Concept cells in the temporal pole: yet another building block of semantic memory

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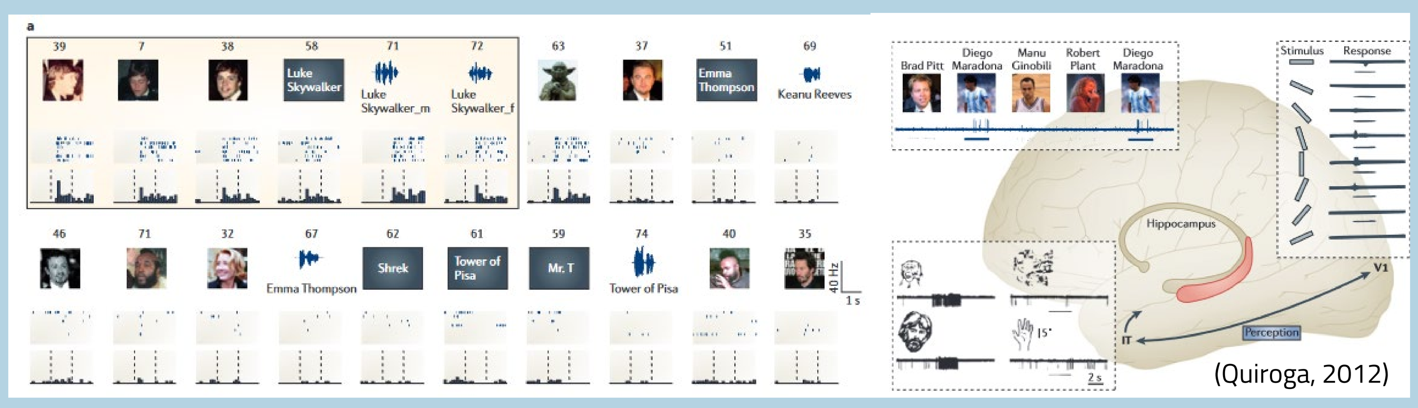
Introduction

Intracranial recordings have revealed that the first responses to faces are located in the fusiform gyrus, with an evoked response at 110 ms. Along the ventral visual pathway, latencies increase progressively, with the slowest responses in the medial temporal lobes. These latter regions are the only ones to respond differently to familiar and unfamiliar faces (Barbeau et al., 2008). Even within these late-responding regions, the hippocampus and temporal pole respond later than other MTL regions such as the perirhinal cortex (Despouy et al., 2020). This implies that the hippocampus and temporal pole could be involved in high-level processes, such as memory, while the other regions of the ventral visual pathway could be involved in perceptual processes.

In line with these findings, highly selective neurons have been observed in the hippocampus, with neurons responding only to images corresponding to a particular concept and to no other images (Quiroga et al., 2005). These concept cells have many properties, for example they are multimodal, with responses to faces but also to written or spoken names (see figure below, for a review see Quiroga, 2016).


(Quiroga, 2012)

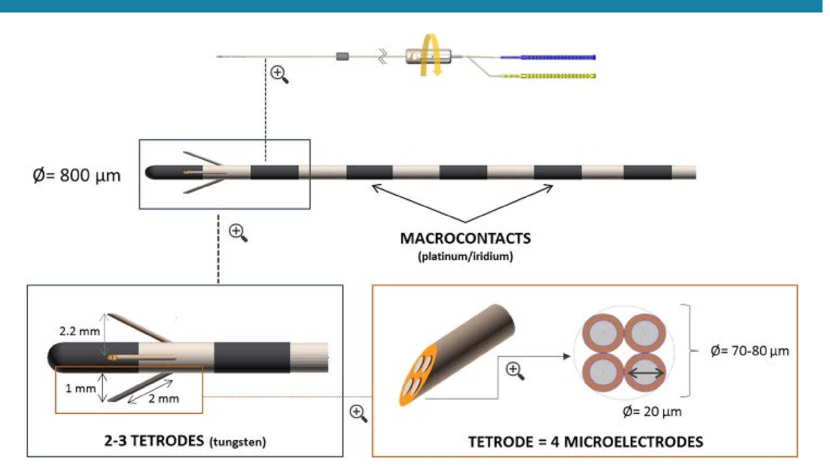
Concept cells have mainly been recorded in the hippocampus. However, they appear to underly semantic knowledge, whereas it is the temporal poles which are usually associated with semantic memory (Ralph et al., 2017). If anything, concept cells should thus be found in the temporal poles.

