
NEC

At Cornell's new MRI Facility, neuroscientists are observing how the brain responds when we think, feel, learn, react, and remember—research that is decoding the body's most complex organ.

A Window Into **the Brain**

BY KARENE BOOKER

Valerie Reyna

Charles Brainerd

Eve De Rosa

Nathan Spreng

Adam Anderson

Neuroscientist Valerie Reyna compares functional MRI—an imaging technique that allows researchers to see the brain in action—to the microscopes and telescopes that allow scientists to peer into cells and the cosmos to explore the mysteries of life. For the first time on Cornell's Ithaca campus, she and fellow researchers can observe how the brain fires when we think and react and compare how such activity differs among age groups and populations. Such work promises to bring into focus what was once out of sight—the hidden factors that drive human behavior.

All this is possible thanks to the new Cornell MRI Facility in Martha Van Rensselaer Hall, which includes a powerful 3-tesla MRI machine. The tool, funded by the college, the university, and a $2 million grant from the National Institutes of Health, allows the college's behavioral scientists to investigate brain development and function—a top-of-mind topic for many experts in the field. Indeed, earlier this year the federal government launched a "grand challenge"—dubbed the BRAIN (Brain Research Through Advancing Innovative Technologies) Initiative—to map the brain's intricate networks to better understand human cognition. Cornell scientists, by linking the biological mechanisms of the brain to behavior, are making important discoveries related to healthy development from infancy to old age, decision-making, emotional processing, memory and attention, Alzheimer's and other neurodegenerative diseases, and developmental disorders.

Reyna, co-director of the Cornell MRI Facility and director of the college's newly formed Human Neuroscience Institute, said functional MRI gives her and fellow researchers the power to ask novel questions and test longstanding psychological and behavioral science theories with new data. She is leading one of the first studies in the facility: a team of economists, psychologists, and neuroscientists are using the tool to better understand how teens and adults process emotions, gauge risks, and make decisions.

"A lot of psychology traditionally relies on self-report," Reyna explained. "With the advent of fMRI, brain scan data can be integrated with other data—behavioral, social, and ecological—to shed light on the mechanisms driving behavior. We can look at the brain from the micro neurochemistry level to the macro social level, bringing basic research to bear on important social questions, such as why people make the decisions they do—for example,

> > >

MRI technologist Emily Qualls, human development student Elizabeth DuPre '15, and assistant professor Nathan Spreng (l-r) discuss neuroscience research in the new Cornell MRI Facility.

having unprotected sex even when they have a friend who has contracted HIV. We're discovering the hidden factors that are shaping how people see their options."

Magnet attracts new talent

While the MRI Facility enables new research directions, it is also bringing top minds to Cornell and "attracting great people to ask great questions," Reyna said. In the past two years, three highly regarded brain researchers have joined the Department of Human Development—all were drawn by the tool's capabilities and the college's investments in neuroscience research.

Neuroscientist Nathan Spreng came to Cornell in 2012 from Harvard University, largely because of the MRI machine, which he called "one of the most flexible instruments for looking deeply at the structure and function of the living human brain."

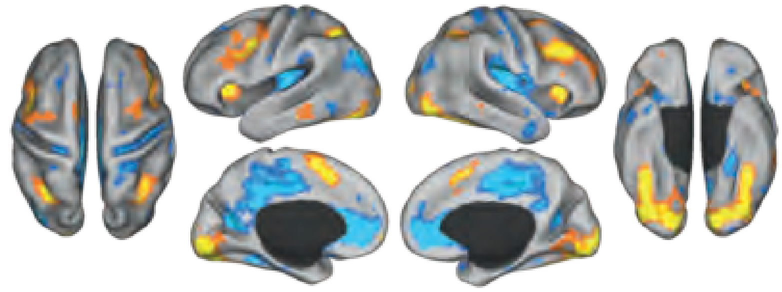
Spreng, assistant professor of human development and Rebecca Q. and James C. Morgan Sesquicentennial Faculty Fellow, uses fMRI to study large-scale brain networks and how these systems interact to support complex cognition. Over the summer, he and student research assistants used the scanner to collect data for a study examining interactions between the brain's mechanisms for working memory and long-term memory, which will shed light on the basic processes of memory and attention control. In another study, Spreng is investigating the relationship between memory and imagination and how the pattern of brain activity changes with advancing age—hoping to better understand the neurological basis for healthy aging and conditions such as autism and dementia.

"The questions we're trying to solve require technological innovation and advances in methodology . . . We want to be part of making Cornell a leader in this kind of work." —Adam Anderson

According to Spreng, the MRI Facility also provides opportunities to partner with other Cornell faculty using the device as well as its technical team—Wenming Luh, MRI physicist and technical director; Emily Qualls, MRI technologist; Hui Han, hardware physicist; and soon a neuroinformaticist—to collectively search for hardware and software improvements to see the brain in new ways. "Methods innovation is what drives neuroscience discoveries," Spreng said.

This fall, the college welcomed two more neuroscience researchers, husband and wife Adam Anderson and Eve De Rosa, from the University of Toronto. Anderson's research explores the psychological and neural underpinnings of emotions—what they are, how they are generated in the brain, and how we regulate them. De Rosa uses neuroimaging and behavioral measures in humans, and additional measures in rats, to study learning and attention with a focus on the role of the neurochemical acetylcholine.

"One of the things that attracted us to Cornell was having a sense of impact beyond being published in the best journals," said Anderson, associate professor in the Department of Human Development. "Cornell's mission, diversity, and interdisciplinary research context will give our work broader significance. We're also here because of the opportunity for technological advances that will allow us to do things we couldn't do before."



