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brain+cognitive sciences



A Message from the Department Head Mriganka Sur

Fall semester, 2010, began with a pleasant surprise. The long-overdue National Research Council report on Assessment of US Doctoral Programs was released in September, and I am pleased to report that MIT comes out 1st among 94 Neuroscience doctoral programs in the US.

The report by the National Research Council, an arm of the National Academies of the US, is based on a large amount of data on faculty, students, and graduate programs collected in 2006. The analysis rated over 20 indices such as faculty publications, citations, grants, awards, and diversity; and student quality, performance, outcomes, diversity, and quality of life. The ranking metric is complex, and there has been considerable discussion about it. Nevertheless, the analysis shows that across these measures, the mean ranking and range for MIT (and the BCS graduate program) is the best of any Neuroscience graduate program in the nation.

In the previous NRC assessment and rankings done in 1995, MIT ranked 14th in Neuroscience. I believe our considerable jump is due to the focus on excellence that we have consistently emphasized and maintained – something that is evident in the work of our faculty, students and staff. We are proud of them.

Continuing this tradition of excellence, BCS has made two outstanding new faculty appointments in 2010. Myriam Heiman, a molecular neuroscientist who studies mechanisms of selective vulnerability and pathophysiology in two neurodegenerative diseases of the basal ganglia, Huntington's disease and Parkinson's disease, will formally join us in January 2011. In addition to her appointment as Assistant Professor in BCS, she will be a core member of the Broad Institute and an investigator in the Picower Institute for Learning and Memory. Feng Zhang, a molecular neuroscientist who uses synthetic biology methods to develop tools for understanding and controlling brain cells and circuits, will formally start his BCS Assistant Professor appointment in January 2011. He too will be a core member of the Broad Institute, as well as an investigator of the McGovern Institute for Brain Research.

These appointments usher in a new era for BCS – that of active partnership around neuroscience and brain disorders with the Broad Institute, a world-renowned genomics center associated with MIT and Harvard that sits only a block away from our home in building 46. Other BCS faculty hold appointments as associate members of the Broad Institute, and there are multiple collaborations between building 46 labs and the Broad's Stanley Center for Psychiatric Research.

Partnerships and collaborations are of course not a new theme for BCS. Neuroscience and cognitive science are by their nature interdisciplinary, and draw on many other fields for their tools and approaches. In turn, as advances in neuroscience and cognitive science accumulate, they are shaping other fields.

A major example of the intellectual influence that BCS is exerting is the Intelligence Initiative, a partnership between BCS, CSAIL, EECS, the Media Lab and many other MIT groups led by Joshua Tenenbaum and Tomaso Poggio. Artificial Intelligence, or the quest to build intelligent machines, is being transformed by new ideas from cognitive science and neuroscience. A mark of the initiative's visibility within MIT is that it is hosting one of only a handful of symposia in the MIT150 celebrations that will take place next year. The 'Brains, Minds and Machines' event will run over two days (May 3-5, 2011), and showcase the effort to understand the origins of intelligence, build intelligent artifacts and systems, and improve mechanisms for collective decisions. ■

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Please keep
in touch:
bcs_news@mit.edu

On the Cover

A fingerprint captured using GelSight, a technology developed in BCS Professor Ted Adelson's lab. Please see the full story of GelSight in the article on page 5.

From Deep in the Jungle, a Linguistic Mystery

It takes two days by boat to reach the place on the Maici River where the Pirahã people live—and that assumes your starting point is the city of Porto Velho, Brazil, which is itself a long way into the jungles of the Amazon basin. Fortunately for Professor Ted Gibson and his fellow BCS researchers, they were able to fly the last leg, which took only an hour. They had come to the remote jungle to study the language of the Pirahã people, whose culture and language have remained largely unaffected by contact with outsiders.

The motivation for the trip centered on a number of claims made by former missionary and now Bentley University Dean Daniel Everett. Everett lived among the Pirahã for a number of years beginning in the late 1970s and became one of a very few experts in their language and culture. Among the unique features of the language that Everett had noted was its lack of recursion, which, if true, would provide evidence that would counter the hypothesis that recursion is a core feature of human language proposed by, among others, MIT Professor of Linguistics Noam Chomsky. Everett had also noted that the Pirahã did not have any words for ordinal or cardinal numbers and could therefore not count or perform basic mathematics. Ted, along with BCS graduate student Mike Frank and postdoc Ev Fedorenko, wanted to study these claims more closely, and so in 2007 he and Mike, along with Everett, made the long journey to the banks of the Maici.

