MCGOVERN INSTITUTE

BRAINSCAN

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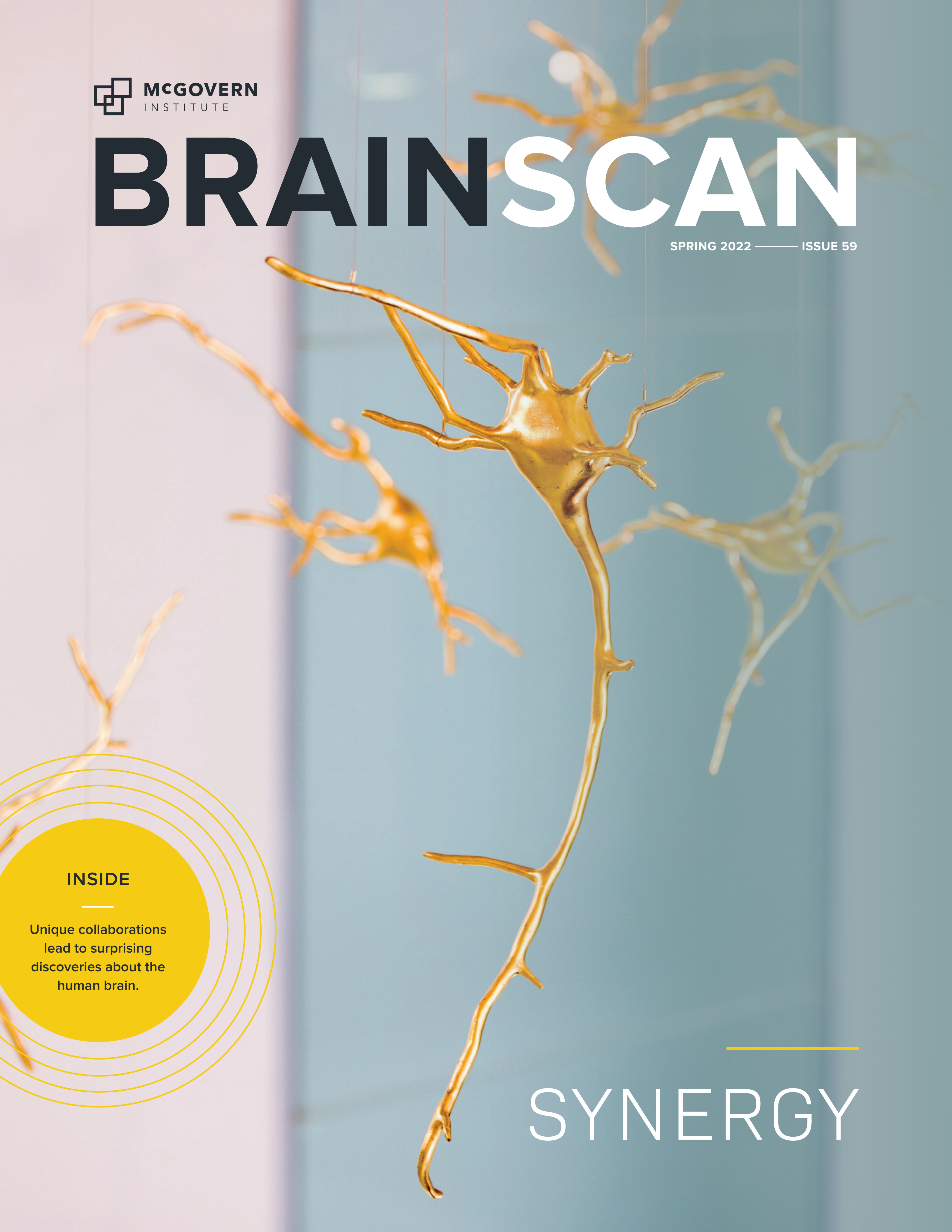


INSIDE

Unique collaborations lead to surprising discoveries about the human brain.

