By understanding the building blocks of human intelligence, can we hope to improve it?
A few months ago I received an unusual invitation to participate as a guest judge for a popular Chinese TV show called “The Brain,” in which contestants perform extraordinary feats of memory, arithmetic and other mental challenges. The abilities of some of these people are truly remarkable, and the show certainly pushed me to rethink some assumptions about the ability of the human brain to learn new mental skills. But specialized skills, no matter how impressive, are not the same thing as general intelligence, and a key question, which the show does not answer, is whether it is possible to raise intelligence through brain training. The idea is very appealing, and although the evidence is not yet conclusive, it is suggestive enough that my colleagues and I are encouraged to pursue it, as you can read in this issue. If we can train the “building blocks” of intelligence through mental exercises, the benefits could be enormous, especially if we can develop methods that can be delivered in a classroom setting. It could be particularly beneficial for economically disadvantaged students who may not have access to the opportunities and resources that more affluent communities take for granted. It could also be helpful to those who struggle with developmental disorders; if early training can build a stronger foundation of cognitive skills, we might help such children to establish a better trajectory than they would otherwise experience.

Bob Desimone, Director
Doris and Don Berkey Professor of Neuroscience

McGovern investigators study intelligence to answer a practical question for both educators and computer scientists. Can intelligence be improved?

A nine-year-old girl, a contestant on a game show, is standing on stage. On a screen in front of her, there appears a twelve-digit number followed by a six-digit number. Her challenge is to divide the two numbers as fast as possible.

The timer begins. She is racing against three other contestants, two from China and one, like her, from Japan. Whoever answers first wins, but only if the answer is correct.

The show, called “The Brain,” is wildly popular in China, and attracts players who display their memory and concentration skills much the way American athletes
demonstrate their physical skills in shows like “American Ninja Warrior.” After a few seconds, the girl slams the timer and gives the correct answer, faster than most people could have entered the numbers on a calculator.

The camera pans to a team of expert judges, including McGovern Director Robert Desimone, who had arrived in Nanjing just a few hours earlier. Desimone shakes his head in disbelief. The task appears to make extraordinary demands on working memory and rapid processing, but the girl explains that she solves it by visualizing an abacus in her mind—something she has practiced intensively.

The show raises an age-old question: What is intelligence, exactly?

The study of intelligence has a long and sometimes contentious history, but recently, neuroscientists have begun to dissect intelligence to understand the neural roots of the distinct cognitive skills that contribute to it. One key question is whether these skills can be improved individually with training and, if so, whether those improvements translate into overall intelligence gains. This research has practical implications for multiple domains, from brain science to education to artificial intelligence.

“The problem of intelligence is one of the great problems in science,” says Tomaso Poggio, a McGovern Investigator and an expert on machine learning. “If we make progress in understanding intelligence, and if that helps us make progress in making ourselves smarter or in making machines that help us think better, we can solve all other problems more easily.”
Brain Training 101
Many studies have reported positive results from brain training, and there is now a thriving industry devoted to selling tools and games such as Lumosity and BrainHQ. Yet the science behind brain training to improve intelligence remains controversial.

A case in point is the ‘n-back’ working memory task, in which subjects are presented with a rapid sequence of letters or visual patterns, and must report whether the current item matches the last, last-but-one, last-but-two, and so on. The field of brain training received a boost in 2008 when a widely discussed study claimed that a few weeks of training on a challenging version of this task could boost fluid intelligence, the ability to solve novel problems. The report generated excitement and optimism when it first appeared, but several subsequent attempts to reproduce the findings have been unsuccessful.

Among those unable to confirm the result was McGovern Investigator John Gabrieli, who recruited 60 young adults and trained them forty minutes a day for four weeks on an n-back task similar to that of the original study.

Six months later, Gabrieli re-evaluated the participants. “They got amazingly better at the difficult task they practiced. We have great imaging data showing changes in brain activation as they performed the task from before to after,” says Gabrieli. “And yet, that didn’t help them do better on any other cognitive abilities we could measure, and we measured a lot of things.”

The results don’t completely rule out the value of n-back training, says Gabrieli. It may be more effective in children, or in populations with a lower average intelligence than the individuals (mostly college students) who were recruited for Gabrieli’s study. The prospect that training might help disadvantaged individuals holds strong appeal. “If you could raise the cognitive abilities of a child with autism, or a child who is struggling in school, the data tells us that their life would be a step better,” says Gabrieli. “It’s something you would wish for people, especially for those where something is holding them back from the expression of their other abilities.”

Music for the Brain
The concept of early intervention is now being tested by Desimone, who has teamed with Chinese colleagues at the recently-established IDG/McGovern Institute at Beijing Normal University to explore the effect of music training on the cognitive abilities of young children.

