Examining Neural Networks for Allocentric and Egocentric Coordination for Spatial Navigation

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Introduction/Abstract

Spatial orientation is the process by which living things perceive and navigate through their environment, which is necessary to the functioning of all organisms. This process can be allocentric, which is based on landmarks and cardinal directions [1], or egocentric in which body orientation is referenced instead (left, right as opposed to east, west) [2]. Both forms of spatial orientation interact [3], for example allocentric information can be decoded to determine a subject's egocentric orientation and vice versa. In this study, we hope to analyze elements of both the parietal cortex, which has previously been known to include both allocentric and egocentric encoding [4], and the allocentric-based hippocampus [1] in determining when and where these forms of reference are transformed.

Methods

Subjects:

- Long-Evans (n=2) or Fisher-Brown Norway (n=2) rats were housed in a 12:12 hour light/dark cycle.
- Rats were motivated with stimulation of the medial forebrain bundle as a reward (n=3) through implanted stimtrodes.

Pretraining:

Alternation–

- A linear path is created on an open field, and the rat receives a direct electrical stimulation to the reward pathway in the brain when alternating to the two ends of the path
- The criterion for alternation training is a complete 50 minute session with constant alternating from one end of the track to the other.

Complex Sequence Task:

- The sequence is composed of repeating elements followed by two differing paths (**1-2-3**-4-**1-2-3**-5) along a circular open field (**Fig. 1**).
- The repeating elements (**1-2-3**) are followed by one of two distinct actions and therefore belong to two spatial contexts. Thus, the rat must maintain a spatial *allocentric context memory* (**Fig. 2** *Top Left*) and determine the appropriate action for the context. In this specific experiment, the rat must either navigate to zone 4 or 5 to receive a reward, depending on the sequence (**Fig. 2** *Top Middle*).
- The task is composed of alternating sets of trials in which the sequence is *cued* (control trials) or *non-cued* (memory trials). On *cued trials*, light is used at each zone of the sequence to signal to the subject which zone will elicit a reward (**Fig. 2** *Top Right*).
- Finally, to test for the subject's memory of the sequence, we assess allocentric memory only trials (4-1 & 5-1; **Fig. 2** *Bottom Left*).
- Recording and inactivation experiments begin when the rat achieves 70% correct on zone 4 and 5 (i.e., before the task has become highly repetitive).

Methods Continued

Figure 1: Behavior Room for Complex Sequence Task

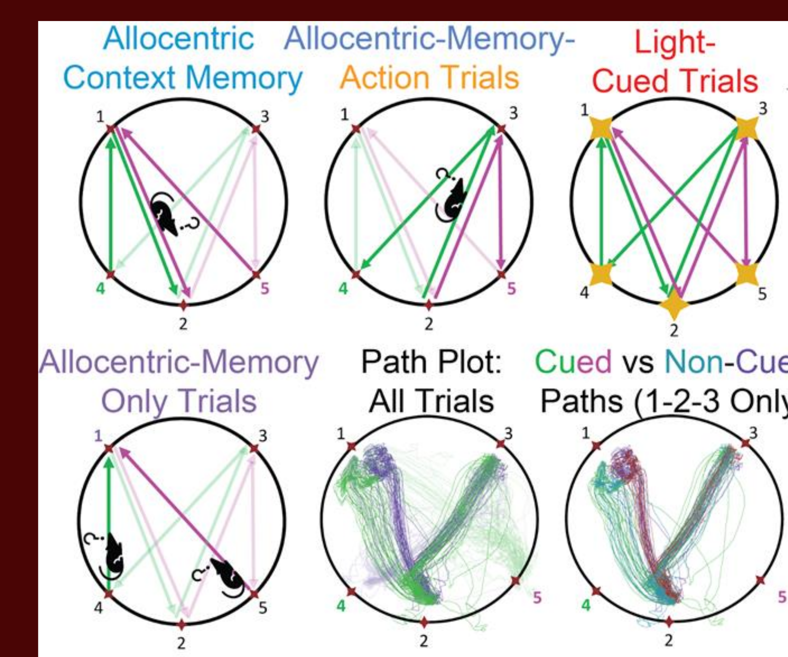

Figure 2: Complex Spatial Sequence Task

Figure 1: The experimental setup includes a table in the middle of the room with 32 equally distributed zones, surrounded by different shapes of black cardboard stuck to the walls. The distal cues, including the cabinets and desks, allow the rat to get oriented in the room space. There is nothing else on/near the table to prevent the use of local cues for orientation in the room space.

