Analyzing Neural Mechanisms of Spatial Navigation

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Introduction

Spatial navigation allows living organisms to perceive their relative locations within an environment, enabling necessary and effective navigation through their surroundings. Navigation based on the orientation of objects in the environment is known as *allocentric*, while navigation using directional cues from an individual's point of view is referred to as *egocentric*.

Investigations of allocentric-egocentric coordination have demonstrated the involvement of parietal cortex (PC) and hippocampus (HPC), among other regions, with the HPC primarily encoding allocentric location while the PC is related to actions and egocentric cues. We explore how future actions are generated using the learned spatial location in the previous tasks to better understand the HPC-PC network.

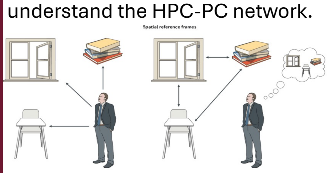

Figure 1. reference from Coughlan *et al.* the different perception from an egocentric (*left*) versus allocentric (*right*) point if view. The egocentric is person dependent while allocentric is object dependent.

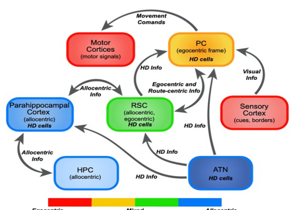

Figure 2. Communication between the parietal cortex and hippocampus is supported by their positions within the brain as well as their functions in encoding allocentric and egocentric information.

Methods

<u>Subject</u>

- Male Fischer/Brown Norway rats (n=5), housed in a 12-hour light/dark cycle.

<u>Complex sequence task</u>

- The animal was trained to run in a sequence of 1-2-3-4-1-2-3-5
- The sequence repeats in locations 1-2-3, but the next location in the sequence is spatially distinct. To accurately navigate to zones 4 and 5, the animal must maintain as reference and transform that allocentric memory into egocentric action.

Results

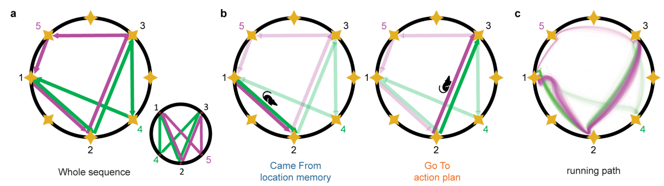

Figure 3. Behavior schematic. a The set up of the complex sequence task. **b** For the animal to choose the 'Go To' location, it must remember the 'Came From' location to correctly navigate to the goal zone. This demonstrates the transformation process of the allocentric memory into egocentric action. **c** An example of the animal performing the task in a behavior session.

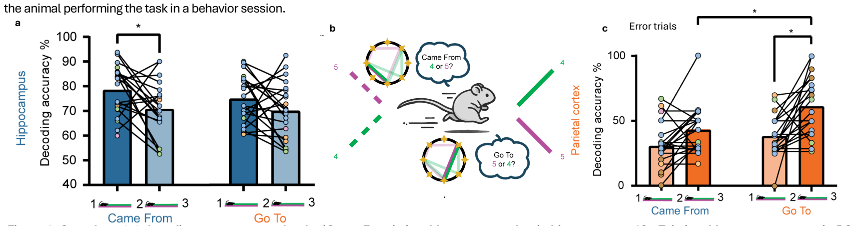

Figure 4. Over the 1-2-3 decoding sequence, as the the 'Came From' signal becomes weaker in hippocampus, 'Go To' signal becomes stronger in PC. a. Represents the decoding accuracy in segments 1-2 and 2-3 in encoding 'Came From' and 'Go To' signals. 'Came From' decoding accuracy decreases in segment 2-3 compared to segment 1-2. **b.** Demonstrates the prediction of error trial decoding patterns. Decoding of the 'came from' signal suggests that the animal came from the wrong zone. Decoding of 'go to' in the error trials will predict the animal will go to the wrong zone or make a wrong plan because he misremembered the 'came from' location. **c.** The 'Go To' decoding accuracy from error trials of segment 2-3 in the parietal cortex increases compared to segment 1-2. *P < 0.05

