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Development of place cells by a simple model in a closed loop context

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Introduction

Experiments on rats show that visual cues play an important role in the formation of place cells. Nevertheless, rats also rely on other allothetic non-visual stimuli such as auditory, olfactory and somatosensory stimuli. Most researchers have seen navigation in the dark as evidence for the importance of path integration as an additional input to place cells. Many place cell models have been developed by combining visual and self motion (path integration) information. However, Save et al. have shown that olfactory cues rather than self-motion information have been used to stabilize the place fields (PF) of rats in the dark [1]. Based on these findings we model place cells by combining visual and olfactory information in a feed-forward network. We also analyze the influence of the directionality of place cells on a goal navigation task.

Methods

In a model we develop place cells from external visual and olfactory cues. Sensory inputs as well as place cells are affected whenever the rat navigates in the environment,

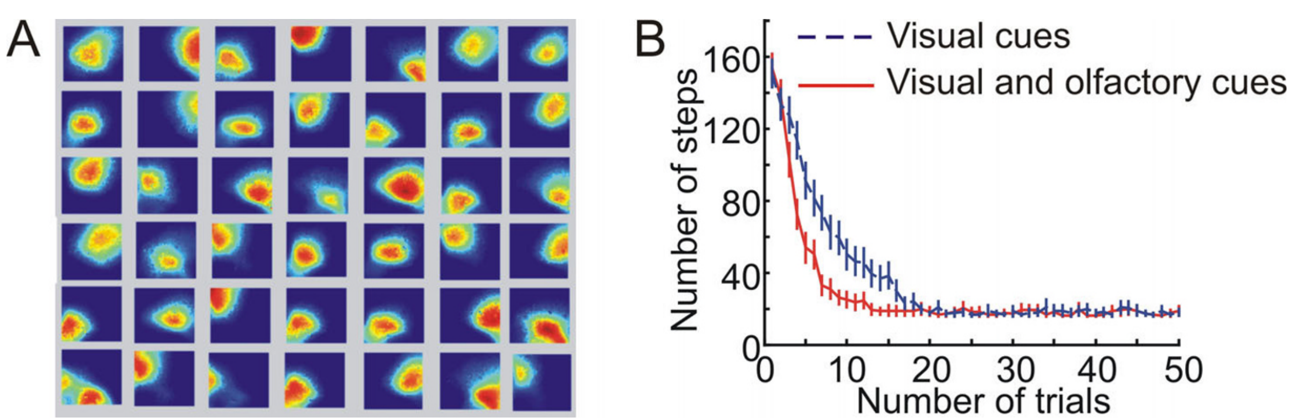

Figure 1
(A) Example of place fields. **(B)** Average number of steps against number of trials needed to find a goal in 100 experiments.

thus closing the loop. We use a fully connected feed-forward network to create place cells where initially random connection weights W are used. Features X derived from visual and olfactory cues are fed to the input layer and the best matching unit (BMU) is found at each time step according to minimal Euclidian distance. We update weights of the BMU by $W^i_{t+1} = W^i_t + \mu(X_t - W^{i_t} W^i_t)$, where μ is a learning rate, $\mu << 1$. The firing rate of place cells is calculated as the following: $r^i_t = exp(-||X_t - W^i_t||^2/2\sigma^2)$, where σ defines the size of the place field. Obtained PFs are used for goal navigation where the model rat had to find the food source by ways of the Q-learning algorithm.

Results

An example of PFs is shown in Fig. 1A and we observed that less directional cells were obtained by using visual and olfactory cues as compared to the case where vision alone was used (~13% vs. ~38%). We have also obtained that use of olfactory information increases performance in a goal navigation task where the model rat finds the food source faster if in addition to the visual information olfactory cues are used (see panel B).

Conclusion

In this study we have shown that formation of place fields by combining visual and olfactory cues and goal navigation by ways of simple model is possible in a closed loop context. We also emphasize the contribution and benefit of olfactory cues in a goal navigation task.

References

1. Save E, Nerad L, Poucet B: **Contribution of multiple sensory information to place field stability in hippocampal place cells.** *Hippocampus* 2000, **10(1):**64-76.