CNBCConnect

Center for the Neural Basis of Cognition

A JOINT PROGRAM | CARNEGIE MELLON UNIVERSITY | UNIVERSITY OF PITTSBURGH

From the co-directors

Twenty years and counting…

The celebration of the CNBC 20th anniversary last year was a time to reflect on the successes of the CNBC and of its faculty and students. The event re-engaged and recognized some of our outstanding alumni and built enthusiasm for the CNBC in the leadership of both CMU and Pitt as well as among local philanthropists and officers from key funding agencies.

As we take stock, we are encouraged to see the ways the evolution of the brain sciences reflects key elements of the vision and scientific pursuits pioneered by CNBC faculty and students over the last 20 years. In particular, the US federal BRAIN initiative, with its focus on developing innovative computational and technological approaches in the service of understanding higher order function, is well aligned with the trajectory along which the CNBC has been traveling.

After celebrating 20 years of success, a natural question is, "What's next?" We will be working with faculty, students, alumni, and others to answer this question, but one thing that's happening now is a transition in leadership. As is clear from the photo, the co-directorships at both CMU and Pitt have changed. Peter Strick and Marlene Behrmann have stepped down from these roles after serving their institutions ably and with dedication. We are extremely grateful for the leadership that Marlene and Peter have provided for the CNBC, and we look forward to their continuing engagement into the future.

Another development is the hiring of new faculty. As part of new initiatives at CMU (BrainHub) and Pitt (Pittsburgh Brain Institute) a number of faculty have been hired in CNBC-related areas including Jana Kainerstorfer (CMU Biomedical Engineering), Maysamreza Chamanzar (CMU Electrical and Computer Engineering), Ruslan Sakakhutdinov (CMU Machine Learning), Andreas Pfenning (CMU Computational Biology), and Chris Donnelly (Pitt Neurobiology), William Stauffer (Pitt Neurobiology) and Marc Coutanche (Pitt Psychology).

Our current faculty continue to prosper including Marlene Behrmann's election into the National Academy of Sciences, Bard Ermentrout's Mathematical Neuroscience Prize, and Marlene Cohen and Susanne Ahmari winning two of the six McKnight Scholar Awards given this year.

There are many umbrella organizations across the country and the world that foster collaborative efforts at the interface between brain and behavioral sciences. We continue to see the CNBC as uniquely successful in many dimensions of these efforts, setting an example for others to follow. We are both very pleased to be playing new roles in helping the CNBC move forward.

Rob Kass (CMU) and Nathan Urban (Pitt)

On the Cover:

Cover art: Purkinje cell from human cerebellum. Drawing courtesy of Cajal Legacy. Instituto Cajal (CSIC). Madrid.

"Neurons and Other Memories: Work In and Around the Brain" curated by Patricia Maurides for the CNBC's 20th Anniversary Celebration.

Layout: Kristen McConnell

CNBC 20th Anniversary: Celebrating the Past, Envisioning the Future

The CNBC celebrated its 20th anniversary on October 17-18, 2014, with scientific talks, art, great food and fellowship. All previous and current co-directors were present: Marlene Behrmann (CMU), Jay McClelland (formerly CMU), Robert Moore (Pitt), Carl Olson (CMU), Peter Strick (Pitt), and Mike Tarr (CMU). Patricia Maurides (CMU Fine Arts) curated an exhibit of works related to mind and brain with the artist Greg Dunn discussing his work, which includes many paintings at the CNBC office in Mellon Institute. Alumni speakers (profiled in the last Connect) returned to share their recent work as

CNBC graduates. Several friends of the CNBC spoke about their work: Helen Mayberg (Emory), John Bruer (James S. McDonnell Foundation), Rafi Malach (Weizmann Institute), and Emery Brown (MIT, Harvard Medical School). We were honored to have the company of President Subra Suresh (CMU) and Chancellor Patrick Gallagher (Pitt) at the banquet where the founding co-directors (McClelland and Moore) shared their memories, and where we presented the first Friend of the CNBC award to Mark Roth, a science journalist for the Pittsburgh Post-Gazette.
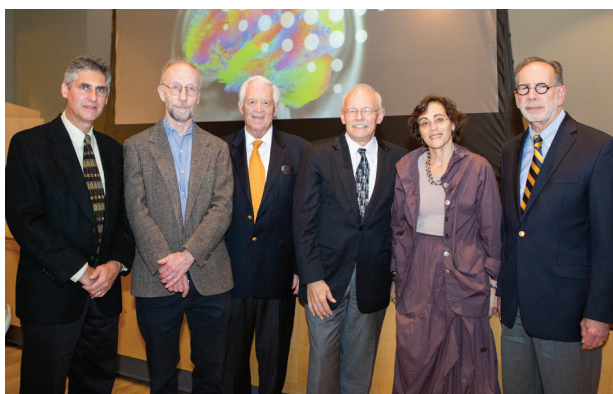
Co-directors past and present (L to R): Mike Tarr (CMU), Carl Olson (CMU), Robert Moore (Pitt), Jay McClelland (CMU), Marlene Behrmann (CMU), and Peter Strick (Pitt).

