BMC Neuroscience

Poster presentation

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Stimulus reconstruction reveals extended 'replay' in the rat hippocampus during exploration

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from Sixteenth Annual Computational Neuroscience Meeting: CNS*2007
Toronto, Canada. 7–12 July 2007

Published: 6 July 2007

BMC Neuroscience 2007, **8**(Suppl 2):P198 doi:10.1186/1471-2202-8-S2-P198

Spatially-modulated firing of hippocampal 'place cells' is thought to subserve spatial learning in the rat. Ensemble recordings have shown that these cells re-express behavioral firing sequences during sleep. Recently, replay of the reverse of behavioral sequences has been reported in the awake rat at reward sites. These phenomena are hypothesized to play a role in memory formation and consolidation.

Here we report findings from simultaneous recordings of ensembles of place cells in area CA1 of the hippocampus during exploration of a 10 m linear track. In contrast to existing replay detection methods which look for patterns in the spiking records of cells, we employ a Bayesian algorithm to reconstruct the position stimulus, and detect replay as trajectories in the stimulus space. Notably, due to the directionality of the recorded place cells, we can reconstruct both the animal's position and direction of movement, which allows us to differentiate between forward and reverse replay.

We apply our method to periods of immobility, and find that both forward and reverse replay are prevalent. Either the start or end point of the replayed trajectories are often anchored to the rat's current location. We detect significant replay events several times per minute. Replay episodes have a mean duration of ~300 ms (max. 700 ms); replayed trajectories span on average ~3 m of the track (max. 8 m) with a corresponding 'virtual' velocity of 8 m/s (0.3 m/s s.e.m.). Replay is correlated with increased power in the ripple-band (150–250 Hz) in the local field potential.

These findings show that place cells in the hippocampus of the behaving rat can express patterns of activity corresponding to traversal of remote locations. The observed 'virtual' trajectories proceed in both the forward and reverse order and extend across a longer timescale than has previously been appreciated.