Pirahã had long been characterized as belonging to the 'one, two, many' family of languages, meaning that the only cardinal numbers were one and two, and that both the Pirahã language and mathematics did not recognize anything beyond this.



Members of the Pirahã tribe. Photo by Ted Gibson.



Former BCS graduate student (now Stanford Assistant Professor) Mike Frank demonstrates a counting experiment. Photo by Ted Gibson.

Without a system of mathematics, it was predicted that the Pirahã would not be able to count reliably beyond three or four items, a finding confirmed by experiments that involved counting items in increasing quantities—from one to ten. A surprising result occurred, however, when the counting tests were run in the opposite direction—from ten to one. In this case the point of transition from 'many' to 'two' to 'one' happened earlier than expected. This discovery indicated that the meaning of what had seemed to be cardinal numbers was more akin to 'very few' and 'few.'

"It was a really exciting moment when we first realized that they really don't count," says Mike. "It was instantly obvious that they think about large quantities differently that you or I might." Ted Gibson agrees: "To me it means that math has never been important to how they live. And if you spend any time with them you begin to see this in many aspects of their culture."

The results of the counting experiments were published in the journal *Cognition* and immediately attracted a lot of attention in both the scholarly and popular press. Ted and his colleagues, however, do not consider their work done and are planning a return trip in early 2011. "We have only scratched the surface of the recursion question, and I'm really interested to see what we can learn." Mike Frank, now Assistant Professor of Psychology at Stanford is also excited to be going. "There is a lot left to study and it was such a great experience last time—I can't wait."

For the next trip, they plan to take the boat. ■

In Memory of Partha Niyogi

We note with great sadness that BCS alumnus Partha Niyogi (PhD '95) passed away on October 1, 2010. After completing his degree, Partha stayed on in Professor Tomaso Poggio's lab in CBCL as a postdoc before leaving to join Bell Labs. He was eventually appointed as the Louis Block Professor in the departments of Computer Science and Statistics at the University of Chicago. His research interests were in learning theory and algorithms, statistical inference, and the various problems of learning and inference that arise in the study of human speech and language. Over the years Partha remained a close friend of Prof. Poggio's and of CBCL. Most recently Partha visited MIT to participate in the Brains & Machines 2008 Seminar Series and LIDS in 2009.

Faculty Profile: Weifeng Xu

Weifeng Xu was born and raised in the northeastern part of China, and is the daughter of architectural engineers who greatly influenced the way she thinks and learns. By the time she graduated from high school, Weifeng's early interests in math and physics—her favorite childhood toys were blocks and a set of furniture she could take apart and reassemble—were replaced by an increased focus on biology. She chose biophysics as her major at Peking University, known for its diversity and strength in humanities and social sciences as well as in basic science.

As an undergraduate, Weifeng was drawn toward electrophysiology and understanding signal propagation throughout the nervous system, and the early focus on her major, which was traditional at the university, provided excellent experimental training. Toward the end of her undergraduate studies, however, Weifeng felt that though she had excellent electrophysiological training, she needed preparation in cutting-edge molecular biology techniques, so she chose a molecular biology lab for her required undergraduate senior thesis. For her doctoral studies, however, she moved to Diane Lipscombe's lab at Brown University,

“MIT is an open atmosphere where you can discuss anything.”

where she worked on cloning and expressing a calcium channel gene to characterize its properties using electrophysiological techniques. The project was difficult because the gene had never been well expressed before, and the results proved surprising. She found novel properties not previously described due to the



The Xu Lab from left to right: Mingna Liu, Yan Liu, Weifeng Xu (accessorized with Angela Wei), Patrick Redman, Stacey Mayers, Kendrick Jones, Alissa Totman, Hongjik Hwang



Photo by Betsy Cullen

difficulty of expressing this channel in the exogenous system. “I feel very fortunate to have worked with Lipscombe,” says Weifeng, “She was an excellent mentor. She taught me how to think independently and critically, how to be really persistent and precise, and how to be a female scientist.”