Figure 2: Zones are numbered clockwise starting at the top left of the open field. The rat always starts at zone 5 and continues to zones **1-2-3**-4-**1-2-3**-5-. When traversing through zones 1-3 (*Top Left*), the rat must keep track of its allocentric spatial context to coordinate the memory for the allocentric context with the correct egocentric action to reach zone 4 or 5 (*Top Middle*). Test trials where the rat navigates through the sequence using allocentric orientation are interleaved with light cued trials (both in sets of three) in which the rat is led through the sequence by sequentially active light cues (*Top Right)*. Allocentric memory only trials in which the rat only needs to remember the location of zone 1 (*Bottom Left*). Path plot for a single 50 min. session showing paths for the 1-2-3-4- and 1-2-3-5- (color-coded) segments of the task (*Bottom Middle*). Paths overlap for the 2-3 segment. Divergence at 1 caused by coming from 4 vs 5. Path plot for only the 1-2-3 segment, color coded for cued vs. non-cued trials (*Bottom Right*). Paths on the 2-3 segment show complete overlap for light cued vs. memory trials. Representative example from n=7 rats when performance was close to 70% correct.

References:

[1] J O'Keefe and L. Nadel, *Oxford: Clarendon* (1978)

[2] J.J. Knoerim and D.A. Hamilton, *Psychological Reviews* 91 (2011)

[3] P Byrne, et al, *Psychol Rev* 114 (2007)

[4] B.L. McNaughton, et al, *The MIT Press. Cambridge* (1995)

Results

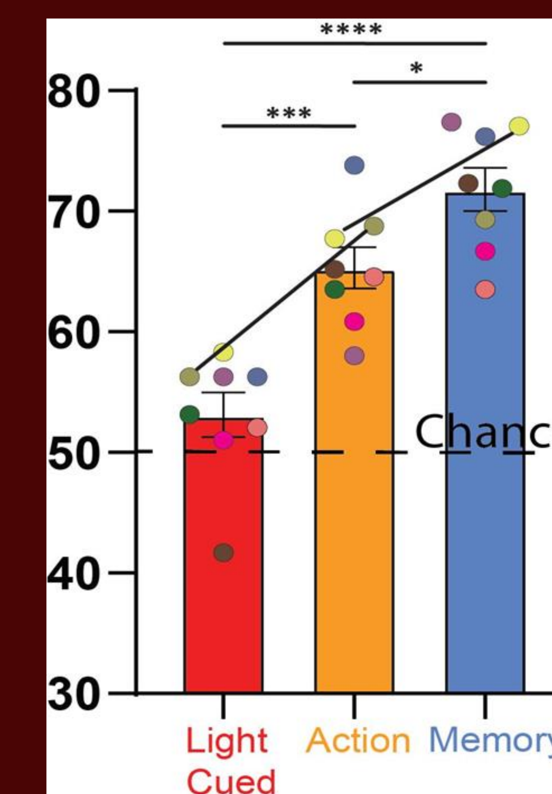

Figure 3

Figure 3: The parietal cortex (PC) encodes the upcoming action and also the allocentric spatial context but only for memory trials and not light cued trials. Mean (+/- standard error of the mean) decoding accuracy for each data set (color coded for data set pairs – cued vs memory are shown for n=8 data sets from 2 rats). PC activity was much more accurate in predicting performance for action and memory trials as opposed to light-cued trials. This suggests that PC is less critical for cued navigation.

