Dynamic Interfacing Between Allocentric and Egocentric Frames via the Parietal-Hippocampal Network During Spatial Navigation

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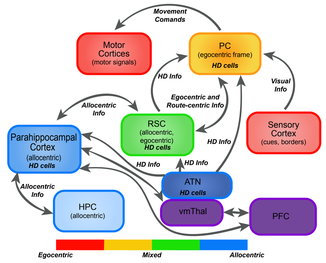
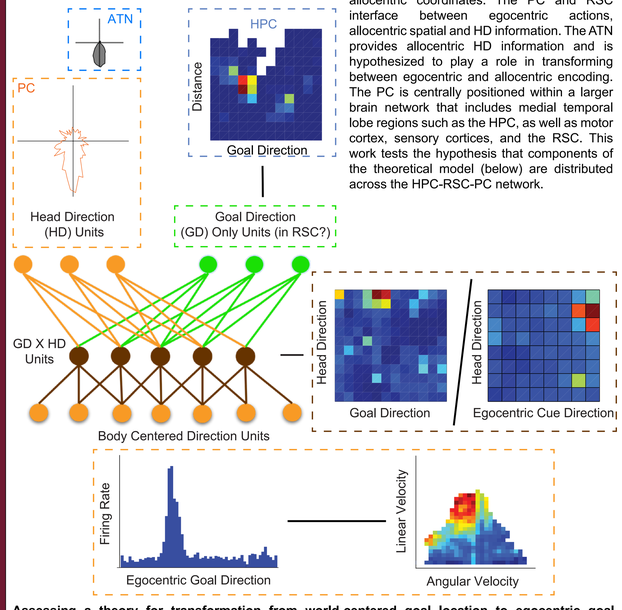
Introduction

- Spatial navigation is essential for survival and in natureal settings requires integration of allocentric and egocentric (and other) frames of reference (Freas and Cheng, 2022; Burgues, 2006; Moser et al., 2017).
- Parietal cortex (PC), anterior thalamic nucleus, and hippocampus (HPC) form a neural network crucial for interfacing between these reference frames (Bermudez-Contreras et al., 2020)
- My previous work showed PC and HPC coordinates allocentric, egocentric, and route-centered bi-directionally (Zheng et al., 2025). However, this task blends but does not clearly differentiate egocentric, allocentric reference frames or transformation in between them.
- Therefore, I performed paired recordings from a novel task that does differentiate these three states developed by our laboratory and made freely available (Brea Guerrero et al., 2023) and a random lights task. This will allow me to look for evidence of patterns of single cell activity that could reflect transformation between allocentric ang egocentric frames of reference.

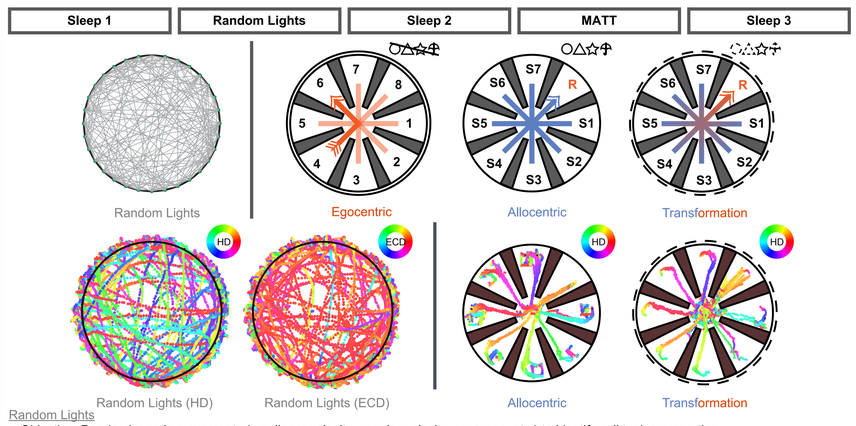


PC-HPC network is anatomically and functionally well-positioned to interface between egocentric and allocentric frames of reference within a larger network. Illustration of anatomical and functional connectivity shows that the ATN-PC-RSC-HPC circuit is anatomically and functionally well-positioned within a network to interface between egocentric and allocentric reference frames. The box colors represent a colormap denoting the relative density of ego- vs. allo-centric encoding for each region, except for prefrontal cortex (PFC) and ventral midline thalamus (vmThal) which are intentionally color coded off the colormap in purple. HPC and parahippocampal regions encode an animal's position in space (or objects) predominantly in allocentric coordinates. The PC and RSC interface between egocentric actions, allocentric spatial and HD information. The ATN provides allocentric HD information and is hypothesized to play a role in transforming between egocentric and allocentric encoding. The PC is centrally positioned within a larger brain network that includes medial temporal lobe regions such as the HPC, as well as motor cortex, sensory cortices, and the RSC. This work tests the hypothesis that components of the theoretical model (below) are distributed across the HPC-RSC-PC network.