The researchers recruited 100 children at a neighborhood kindergarten in Beijing, and provided them with a semester-long intervention, randomly assigning children either to music training or (as a control) to additional reading instruction. Unlike the so-called “Mozart Effect,” a scientifically unsubstantiated claim that passive listening to music increases intelligence, the new study requires active learning through daily practice. Several smaller studies have reported cognitive benefits from music training, and Desimone finds the idea plausible given that musical cognition involves several mental functions that are also implicated in intelligence. The study is nearly complete, and results are expected to emerge within a few months. “We’re also collecting data on brain activity, so if we see improvements in the kids who had music training, we’ll also be able to ask about its neural basis,” says Desimone. The results may also have immediate practical implications, since the study design reflects decisions that schools must make in determining how children spend their time. “Many schools are deciding to cut their arts and music programs to make room for more instruction in academic core subjects, so our study is relevant to real questions schools are facing.”

Intelligent Classrooms
In another school-based study, Gabrieli’s group recently raised questions about the benefits of “teaching to the test.” In this study, postdoc Amy Finn evaluated over 1300 eighth-graders in the Boston public schools, some enrolled at traditional schools and others at charter schools that emphasize standardized test score improvements. The researchers wanted to find out whether raised test scores were accompanied by improvement of cognitive skills that are linked to intelligence. (Charter school students are selected by lottery, meaning that any results are unlikely to reflect preexisting differences between the two groups of students.)

As expected, charter school students showed larger improvements in test scores (relative to their scores from 4 years earlier). But when Finn and her colleagues measured key aspects of intelligence, such as working memory, processing
speed, and reasoning, they found no
difference between the students who
enrolled in charter schools and those who
did not. “You can look at these skills as
the building blocks of cognition. They are
useful for reasoning in a novel situation,
an ability that is really important for learn-
ing,” says Finn. “It’s surprising that school
practices that increase achievement don’t
also increase these building blocks.”

Gabrieli remains optimistic that it will
eventually be possible to design scientifi-
cally based interventions that can raise
children’s abilities. Allyson Mackey, a
postdoc in his lab, is studying the use
of games to exercise the cognitive skills
in a classroom setting. As a graduate
student at University of California,
Berkeley, Mackey had studied the effects
of games such as “Chocolate Fix,” in
which players match shapes and flavors,
represented by color, to positions in a grid
based on hints, such as, “the upper left
position is strawberry.”

These games gave children practice at
thinking through and solving novel prob-
lems, and at the end of Mackey’s study,
the students—from second through fourth
grades—showed improved measures of
skills associated with intelligence. “Our
results suggest that these cognitive skills
are specifically malleable, although we
don’t yet know what the active ingredients
were in this program,” says Mackey, who
speaks of the interventions as if they
were drugs, with dosages, efficacies
and potentially synergistic combinations
to be explored.

Mackey is now working to identify the
most promising interventions—those that
boost cognitive abilities, work well in the
classroom, and are engaging for kids—to
try in Boston charter schools. “It’s just
the beginning of a three-year process to
methodically test interventions to see if
they work,” she says.

Brain Training…for Machines
While Desimone, Gabrieli and their
colleagues look for ways to raise human
intelligence, Poggio, who directs the
MIT-based Center for Brains, Minds and
Machines, is trying to endow comput-
ers with more human-like intelligence.

Computers can already match human
performance on some specifi c tasks such
as chess. Programs such as Apple’s “Siri”
can mimic human speech interpretation,
not perfectly but well enough to be useful.

Computer vision programs are approach-
ing human performance at rapid object
recognitions, and one such system, devel-
oped by one of Poggio’s former postdocs, is
now being used to assist car drivers. “The
last decade has been pretty magical for
intelligent computer systems,” says Poggio.

Like children, these intelligent systems
learn from past experience. But compared
to humans or other animals, machines
tend to be very slow learners. For example,
the visual system for automobiles was
trained by presenting it with millions
of images—traffic light, pedestrian, and
so on—that had already been labeled by
humans. “You would never present so
many examples to a child,” says Poggio.

“One of our big challenges is to understand
how to make algorithms in computers
learn with many fewer examples, to make
them learn more like children do.”

To accomplish this and other goals
of machine intelligence, Poggio suspects that
the work being done by Desimone, Gabrieli
and others to understand the neural basis
of intelligence will be critical. But he is not
expecting any single breakthrough that will
make everything fall into place. “A century
ago,” he says, “scientists pondered the
problem of life, as if ‘life’—what we now
call biology—were just one problem. The
science of intelligence is like biology. It’s a
lot of problems, and a lot of breakthroughs
will have to come before a machine appears
that is as intelligent as we are.”

Work from the Gabrieli lab indicates that ‘teaching to the test’ does not
necessarily raise cognitive skills.
Announcing a New Joint Series with the Broad Institute

We are pleased to announce a new monthly seminar series co-hosted by the Poitras Center and the Stanley Center for Psychiatric Research at the Broad Institute. The Translational Neuroscience Joint Seminar Series will feature researchers from universities and pharmaceutical companies who study the molecular basis of psychiatric disorders.