Do concept cells also exist in the temporal pole? What are their characteristics?

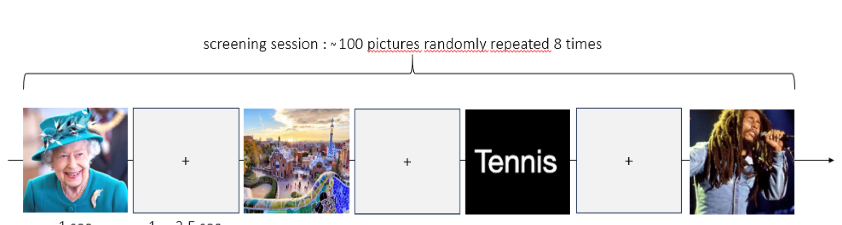
Methods

Patients. 20 patients were analyzed, 10 of them had electrodes implanted in the temporal poles.

Electrodes. The macroelectrodes (Dixi Medical, France) had a diameter of 0.8 mm and contained 5 to 18 contacts (platinum/iridium). Hybrid electrodes (Dixi Medical, France) consisted of a standard macroelectrode but fitted with two tetrodes extending from the shaft between the 2 deepest contacts.

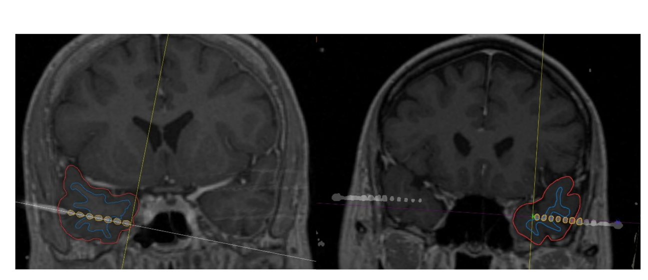


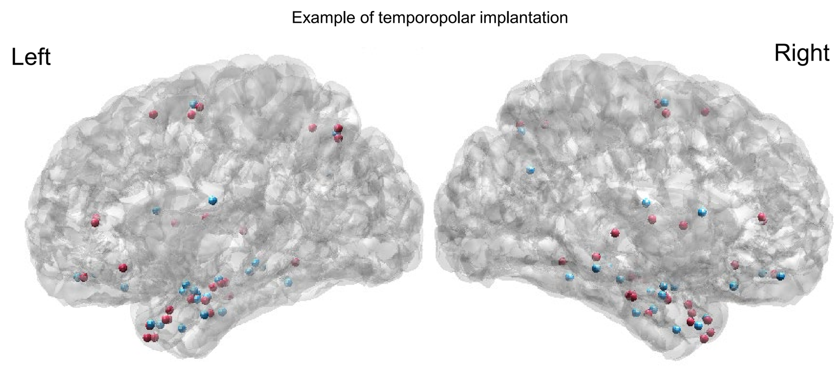
Experimental sessions. Patients were in their room and were presented with a large number (~100) of images of famous people, landmarks, familiar objects, some of them related to the interest of the patient. iEEG signal were acquired with a 256 channel Atlas System (Neuralynx).



Data analysis. We analyzed activity from single-units in the temporal pole obtained with the following procedure:

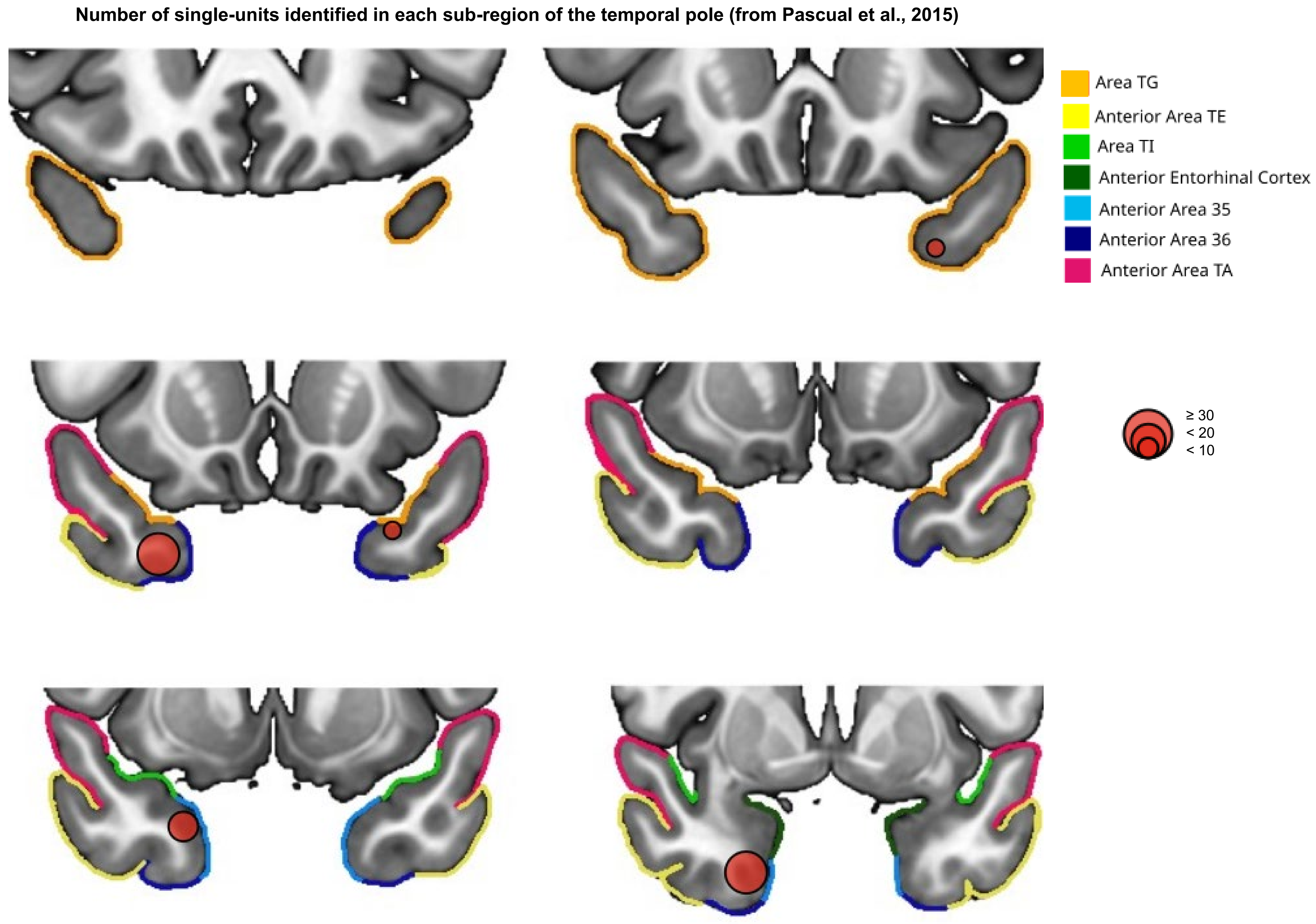
- Automatic detection of artifacted periods
- Band-pass filter between 300 and 3000 Hz
- Spike-sorting applied offline with Spyking-circus (Yger et al., 2018).
- Manuel curation of clusters
- Identification of single-units based on the following criteria: 1) Spike shape and variance, 2) Refractory periods on the auto-correlogram. 550 single-units were observed across several brain areas. **129** were in the temporal poles (TP).
- Analyses of neuronal responses to stimuli with Pynapple (Viejo et al., 2023)