After completing her graduate studies, Weifeng wanted to examine more native cell types, like neurons, and to look at synaptic transmission. She found this opportunity as a post-doc in the lab of Rob Malenka, a synaptic physiologist at Stanford. There, Weifeng developed a new experimental system to manipulate genes in neurons using virus mediated gene transfer and knockdown genes. It was a collaborative effort between her and another post-doc, Oliver Schlueter. It took over two years to develop a system that can knockdown the endogenous gene while simultaneously expressing the exogenous protein. This way, they can replace the endogenous protein with what they are interested in testing. They were able to measure synaptic transmission using electrophysiological techniques. Their major interest was proteins that enriched in the postsynaptic site of the neuron. One discovery Weifeng made as a result involved the structural/functional analysis of a family of proteins that control glutamate receptors: she found different members of this gene family had different ways of regulating the glutamate receptor function. This potentially provides a molecular mechanism for neurons to diversify synaptic transmission using different members of this gene family. Weifeng also explored the molecular mechanism of synaptic plasticity

GelSight Turns Touch Into Image

When Ted Adelson, the John and Dorothy Wilson Professor in BCS, had his first child, he was not only looking forward to the joys of becoming a father. As someone who studies visual perception, he was eager to watch his daughter's visual system develop. Instead, he explains, "I became more and more impressed with her ability to make sense of the world with her fingers and mouth. I've always thought of vision as the most important sense we have, but I became intrigued by how subtle and complex the information from touch is." Inspired by recent breakthroughs in tactile sensing that can resolve texture as small as the writing on a coin, and informed by his work in material perception, Adelson created a sensor that can capture the experience of touch, using materials he already had at home.

Research on how humans experience touch is much more limited than that of vision. "You can make an argument," says Kimo Johnson, a postdoc in Adelson's lab, and the lead author on "Retrographic sensing for the measurement of surface and shape" (Computer Vision and Pattern Recognition, 2009), "that the sense of touch hasn't been extensively studied because there hasn't been a way to measure it."

Enter GelSight, a simple sensor made from elastomer, or another clear gel such as silicone, covered with a metallic, reflective skin. GelSight is unique because of the way the material mimics flesh. "GelSight is compliant, so you can actually create an image of what you are feeling," explains Johnson, "it is like having a camera under your skin." Unlike some methods of scanning texture, GelSight is able to capture the surface geometry of a wide range of materials, even if the object is shiny or transparent. GelSight does not take a picture of the object; it converts pressure and shape into an image.

When an object is pressed against the top of the GelSight sensor, your eye can clearly see the details of the surface geometry. A fingertip will display the details of the fingerprint, and the laser ink printing on a piece of paper will appear in relief. In order to create an image that can be studied and understood by a computer, the sensor needs to be illuminated from three angles. A RGB camera can then



A prototype GelSight finger sensor.



Illuminating the GelSight elastomer from three different directions allows the sensor to generate a 3-dimensional image.

take a picture from which a computer can generate a 3D image.

Although Adelson created GelSight with the intention of studying touch, the possible applications have gone off in many different directions. Since the sensor is able to capture microscopic images, very small cracks or scratches can be detected. This application could be useful for NASA in inspecting their aircraft and spacecraft, especially considering GelSight's portability. Because of GelSight's similarity to skin and flesh, it has also been targeted as a possible material for robotic and prosthetic fingers. Together with Dr. Mandayam Srinivasan, director of the MIT Touch Lab, Adelson has received an NSF grant to develop a robotic finger that can mimic the sensory motor abilities of a human.

Further down the road, Adelson hopes to use GelSight to study touch in a way similar to the way he currently studies vision. By creating a visual image of what the skin experiences as touch, he brings tactile information into territory that is familiar. "My long-term ambition," he says, "is to use GelSight to help understand human touch, so the next question is—how do you deliver this information to the brain?" Such delivery might require converting the visual information created by the 3D image into a tactile, aural, or neural signal.