SYNERGY

SYNERGY

Harmonious research

As director of the McGovern Institute, I often witness examples of synergy throughout our scientific community. From dynamic faculty lunches to interdisciplinary collaborations, innovative ideas and unexpected discoveries often emerge.

In this issue, you will read about two such discoveries. Through clinical partnerships, Nancy Kanwisher and Ann Graybiel have exposed surprising features of the human brain that highlight the clinical relevance of our basic research studies.

You will also meet some of our graduate students and learn what they have to say about working in an interdisciplinary research environment.

I hope after reading this issue, you will agree that the McGovern Institute is, indeed, greater than the sum of its parts.

ROBERT DESIMONE

Director, McGovern Institute

Doris and Don Berkey Professor of Neuroscience, MIT

SCHWERPUNKT

At the McGovern Institute, 100 gold neurons seemingly float at random above the lobby (cover image) and transform into the shape of a brain at the focal point on the third floor (above).

UNEXPECTED SYNERGY

Clinical collaborations reveal surprising discoveries about music, language, and how the brain makes decisions.

Recent results from cognitive neuroscientist Nancy Kanwisher's lab have left her pondering the role of music in human evolution. "Music is this big mystery," she says. "Every human society that's been studied has music. No other animals have music in the way that humans do. And nobody knows why humans have music at all. This has been a puzzle for centuries."

"It is now clear that music and language are segregated in the human brain."

NANCY KANWISHER

‹ The Kanwisher lab has identified a population of neurons in the human brain that respond only to vocal music. Image: Andrea Ucini

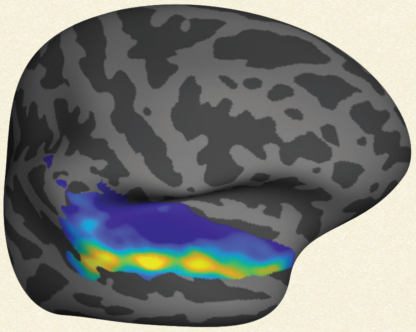
Some biologists and anthropologists have reasoned that since there's no clear evolutionary advantage for humans' unique ability to create and respond to music, these abilities must have emerged when humans began to repurpose other brain functions. To appreciate song, they've proposed, we draw on parts of the brain dedicated to speech and language. It makes sense, Kanwisher says: music and language are both complex, uniquely human ways of communicating. "It's very sensible to think that there might be common machinery," she says. "But there isn't."

That conclusion is based on her team's recent discovery of neurons in the human brain that respond only to music. They first became clued in to these music-sensitive cells when they asked volunteers to listen to a diverse panel of sounds inside an MRI scanner. Functional brain imaging picked up signals suggesting that some neurons were specialized to detect only music — but the broad map of brain activity generated by an fMRI couldn't pinpoint those cells.

SINGING IN THE BRAIN

Kanwisher's team wanted to know more — but neuroscientists who study the human brain can't always probe its circuitry with the exactitude of their colleagues who study the brains of mice or rats. They can't insert electrodes into human brains to monitor the neurons they're interested in. Neurosurgeons, however, sometimes do — and thus, collaborating with neurosurgeons has created unique opportunities for Kanwisher and other McGovern investigators to learn about the human brain.

Kanwisher's team collaborated with clinicians at Albany Medical Center to work with patients who are undergoing monitoring prior to surgical treatment for epilepsy. Before operating,



Song-selective neural population (yellow) in the "inflated" human brain. Image: Sam Norman-Haignere

a neurosurgeon must identify the spot in their patient's brain that is triggering seizures. This means inserting electrodes into the brain to monitor specific areas over a few days or weeks. The electrodes they implant pinpoint activity far more precisely, both spatially and temporally, than an MRI. And with patients' permission, researchers like Kanwisher can take advantage of the information they collect.