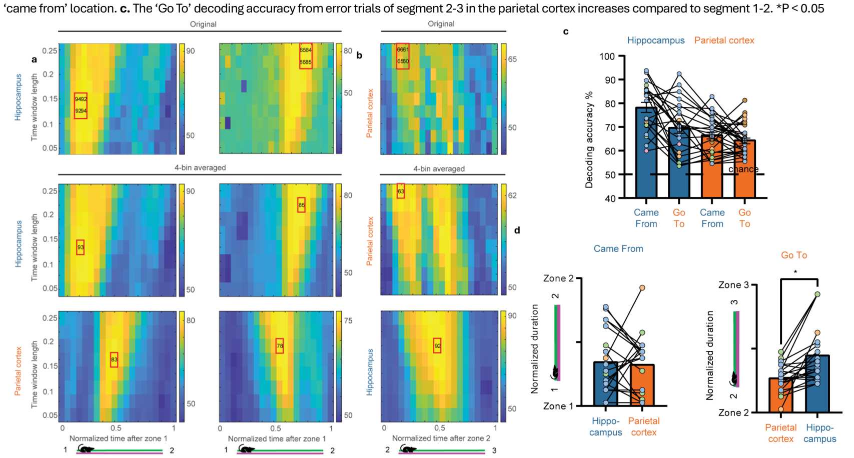

Figure 5. Temporal Decoding Reveals Sequential Patterns Across Hippocampus and PC of 'Came From' and 'Go To' Information. Lighter colors represent higher accuracy. **a.** The x-axis represents the normalized time it takes to travel from the one zone in the sequence to the next goal zone, and the y-axis is different parameters for decoding. *Top Row:* The original decoding matrix for the hippocampus. *Middle Row:* Every 4 adjacent bins in the hippocampus matrices are averaged. *Bottom Row:* The averaged decoding matrix of the segments in the PC. **b** This part represent the 'Go To' signal results. *Top:* The original PC matrix. *Middle:* Averaged 4 adjacent bins for the PC. *Bottom:* Averaged 4 adjacent bins for the hippocampus. **c.** Although decoding accuracy varies across 'Go To ' and 'Came From' signals in the PC and the hippocampus, it maintains over 50% (chance) on all of them. **d** Temporal order of decoding peaks for 'Came From' decoding in segment 1-2 (*left*) and 'Go To' decoding in segment 2-3 (*right*). 'Came From' decoding leads in hippocampus or PC, while 'Go To' decoding happens in PC significantly. *P < 0.05; ***P < 0.001.

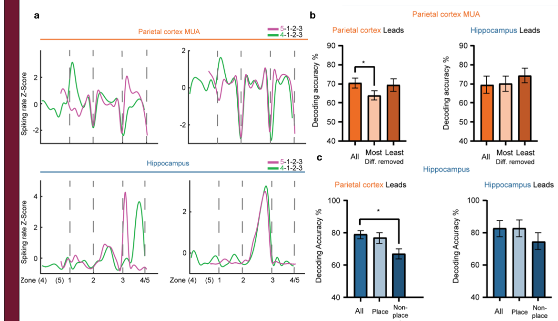

Figure 6. Route-centered encoding may underlie 'Came From' signals. a Spiking rate Z-score for segment 1-2-3-4 (green) and 1-2-3-5 (purple) are demonstrated. **b** Removing the most differentiated PC multi-unit activity (MUA) results in a significant decrease in decoding accuracy when the PC is the lead (reference figure 4). **c** There is a significant difference in decoding accuracy when place cells are removed in PC leading segments. *P < 0.05

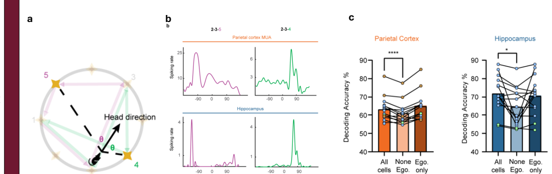

Figure 7. Ego tuning for future goal locations underlies 'Go To' signal. a Schematic of relative goal location fixed with respect to the current head direction (i.e., egocentric goal direction). **b** The relative head direction correlated with the spiking rate in the PC MUA and hippocampus determine the egocentric tuning. **c** There is a significant decrease in decoding accuracy when the egocentrically tuned cells/MUA clusters are removed. *P < 0.05; ****P < 0.0001

Conclusion

- 'Came From' and 'Go To' signal exist in both the PC and the hippocampus.
- In route-centered encoding, when the PC leads, it may relay 'came from' signals to hippocampal non-place cells. When the hippocampus leads, both the non-place and place cells contain the 'came from' signal.
- Egocentric tuning for future goal locations underlies 'Go To' signal, and it appears in the PC before being relayed to the hippocampus.

References

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