McGOVERN INSTITUTE
FOR BRAIN RESEARCH AT MIT

BRAINSCAN

SUMMER 2019 — ISSUE 49

SOUND

McGOVERN MUSINGS

Perspectives from our community

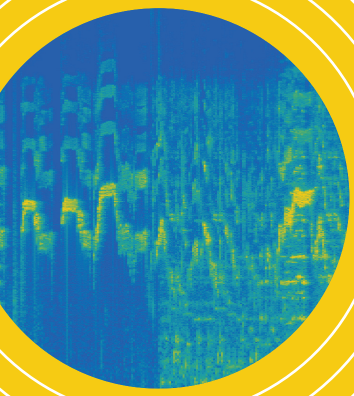
Music has been important in my life. I grew up listening to classical music in my childhood home in Germany, and I remember with fondness singing songs with my family at the holidays. Music, quite simply, makes me feel good. But why?

Sound is a mystery. A beautiful aria can produce internal sensations like jubilance, unification, elation, and joy. Atonal sound, on the other hand, can provoke, disturb, and even frighten the listener.

Hearing is the auditory gateway to our mind's world. Sound is in our mind, free, able to roam unrestrained and without limits.

Just listen!

LORE HARP MCGOVERN
Co-Founder, McGovern Institute



THE ART OF MUSIC

A spectrogram of Lore Harp McGovern's favorite song, *Sempre libera*, from Giuseppe Verdi's opera, *La Traviata*. Image: Dana Boebinger, McDermott Lab

Sound Effects

From the McGovern Institute to the Bolivian rainforest, Josh McDermott is on a mission to understand how the brain unpacks sound.

Sound is not only a fundamental way of sensing what's happening in the world around us — it also links into the rich tapestry of our internal world, feeding into emotion, memory, and cognition. Sound waves influence the membranes and inner hair cells of the ear, but it is the interpretation of sound by the brain that is key to perception.

Josh McDermott, an associate professor in MIT's Department of Brain and Cognitive Sciences who recently joined the McGovern Institute as an associate member, became drawn to sound after studying vision in his early research career. He now operates at the intersection of psychology, neuroscience, and engineering to study how people hear and interpret sound. This pursuit stretches from studying regions of the brain that respond to sound, all the way through to how sound and music is perceived in different regions around the world.

MIXED SIGNALS

One strand of McDermott's research focuses on uncovering the functional organization of the auditory cortex. In 2015, his lab found a neural population in the human auditory cortex that responds selectively to music. The same

“Studying people with different backgrounds helps us understand what aspects of auditory perception are culturally determined and what are universal.”

— MALINDA MCPHERSON, MCDERMOTT LAB

study, conducted in collaboration with the Kanwisher lab, also found distinct populations selective for speech, and acoustic properties such as pitch and frequency. The acoustically-responsive populations were located within the “primary” auditory cortex, which performs the first stage of cortical processing of sound. Speech and music-selective neural populations were found beyond this primary region.

“We think this provides evidence of a hierarchy of processing in which the brain responds to elementary acoustic dimensions in the primary auditory area, followed by a second stage of processing that represents more abstract properties of sound related to speech and music,” McDermott says.

Such neural activity in the auditory cortex is being better understood in the McDermott lab through computational modeling that explains the brain’s responses and the behaviors they mediate.

One focus of McDermott’s lab is a class of problems called “scene analysis,” the process of teasing apart the causes of sounds in the world. A classic example is the “cocktail party problem,” where we focus on one conversation despite the chatter around us.

To better understand how the brain solves these problems, McDermott’s lab has made large-scale measurements of natural sounds to discover the underlying regularities. These statistics suggest new hypotheses about how humans separate sound signals, be it one voice at a noisy cocktail party, or birdsong from a waterfall.

BROAD BANDWIDTH

McDermott hopes that building computational models based on these analyses could one day power hearing prosthetics, but he also wants to know whether these models hold true across species and cultures. These issues are particularly relevant in audition, because speech and music are both uniquely human and variable across cultures, providing valuable windows into our evolutionary history and the role of experience in shaping perception.