"The intracranial recording from human brains that's possible from collaboration with neurosurgeons is extremely precious to us," Kanwisher says. "All of the research is kind of opportunistic, on whatever the surgeons are doing for clinical reasons. But sometimes we get really lucky and the electrodes are right in an area where we have long-standing scientific questions that those data can answer."

The unexpected discovery of song-specific neurons, led by postdoctoral researcher Sam Norman-Haignere, who is now an assistant professor at the University of Rochester Medical Center, emerged from such a collaboration. The team worked with patients at Albany Medical Center whose presurgical monitoring encompassed the auditory-processing part of the brain that they were curious about. Sure enough, certain electrodes picked up activity only when patients were listening to music. The data indicated that in some of those locations, it didn't matter what kind of music was playing: the cells fired in response to a range of sounds that included flute solos, heavy metal, and rap. But other locations became active exclusively in response to vocal music. "We did not have that hypothesis at all, Kanwisher says. "It really took our breath away," she says.

When that discovery is considered along with findings from McGovern colleague Ev Fedorenko, who has shown that the brain's language-processing regions do not respond to music, Kanwisher says it's now clear that music and language are segregated in the human brain. The origins of our unique appreciation for music, however, remain a mystery.

CLINICAL ADVANTAGE

Clinical collaborations are also important to researchers in Ann Graybiel's lab, who rely largely on model organisms like mice and rats to investigate the fine details of neural circuits. Working with clinicians helps keep them focused on answering questions that matter to patients.

STORY CONTINUES ON PAGE 6

Diverse Perspectives STRONG SCIENCE

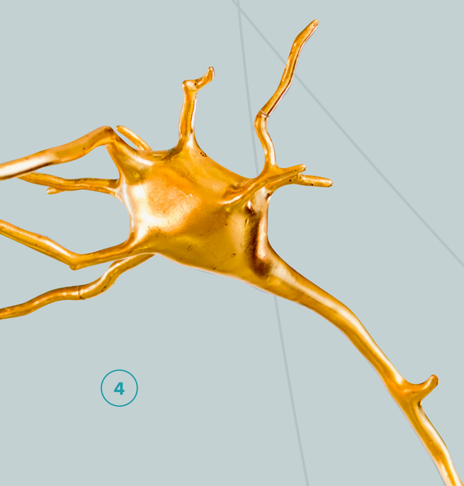
See more collaboration at **collaboration.mit.edu**

QUIQUE TOLOZA | HARNETT LAB

The brain cannot be solved by any one discipline in isolation because its behaviors inherently span all of the sciences, with many degrees of complexity. Physics gives me the foundation to mold some of these behaviors into easier problems that I can begin to tackle.