Results from the first cognitive neuroscience fMRI study at the Cornell MRI Facility, which required participants to match pictures of faces during a working memory task. Brain activity is shown in gold, and deactivated regions are in blue. Image provided by Nathan Spreng.

Although much of psychology focuses on understanding and treating disorders, Anderson is interested in human flourishing and the nature of happiness—what it is and its function and adaptive value. Answering such basic research questions may one day translate into ways to boost happiness.

He said the MRI Facility, which is open to researchers across campus, will be crucial to fostering collaborations among behavioral researchers, physicists, and engineers who can partner on novel solutions.

"The questions we're trying to solve require technological innovation and advances in methodology," Anderson said of his lab. "We're looking at parts of the brain involved in emotions, for example, which are hard to see using current methods and need special techniques to assess signal in those areas. We want to be part of making Cornell a leader in this kind of work."

De Rosa, associate professor of human development and Rebecca Q. and James C. Morgan Sesquicentennial Faculty Fellow, said fMRI aids in testing psychological explanations for human behaviors.

For instance, in one study her team asked participants to judge the gender of faces superimposed upon buildings that they were told to ignore, with young and older adults performing equally well on the task. But, later, in a surprise memory test, older adults were better able to identify the building associated with each face.

The fMRI data revealed that the older adults had difficulty ignoring the building information—their brains lit up in the visual areas that process place information and could more easily recall the buildings in the follow-up test. De Rosa thinks diffuse attention shown by older adults may have its own purpose, such as supporting more positive emotional states and creative problem solving.

Khena Swallow, assistant professor of psychology in Cornell's College of Arts and Sciences, also joined the faculty this year and relies on MRI for her research. Swallow is using behavioral, neuroimaging, and eye-tracking methods to investigate memory and attention to better understand what goes on in the brain during multitasking, task switching, and responding to daily events.

"In behavioral work, there can be lots of potential explanations for a particular result," Swallow said. "Some explanations make specific predictions about brain activity and these can be tested using fMRI."

And it's not just behavioral scientists lining up to use this powerful new tool—faculty across the college and university are initiating a wide range of studies such as looking at the neurological response to fashion and retail environments, vocal tract function and the dynamics of speech motor control, assessing a gene therapy approach to preventing arthritis, the microstructure of heart valve tissue, and the physiology of corn and rice roots under stress, to name a few.

Behavior and the brain

While the MRI Facility draws researchers from across Cornell, the college's primary focus is on human brain research at the new Human Neuroscience Institute.

"Prioritizing the word 'human' in the name of the institute underlines the common commitment to human development," Reyna said, adding that its focus is on the neural basis of human behavior—understanding how brain circuits, systems, and networks drive cognition and behavior, with broad implications for enabling people to lead happier and more fulfilling lives.

The institute's other faculty affiliates are human development researchers Adam Anderson, Charles Brainerd, Eve De Rosa, and Nathan Spreng. Among their many research interests are: the brain systems that underlie cognitive, social, and emotional development across the life span; cognitive changes associated with normal aging and those linked to cognitive impairment and dementia; high-risk behavior in adolescents and young adults; and developmental disorders such as autism.

Reyna said the institute provides the formal structure to engage faculty on a common subject by facilitating their access to infrastructure, tools, and services for neuroscience research; developing opportunities for collaboration in research and for student education in behavioral, cognitive, and social neuroscience; and applying the results of the department's neuroscience research to inform social and behavioral interventions.

"We find this area of research vitally important because of the large potential for solving human problems that is contained in the small, spongy mass that is the human brain," Reyna said. • • •

Karene Booker is an extension support specialist in the Department of Human Development.

For more information:

mri.cornell.edu

Adam Anderson
aka47@cornell.edu

Charles Brainerd
cb299@cornell.edu

Eve De Rosa
edd56@cornell.edu

Valerie Reyna
vr53@cornell.edu

Nathan Spreng
rns74@cornell.edu

Uncoiling MRI Technology

The key advantage of magnetic resonance imaging is that it allows researchers to see inside living tissues, providing detailed pictures of internal structures without using invasive procedures. An array of specialized techniques allows scientists to visualize blood flow, water and tissue movement, the presence and concentration of various organic molecules, and more.

The core of an MRI machine is made up of coils of wire. Electricity is passed though the wire to create a magnetic field, which aligns the spins of hydrogen protons in water, which is abundant in people and most other life.

A coil, fit specifically for the body part to be imaged, transmits pulses of radiofrequency waves (similar to those used in cellphones and TV and radio broadcasting), causing some of the hydrogen protons to absorb the energy and temporarily change their spins. When the pulse is turned off, the hydrogen protons return to their prior state and give off a detectable energy signal that the coils identify and send to the MRI computer. During imaging, additional small gradient magnetic fields are used to encode this signal with spatial location. A map of the internal tissues can be reconstructed from the signal since protons in different tissues return to equilibrium at different rates.

One of the main techniques investigators use to visualize neural activity in the brain is functional magnetic resonance imaging (fMRI). The technique uses the MRI machine to generate images of brain activity as people perform experimental tasks.

The most common fMRI method detects changes in blood flow when activated areas of the brain are recharged by fresh blood that is rich in oxygen and glucose. Oxygen-rich blood has different magnetic properties than oxygen-poor blood, and these differences in the "blood oxygen-level-dependent" (BOLD) signal can be measured and mapped to provide a picture of brain activity. The resulting images are huge and require complex processing and statistical analyses to extract meaningful data—the work of computing resources connected to the MRI machine.