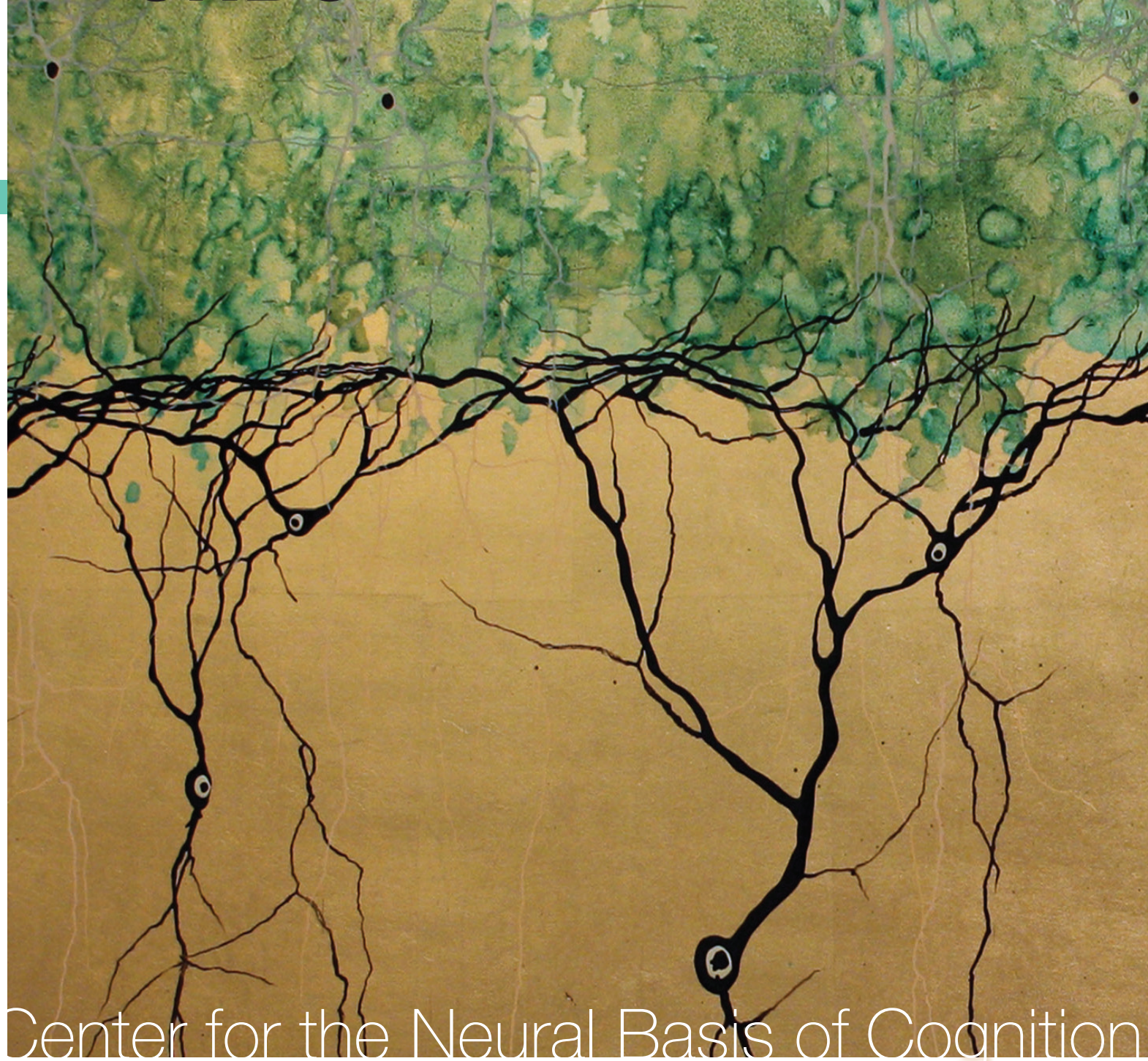


SUMMER
2011

CNBCconnect



Center for the Neural Basis of Cognition

A JOINT PROGRAM | CARNEGIE MELLON UNIVERSITY | UNIVERSITY OF PITTSBURGH

From the co-directors

CNBC – stronger than ever Welcome to the first issue of CNBConnect, our biannual newsletter that will keep CNBC members, alumni and friends up to date on what is happening with our center. The CNBC was one of the first centers devoted to the integration of the neural, cognitive and