Currently, the researchers are exploring the limits of the spatial resolution of GelSight. They have captured images of everything from the activity of soap bubbles to the taste buds on a human tongue. Video demonstrations of GelSight are available online at <http://www.mit.edu/~kimo/gelsight/>, and are also posted on YouTube. ■



The incoming graduate class, left to right. Back Row: Gerald Pho, Matthew Greene, Leon Bergen, Ben Deen, Sam Norman-Haignere. Middle Row: Kartik Ramamoorthi, Steve Ramirez, Cristina de la Prat Camayd, Jon Malmaud, Simon Kornblith, Evan Ehrenberg. Front Row: Danielle Feldman, Elizabeth Gutierrez Roman, Karen Mei, Silvana Konermann.

To help prepare them for their first paper-writing experience, we asked this year's incoming class to write a brief biography containing a minimum number of citations (catch phrases - highlighted). The results? Well you judge:

Leon Bergen

I grew up in New Jersey and graduated in 2009 from Swarthmore College with a degree in math and philosophy. After a year of **metaphysical uncertainty** in the philosophy Ph.D. program at MIT, I **limped into port** and joined Tedlab and the Computational Cognitive Science group. I am mostly interested in computational models of language, especially semantics and pragmatics, and I have also done some work on social cognition. **In the interest of full disclosure**: although I'm a Jersey native, I have never appeared on "Jersey Shore," and my life doesn't involve much **shocking debauchery**.

Ben Deen

Ben is an incoming graduate student in Brain and Cognitive Sciences. Originally from New York City but having spent too much time in suburbia, he welcomes the **unbelievable fabulousness** of living right beside Boston. As an Eastgate resident, he bears frequent witness to acts of shocking debauchery. Ben considers it a metaphysical certainty that the fields of neuroscience and cognitive science will eventually be combined, and thus his interests straddle both. In his spare time, if any, he might be found hiking, playing the drums, or listening to music (anything but ABBA or country music).

Evan Christopher Ehrenberg

I'm 16, so I can't yet fully thank **god for myelin** and all its **unbelievable fabulousness**. I'm a schemer with a lisp who plays piano with one hand while solving Rubik's cubes with the other. I've scaled Egypt's pyramids, cruised through the locks of the Panama Canal, traversed lava flows as night was falling, and paid tribute to the gods in Olympia. I not only

graduated with highest honors from UC Berkeley, but I was also valedictorian of my homeschool. **In the interest of full disclosure**, I study how networks of neurons collaborate to realize perception and memory and model them to create biologically inspired AI systems.

Danielle Feldman

Danielle originates from the land of **shocking debauchery** that is the West Village in NYC. She attended CUNY Hunter College and worked in molecular immunology, but, **in the interest of full disclosure**, almost wound up in pastry school. After a summer of neurobiology work, Danielle knew, with **metaphysical certainty**, that a life without lab benches was **sheer unmitigated nonsense**. In the meantime, she maintains artsy hobbies in the hopes of parlaying her cookie and scarf knitting skills into barter for ABBA records. Quite random indeed, but she simply can't get enough of their **unbelievable fabulousness**.

Matthew Jason Greene

This actor was born as Björn Kristian Ulvaeus in Gothenburg, Sweden. Due to a **creeping paranoia** that people were e-stalking him after his involvement in a fringe band called **ABBA**, he illegally changed his name to the much more common, and thus more difficult to google, Matthew Greene. As Matthew Greene, he was involved in the hit production "Columbia University" for a 4-year run in New York City, until an episode of **shocking debauchery** forced him to flee the state. Now, we are happy to have him as "Male Grad Student #4" in our "MIT BCS" production **UNBELIEVABLE FABULOUSNESS**.