To test the extent to which human audition varies across cultures, the McDermott lab travels to Bolivia to study the Tsimane’ — a native Amazonian society with minimal exposure to Western culture. They found that the Tsimane’ rate consonant and dissonant chords and vocal harmonies as equally pleasant, despite being able to tell them apart. This suggests that the perception of chords as “pleasant” is not biologically universal, even though the acoustic dimension that differentiates them may be something all cultures are sensitive to.

McDermott returns to Bolivia each year to analyze this question and document the changes that are occurring as electricity and other technologies arrive in remote regions.

NOTES FOR THE FUTURE

In the longer term, McDermott hopes to understand the computational principles underlying sound perception to the point where we can predict what a person will hear using the model alone. This could be an essential part of understanding how to restore speech perception in individuals with damaged hearing, but could also help to build machine systems that recognize and interpret sound.

“In the end,” explains McDermott, “I’d also really like to know what we come to the table with, and what experiences are needed in order to build a sensory system that has the incredible abilities that we have.”

SOUND BYTES

Labs across the McGovern Institute are exploring how the brain makes sense of sound.

We asked grad students to tell us what question they are trying to answer and what tools they're using to do it.

KEVIN SITEK
(Gabrieli/Ghosh Labs)

Can we create an atlas of the subcortical human auditory pathway to help others understand this complex system?

Tools: Anatomical & diffusion MRI

HEATHER KOSAKOWSKI
(Kanwisher/Saxe Labs)

Are we born with uniquely human traits, like music perception?

Tool: fMRI

MARK SADDLER
(McDermott Lab)

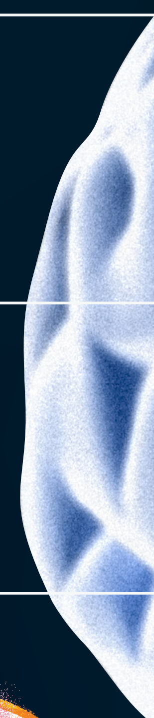
Can artificial neural networks explain the brain's response to pitch and the auditory behaviors it mediates?

