How does the hippocampus support the ability to remember the order of events in episodic memories?

How do we remember events? We can tell stories about things that happened to us, but how does the brain string together the parts of the story? At the NSF-funded CELEST Science of Learning Center, Howard Eichenbaum, Joe Manns, and Chris MacDonald have been trying to answer these questions.

This kind of episodic memory is known to depend on the hippocampus – but it's unclear how or why. To investigate this, we first removed the hippocampi from a group of rats and tested them to see if they could remember the order of a sequence of smells. The rats performed poorly – their hippocampi, it seemed, were critical to their ability to remember.

Then, using normal rats, we recorded the activity of about 30 neurons in the rats' hippocampi while teaching them the same sequence of odors. We found that the neurons fired in a unique pattern during the seconds that the rat spent smelling each unique odor – but also in a *different* unique pattern during the seconds before and after each smell. We believe this is a "timing signal," a way for the hippocampus to encode the sequence of events.

We then modified the smell-memory task to see whether the rats would remember only smelling an odor, or also the moments just after smelling the odor – in other words, the context of the event. In this new study, the rats were shown an object (Object A); then ten seconds later, smelled an odor (Odor 1); the sequence was repeated with Object B and Odor 2 (see figure). The rats then had to remember which object went with which odor in order to respond correctly. We found a large number of cells that fire during specific phases of the task and at particular times during each phase. In particular, different hippocampal neurons fire in a specific pattern during the ten-second delay, indicating a timing signal as observed in our earlier study. Furthermore many cells fire only during the events that define each type of episode (see Object and Odor in figure), and even disambiguate the overlapping blank delay (see Delay in figure). Thus, hippocampal networks “map” each episode, containing information about the passage of time in the experience and the specific events that define each experience.