

sea anemones (the tentacled host animal in which clownfish live for protection from predators) for longer periods. One barometer of personality is that behavior is consistent over time, and these animals are nothing if not consistent. “The individuals who didn’t travel very far on one day were the ones who also didn’t travel very far the next day,” Buston says. “Individuals that are really active are consistently very active.”

He isn’t taking Nemo’s word for these personality quirks. He and students working through the Undergraduate Research Opportunities Program, which offers BU undergrads the opportunity to participate in research projects with a faculty mentor, trained video cameras on seven pairs of (not romantically involved) clownfish in 30-gallon tanks at the biology department. (Clownfish don’t wander far from their anemones in the wild, so the constraints of a tank don’t impede accurate observation.) The researchers taped the clownfish for 10-minute intervals twice a day for three days. The cameras captured whether the fish left their anemone and how far they traveled, the time spent outside of the anemone, and how they acted with each other.

“This is uncharted territory,” says Curran Uppaluri (CAS’13), one

of Buston’s student assistants, who says he joined the project because it enabled him to follow a hypothesis through to a “full-fledged experiment with telling results.

“Also,” he says, “it didn’t hurt that the clownfish were excessively adorable.”

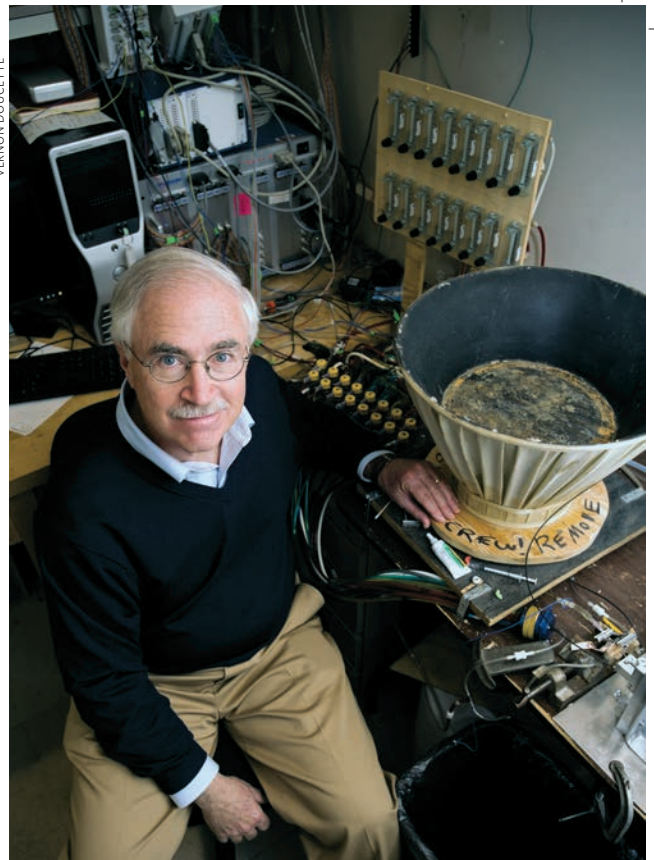
Research conducted elsewhere has found distinctive traits among many marine animals—for example, eels and groupers are cooperative souls, known to help one another hunt prey. For Buston, the bigger question is why a variety of personalities in a single species is maintained by natural selection. After all, if evolution suggests that certain traits are better suited to adapt an individual to his or her environment and will be passed on, what can be good about varying traits?

His next research will try “to understand if different personalities do better in different contexts.” For instance, boldness in venturing far is helpful if a fish needs to find new food supplies, but when a predator is prowling around your anemone, discretion could be the better part of valor.

These further studies will require lots of fish, about 180, and lots of time—“30 or more years,” Buston says. “So assuming that I were to get tenure, then I would be working with them until I retire.”

» What can be good, evolutionarily, about varying personality traits?

VERNON DOUGETTE



MARKING TIME Howard Eichenbaum says understanding the firing of neurons in the brain’s hippocampus could help us design drugs to treat memory disorders and the age-related memory loss that affects almost everyone.

What Is Time?

UNDERSTANDING HOW THE BRAIN TRACKS TIME MAY HELP UNRAVEL THE MYSTERY OF MEMORY BY ART JAHNKE

For a small group of researchers at BU’s Center for Memory & Brain, space is not the final frontier; time is. And they’re finding that the way the brain registers time is remarkably similar to the way the brain registers space.