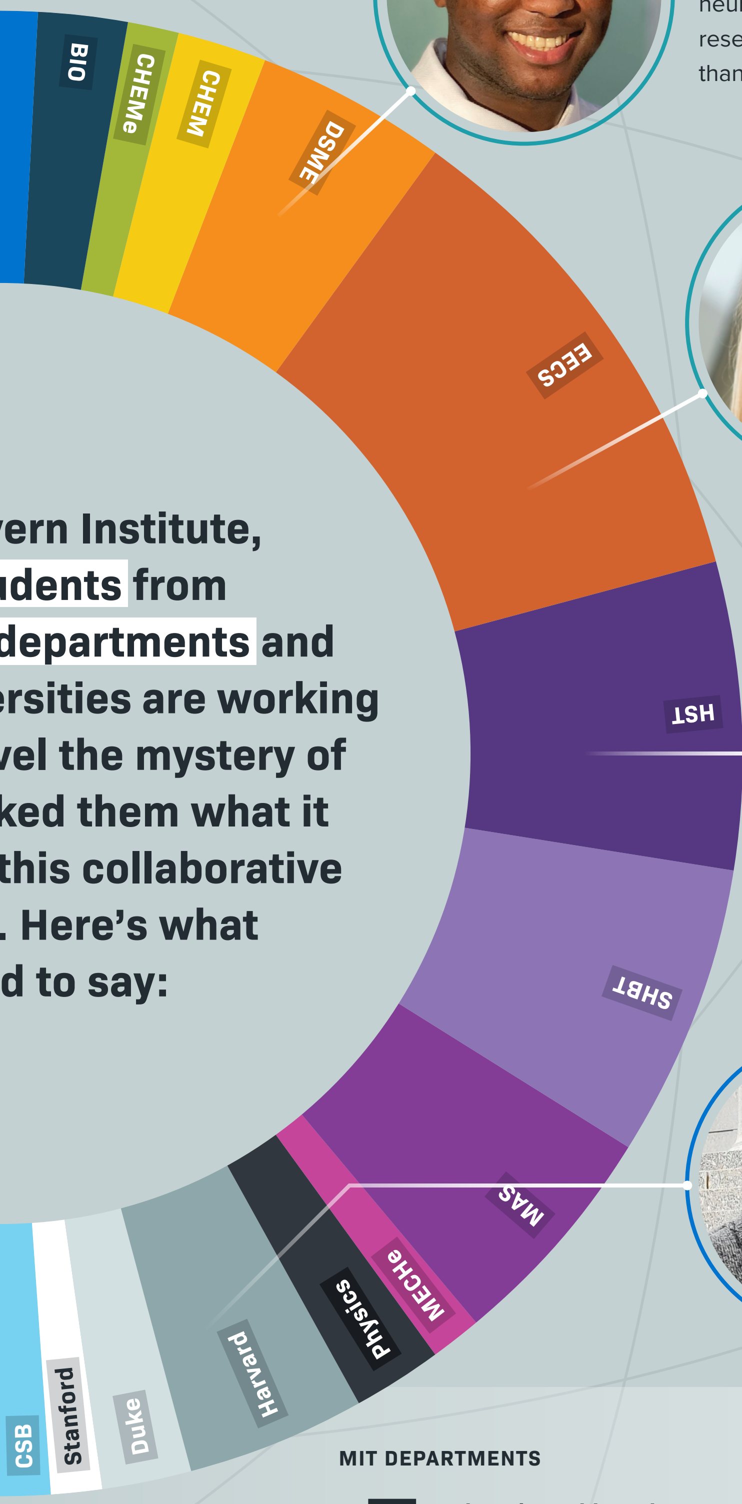
SAIMA MALIK-MORALEDA | FEDORENKO LAB

Collaboration allows me to learn about language in a more comprehensive manner—from hair cell oscillations in the cochlea to neural oscillations in the language network—in turn shaping the questions I ask in my own research.



HANNAH FIELD | ANIKEEVA LAB

Collaboration is at the crux of my research on repairing nerve injury. My background as an electrical engineer allows me to tie together scientific ideas and engineering tools into a single, deliverable product.



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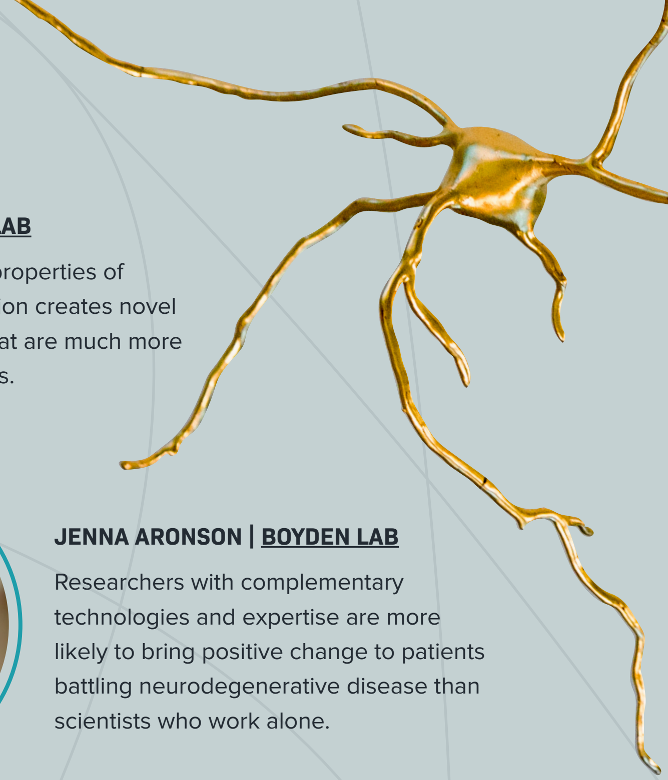


