electrodes in this study).

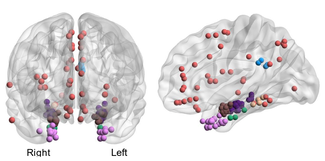
Experimental sessions. Patients were in their room and were presented with a large number (~100) of images of famous people, landmarks, common objects, some of them related to their interest. iEEG signals were acquired with a 256-channel Atlas System (Neuralynx).

Data Analysis. Spike sorting was performed offline on band-pass filtered signal (300-3000 Hz) with Spyking-circus (Yger et al., 2018) implemented in Spikeinterface (Buccino et al., 2020). Manual curation was then performed in order to remove noisy clusters and check for overmerged clusters with Klusters.

After manual curation, neuronal analyses were performed using Pynapple (Viejo et al., 2023) and python homemade scripts (available on Git-Hub)

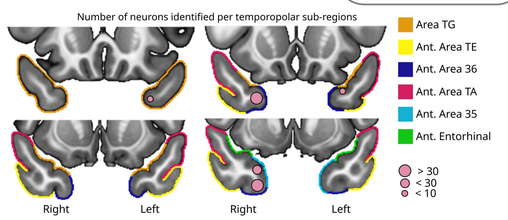


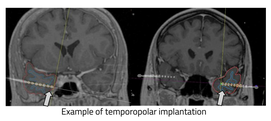


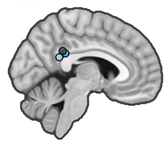


Yield: 1146 single neurons

Temporal pole: 239
Hippocampus: 185
Parahippocampal cortex: 51
Amygdala: 110
Rhinal cortex: 37
Posterior cingulate cortex: 134

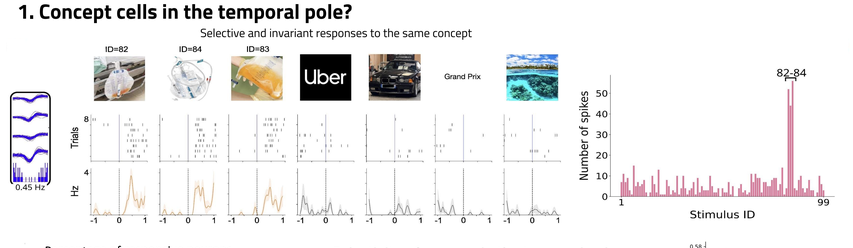


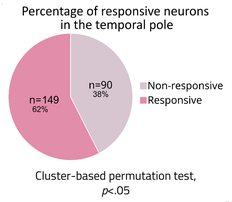

Example of temporopolar implantation

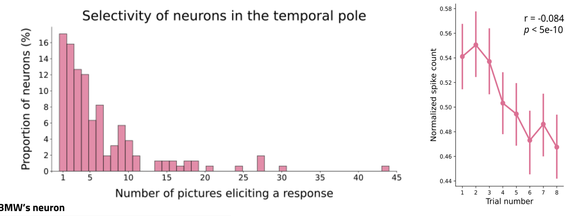


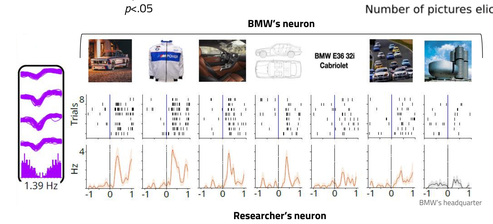
Results

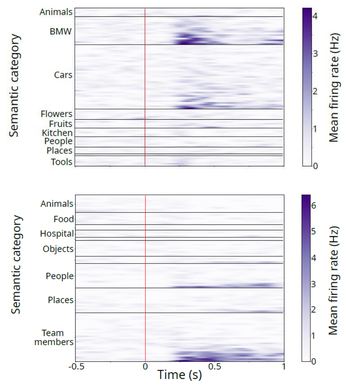
1. Concept cells in the temporal pole?