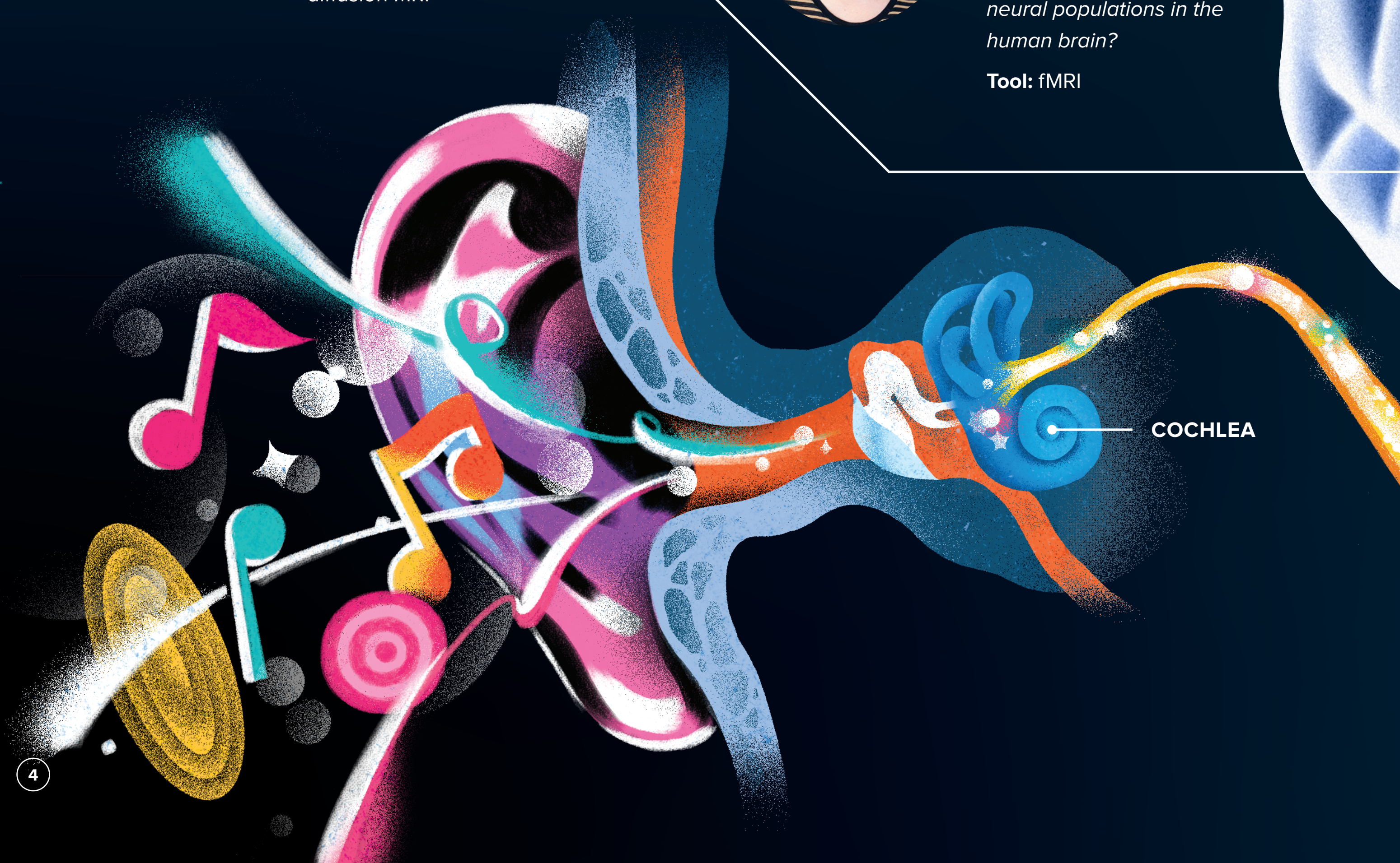
Tool: Computational models

DANA BOEBINGER
(Kanwisher/ McDermott Labs)

Does musical training enhance the music-selective neural populations in the human brain?

Tool: fMRI



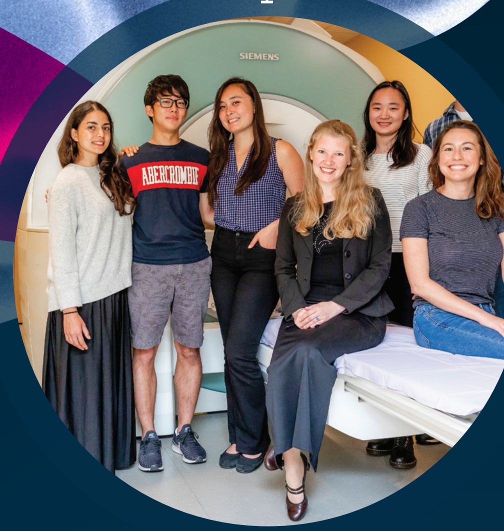


ANATOMY OF SOUND

15,500 hair cells along the spiraling cochlea detect high frequencies (like a crying infant) or low frequencies (a large barking dog). As the hair cells move up and down, chemicals rush into the cells, creating an electrical signal that is carried by the auditory nerve to the brain, which turns it into a sound that we recognize and understand.

KEY DISCOVERIES

Functionally specific brain regions identified by McGovern researchers



FEDORENKO LAB

What are the precise mechanisms that support linguistic interpretation and production?

