Rat Neurons, Robotic Arms, and Art

By Danna Voth

In an experiment that literally deals with a mind-body split, a team of artists and scientists has been collaborating to explore the basic mechanisms of creativity, learning, and memory. Scientists in Steve M. Potter's lab at the Georgia Institute of Technology in Atlanta and scientists and artists at SymbioticA, the Art & Science Collaborative Research Lab in the School of Anatomy and Human Biology at the University of Western Australia, have paired cultured rat cortical cells with a robotic arm that, working together, can produce a drawing. The rat neurons and glial cells lived in Potter's lab in a special petri dish called a multielectrode array (MEA) outfitted with a grid of 60 two-way electrodes. The robotic arm resided in the gallery housing SymbioticA's art exhibition—last summer in Perth, and this summer in New York City—11,241 and 748 miles away from Atlanta, respectively. The collaborative team calls this project Meart, standing for multielectrode array art.

How neurons create a masterpiece

To make a dish of cultured neurons, Potter's team deposits about 10,000 to 50,000 embryonic 18-day old rat or mouse cortical cells into the MEA, which is bathed in special nutrients. The cells begin to reconnect, reestablishing contact with other neurons. Lately, Potter's team has been using transgenic mice whose neurons come prelabeled with a fluorescent protein.

"There are a lot of things that the cultures have in common," Potter says, "but we also realize that each dish has its own individual personality." The dish's characteristics could depend on the number, density, or proportion of glial to neuron cells.

The rat cells' neural activity drives the drawing of the picture. The electrodes in the MEA record the neural firing pattern, which software then translates into signals that direct the robotic arm to choose how many colored markers to use and in which
direction to move across the paper. The electrodes in the array were two-way, which let the team give the neurons feedback, creating a closed-loop system. To make the connection between Atlanta and Perth or New York, the scientists and artists sent data through the Internet. The feedback consisted of a pixelated snapshot of a random gallery viewer, which was to serve as the inspiration for a portrait, compared to a pixelated picture of the actual image the robot drew.

“There’s some sort of mapping between space in the image and the electrodes,” Potter says. “The difference between the desired image and the actual drawing is what sets the stimulation feedback.”

Potter is hoping to find evidence that the dissociated rat cortex cells respond to the feedback in a way that indicates they’ve learned something about themselves and their environment. By studying a single-cell layer, or planar array, of networked neurons and glial cells while monitoring a representation of its activity, Potter’s team hopes to observe morphological changes in the networks—such as changes in synapse number or size, outgrowth or pruning of dendritic and axonal arbors, formation of dendritic spines, or perhaps interactions with glial cells—at the moment that learning occurs. “We’re very interested in how the shape of brain cells changes when you learn something,” Potter says.

To help him look at living specimens in very thin sections—such as in his planar array—without killing them, Potter is building a special two-photon microscope. He wants to be able to study the rat neurons while they engage in learning. “We make a lot of time-lapse movies of the cells growing and forming connections and changing their shape,” Potter says. “Very soon, hopefully, we will also be doing the microscopic imaging at the same time so we can watch the process of learning while it happens at the cellular level.”

Thomas DeMarse, who worked with Potter on the Atlanta-Perth exhibition, says, “The experiment is looking at neural computation, neural processing—how the neurons encode information and translate that into a movement.” Understanding how the activity patterns are encoded in the network at a cellular level and how feedback changes network activity in the brain could enable development of non-silicon-based computing systems that could be more versatile, like brains, and more fault tolerant, like biological systems. DeMarse says knowledge gleaned from this research might help sufferers of Alzheimer’s disease. “We’d really like to know if there’s a way in the wetware itself that, if you knew how the memory was getting in, you could enhance it.”

The collaboration

Potter’s group worked with connecting neuron cultures to computers before becoming involved in Meat. The group developed a robotic device whose movements are controlled by a cultured neural network they call a hybrid. SymbioticA, too, had previously conducted research involving music-stimulated neural activity that controlled a robotic arm. They used fish neurons cultured on silicon and Pyrex chips, and the robotic arm produced visual art and a sound piece. The created music was feedback. The SymbioticA team called that project “Fish and Chips.”

Meat came about when SymbioticA’s artist-in-residence, Guy Ben-Ary, emailed Potter in 2001, noting the similarity in the two groups’ projects. They decided to work together on controlling SymbioticA’s robotic arm with neurons in Potter’s lab.

Creativity and art

At SymbioticA, artists work with technology in a scientific department and can access all the scientific labs. Artists can then comment on technology that they have an active part in using. The SymbioticA team aims to present artwork based on combinations of software, hardware, and wetware that will both explore creativity and raise ethical questions about the use of biotechnologies in future scenarios. Oron Catts, artistic director at SymbioticA, and SymbioticA’s Ionat Zurr coined the term semiliving objects to describe objects that are partly constructed and partly grown.

Ben-Ary says semiliving objects “live in the fuzzy border of somewhere between the animate and inanimate or the alive or dead. They’re made of cells and you need to feed them and they die, but they don’t speak to the kind of definitions that we are aware of at this time.”

With the possibility that the Meat system could exhibit complex or adaptive behavior, Ben-Ary wonders, “what would happen if those entities might in the future be intelligent, or might have some sort of emerging behavior? How are we going to treat them?”
Another question Ben-Ary wanted to raise in this project is about creativity and who (or what) can be considered creative. “Being creative and artistic is something that traditionally was reserved for humans and other life forms,” he says. “With Meart we tried to create something that might be perceived by others as creative.” Ben-Ary said that people had mixed reactions to Meart, from “complete disgust to complete fascination, but you probably won’t find anyone who saw Meart and is kind of indifferent.”

At one point in the experiment, Ben-Ary noticed that the robotic arm was moving repetitively on one spot, almost tearing the page there. He contacted Potter’s lab and learned that the culture had died. “It was the first time I had to deal with death in an artwork, which is something weird when you talk about an art work dying,” he says. While the exhibition was in New York City, a curator from a midtown gallery asked to exhibit Meart’s drawings. “That was quite funny for us,” Ben-Ary says. “The question is, what is the art? Is it all the art—the whole system—or is it the drawings?” The day before the exhibition, the two cultures that produced the nine drawings to be shown died. Ben-Ary decided to treat the cultures as the artists, naming them and writing a dedication to them. “It’s still on the gallery wall. The reaction of people is really weird—they don’t know how to deal with that.”

Is the artist learning?

Scientifically, Meart has not shown definite signs of learning. The first try, which bridged the distance from Perth to Atlanta, was able to use only a couple of the electrodes. The second try, connecting New York City with Atlanta, was better, using all 60 of the electrodes, but it didn’t indicate that the cultures had learned anything yet. Potter’s graduate student, Doug Bakkum, says, “the system was too noisy to actually infer learning. For example, the arm was pretty inaccurate, the video feedback was pretty inaccurate, and the algorithms were a little inaccurate themselves.”

So it’s back to work for Potter’s group. He says he will keep pushing Bakkum and everyone until “there is some evidence that nobody will doubt whether the thing has learned something.” he says. “It should be manifested in changes in the drawings that are really obviously better or somehow better in a way that we intended. Then comes the really exciting part, doing the microscopic imaging at the same time the learning process is happening.”

Potter is happy that the collaboration of two different groups—artists and scientists—from completely opposite sides of the globe has worked so well. “Bringing these two worlds together is not so easy—they really are different cultures, but one of the things they have in common is the creative process,” Potter says. “Not only are we revealing to the world our creative process as researchers, but we’re also studying the basic mechanisms of creativity itself.”