QUILEE SIMEON | YANG LAB

Much like the emergent properties of neural circuits, collaboration creates novel research opportunities that are much more than the sum of their parts.

JENNA ARONSON | BOYDEN LAB

Researchers with complementary technologies and expertise are more likely to bring positive change to patients battling neurodegenerative disease than scientists who work alone.

GAL RAZ | SAXE LAB

Working at the interface between developmental psychology and computational cognitive science challenges me to do work that is innovative, relevant for multiple fields, and above all, a learning experience.

CORBAN SWAIN | BOYDEN LAB

The confluence of engineering, biology, and neuroscience disciplines within my own growing skill set and across my colleagues' expertise is a big part of what makes my work exciting and gratifying day to day.

MIT DEPARTMENTS

- **BCS** Brain and Cognitive Sciences
- **BE** Biological Engineering
- **BIO** Biology
- **CHEMe** Chemical Engineering
- **CHEM** Chemistry
- **CSB** Computational and Systems Biology
- **DMSE** Materials Science and Engineering
- **EECS** Electrical Engineering and Computer Science
- **HST** Harvard-MIT Health Sciences and Technology
- **MAS** Media Arts and Sciences
- **MECHe** Mechanical Engineering
- **SHBT** Harvard-MIT Speech and Hearing Bioscience and Technology

CONTINUATION OF STORY FROM PAGE 3

In studying how the brain makes decisions, the Graybiel lab has zeroed in on connections that are vital for making choices that carry both positive and negative consequences. This is the kind of decision-making that you might call on when considering whether to accept a job that pays more but will be more demanding than your current position, for example. In experiments with rats, mice, and monkeys, they've identified different neurons dedicated to triggering opposing actions — "approach" or "avoid" — in these complex decision-making tasks. They've also found evidence that both age and stress change how the brain deals with these kinds of decisions.

In work led by former Graybiel lab research scientist Ken-ichi Amemori, they have worked with psychiatrist Diego Pizzagalli at McLean Hospital to learn what happens in the human brain when people make these complex decisions.

By monitoring brain activity as people made decisions inside an MRI scanner, the team identified regions that lit up when people chose to "approach" or "avoid." They also found parallel activity patterns in monkeys that performed the same task, supporting the relevance of animal studies to understanding this circuitry.

In people diagnosed with major depression, however, the brain responded to approach-avoidance conflict somewhat differently. Certain areas were not activated as strongly as they were in people without depression, regardless of whether subjects ultimately chose to "approach" or "avoid." The team suspects that some of these differences might reflect a stronger tendency toward avoidance, in which potential rewards are less influential for decision-making, while an individual is experiencing major depression.

Learn how CRISPR has moved from the lab to the clinic
mcgovern.science/CRISPRtrials

The brain activity associated with approach-avoidance conflict in humans appears to align with what Graybiel's team has seen in mice, although clinical imaging cannot reveal nearly as much detail about the involved circuits. Graybiel says that gives her confidence that what they are learning in the lab, where they can manipulate and study neural circuits with precision, is important. "I think there's no doubt that this is relevant to humans," she says. "I want to get as far into the mechanisms as possible, because maybe we'll hit something that's therapeutically valuable, or maybe we will really get an intuition about how parts of the brain work. I think that will help people."