computational sciences. As you will read in this newsletter, the CNBC continues to take a leading role in both research and training with respect to the study of the mind and brain. We are pleased to report that not only are we maintaining the standards of excellence established over the past 15+ years, but we are embarking on many new projects, faculty hires, training programs, and, as always, cutting-edge research that spans many disciplines.



Peter Strick and Michael J. Tarr

These are very exciting times for the CNBC community. Over the past several years we have created a new Ph.D. program in Neural Computation (as well as a joint Neural Computational/Statistics Ph.D.), established new research initiatives in areas such as neural prosthetics, created summer training programs in neuroimaging and neural computation, and obtained multiple training grants to support Ph.D. programs in neural computation, multimodal neuroimaging, and brain and behavior. At the same time we have been expanding the scope of CNBC, forging ties to many new departments within both universities and hiring new faculty members, including Marlene Cohen (see this issue), Aaron Batista, Wayne Wu, Byron Yu and a new CMU co-director. These and other successes are part of the reason why the administrations of both CMU and PITT have made significant commitments to further advance the study of the mind and brain. CMU recently announced a Brain, Mind and Learning fundraising initiative to help create sustainable funding for faculty positions, graduate training and research innovation, while Pitt has formed the Neuroscience Imaging Center to further the science of neuroimaging across all levels of analysis.

As the CNBC community and alumni base continues to grow, it is important to find ways to remain connected. We hope you will be able to join us at the Pittsburgh Neuroscientist Reunion Reception, at the Society for Neuroscience meeting in Washington, D.C., on Monday, November 14, 6:30-8:30 p.m., Hamilton Crown Plaza, 14th & K Street, NW.

On the Cover:

Ganglion cells from the visual system that integrate and process data collected by photoreceptor cells.

If you would like a CNBC poster celebrating 15 years studying the mind and brain, including the art used on the front cover of this newsletter, or if you have news you would like to share, please email us at: cnbc-newsletter@cnbc.cmu.edu

ARTWORK BY Greg Dunn
www.gregadunn.com

New Course Spotlight: **Rob Kass** *Statistical Models of the Brain*

Shortly after the advent of our Ph.D. program in Neural Computation we began a neural computation journal club. The first article we read was a nice essay by Larry Abbott in *Neuron*, in which he reflected on the past 20 years of theoretical neuroscience. One thing that struck me was that when Abbott discussed statistical models, he put them on the same footing as other kinds of models—such as those involving differential equations. Throughout science, statistical models are used as effective vehicles for data analysis, but Abbott’s remarks made me think about the ways statistical models have also shaped conceptual framework for understanding neural function. I realized that this conceptual role, which goes beyond rigorous data summary, has been played by statistical models for a very long time in diverse settings including the behavior of ion channels, neurotransmitter release, action potential generation, neural coding, system dynamics, and, at the behavioral level, perception, movement and decision making.

This led me to develop the new course “Statistical Models of the Brain,” which examines some of the most important methods and claims that have come from applying statistical thinking to the brain. I offered this for the first time in Spring 2011. Students read sources ranging from George Miller’s “The Magical Number Seven, Plus or Minus Two,” to Shadlen and Newsome’s arguments for balanced excitation and inhibition in cortex, to Bressler and colleagues’ results on beta oscillation connectivity in sensorimotor cortex, and to Wolpert and colleagues’ work on Bayesian integration in sensorimotor learning.