Elizabeth Gutierrez Roman

Coming from the land of [unbelievable fabulousness](#), better known as Puerto Rico, Elizabeth has a feeling (of [metaphysical certainty](#)) that she'll love having Cambridge as her new home. Training in neurobiology and working with *Drosophila*, she felt a [creeping paranoia](#) that someday she'd wake up with larvae in her hair. Thus, she made a quick decision to go into the safe haven of cognitive neuroscience. [Thank God for myelin!](#) Elizabeth has a love relationship with coffee and chocolate, and (in the interest of full disclosure) a secret affair with Frank Sinatra. [In the immortal words of ABBA: "Mamma Mia!"](#)

Simon John Kornblith

[As night was falling](#) after a long day in the monkey lab, Simon came home to prepare a nice calamari dinner. A wave of [creeping paranoia](#) washed over him as he prepared to place the breaded cephalopod into the hot oil bath that would transform it into a meal of [unbelievable fabulousness](#). Suddenly, the creature came to life, squirting ink toward Simon's speakers and silencing the catchy hooks of the popular Swedish pop group [ABBA](#), but it was too slow. With one fell swoop, Simon decapitated the undead beast, saving the world as we know it. ([Thank God for myelin](#))

Owen Ardron Lewis

Drawn by the [unbelievable fabulousness](#) of the MIT BCS program, I [limped into port](#) here in May, after the tempestuously hurried completion of my Masters thesis in applied math at the University of Colorado. Over the summer, I intended to work with Tomaso Poggio on machine learning and computer vision. As it turned out, the summer ended up including more [shocking debauchery](#) than actual research. In future, I want to continue to work in computation, but I'm also looking forward to learning the ins and outs of myelin, axons, [GABBAergic neurons](#) [recently discovered by a team of Swedish researchers], etc.

Jonathan Matthew Malmaud

[As night was falling](#) on my time as an undergrad at Caltech, I decided to eschew a traditional computer science grad program for the [shocking debauchery](#) of computational neuroscience. While at Tech, I helped shape [the world as we know it](#) through my Bayesian neuroeconomics research. I am confident in my decision to pursue a PhD, for in the immortal words of Mriganka Sur, "the greatest discoveries in science often...soar...from...j...on" (TechTalk 11/30/05). I currently remain agnostic between working with the [unmitigated nonsense](#) of animal research or pursuing the spiritual and [metaphysical certainty](#) of theoretical research.

Yuan Mei

Even though I hail from the middle of nowhere, i.e. South Dakota, I had the [creeping paranoia](#) that neuroscience can change [the world as we know it](#). At Rice University, I studied mouse models of Alzheimer's disease and lysosomal storage disorders. It became a [metaphysical certainty](#) to me that I wanted to study molecular neuroscience and that MIT was a place of [unbelievable fabulousness](#). When I'm not [thanking god for myelin](#), [limping into ports](#), or committing [shocking debauchery](#), I like to run, shop, cook, and dance to [ABBA](#).

Samuel Victor Norman-Haignere

[The world as we know it](#) is collapsing into [unmitigated nonsense](#). We see the chaos everywhere: on the news and in our TVs. But I believe with absolute [metaphysical certainty](#) that the solution to this [creeping paranoia](#) is science. And at the heart of science are brains. Previously I studied what spontaneous brain fluctuations might tell us about the brain's functional structure. At MIT, I'd like to continue parceling the brain into its natural units, while at the same time trying to understand the basic computations these units might be performing. This is my task. [Thank god for myelin.](#)

Gerald Pho

[In the interest of full disclosure](#), Gerald Pho is from the [unbelievable fabulousness](#) that is Cleveland, Ohio. He graduated from Case Western Reserve University this past May with a B.S.E. in Biomedical Engineering, where he tested deep brain stimulation on rodents as a treatment for epilepsy. After much deliberation, Gerald made "The Decision" to leave Cleveland and take his talents to Boston and MIT. His current research interests include using electrophysiology and optogenetics and other [unmitigated nonsense](#) to understand how neural circuits give rise to behavior and cognition. Outside the lab, Gerald likes to eat, to play tennis, and to [thank God for myelin](#).

Cristina de la Prat Camayd

[In the interest of full disclosure](#), it should be noted that the [unmitigated nonsense](#) that comprises the world as we know it would be nothing without the [unbelievable fabulousness](#) that is Cristina Camayd. In her free time Cristina enjoys parasailing, cucumbers, and the letter Z. Upon arriving to Boston, she [limped into port](#) and was overtaken by a [creeping paranoia](#) that [shocking debauchery](#) would take on a whole new meaning in this town. [In the immortal words of ABBA –Mamma Mia!](#) At the end of the day it seems to be a [metaphysical certainty](#) that everyone will [thank God for myelin](#)... and Cristina.