In Memoriam

With deep regret we announce the recent passing of Gerald J. Burnett '64 SM '65 of Pebble Beach, California. Jerry became involved with the McGovern Institute in our earliest years and was among the first to join our Leadership Board. Together with his wife Marge, Jerry was a generous supporter of several McGovern research initiatives including a successful multi-year collaboration between the Poggio and DiCarlo labs focused on the brain's ability to recognize objects. We remain grateful for Jerry's passion for interdisciplinary and pioneering brain research, and he will be greatly missed by our community.

New Funding for Neurodegenerative Research

Longtime McGovern supporters Kenneth Luey '75 and Cathy McCann recently created the McCann-Luey Research Fund to support cutting-edge research into neurodegenerative disorders such as Parkinson's, Alzheimer's, and ALS. The first lab to benefit from this fund is Polina Anikeeva's Bioelectronics Group, which is investigating how Parkinson's disease originates and propagates through the brain, central nervous system, and enteric (gut) nervous system. We are grateful to Ken, Cathy, and their more than two dozen relatives and friends for supporting this critical research.

Awards

NANCY KANWISHER
Award in the Neurosciences, National Academy of Sciences

GUOPING FENG
Fellow, American Association for the Advancement of Science


Image: MIT News, iStockphoto

COGNITIVE NEUROSCIENCE

Swapping Saliva

The **Saxe** lab has found that "saliva sharing" plays a crucial role in babies' interpretation of the social world around them. Babies expect people who share saliva (e.g., kissing, sharing food) to come to one another's aid when one person is in distress, according to the study. Such cues help babies determine who they can count on to take care of them — a critical skill for navigating complex social relationships.

BRAIN IMAGING

Reading Network

In the largest brain imaging study of its kind, the **Gabrieli** lab has found surprisingly few links between white matter structure and reading ability in children. Their findings suggest that if white matter deficiencies are a significant cause of reading disability, new strategies will be needed to pin them down.

CELLULAR & MOLECULAR NEUROSCIENCE

Curbing Cocaine Use

A new study by **Ann Graybiel** has found that activating a specific acetylcholine receptor in the brain reduces cocaine use in rodents, pointing toward a potential therapeutic strategy for people battling addiction.

COMPUTATIONAL NEUROSCIENCE

Artificial Hearing

New research from **Josh McDermott** suggest that natural soundscapes have shaped our sense of hearing, optimizing it for the kinds of sounds we most often encounter. Using computational models to explore factors that influence how humans hear pitch, their model's pitch perception closely resembled that of humans — but only when it was trained using music, voices, or other naturalistic sounds.

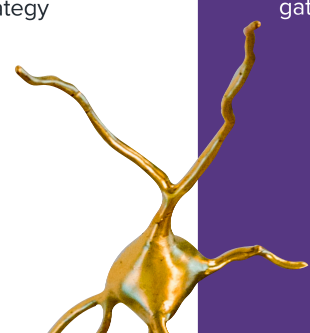
In a separate study, the **McDermott** lab developed a computer model that can determine the direction that a sound is coming from. The model, which consists of several convolutional neural networks, not only performs the task as well as humans do, it also struggles in the same ways that humans do.

SIRMA ORGUC

"Interdisciplinary research is key to enabling innovations previously undiscovered by isolated investigation."

SIRMA ORGUC completed her PhD in Polina Anikeeva's lab and has pivoted her research into computational neuroscience with clinician scientist and Picower Investigator Emery Brown as part of the Schmidt Science Fellows Program.

Learn more at
schmidtsciencefellows.org



DID YOU KNOW

17

languages are spoken in Polina Anikeeva's lab?

"Our group is diverse by design," says Anikeeva, whose bioelectronics lab members hail from 12 different countries. "I firmly believe that culturally monotonous labs generate boring science. It's just like the brain — from the diversity of cell types comes beauty and complexity."

Learn more at
bioelectronics.mit.edu

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