SPATIAL NON-GRID CELLS IN THE PRIMATE ENTORHINAL CORTEX

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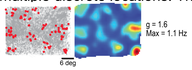
Introduction

Grid cells have been identified in the entorhinal cortex (EC) of rodents[1], bats[2], and humans[3,4], and by our group in the monkey EC[5]. While a stationary rhesus monkey freely viewed complex images, EC neurons represented eye postion on the screen by firing when the monkey fixated multiple discrete locations. These firing fields possessed spatial periodicity and formed a grid-like pattern:



Limitations:

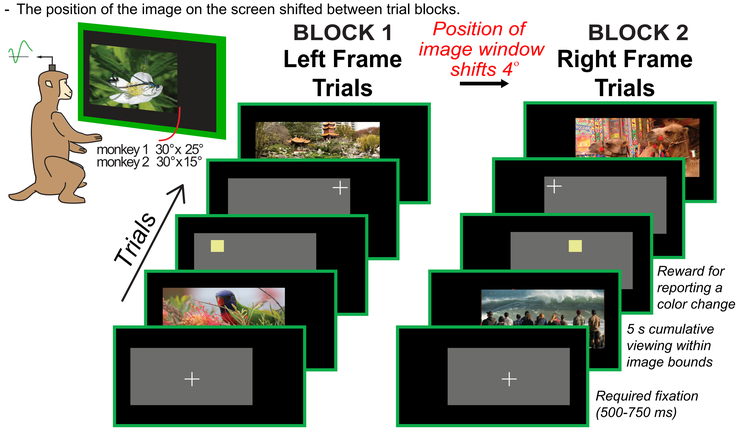
- Most grid cells were identified using relatively small images (11°x11°) that showed few firing fields.
- Because the images remained in the same position on the screen, the frame of reference is unknown.
- The extent of any non-grid spatial representation in the primate EC is unclear.

Questions:

- Can we observe repetition of the grid pattern across a larger visual space?
- Do neurons represent eye position in a head-centered, *egocentric* reference frame, or a world-based, *allocentric* reference frame?
- What proportion of entorhinal neurons represent eye position?

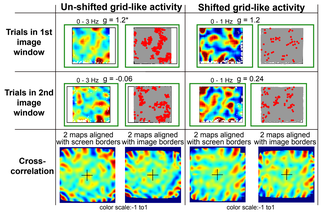
Methods

- The spiking activity of EC neurons was recorded as monkeys freely viewed large, complex images.
- The position of the image on the screen shifted between trial blocks.

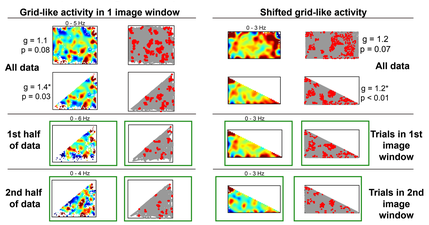


Grid-like spatial representations

- 13 / 349 of cells had significant grid scores and stable spatial activity.
- The spatial representation of these cells could either shift or not along with the image window location.

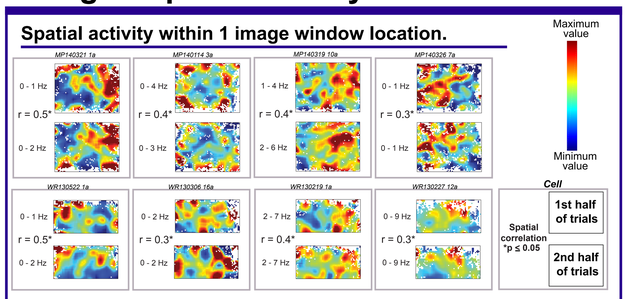


- Because we on average covered 4-7x more screen space than the previous report of grid activty, we tested whether grid-like representations were evident in a smaller region of the screen.
- Using half the screen space resulted in much clearer grid fields and a higher proportion of cells with stable grid activity (13%). This percentage is comparable to our earlier report[5].

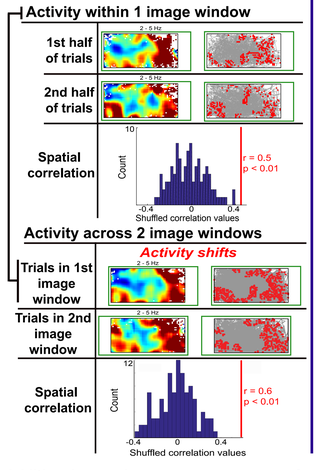


Non-grid spatial activity is robust

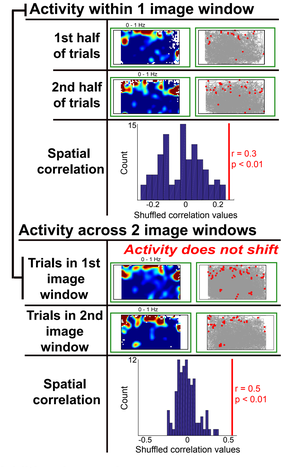
Spatial activity within 1 image window location.



