A Grid & Place Cell Model of Path Integration Utilizing Phase Precession Versus Theta

Grid cells in dorsomedial Entorhinal cortex fire in a strikingly regular array of locations as a rat explores (Hafting et al., 2005). Nearby grid cells have similar orientation and scale, but shifted to tile the environment.

Grid scale increases as recording site moves from dorsal to ventral

Combining band cells to make grid cells (taking product of firing)

2 band cells (90° & 30°) or 3 band cells (150°, 90° & 30°) will do

Most frequent winner/100 random selections of 3 band cell orientations:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Firing Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>8.5</td>
</tr>
<tr>
<td>15°</td>
<td>6.8</td>
</tr>
<tr>
<td>30°</td>
<td>5.2</td>
</tr>
<tr>
<td>45°</td>
<td>3.9</td>
</tr>
<tr>
<td>60°</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Grid orientation follows sensory cues

Place cell at peak rate
(MPO in phase with θ)

Band cells phase-reset by place cell (MPOs in phase with θ)

Thresholded sum of 60 randomly chosen grid cells gives realistic looking place fields:

Model is consistent with place fields 'remapping' while grids shift

Recurrent connections from a band cell will form predominantly to next cell with same preferred direction (ø) and phase diff = lag of MPO response (90° = 25ms). Then phase will propagate correctly through the local set, only the band at start run needing to be phase-reset, and band and grid cells will show predominantly late-early phase precession.

Once set up by interference, these connections would be support P.I. more efficiently than between place cells, as can be fine-tuned throughout environment.

The Boundary Vector Cell model (see Barry et al. poster) is consistent with phase reset of grids by sensory input at edge of environment.

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Conclusion: grid cell firing could result from interference of multiple MPOs with theta, phase reset by place cells.