Effect of dorsal or ventral hippocampus inactivation on goal-directed spatial navigation in rats and computational models

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1. Introduction

- The hippocampus is essential for goal-directed spatial navigation.

- Previous studies have shown that dorsal hippocampal place cells possess small, stable, and spatially selective firing fields, while ventral cells have larger, less stable, and less spatially selective fields (Kjelstrup et al, 2008).

- Theoretical and modeling studies have suggested ways in which information along the dorso-ventral axis emerges and can be used for spatial navigation (Lyttle et. al. 2013, Erdem & Hasselmo, 2014, de Almeida et. al 2012, Monaco & Abbott 2011).

- The functional significance of these differences in memory-based goal-directed spatial navigation remains unclear.

- We hypothesize that the dorsal and ventral levels of the hippocampus-entorhinal systems are differentially involved when the animal makes navigation decisions at multiple spatial scales.

- To test this idea we used a learning task in which animals had to memorize the locations of a set of rewarded feeders, and recall these locations in the presence of small or large obstacles.

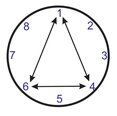
2. Methods

Animals

- Male brown norway rats, 7-8 months old.
- Bilateral cannulae in Dorsal or Ventral Hippocampus.

Behavioral Apparatus

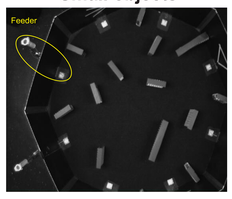
- Open field arena with 8 equally spaced feeders containing sugar water.



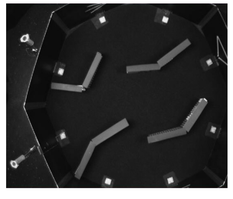
Memory Item= Set: 1,4,6
(in no particular order)

- Objects: Lego blocks

Small objects

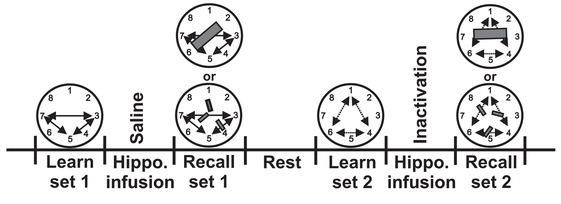


Large objects



Hippocampus inactivation

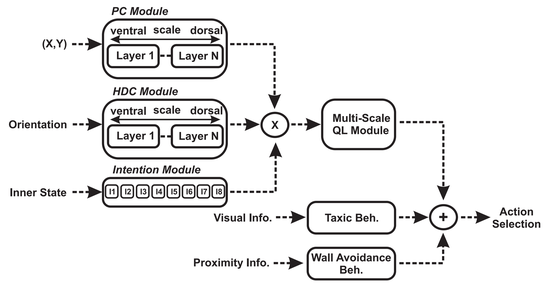
- Experimental protocol.



Infusion: Bupivacaine hydrochloride (bilateral, 2.5%, 1μl/side)

Computational Modeling

- Multi-scale Q-Learning: Model Architecture.



- Multi-scale Q-learning: Equation.

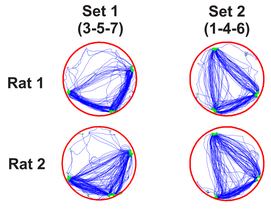
$$Q(s,a) = A(s) * [Q(s,a) + \alpha * (r + \gamma \max_{a',s'} A(s') * Q(s',a') - Q(s,a))] + (1 - A(s)) * Q(s,a)$$

Q(s,a): Q value of performing action a in state s, A(s): activation of cell s, α: learning rate, γ: reward discount factor

- Robot Model Aldebaran NAO v4.

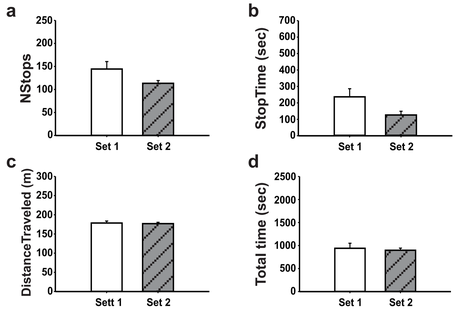
3. Behavioral performance (Learning)

Performance of goal-directed navigation during learning

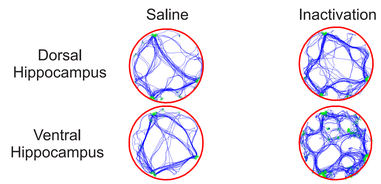


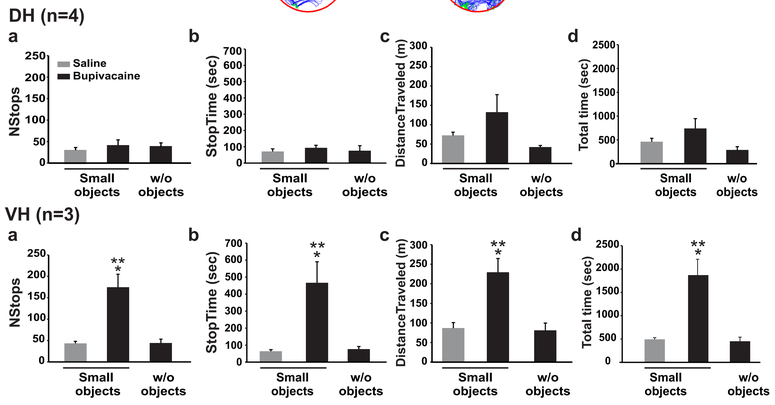
Rat's path is denoted by the blue line and the stops are denoted in green.