Kartik Ramamoorthi

[In the interest of full disclosure](#) it should be known that until his arrival in Boston two years ago, Kartik's life and education had been solely shaped by the great state of New Jersey. It is with [metaphysical certainty](#) that he will inform you of these facts within five minutes of meeting him. While he was at Rutgers University he developed his interest in neuroscience and pursued it all the way to MIT where he found his way to the lab of Yingxi Lin (best known for its [shocking debauchery](#) and [unmitigated nonsense](#)), in the McGovern Institute.

Steve Ramirez

[In the immortal words of ABBA:](#) You can dance! You can jive! Having the time of your life! That pretty much sums up my experience at Boston University as an undergrad. I hope to add, "you can engage in [shocking debauchery!](#)" after my time at MIT. [In the interest of full disclosure](#), I want to be a professor, and science is fun because nature has a (reasonable) [creeping paranoia](#) that we'll figure her out. I love opposing forces, like running marathons and inhaling medium-well burgers (not at the same time). If I could rap, I would, yo.

continued from p.04

which is a way neurons change the strength of their connectivity when they receive patterns of activity. She believes that a cellular mechanism of information processing is the initial point of learning before a signal gets integrated into the network level. She succeeded in dissecting the structure of the protein PSD95 and identified its important domains that would mediate one particular type of synaptic plasticity. The ultimate goal is to understand how the protein network in the postsynaptic site is dynamically regulated to differentiate the input pattern and code the input into specific changes of the synaptic strength. This will help us understand how genes are involved in higher brain function. "My personal reason for pursuing these molecules," she explains, "is because they are likely players in many neurological/psychiatric diseases. Better understanding how the brain works will help in finding cures for autism, schizophrenia, bi-polar disorders, etc."

Weifeng chose to come to MIT for its engineering (RLE)—people always comment that she thinks like an engineer. What she has liked most here is that things are handled in a logical way and there doesn't appear to be behind-the-scenes politics. "Everyone is passionate about research," she says. "There is an open atmosphere where you can discuss anything. There is also an emphasis on innovation, which is so important for neuroscience to progress, and there is no better place to incorporate ideas into reality than collaborating across disciplines." One thing she has already learned at MIT is the art of the elevator speech: how to explain complicated scientific questions to anyone in the duration of an elevator ride.

In addition to her research, Weifeng spends as much time as possible with her daughter, who will soon be 3. Weifeng's husband, who holds a PhD in biology and an MS in managing information systems, works as a software engineer and has developed his own trading system which he uses to do investments from home. She used to hike, travel around the states, listen to music, bike ride, swim, and she even picked up scuba diving prior to her daughter's birth. Now her schedule revolves around her research and her family. "My goal is to emulate my mentors," she says. "I feel blessed to be here now rather than even 10 years ago, when trying to balance a family and a career in science was even more challenging. I hope to show that it's possible to be a good scientist and a good mother." ■

Honors and Awards

FACULTY

Ted Adelson was elected to the National Academy of Arts & Sciences.

Earl Miller was selected as the 2011 Biomed Distinguished Lecturer, University of Leuven, and was given the 2010 MERIT Award, National Institute of Mental Health.

Aude Oliva was elected a Fellow of the Association for Psychological Science.

Mriganka Sur was recognized as one of the 50 most notable alumni of the Indian Institute of Technology. He presented several keynote lectures worldwide, including the Nobel Conclave and Symposium hosted by IIT Allahabad.

Li-Huei Tsai was awarded the 2010 Glenn Award for Research in Biological Mechanisms of Aging.

STAFF

Wasim Malik, a Research Affiliate in BCS and an Instructor in anesthesiology at Harvard Medical School, was awarded the Shore Career Development Award from CIMIT.

Postdoc Sarah Weigelt was awarded the Otto Hahn medal of the Max Planck Society for her PhD thesis titled "Neurovision: neuroimaging investigations of illusory perception."

STUDENTS/ALUMNI

Alumnus David Freedman (PhD 2002), who is now an Assistant Professor at the University of Chicago, was recently awarded a Sloan Research Fellowship and received a CAREER Award Grant from The National Science Foundation.