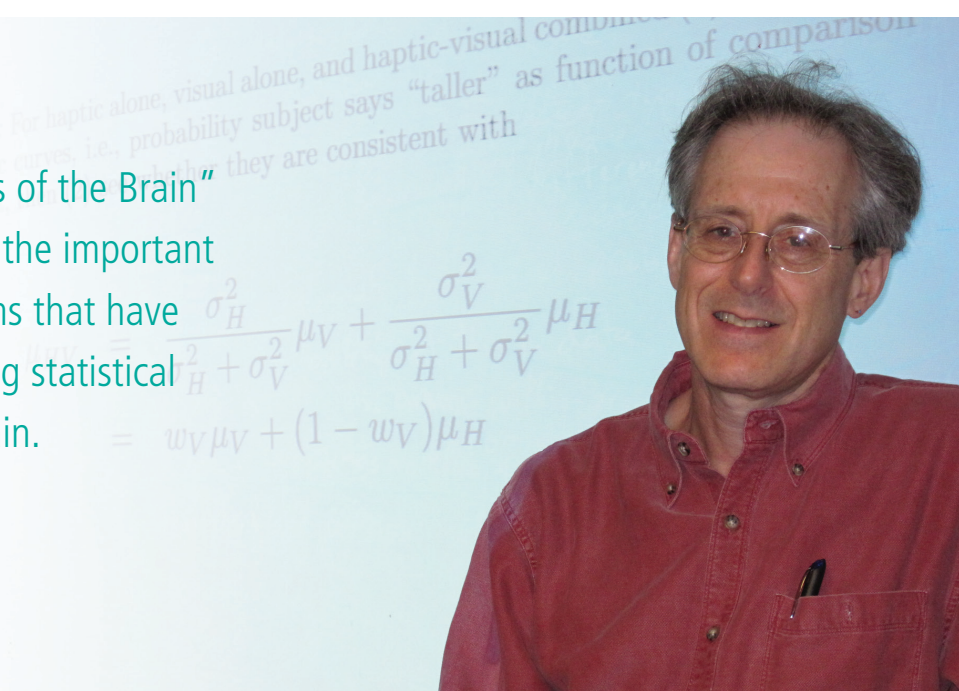
In every case my aim is to have students appreciate what particular statistical models have contributed to our understanding of the brain. In addition, they have homework exercises in which they must apply and interpret models themselves. I believe the course complements nicely the other computational offerings in the CNBC core curriculum.

Two features of the course production are a little unusual. The first is that more than a quarter of the lectures have been delivered by other faculty. Capturing distributed expertise has allowed the topics to be broader than they would otherwise be. The second is that students have been asked to post blog comments on the readings, comments that are private until I share and discuss them during the lecture. Commenting is mandatory and becomes part of the basis for assigning grades—though the comments can be very short, and can simply pose a question. This forces students to engage with the material, and it also identifies important points of confusion. I’m very enthusiastic about this as a teaching device.

Overall, the course has been a huge effort for me, as much as any in my 30+ years of teaching, but it has been very rewarding. The students, who have diverse backgrounds typical of the CNBC, have been terrific, tolerating a few inaugural mistakes and elevating discussions with insightful questions and comments. I’m already looking forward to doing it again. I plan to teach this course every two years.

“Statistical Models of the Brain”

examines some of the important methods and claims that have come from applying statistical thinking to the brain.



New Faculty Spotlight: **Marlene Cohen** *Deconvoluting Neuronal Group Think*



As an undergraduate at MIT, Marlene Cohen began with mathematics but fortuitously stumbled into neuroscience. “I was looking around for a research job and heard a great talk by Matt Wilson relating the activity of groups of neurons in the hippocampus to a rat’s behavior in a spatial navigation task.” This led to a research project with Wilson involving countless hours observing rats navigating through artificial environments while monitoring their neural activity. The experience provided Cohen an opportunity to merge her studies in mathematics with an additional major in neuroscience. “My time in the Wilson lab convinced me that I wanted to study how groups of neurons perform computations and guide behavior.”