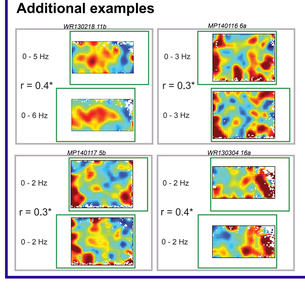
Activity can shift along with image window location



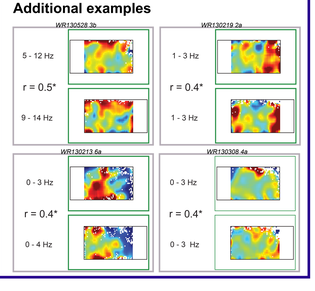
Activity can also not shift with image window location



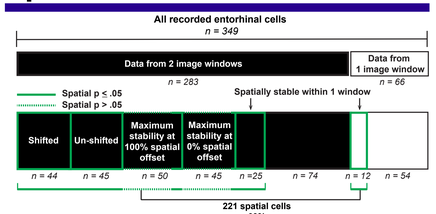
Additional examples



Additional examples

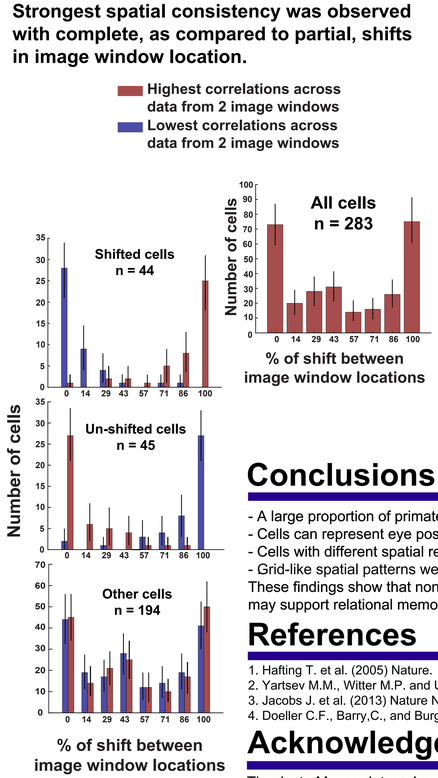


Spatial cells are common



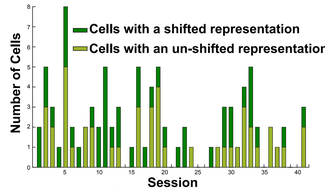
Spatial shifts are complete

Strongest spatial consistency was observed with complete, as compared to partial, shifts in image window location.

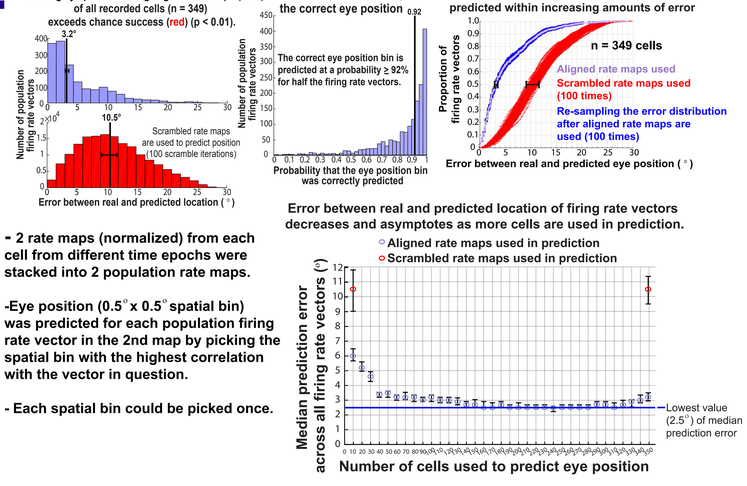


Spatial reference frames across the population

Cells with different spatial reference frames were recorded simultaneously.



Eye position can be predicted from cell activity



- 2 rate maps (normalized) from each cell from different time epochs were stacked into 2 population rate maps.

-Eye position (0.5° x 0.5° spatial bin) was predicted for each population firing rate vector in the 2nd map by picking the spatial bin with the highest correlation with the vector in question.

- Each spatial bin could be picked once.

Error between real and predicted location of firing rate vectors decreases and asymptotes as more cells are used in prediction.

Conclusions

- A large proportion of primate entorhinal neurons represent eye position.
- Cells can represent eye position relative to visual objects (allocentric reference frame).
- Cells with different spatial reference frames can be recorded simultaneously.
- Grid-like spatial patterns were found in a small percentage of the population.

These findings show that non-grid, visuospatial representation is a fundamental property of entorhinal neurons and suggest these neurons may support relational memory and motor planning by coding attentional locus in distinct, behaviorally relevant frames of reference.

References

1. Hafting T. et al. (2005) Nature.
2. Yartsev M.M., Witter M.P. and Ulanovsky, N. (2011) Nature.
3. Jacobs J. et al. (2013) Nature Neuroscience.
4. Doeller C.F., Barry,C., and Burgess, N. (2010) Nature.
5. Killian N.J., Jutras M.J. and Buffalo, E.A. (2012) Nature.
6. Brandon, M.P. et al. (2011) Science.

Acknowledgements

Thanks to Megan Jutras, Laura Kakalios, Kiril Staikov and Kelly Morrisroe for technical assistance, to Nathan Killian for supplying example Matlab code and for helpful discussion, and to all the members of the Buffalo lab for helpful discussion.
Funding for this work was provided by NIH 2R01MH080007, R01MH093807 and NIMH P51 OD010425.