Optogenetics device shines a new light on brain function

A decade ago, scientists discovered that light-responsive genes, when implanted in specific brain cells, could be used to precisely control the activity of those cells. Using various wavelengths of light, scientists were able to stimulate neural activity in the brain, and capture and record that activity in real time.

Today, optogenetics, as this field is now known, is opening broad new avenues to understanding the complexities of the brain’s neural networks. The information gathered from this neural “eavesdropping” has the potential to inform a wide range of research, from cataloguing the way in which neurons normally regulate the body’s function, to more focused medical challenges, such as understanding Parkinson’s disease or even mental illness.

These kinds of investigations call for a new class of instrumentation, which is being developed at Université Laval through a collaboration between electrical engineers and members of the Québec Mental Health Institute Research Center (CRiUSMQ).

Leading the way is Dr. Benoit Gosselin, associate professor of Electrical and Computer Engineering. He and his colleagues have designed a wireless bioinstrument that combines optical stimulation with an electrical readout that gives instantaneous brain response in real time.

It’s a significant advancement in brain science, he says. “It enables you to simultaneously activate those neural connections and then see how they connect to other neurons or brain areas.”

In contrast to the bulky array of connections that would otherwise be needed to accomplish these tasks, Dr. Gosselin’s optogenetic hardware has been reduced to an ultralight, tiny package that can be inserted easily into the brains of laboratory mice. The animals experience little or no physical interference from the sensors, so they can move freely, enabling findings that will reflect their typical behaviour.

“We have come up with the first system that combines both functions—optogenetics and electrophysiology—that can be used with moving animals. To understand disease and brain function, you need to have the animals freely moving,” says Dr. Gosselin.

The successful integration of optical stimulation and wireless recording earned one of Dr. Gosselin’s graduate students, Gabriel Gagnon-Turcotte, the 2015 Mitacs prize for exceptional innovation. It also received a Best Paper award (second place) at the IEEE BioCAS’15 Conference.

More recently, the system was recognized for its potential to accelerate drug development for neurodegenerative diseases such as Alzheimer’s. Dr. Gosselin and his collaborator Dr. Yves De Koninck received $150,000 from the Weston Brain Institute to accelerate the development of the technology, aimed at tracking mouse brain response to drugs on individual neurons by the millisecond, during actual behaviour.

Building on his PhD research into brain sensors at Polytechnique Montréal under supervisor Dr. Mohamad Sawan, Dr. Gosselin has been working on his optogenetic technology since 2011, when he struck up a collaboration with Doric Lenses, a Québec-based manufacturer of electronic optical components that has regularly conducted its R&D work with Laval. Doric is now marketing the second generation of this wireless optogenetic monitoring system, a sign of progress that Dr. Gosselin credits largely to CMC Microsystems.

“CMC gave me the opportunity to populate my lab with all the design tools to do this research,” he says.

Access to fabrication was crucial, he adds. “My project combines different technologies, and CMC is connected to so many fabrication partners for different technologies, it makes it possible to combine these technologies into a single microsystem. When you want to miniaturize a complex system that includes different functionalities, you need to be working with the latest CMOS, and it’s important that CMC provides this access to us.”

“CMC also helped us build a relationship with companies like Doric Lenses in order to commercialize this technology.”

Commercial opportunities aside, tools for brain research are challenging, Dr. Gosselin says, which provides great learning and innovation opportunities for his students. “They’re using MEMS and microelectronics; some are doing circuit design, others instrumentation, creating prototypes, and dealing with packaging integration and encapsulation. At least four students have been named on our patent applications.”

“It’s a very challenging field, but also very rewarding and exciting.”

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