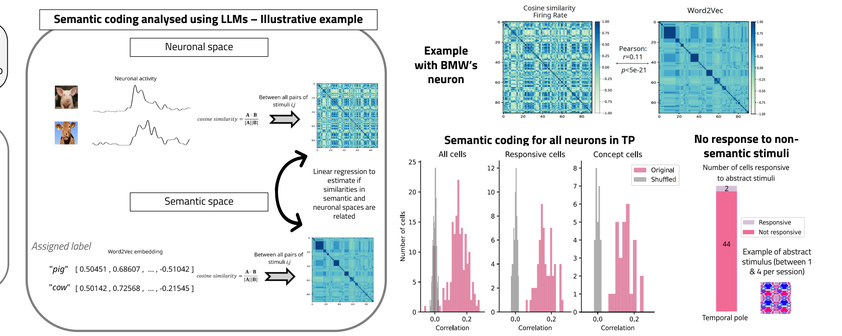




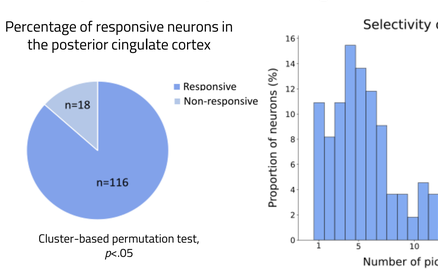


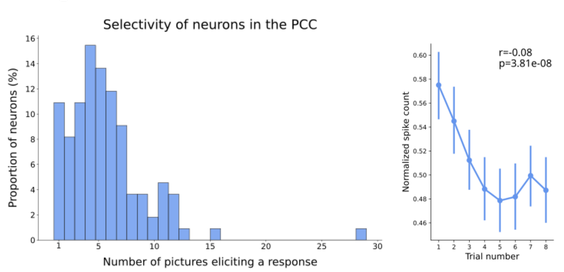






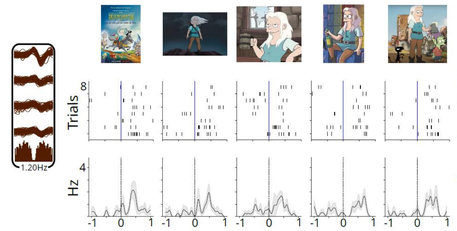
2. Concept cells in the posterior cingulate cortex?

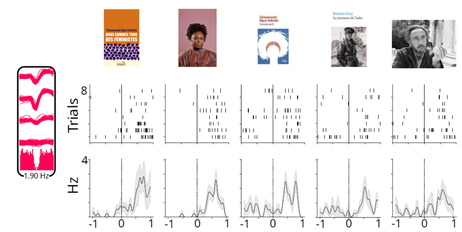




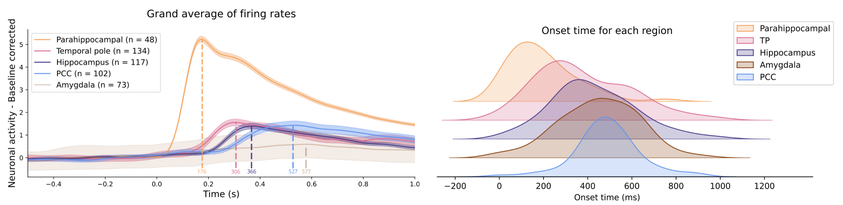
Results

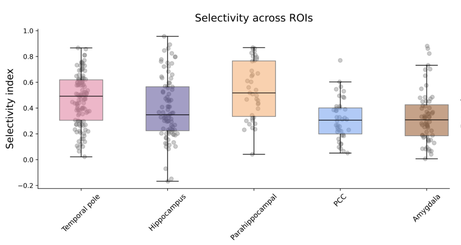
2. Concept cells in the posterior cingulate cortex? (Next)

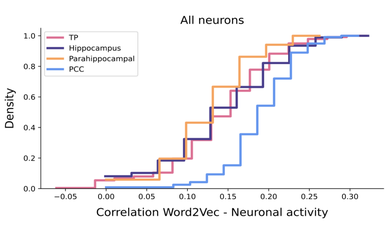




3. Comparison with neurons recorded in the MTL







Conclusion

Here, we report for the first time that concept cells can be recorded beyond the MTL, in particular from the temporal pole and the posterior cingulate cortex. No such cell was recorded in other brain areas, which included the frontal and parietal lobes, as well as the insula. These cells have similar properties than those observed in the MTL: invariant and selective response, semantic properties BUT different latencies. Shorter latencies are observed in the temporal pole, while they are longer in the posterior cingulate cortex. These results suggest a hierarchy in memory networks.

Altogether, these results indicate that memory should be conceptualized as a system involving more than the MTL.

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