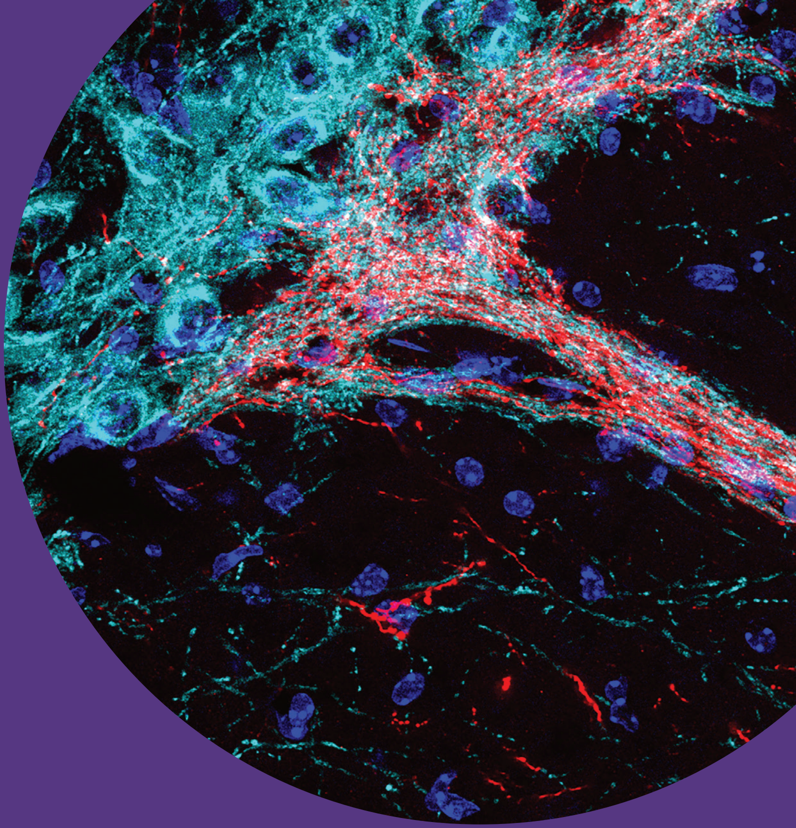
Tools: EEG, fMRI, MEG, intracranial recordings & computational models

*Language-specific regions are located in left hemisphere.

Alumnus gives MIT $4.5 million to study effects of cannabis on the brain

Charles R. Broderick, an alumnus of MIT and Harvard University, has made gifts to both alma maters to support fundamental research into the effects of cannabis on the brain and behavior. The gifts, totaling $9 million, represent the largest donation to date to support independent research on the science of cannabinoids.

The gift to MIT will provide $4.5 million over three years to support independent research for four scientists at the McGovern and Picower institutes. McGovern Investigator John Gabrieli will monitor any potential therapeutic value of cannabis for adults with schizophrenia or autism spectrum disorders using fMRI scans and behavioral studies. Ann Graybiel, the second McGovern scientist supported by the fund, will study how cannabinoid 1 receptors in the striatum, a deep brain structure implicated in learning and habit formation, may influence dopamine release in the brain.



Ann Graybiel will study the effects of phytocannabinoids on dopamine-containing neurons (turquoise) in basal ganglia circuits. Image: Jill Crittenden, Ann Graybiel

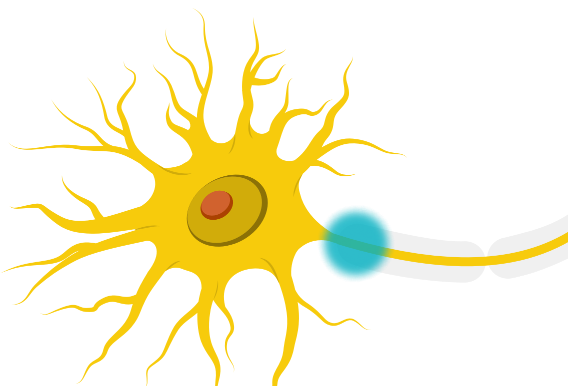
Mind Your Language

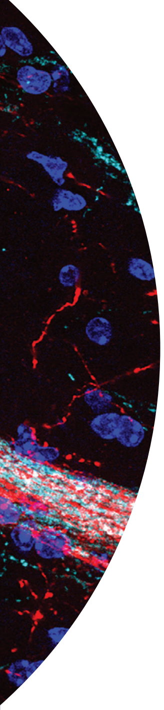
Whether you're crying through *Titanic* or ordering coffee, you're leveraging the rich tapestry of language. Unpacking the complexity of language drives Ev Fedorenko, who recently joined the McGovern Institute as an associate member. Fedorenko uses a range of approaches to understand the computations and representations that allow us to understand and produce language. Using such approaches, her lab has uncovered, among other key findings, brain regions that are selective for language and support its processing.