Assessing a theory for transformation from world-centered goal location to egocentric goal direction encoding in RSC and PC using HD information from the ATN and HPC allocentric encoding. *Top Left*. HD cells in ATN (grey) and PC (orange; likely from ATN). *Top Right*. HPC cell encoding the position of the same goal as encoded by PC in egocentric coordinates (*bottom left*) but in allocentric coordinates (map-like direction and distance). Map-like goal direction only information (possibly sent from HPC to RSC then to PC) is hypothesized to converge with HD information from ATN in PC to produce cells there encoding a specific combination of these variables (*Middle*). The output of these conjunctive cells is body-centered position (*Bottom Left*) of the goal which is converted to the appropriate action code (*Bottom Right*; both found in PC). *Middle Right*. A conjunctive cell (hypothesized to perform ego- to allo- centric transformation). The same cells seem to form the hidden layer for both allo-ego & ego-allo transformations.

Methods



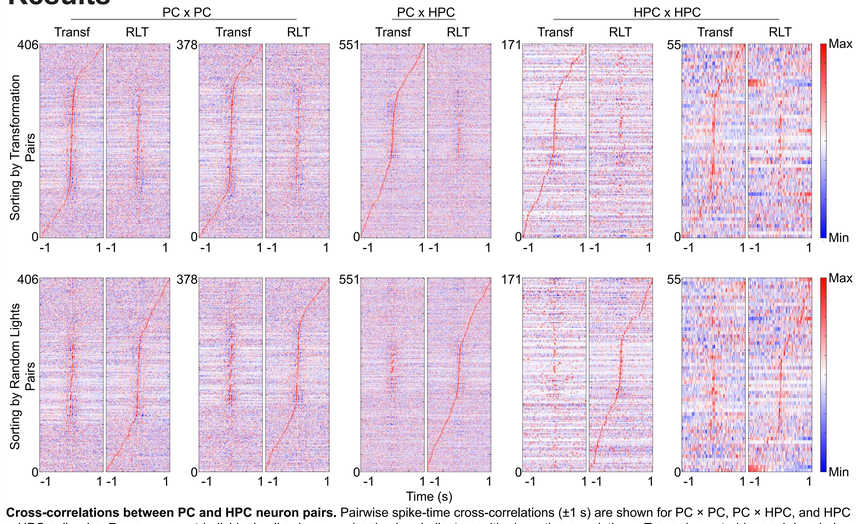
Random Lights
- Objective: Randomize rat's movements (e.g. linear velocity, angular velocity, coverage, etc.) to identify cell tuning properties.
- 32 lights around the table edge was randomly on. Rat goes to the light cue to get reward.

Egocentric
- Objective: Learn a specific motion path to obtain the reward, with the starting point randomized in each trial. Distal cues are not available.
- Rewarded zone determined relative to the starting zone, maintaining a consistent relation regardless of the starting point.
- Setup: Rat is placed in plexiglass box → Covered with an opaque box → Black box is retrieved → Transparent box is removed → Animal navigates the maze. → Trial ends.

Allocentric
- Objective: Use distal cues to navigate to the unmarked reward zone
- Setup: Rat is placed in plexiglass box → Box is retrieved → Animal navigates the maze → Trial ends.