This perspective motivated the next stage in her graduate work at Stanford with William Newsome where she switched from memory to vision. “It was a good move. I have the worst sense of direction of anyone I know, but my vision is pretty good, so the visual system seemed like a better fit!” she jokes. The patience acquired in watching rats gave her the perseverance to undertake technically demanding work recording from two neurons simultaneously for long periods of time. Fortunately, the efforts paid off.

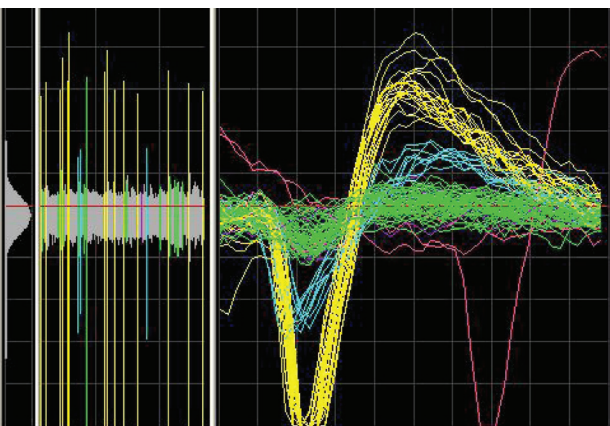
be relatively inflexible, a result of hard-wired features of the brain. Cohen and Newsome showed that in the middle temporal area (area MT), correlations were much more flexible than scientists had previously assumed. Indeed, they could change from moment to moment based on the animal’s current task.

This work cemented for her the importance of looking at population effects: “Typically, in single cell recordings, we look at the average activity of one neuron over many trials. But animals often have to use what they see to make a quick decision based on what the whole population of neurons is doing at that moment. Looking at many neurons gives us a snapshot of the information available to the animal in making a decision.”

Cohen quickly realized that a more efficient method was needed to generate the data to tease apart the complicated relations between noise correlations, the tuning properties of the neurons at issue and the animal’s current task. After finishing at Stanford, Cohen made the transcontinental trek back to the East Coast where she worked with John Maunsell at Harvard Medical School. She arrived with two goals: (a) to use multielectrode arrays to record simultaneously from multiple neurons and (b) to put attention into the mix. Maunsell had recently relocated to Boston, and this gave Cohen the opportunity to design and build a new rig from scratch for multielectrode recording, a skill she will soon put to use in setting up her new lab at the Center for Neuroscience at the University of Pittsburgh and in the CNBC. “Setting up multielectrode recordings as a postdoc was a fantastic opportunity for me,” she notes. “I got experience setting up a new technology while benefitting from John’s advice, skill and experience. There are so many aspects of starting a lab that are new to me, and I’m grateful that this one is familiar.”

Her post-doc work addressed three questions that she will continue to tackle in the CNBC: How is visual information encoded in groups of neurons? How does the coding of that information change across different circumstances? How does this information get used to guide behavior?

For example, previous work has shown that an animal’s attention to a spatial location can modestly increase the firing rate of neurons selective for that location as well as improve behavioral performance. Cohen’s previous work on noise correlations made her wonder whether attention



Population data obtained from a multiunit electrode.

Electrophysiologists are well aware that presenting the same stimulus repeatedly to a neuron leads to a different response on each trial. How can such variable neuronal response be useful to the brain? One answer is that the brain makes behavioral

decisions by “polling” from many neurons, just as political pollsters make predictions based on large samples. At the same time, neurons, like people, do not operate independently. Instead, some of the response variability is correlated across neurons, a link referred to as *noise correlation*. Just as voters’ opinions are affected by the opinions of others, neural responses fluctuate together to a certain extent.