This will be the first talk series co-hosted by the Poitras Center for Affective Disorders Research, which was established at the McGovern Institute in 2007 by Patricia and James Poitras ’63 to support research into the biological basis of psychiatric disorders such as bipolar disorder, depression and schizophrenia. The Stanley Center was also founded in 2007 with a similar long-term goal: to discover the biology of psychiatric disorders and lay the groundwork for effective therapies.

The monthly seminar series is open to the public. All talks will take place in the Singleton Auditorium (MIT Bldg 46-3002) on Tuesdays at 3pm. More information, including dates, speakers and talk titles, can be found on our website.

Charles Gilbert to Receive Scolnick Prize

The 2015 Scolnick Prize for Neuroscience will be awarded to Charles Gilbert of The Rockefeller University, for his work on the function and plasticity of the visual cortex. The award will be presented at the McGovern Institute on March 20 at 4pm, after which Dr. Gilbert will give a lecture entitled “The Dynamic Brain.” There will be a reception following the lecture. The event is free and open to the public.

New Fund to Support Genetic Models of Brain Disease

Longtime friends of the McGovern Institute Edward and Kay Poitras have made a very generous commitment to create The Edward and Kay Poitras Fund for Frontiers in Genetic Models. The fund will help launch the McGovern Institute’s interdisciplinary initiative to create new genetic models of brain disorders. This initiative, led by Poitras Professor of Neuroscience Guoping Feng, is a global partnership involving more than a dozen universities and scientific institutions in four countries.

Family Creates Research Fund in Memory of Son

The family of Greg Hutko ’10 has generously created The Gregory Lloyd Hutko ’10 Fund for Psychiatric Research at MIT’s McGovern Institute for Brain Research. Created in Greg’s memory, the fund will accelerate research into the biological basis of disorders such as depression, bipolar and schizophrenia and support investigations into potential new treatments for these diseases. The Hutko family encourages MIT students, alumni and their families to learn more about psychiatric illness by connecting with the National Alliance on Mental Illness (NAMI), which provides support and classes for family and friends of individuals living with mental illness. Visit www.nami.org to learn more and to find a local chapter.

A fund for psychiatric research has been set up in memory of Greg Hutko ’10.
By studying the nervous system of the nematode *C. elegans*, Bob Horvitz’s lab has discovered a novel taste receptor for hydrogen peroxide. The molecule allows worms to respond to bright light, which causes the formation of hydrogen peroxide. This finding lends support to the idea that there may be similar receptors in humans, in addition to the known taste receptors for sweet, salty, bitter, sour and savory.

**Jim DiCarlo** and colleagues compared the behavior of a ‘deep neural network’ computer vision model to that of primate visual system and showed that the two systems achieve similar performance on object recognition tasks.

MIT researchers led by **Ed Boyden** have invented a new way to visualize the nanoscale structure of the brain and other tissues. Unlike traditional microscopy, which involves magnifying the image, the new method works by physically enlarging the specimen itself, in some cases more than five times in each dimension. This is achieved by embedding the specimen in the same polymer material used in baby diapers, which expands dramatically when it absorbs water. The new method makes it possible to see fine structures such as synapses at a level of detail that would otherwise be invisible to conventional microscopes.

**“From the depths of the disposable baby diaper has emerged a new technique to see tiny details under the microscope.”**

—PBS NewsHour

**Ed Boyden**’s expansion microscopy research received widespread news coverage, including a feature article in the *New York Times*, the *Boston Globe*, and *PBS NewsHour*.

*Technology Review* profiled McGovern Institute director **Robert Desimone**. The article, which features some of the institute’s latest genetic and brain imaging research, describes how Desimone’s early experiences working at a state mental hospital helped shape his professional career.

**National Public Radio** interviewed **John Gabrieli** about the growing evidence that brain measures can predict which patients will respond best to a given psychiatric treatment, or which children will face difficulties with reading or math. The results of these tests are often better than currently available clinical measures, he says.
**Sharp Lecture in Neural Circuits**

Dr. Cornelia “Cori” Bargmann of The Rockefeller University delivered the fourth annual Sharp Lecture in Neural Circuits on Tuesday, March 2. Bargmann studies how genes, experience and neural circuits influence behavior in the nematode worm C. elegans. Last year’s Sharp lecturer was May-Britt Moser, who subsequently shared the 2014 Nobel Prize in Physiology or Medicine for her discovery of the brain’s “inner GPS” navigation system. The Sharp lectures may be viewed on our website.

**Building 46 Holiday Party**

On December 11, members of the McGovern Institute, Picower Institute and Department of Brain and Cognitive Sciences celebrated the holidays with a party in the atrium of Building 46. Pictures from the event can be viewed on our website.