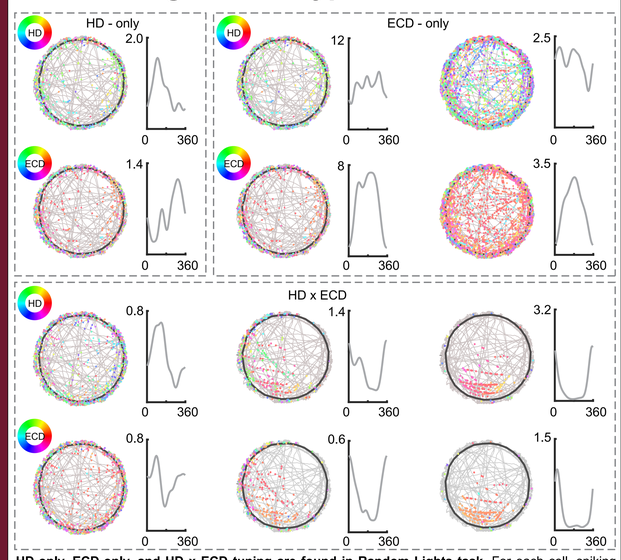
Transformation
- Objective: Use distal cues for allocentric reward location then with cues obscured convert this location to a egocentric location to navigate to the same unmarked reward zone using self-centered motion plans.
- Setup: Rat is placed in plexiglass box → Covered with an opaque box → Distal cues are covered by a screen → Black box is retrieved → Transparent box is removed → Animal navigates → Trial ends.

Results



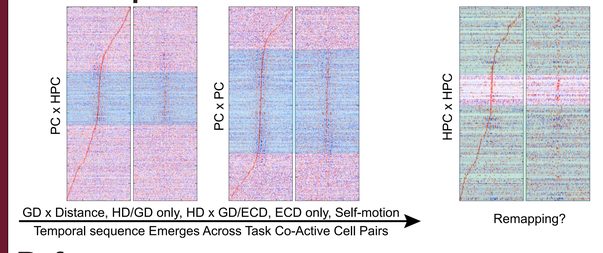
Cross-correlations between PC and HPC neuron pairs. Pairwise spike-time cross-correlations (±1 s) are shown for PC × PC, PC × HPC, and HPC × HPC cell pairs. Rows represent individual cell pairs; warm/cool colors indicate positive/negative correlations. *Top:* pairs sorted by peak lag during Transformation task reveal that many PC × PC cell pairs, less PC × HPC pairs, and few HPC x HPC pairs cross correlate for both tasks. *Bottom:* sorting by Random Lights task shows a similar pattern across the tasks.

Random Lights Cell Type Classification



HD-only, ECD-only, and HD x ECD tuning are found in Random Lights task. For each cell, spiking locations are plotted over the maze trajectory, color-coded by either HD or ECD. HD-only cells exhibit direction-locked firing aligned to head orientation, ECD-only cells fire based on cue direction relative to the animal, and HD×ECD cells show conjunctive tuning to both reference frames. Corresponding tuning curves (*right*) illustrate selective angular modulation for each cell type.

Next Step



References

Bermudez-Contreras E, Clark BJ, Wilber A. The Neuroscience of Spatial Navigation and the Relationship to Artificial Intelligence. Front Comput Neurosci. 2020 Jul 28;14:63. doi: 10.3389/fncom.2020.00063

Burgess N. Spatial memory: how egocentric and allocentric combine. Trends Cogn Sci. 2006 Dec;10(12):551-7. doi: 10.1016/j.tics.2006.10.005.

Dragoi G, Tonegawa S. Preplay of future place cell sequences by hippocampal cellular assemblies. Nature. 2011 Jan 20;469(7330):397-401. doi: 10.1038/nature09633.

Freas, C. A., & Cheng, K. The basis of navigation across species. Annual Review of Psychology 2022, 73(1), 217–241. doi: 10.1146/annurev-psych-020821-111311

Moser EI, Moser MB, McNaughton BL. Spatial representation in the hippocampal formation: a history. Nat Neurosci. 2017 Oct 26;20(11):1448-1464. doi: 10.1038/nn.4653.

Zheng, Y., Zhou, X., Moseley, S. C., Ragsdale, S. M., Alday, L. J., Wu, W., & Wilber, A. A. (2025). A Hippocampal-parietal Network for Reference Frame Coordination. Journal of Neuroscience.

Guerrero, A.B., Oijala, M., Moseley, S.C., Tang, T., Fletcher, F., Zheng, Y., Sanchez, L.M., Clark, B.J., Mcnaughton, B.L. and Wilber, A.A., 2023. An integrated platform for in vivo electrophysiology in spatial cognition experiments. ENeuro, 10(11).

Acknowledgements

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