Recall performance was comparable for Set1 and Set2 without objects

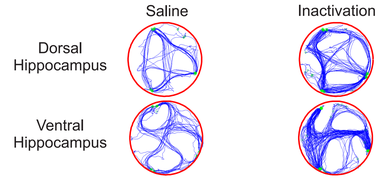


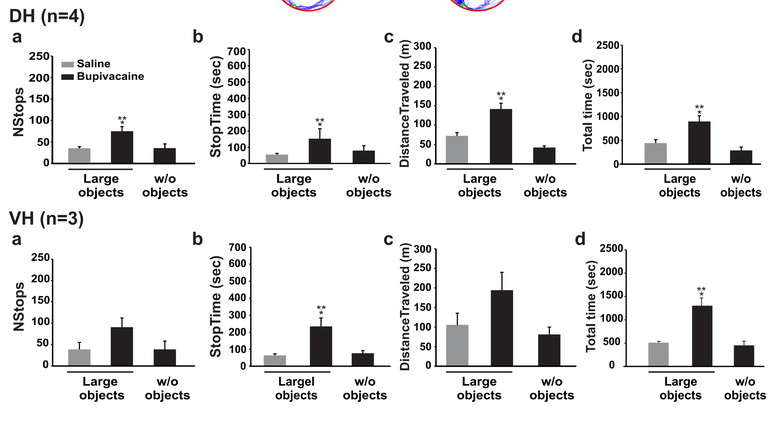
4. Behavioral performance after dorsal or ventral hippocampus inactivation (small objects)



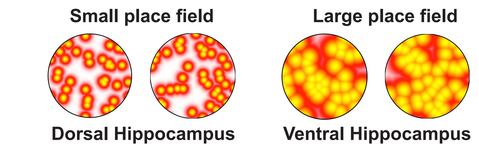


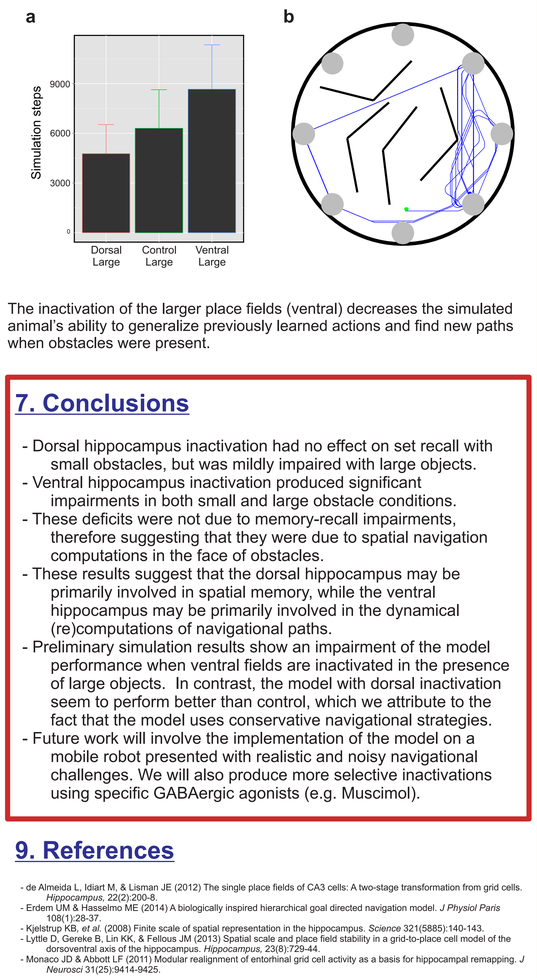
5. Behavioral performance after dorsal or ventral hippocampus inactivation (large objects)





6. Computational model





The inactivation of the larger place fields (ventral) decreases the simulated animal's ability to generalize previously learned actions and find new paths when obstacles were present.

7. Conclusions

- Dorsal hippocampus inactivation had no effect on set recall with small obstacles, but was mildly impaired with large objects.
- Ventral hippocampus inactivation produced significant impairments in both small and large obstacle conditions.
- These deficits were not due to memory-recall impairments, therefore suggesting that they were due to spatial navigation computations in the face of obstacles.
- These results suggest that the dorsal hippocampus may be primarily involved in spatial memory, while the ventral hippocampus may be primarily involved in the dynamical (re)computations of navigational paths.
- Preliminary simulation results show an impairment of the model performance when ventral fields are inactivated in the presence of large objects. In contrast, the model with dorsal inactivation seem to perform better than control, which we attribute to the fact that the model uses conservative navigational strategies.
- Future work will involve the implementation of the model on a mobile robot presented with realistic and noisy navigational challenges. We will also produce more selective inactivations using specific GABAergic agonists (e.g. Muscimol).

9. References

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10. Acknowledgements

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