The problem with such correlations is that they seem to have the disadvantages of “group think.” Behavior must be flexible in response to an ever-changing environment yet noise correlations were taken by many researchers to

Graduate Student Spotlight: **Ran Liu** *A Place for Hearing*

modulates correlations as well. She recorded from groups of neurons in visual area V4 and found that attention has a much larger effect on correlations than on firing rates, cutting correlations in half while only increasing firing rates by about 10 percent. This change in correlation could account for most of the behavioral improvement. By decreasing correlations (neuronal group think), neural responses become more independent and this improved the information available in the population of neurons, much as polling a group of independent-minded voters is more informative than polling a group whose opinions are strongly swayed by each other.

A second interesting line of her post-doctoral work relating to attention concerns a well-known fact: we tend to do better on a task when our attention is focused, yet no matter how hard we concentrate, our minds sometimes wander. Cohen taught animals to detect subtle changes in a visual scene. While her animals would often perform the task successfully, there would be an occasional trial where the animals got things wrong. Cohen hypothesized that these errors occurred in part because the animal's attention had wandered. She then used the responses of groups of visual neurons to identify trials when the animal's attention was directed appropriately or inappropriately for the task. The responses of the population of neurons allowed her to predict whether the animal would be able to detect an upcoming change in the scene. When the animal lacked attentional focus, it tended to fail at the task; where it was paying attention, it succeeded.

Cohen is looking forward to the next stage in her life including exploring Pittsburgh. "My husband and I have spent quite a lot of time over the last decade hiking around California and New England with our dog, and we're looking forward to having a new area to explore." Cohen is also an avid musician (flute, clarinet and saxophone) and if time permits, she hopes to find opportunities to continue playing. The collaborative atmosphere at the CNBC was a major draw for her, something she acquired a keen sense for on her visits here. "The breadth, depth and friendliness of the neuroscience community in the CNBC and at CMU and Pitt was one of the main things that drew me here. I don't know of another community with so many groups doing research that is directly relevant to my work, from the tremendous number of primate labs to the exceptional computational, cellular and cognitive neuroscience groups. What impressed me most was how much everyone seemed to know about what other groups were doing. It's clear that this is an interactive and collaborative community, and I'm honored to join it."

Ran Liu's current interest in the auditory system is the result of a happy collision of two parts of her life: music (the piano) and a cognitive science major at Carnegie Mellon University. The point of collision was a course on music and audition taught by CNBC faculty member

Lori Holt (CMU Psychology) which turned Liu on to the complexities of the auditory system. This in turn led to a Senior Honors Thesis with Holt where Liu focused on auditory categorization and learning.

After graduating from CMU, Liu left for a brief stint in graduate school in neuroscience in New York, but missed the intellectual community that she had grown

accustomed to in Pittsburgh. As there's no place like "home," she returned in 2008 to complete her graduate studies with Holt in Psychology at CMU and in the CNBC. As Holt notes, "In working together on her Honors Thesis, I knew we could expect big things from Ran. I am really pleased that she has found her way home to CMU psychology and the CNBC to pursue her graduate studies."

Liu's return enabled her to complete the work begun in her Honor's Thesis, leading to a 2011 paper in the *Journal of Cognitive Neuroscience*. In this work, Liu and Holt use a paradigm in which subjects play a video game that involves keeping track of different types of "aliens." Unbeknownst to their subjects, certain auditory stimulus categories are correlated with alien types, and the subjects implicitly learn the statistical correlation between auditory and visual categories, as evidenced by post-training behavioral measures. Interestingly, Liu and Holt found that such learning is correlated with neurophysiological changes, as measured by EEG, that are similar to those seen in infants between 6 and 12 months, a time that is associated with the initial acquisition of language categories.

This work is a first step in a larger, perhaps life-long project: "I'm interested in understanding the mechanisms through



Graduate Student Spotlight: **Ran Liu**
A Place for Hearing continued

which the brain acquires and accomplishes spoken language comprehension," says Liu. "That is, how does it take continuous auditory information from the environment and reliably map it onto semantics, and how is this mapping learned?" Liu's initial plans are focused on characterizing the types of perceptual learning mechanisms that are used for speech acquisition. This involves understanding how constraints on the auditory system interact with statistical information present in the environment to produce the kind of learning observed in natural spoken language acquisition.