McGovern Talks Online

Did you miss our symposium or Scolnick Prize lecture this spring? Don't worry! Our YouTube channel has you covered:

youtube.com/mcgoverninstitute





COMPUTATIONAL NEUROSCIENCE

Decision Making

Mehrdad Jazayeri identified a brain circuit that helps break decisions down into smaller pieces. The brain performs two computations using a distributed network of areas in the frontal cortex. First, the brain computes confidence over the outcome of each decision to figure out the most likely cause of a failure, and second, when it is not easy to discern the cause, the brain makes additional attempts to gain more confidence.

SYSTEMS NEUROSCIENCE

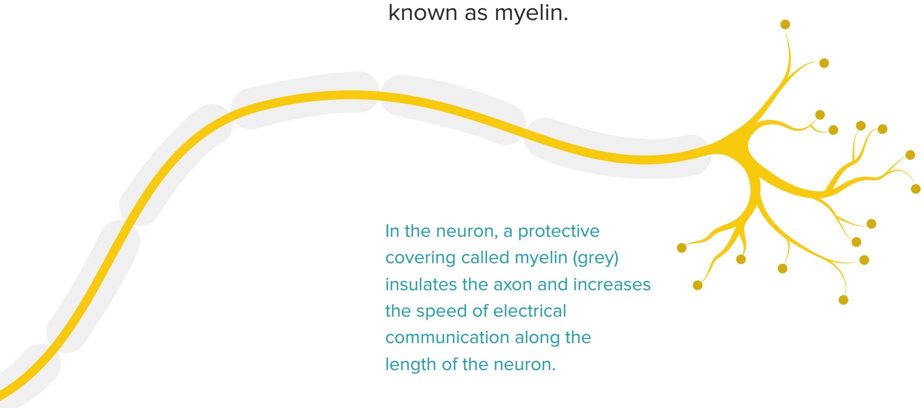
Neural Antennae

A new study from **Mark Harnett's** lab has found that dendrites play a surprisingly large role in neurons' ability to translate incoming signals into electrical activity.

CELLULAR & MOLECULAR NEUROSCIENCE

Williams Syndrome

In a study of mice, **Guoping Feng's** lab found that loss of one of the genes linked to Williams Syndrome leads to a thinning of the fatty layer that insulates neurons and helps them conduct electrical signals in the brain. The researchers also showed that they could reverse the symptoms by boosting production of this coating, known as myelin.



In the neuron, a protective covering called myelin (grey) insulates the axon and increases the speed of electrical communication along the length of the neuron.

GENOME ENGINEERING

Jumping Genes

Feng Zhang has characterized and engineered a new gene-editing system that can precisely and efficiently insert large DNA sequences into a genome. The system, harnessed from cyanobacteria and called CRISPR-associated transposase (CAST), inserts new DNA at a designated site in up to 80 percent of cells, with minimal editing errors. This new approach avoids creating double-stranded DNA breaks or relying on the cell's own repair machinery.

Autism Model

Guoping Feng, **Robert Desimone** and colleagues in China have engineered macaque monkeys to express a gene mutation linked to autism and other neurodevelopmental disorders in humans. These monkeys show some behavioral traits and brain connectivity patterns similar to those seen in humans with these conditions. The new model could help scientists to develop better treatment options for some neurodevelopmental disorders.

Awards

ED BOYDEN | Member, National Academy of Sciences

GUOPING FENG | Member, American Academy of Arts and Sciences

MARK HARNETT | 2019 McKnight Scholar Award

DID YOU KNOW

LULLABY

is a form of music that caregivers around the world use to calm and soothe newborns?

Music is universal, but its role in brain development is unknown. The adult brain has specific regions that respond to music, but when do these regions develop? Are we born with them?

The Kanwisher lab is recruiting 2- to 8-week-old infants to answer this question. While babies sleep, researchers use infant-sized brain imaging technology to look at early neural responses to speech and music. The results will help us understand the role music and speech play in brain development.

Interested in participating? Visit our website:
mcgovern.mit.edu/participate

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