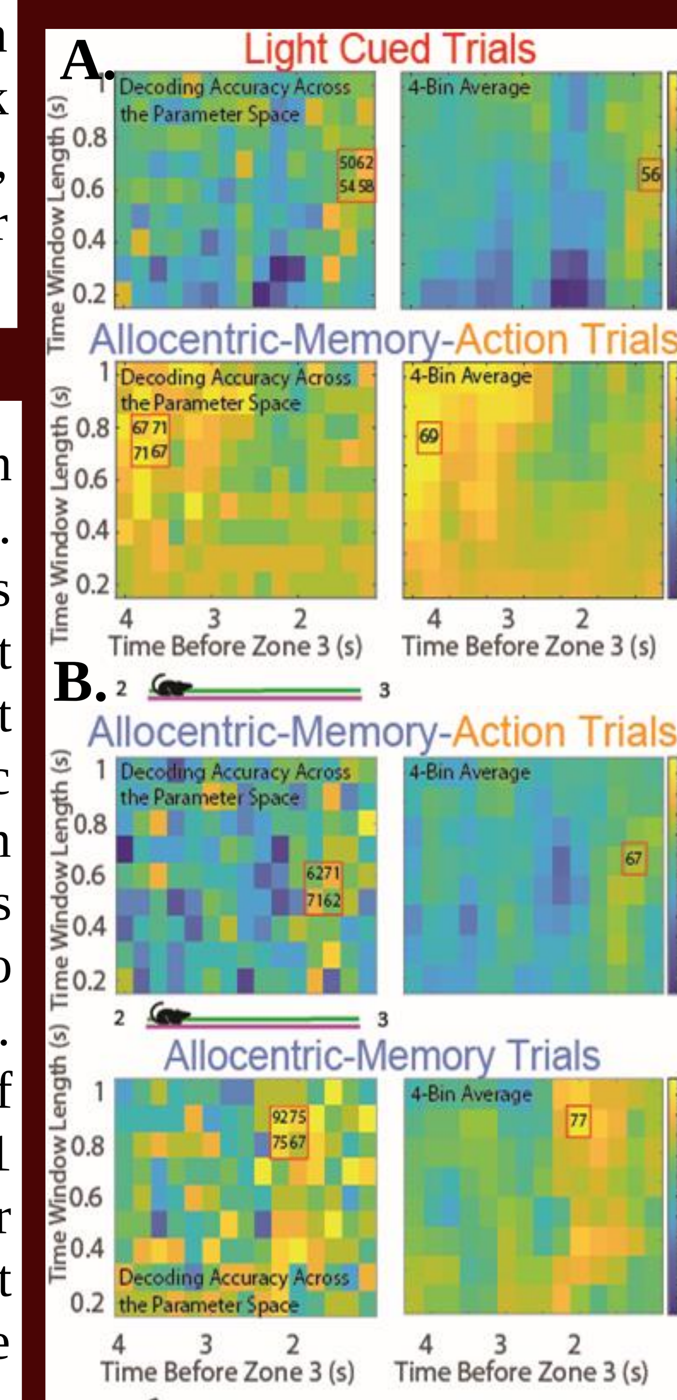

Figure 4

Figure 4: The PC signals correct performance and error trials for allocentric-memory-action trials. A. A leave one out decoding approach was used to build a model from parietal cortex cell activity during the zone 2-3 traversal to predict the future choice for the zones in the sequence, which require translating the spatial context memory into the appropriate action (zone 3-4 & 3-5). Example heatmaps including cell activity for action (*Bottom Left*) and light cued trials (*Top Left*). Each set of 4 adjacent bins is averaged and the peak is selected from this averaged heatmap to ensure that decoding accuracy represents a peak in this parameter space (*Right*). These corresponding data points are connected with a line between the light cued group and the action group on **Figure 3**. **B.** Example heatmaps of the decoding parameter space for action (*Top Left*) and memory trials (*Bottom Right*). The corresponding data points are connected with a line between the action group and the memory group on **Figure 3**. Note the allocentric spatial appears first in the hippocampus and then in the PC.

Acknowledgements

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