This research path is one teeming with possibilities. Liu has found it important to approach these questions by tackling them at multiple perspectives intellectually. She credits the graduate training at the CNBC and its diverse faculty for providing the knowledge base for thinking at different levels, from conceptual questions to basic neuroscience to computational approaches. Moreover, she's taken advantage of the wide diversity in expertise within the CNBC community. For example, while her prior work focused on EEG, her explorations have led her to look into using MEG and to interact with an active, interdisciplinary group of CNBC students and post-docs with interests in the theoretical and practical features of MEG.

Liu received two years of initial support from an NIH-supported B² training grant focusing on training promising young scientists focused on neuroscience and behavioral studies. She was also recently awarded an NSF Graduate Research Fellowship. Moreover, the CNBC traditionally provides its graduate students with funds for travel and computer equipment, but it also aims to foster intellectual engagement. Students, for example, play the primary role in selecting and hosting colloquium speakers. Liu has taken advantage of this, having the opportunity to recently host the visit of David Poeppel (NYU), a major researcher in Liu's areas of interest. "As the student host, I had the opportunity to spend a lot of time with Dr. Poeppel and discuss his research, my research, big theoretical questions and new directions in our field. I'm hugely appreciative that the CNBC provides these intellectually and professionally valuable opportunities to its graduate students." Undoubtedly, there will be more opportunities and achievements to come.

Research Spotlight: **Alison Barth**
Neuronal Social Networking

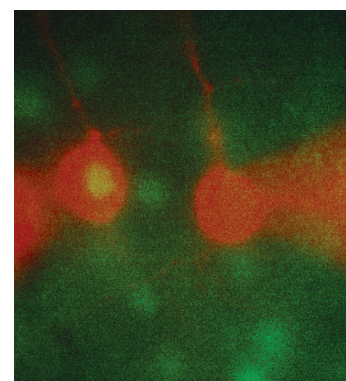
A common saying is that we only use a fraction of our brains, but something like this is borne out by work in neuroscience. Electrophysiological recordings from the brain have shown that even in the earliest sensory areas, only a small number of sensory neurons are active at a time with the majority of neurons seemingly firing little, if at all. To understand what the most active subpopulation of neurons are doing, it will be necessary to identify them, but that might seem like finding a needle in a haystack.

In a recent paper published in the journal *Neuron*, Alison Barth and post-doctoral associate Lina Yassin (CMU Biology) along with their collaborators in Germany, Jean-Sebastien Jouhanneau and James Poulet (Department of Neuroscience, Max Delbrück Center for Molecular Medicine) have identified some of the neurons that seem to dominate the activity landscape in the brain and begun to investigate what makes them so special. Former CNBC graduate student Brett Benedetti and current student Jing Wen are also coauthors on the work.

To identify cells with a recent history of activity, Barth and co-workers visualized activity-dependent gene expression using transgenic mice developed by the Barth lab. These mice express the green fluorescent protein, GFP, whose expression is driven by the activity-dependent transcription factor c-fos. Molecular biological studies have shown that c-fos dependent genes are expressed during recent, experience-dependent neural events. When the fosGFP transgenic mice are actively exploring their environments, there is increased activity in various regions of the brain that can be detected by the fos-dependent expression of GFP. This can be visualized directly, as seen in Figure 1 (green cell picture). Visualized cells, the active subpopulation, can then be directly targeted for electrophysiological recordings.

"Developing the fosGFP transgenic mice was a huge advance for us because it provided a way to focus our attention on the neurons that had a history of elevated activity," explains Barth.

Two cells filled with red dye prior to recording. FosGFP+ cell is on the left with green nucleus visible, FOSGFP- cell on right.





