Supplemental Figure Legends:

Supplemental Figure 1: A comparison of place field sizes and in-field firing rates at a low (20-40cm/s) and high (80-100cm/s) velocity bins. Only place fields that were traversed at a low and high velocity were included in this analysis. Place field boundaries were determined across all velocity bins using the criterion that a unitary place field shows 360º of theta phase precession. The difference between the location of the first and last spike, within a velocity bin, was then calculated to quantify the size at different velocities. This method for determining the boundaries of place fields has been described previously (Burke et al., in press; Burke et al., 2008; Maurer et al., 2006a). **(A)** The left panel shows the mean size of place fields in the low and high velocity bins. The right panel compares an individual place field size when the rat runs at two different velocities (i.e., low and high velocity bins). The lines connect data from individual place fields for the low and high velocity bins. There was no statistically significant difference in place field size between the different velocities. **(B)** The left panel shows the mean in-field firing rate for the two different velocity bins and the right

panel shows the mean in-field firing rate for individual fields paired across the low and high velocity bins. A statistically significant change was detected in the in-field firing rate between the low and high velocity bins (as seen in previous publications; e.g., McNaughton et al., 1983a).

Supplemental Figure 2: Cartoon illustration of vector correlation methods. The ***top-left*** schematic is a theoretical spike raster of 8 neurons firing within three consecutive theta cycles (each black line denotes the peak of a theta cycle; note the similarity to Figure 3 of Tsodyks et al., 1996). These neurons are sorted by their spatial location of maximal firing rate. The raw spikes are binned based on their phase of firing relative to the theta rhythm and were used to construct the temporal population matrix (***upper-right*** panel). The hotter the color, the higher the spike count. Blue colors are bins without any spikes and the vertical solid white lines are theta peaks (black arrow at central theta trough). The ***bottom-left*** panel shows the hypothetical spatial population matrix, calculated for the entire behavioral epoch, where each row is a cell and each column is a spatial bin. Once again, hot colors are spatial bins with high spike density while cool colors are regions with little to no spikes. On the ***bottom-right*** is the hypothetical result of correlating each column of the temporal population matrix (the composite population vector for each theta bin over three theta cycles) with each column of the position population matrix. Hot colors are high correlation values while cool colors are low correlation values. Vertical solid white lines are theta peaks whereas the dashed diagonal white line is the rat's hypothetical position in space. The solid black arrow is overlaid to highlight the reconstructed hippocampal look-ahead to prospective locations (defined by the bins with the highest correlation values; analogous to the dashed black

line in Figure 1). The difference between the hippocampal look-ahead and the rat's position in space, the jump back, is denoted by the double green arrow (analogous to the vertical red lines in Figure 1).

Supplemental Figure 3: Example of a temporal population matrix (left) and spatial population matrix (right) for a single data set of 83 cells. The spatial population vector was constructed for the entire behavioral epoch (20 minutes of small track running). The temporal population vector, on the other hand, was constructed for a ***single temporal epoch*** (5 theta cycles are shown in this example for simplicity although 7 theta cycles were used in the analysis). Hot colors in the spatial population vector represent high occupancy normalized firing rates while cool colors are low firing rates (vertical white lines are theta peaks). In the temporal population vector, hot colors are high spike counts while cool colors (light blue) represent one spike. Note that not all columns of the temporal population vector contain spikes (dark blue).

Supplemental Figure 4: *Stacked matrices of Time by Space correlations for 4 iterations (n Theta cycles by p Positions by t temporal bins).* Each seven theta cycle window provides a single **r** matrix (hot colors are regions of high correlation). The white line is the rats' relative position for that temporal window. By moving the window by one theta cycle (i.e., moving up one page in the matrix stack), we are provided with another **r** matrix, which is stacked on top of the previous **r** matrix (this process is analogous to the stacking of firing rate maps for individual neurons used in Leutgeb et al., 2005). For this behavioral epoch, thousands of **r** matrices were generated. In the next step, each page of the stack is sorted according to velocity and averaged. The vertical bands of

dark blue are bins where no cells fired an action potential and therefore, all values were set to *NaN* (not-a-number).

Supplemental Figure 5: (**A**) CCG-lag by distance between fields for the dorsal hippocampus-small track condition at velocities between 15-25 cm/s. (**B**) Note that the density profile of distances is essentially Gaussian when projected onto the x axis (bottom histograms), whereas the density profile of the CCG-lag is multi-modal when projected onto the y axis (**C**; Skaggs et al., 1996; Dragoi and Buzsaki, 2006). **C** is essentially the summation of all cross-correllograms between all cell pairs for a given velocity bin.

Supplemental Figure 6: Schematic of a hypothetical look-ahead in the dorsal and middle hippocampus. (**A**) A hypothetical situation during which a rat occupies a specific location (red dotted line) where four place fields overlap in the dorsal (black Gaussians) and middle (green Gaussians) hippocampus. Note that in this hypothetical situation, the rat would occupy the same number of fields in the dorsal and middle hippocampus (there is the same number of assemblies active per theta cycle between the two hippocampal regions). (**B**) If each place field is associated with a single assembly, then it can be inferred that the network 'looks-ahead' the same number of assemblies per theta cycle (green dots represent the middle hippocampal look-ahead *of assemblies*; black dots represents the dorsal hippocampal look-ahead *of assemblies*). (**C**) The assemblies associated with each field place field are spaced farther apart in the middle hippocampus compared to the dorsal. Therefore, the consequence of looking ahead across the same number of assemblies between the two regions is that the middle

hippocampus looks ahead a greater distance (green line is the middle hippocampal look-ahead *in position; black* line is the dorsal hippocampal look-ahead *in position)*. Note that the slope of the look ahead (cm per msec) is greater in the middle hippocampus compared to the dorsal hippocampus which explains the observation of larger place fields in middle and ventral hippocampal regions (Jung et al., 1994; Kjelstrup et al., 2008; Maurer et al., 2006a; Maurer et al., 2005).

Supplemental Movie: A contour plot of the distance between place fields (x-axis) versus CCG-lag (y-axis) over a range of velocities (v) from 6 cm/s to 70 cm/s. Note that the slope is shown in green and moves from a near vertical value at low velocities and becomes less vertical as the rat moves faster. This corresponds to an increase in the inverse slope (i.e., the rate of cell assembly transition) at higher velocities. For the quantification of the velocity dependence, a moving velocity widow was employed with a constant width of 10 cm/s.