Example of temporopolar implantation



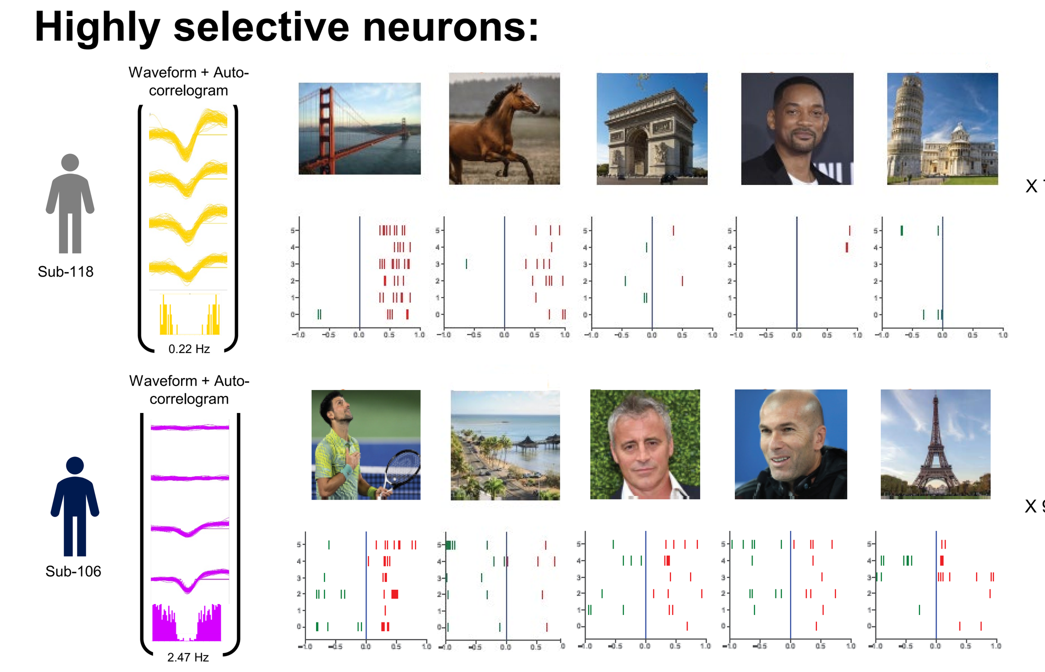
Tetrodes implanted in all patients (in red) and tetrodes with single-units identified (in blue)

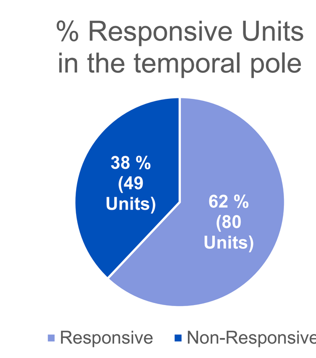
Number of single-units identified in each sub-region of the temporal pole (from Pascual et al., 2015)

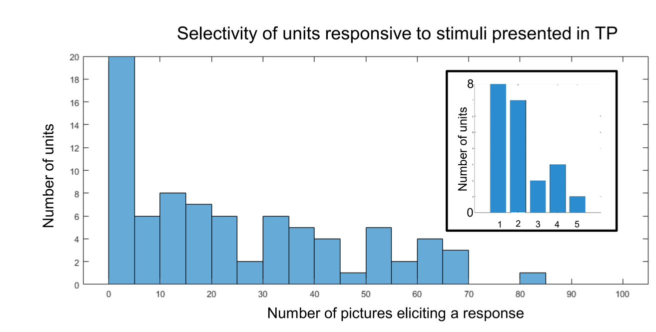


Results for the temporal pole

Highly selective neurons:



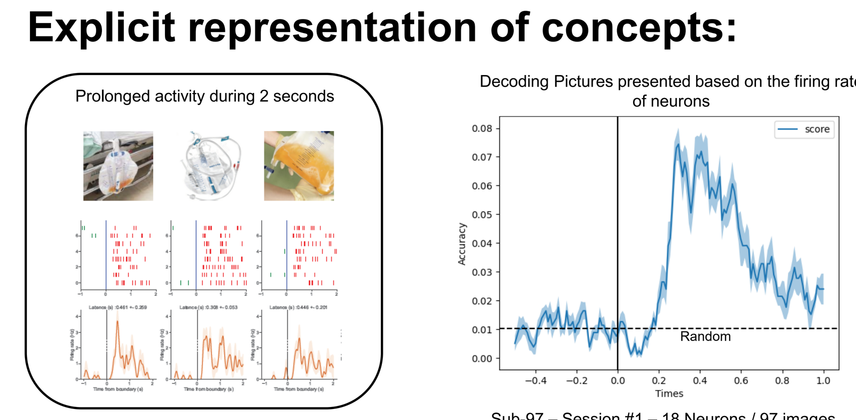




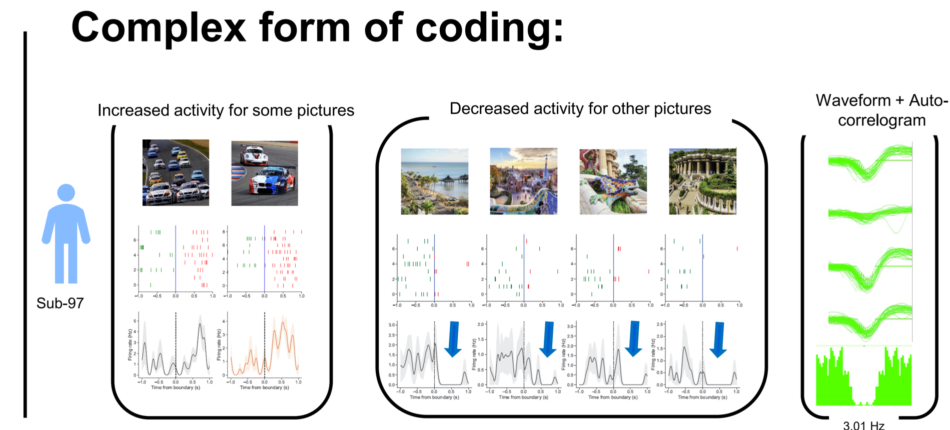
Invariant responses:

Semantic coding:

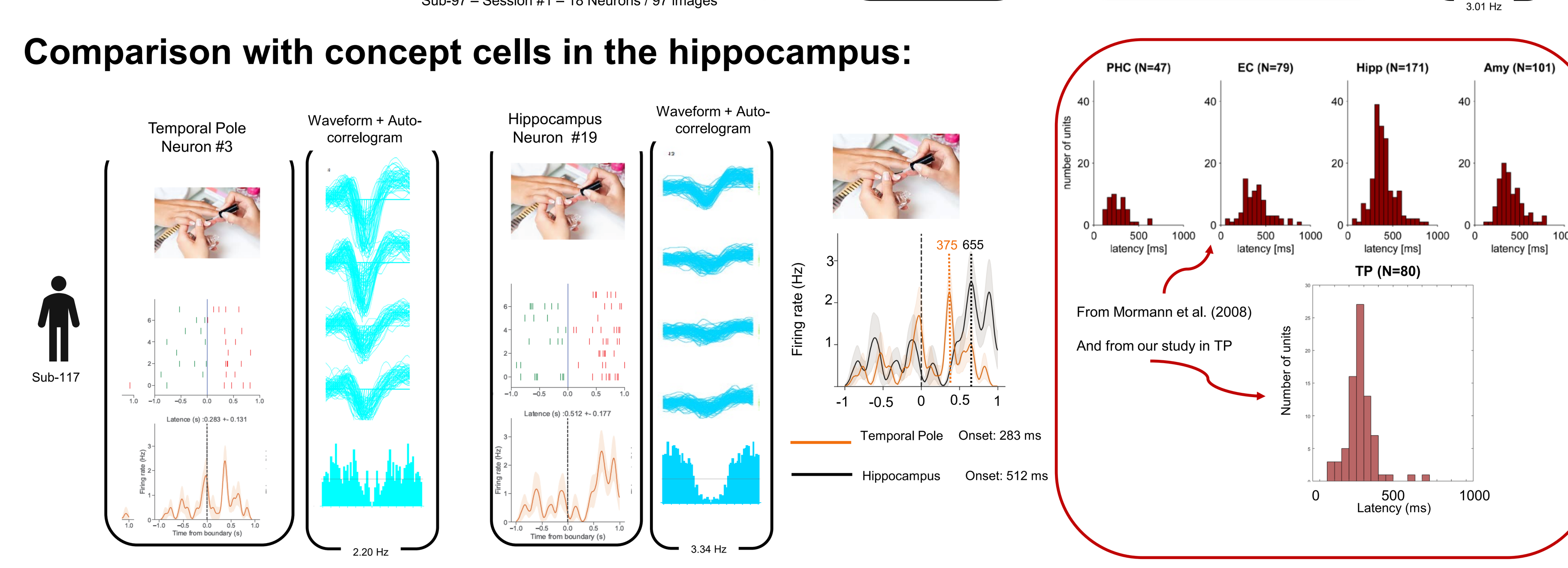
Explicit representation of concepts:



Complex form of coding:



Comparison with concept cells in the hippocampus:



Conclusion

Concept cells were identified in the temporal pole:

- Invariant response
- Semantic coding
- Able to code recent concepts
- Explicit representation of concepts (2 seconds analyses)
- Complex coding with excitatory and inhibitory responses
- Latencies around 250 ms
- Shorter latencies than in the hippocampus

➡ Does the temporal pole first process semantic information and then transfer it to the hippocampus?

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