“What was surprising to us in the beginning was that even in animals that hadn’t been particularly stimulated, there was some low level of fosGFP expression in the neocortex,” said Barth. To further investigate this subpopulation of neurons, Barth and colleagues examined mice that were not behaviorally active but in a quiescent state. Under these conditions, they found that about 15 percent of sensory cortical neurons showed GFP expression.

Although it was likely that neural activity drove fosGFP expression in these cells, it was by no means clear that these neurons would continue to be active at the time of recording, since the GFP marker took hours to appear. However, using targeted whole-cell recordings in anesthetized animals, Barth’s team found that fosGFP-expressing neurons, unlike their fosGFP- neighbors, continued to be highly active, both in vitro and also in vivo. The persistence of this elevated activity prompted the group to investigate what was driving this firing, hours after the transgene had been induced.

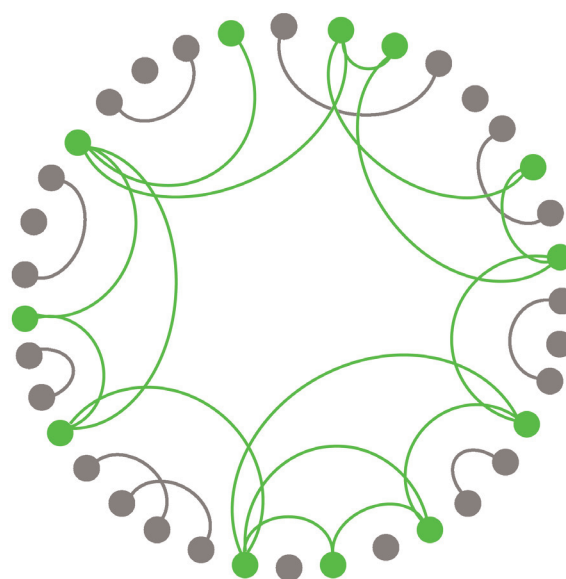
The study found that fosGFP-expressing neurons were not intrinsically more excitable than their quiescent, GFP non-expressing (GFP-) neighbors. Rather, they received greater excitation and inhibition signals. Paired recordings across each of the four possible combinations between fosGFP-expressing and GFP- cells showed that fosGFP-expressing cells were connected with each other in a way that allowed them to inter-communicate. Together, these linked cells constitute a network of highly active neurons.

The result has generated quite a bit of excitement. Barth was recently invited to present the work at the annual Cosyne meeting in Salt Lake City, Utah, a computational neuroscience conference. Indeed, the results are of broader interest, especially in understanding how information is

coded in the brain. Neuroscientists have long proposed the existence of a sparse code, namely that information is borne by a small subset of neurons. Barth’s work suggests that it may be possible to identify these sparsely coding neurons to better understand how they are selected, how they are maintained, and what information they carry.

“One of the fundamental questions about the cerebral cortex is what computations are performed by the huge numbers of neurons in this structure. We also need to carry out time-lapse experiments to see whether these fosGFP-expressing neurons are a stable or fluctuating population. Our work has not yet revealed whether these cells are special from the beginning, or whether they are simply enjoying their 15 minutes of fame,” Barth explains.

The team’s findings that these highly active neurons are densely interconnected also suggest an organized structure within neocortical networks. Active cells may serve as a hub, connecting less active cells to more active networks, facilitating information propagation. Barth is currently collaborating with computer scientists at Carnegie Mellon to investigate how other types of network models, such as those applied to the Internet or air travel, can inform future research into highly active subnetworks in the cortex. It is a striking fact that so little of the brain is seemingly used at a time, but the crucial next step is to understand why this is so.



Representation of highly interconnected subset of neurons.