Howard Eichenbaum, director of the Center for Memory & Brain (CMB) and a College of Arts & Sciences professor of psychology, is studying the firing of neurons in the hippocampus, a structure near the center of the brain that plays a major role in



memory. Understanding how those firings pinpoint our position in time (and space), says Eichenbaum, is more than an academic triumph; decoding the machinations of the hippocampus could help us design drugs to treat memory disorders such as Alzheimer's, which is expected to enfeeble one in eight baby boomers, as well as the age-related memory loss that affects almost everyone.

Eichenbaum's effort to document the brain's recording of time is deceptively simple. First, he tracks the firing of neurons in the brains of rats while they perform a specific task. Then he tracks the firings while the rats perform the task with an interlude during which they are deprived of external stimuli—left, essentially, with nothing but time. If the neurons fire in new and unfamiliar patterns during the stimulus-free interlude, Eichenbaum reasons, they must be literally marking time.

Eichenbaum presented his rats with either a square object or a cylindrical object, and then rewarded the animals when they learned to associate each object with a particular odor, oregano or cinnamon. After being introduced to the object, the rats were placed in a stimulus-free chamber for 10 seconds. A door was opened, and the rat was presented with a pot of sand, scented with one of the two odors. If the scent matched the one the rat knew to be associated with that object's shape, the rat would dig for a sweetened cereal reward. If the scent did not match the object, the rat did not dig, and was rewarded for not digging. Throughout the drill, the researchers record, from surgically implanted electrodes, neural activity in the rat's hippocampus, the part of the brain believed to encode episodic memories.

"The neurons in the hippocampus do something interesting," says Eichenbaum. "They fire in different patterns when the rats inspect the different objects. They seem to encode information that identifies either the block or the cylinder."

But what Eichenbaum found particularly interesting happened during the "empty" delay period, when the rats were deprived of external stimuli. There, while some firings matched the pattern associated with the task at hand, others (about a third) did not.

"They fired at different moments," says Eichenbaum. "Some fired when the rat first walked in, some in the next second, some in the third second, some in the fourth. If you look at all the cells, you see something that looks like ticks of a clock, like they are pacing through the empty period of time. It looks like time is being filled up."

Eichenbaum and his team went to great lengths to remove every possibility that external stimuli, the animal's behavior, or the location of the animal could account for the apparent timing signal; their analyses removed all of these

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possibilities except, of course, time. The firing continued. Eichenbaum increased the empty time from 10 seconds to 20, and what he saw was more of the same: the neurons kept firing. "Some cells drop out," he says. "Some fire at different times, and some that weren't firing start to fire."

The firings occurred in cells that Eichenbaum and his team named, appropriately, "time cells," which happened to be very similar to "place cells" studied by CMB colleague Michael Hasselmo, a CAS professor of psychology. In another series of rat experiments, Hasselmo had shown that place cells, also found in the hippocampus, fire when rats move from one place to another. Hasselmo and others believe that the firings are a method of "path integration," tracking the rat's movement in space.

How is a researcher to know if the cells are responding to time, as Eichenbaum's research suggests, or to how far the rat has traveled on a path, as suggested by Hasselmo's work? One way is to study the firings while the rats are moving and while they are stationary. The two researchers had the rats run on a figure eight apparatus outfitted with a treadmill control position in the center. When the rats reached the treadmill, they were made to run in place for 15 seconds. Their neuronal activity was monitored while they ran along the track and while they ran in place. So, were the cells firing in response to time or to distance traveled on the treadmill? The answer, says Eichenbaum, is both.

"Some cells seem to respond mostly to distance," he says. "And some respond mostly to time. Interestingly, when the rats run on the treadmill for a specific time, some cells track time very closely and are hardly influenced by distance. Conversely, when the rats run on the treadmill for a specific distance, some cells track distance very closely and not time." Thus, he says, it seems the constant parameter (time or distance) has special status in how the hippocampus represents the experience.

Where does Eichenbaum go from here? "The next step might look at how time cells arise in the hippocampus," he says. "We want to examine the areas that send information into the hippocampus to compose the time signal."

Knowing that, and knowing other things about the physiology of the hippocampus, he says, can improve our understanding about how memories degrade in memory disorders and therefore might also offer insights about how drugs could work to improve memory.