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Honors & Awards

Faculty

John R. Anderson was the 2011 recipient of the Benjamin Franklin Medal in Computer and Cognitive Science, an honor given to trailblazers in science, business and technology

Carmen Andreescu received a 2011 Honorable Mention for the Donald F. Klein Young Investigator Award from the Anxiety Disorders Association of America

David Creswell was featured as "rising star" in the Association for Psychological Science (APS) Observer, Vol. 24(5), May/June 2011

Kirk Erickson received a Junior Scholar award from the Claude D. Pepper Center for Older Adults

Peter Gianaros was the recipient of a 2010 APA Distinguished Early Career Scientific Contribution to Psychology award

Lori Holt was named a fellow of the Association for Psychological Science

Karl Kandler was nominated to serve as chair for the NIH auditory study section NIH R01

Roberta Klatzky was the recipient of the Kurt-Koffka Medal for research in perception and action by Giessen University of Germany

Lynne Reder was elected to the Governing Board of the Psychonomic Society

Etienne Sibille, **Natasha Tokowicz** and **Mark Wheeler** were granted tenure

Peter Strick was appointed to the special faculty rank of Distinguished Professor of Neurobiology

Michael J. Tarr was named the George A. and Helen Dunham Cowan Professor of Cognitive Neuroscience

Nathan Urban was named the Dr. Frederick A. Schwertz Distinguished Professor of Life Sciences

2011 Ph.D.s

Aushra Abouzeid, 4/5/11 Math Pitt (Ermentrout)

Amanda Clause, 2/10/11 CNUP Pitt (Kandler)

Corey Flynn, 3/4/11 Biology CMU (Crowley)

George Fraser, 4/4/11 CNUP Pitt (Schwartz)

Christopher Gaiteri, 2/22/11 CNUP Pitt (Sibille)

Ken Hovis, 1/31/11 Biology CMU (Urban)

Bistra Jordanova, 1/14/11 Biology CMU (Ahrens)

Daniel Jimenez, 5/5/11 CNUP Pitt (Urban)

Kyung Hwa Lee, 5/23/11 Psychology Pitt (Siegle)

Sashi Marella, 5/2/11 CNUP Pitt (Ermentrout)

J. Patrick Mayo, 3/15/11 CNUP Pitt (Sommer)

Paul Middlebrooks, 5/18/11 CNUP Pitt (Sommer)

Linda Moya, 2/28/11 Psychology CMU (Behrmann)

Ranmal Samarasinghe, 6/15/11 CNUP Pitt (DeFranco)

SooYoon Shin, 5/20/11 CNUP Pitt (Sommer)

Kristen Stedenfeld, 6/7/11 CNUP Pitt (Sved)

Ashwin Vishwanathan, 11/10/10 Bioengineering Pitt (Zeringue)

Joost Wagenaar, 3/25/11 Bioengineering Pitt (Weber)

Students

Andrea Weinstein, graduate student in the Psychology Department at Pitt, was a recipient of The International Neuropsychological Society Phillip Rennick Award for excellence in pre-doctoral research (a \$500 honorarium for a talk given at the International Neuropsychological Society)

Alumni

Joshua Brumberg ('97 Simons Lab) has just been promoted to Full Professor in the Department of Psychology at Queens College and the Graduate Center, CUNY

Randy Bruno is currently an Assistant Professor at Columbia. This past year, he was named a Rita Allen Scholar and a Klingenstein Fellow

Mauricio Delgado was the recipient of the Presidential Early Career Award for Scientist and Engineers

Charles Geier accepted an Assistant Professor position (tenure-track) in the Department of Human Development and Family Studies at Penn State University

Tom Nichols accepted a position at the University of Warwick, UK, joint between the Department of Statistics and the Warwick Manufacturing Group

Suzy Scherf accepted a position as Assistant Professor of Psychology at Penn State beginning this summer

PostDocs

Christopher D'Lauro (Tarr) accepted a position as an Assistant Professor in the Department of Behavioral Sciences and Leadership, United States Air Force Academy

John Ryan (Gianaros) National Research Service Award (F32) from NIDDK

Anne Marie Oswald (Urban) accepted a position as Assistant Professor of Neuroscience at Pitt

Staff

Melissa Stupka (HS'02), graduate program coordinator, married Christopher Anderson (HS'02) on June 4, 2011