Alumni Speakers (L to R): Vivenne Ming (Gild, UC Berkeley), Nathaniel Daw (NYU), Randy Bruno (Columbia), Elizabeth Tricomi (Rutgers), Yuko Munakata (Colorado), David Redish (Minnesota), and Rebecca Berman (NIMH) [Matthew Roesch (Maryland) not pictured].

Emery Brown

Rafi Malach

John Bruer

Helen Mayberg

Peter Strick, Mark Roth, and Marlene Behrmann

Artist Greg Dunn discusses one of his paintings.

Faculty Spotlight:
Matt Smith

Matt Smith, Assistant Professor in Ophthalmology (Pitt) and CNBC, is among a significant number of researchers in the CNBC community who combine electrophysiological recording in cortex with computational approaches in order to understand the neural basis of cognition. In particular, Smith's lab studies how groups of neurons represent visual information, and how that representation is altered during eye movements and attention. "One thing I'm particularly interested in is local and global neuronal interactions," Smith notes. "That is, neurons have access to signals shared among nearby neurons that represent what's going on in that millimeter of cortex, and other signals that represent what's happening in other brain regions many centimeters away." To tease apart these neuronal interactions, Smith's lab uses experiments where their subjects repeat tasks to allow measurements of variability to uncover how information flows locally and globally.

In a recent paper in *Nature Neuroscience*, with CNBC post-doctoral associate Adam Snyder, Smith and coworkers recorded EEG signals at the scalp along with a Utah array to monitor the activity of many neurons. This allowed an estimation of the shared signals among local neurons that related them to global brain oscillations. As EEG is a common signal used in human neuroscience, Snyder and Smith probed its relation to underlying neural activity. Using a spatial attention task, Snyder and Smith found that the EEG signal did not show a linear relationship with the activity of small groups of neurons. This was surprising, since the expectation has been that EEG oscillations arise simply because of the shared fluctuations of underlying neurons – more EEG power at the scalp implies more coordination in the neurons. The results show that the relation is not that simple, with the lowest amount of neuronal coordination present at intermediate levels of oscillation in the EEG. This motivated constructing a better model of the non-linear relationship that incorporated inhibitory as well as excitatory neurons. They then tested the model by showing that it could better explain the relationship between EEG oscillations and the animal's variation in performance on the spatial attention task.

An additional research track focuses on visual and eye movement signals in the frontal eye fields (FEF). "We want to know when and what kinds of information passes between oculomotor and visual cortex and how that impacts population codes," Smith notes. Currently, Sanjeev Khanna, a graduate student in Pitt Bioengineering and the CNBC, is working on how interactions among FEF neurons, and between FEF and V4, are modulated during eye movement planning. The goal is to understand how visual information passes around the visual field during eye movements.

Smith and his lab also form a part of "Brain Group," a lab meeting of vision researchers doing electrophysiology that includes the labs of Carol Colby (Pitt CNUP, CNBC), Carl Olson (CMU CNBC), Tai Sing Lee (CMU CNBC, Computer Science), Marlene Cohen (Pitt CNUP, CNBC) and Raj Ghandi (Pitt Bioengineering, CNBC).

Smith began studying biology and psychology, with a minor in computer science, at Canisius College in Buffalo, NY, where he studied the neural basis of hemispheric lateralization and the ability to distinguish left from right using behavioral and neuroanatomical investigations in rats. For graduate school, Smith worked with Tony Movshon at NYU on primate vision, recording all across the visual system —LGN, V1, V2, MT—and investigated how the spatial and temporal responses of individual neurons could reflect the neural circuits performing computation. After receiving his PhD, Smith came to Pittsburgh first as a post-doc with Tai Sing Lee and then with a K99/R00 award to study with Marc Sommer (formerly Pitt CNUP and CNBC; now at Duke). With Lee, Smith focused on the neural signals that underlie visual pop-out and also began recording from large populations of neurons with electrode arrays. In the Sommer lab, he continued with this method, recording from dozens of neurons and analyzing their statistical interactions, with a focus on middle levels of the visual hierarchy and interactions with the oculomotor system.

As a resident in Pittsburgh for 13 years now (with his wife, a pediatric neurologist, and daughter), Smith has come to appreciate the city saying, "My family and I love being in the city with not too much distance between work and home. We definitely enjoy lots of activities in the city like concert series, baseball games, and outdoor festivals. I really enjoy biking and running in the trails and parks here."

Part of the attraction of Pittsburgh has been the intellectual life at the CNBC. "I've been lucky to be able to collaborate with a variety of different people that have expertise outside my strengths," he states. "I find it so much more enriching as a scientist to be able to bring those different ideas and perspectives into my work." Smith also finds the neuroscience community here to be very generous with their time and expertise. "It really makes it a genuine community and not just a collection of scientists," he continued. "I don't know of any other place that can match all those attributes at once. The thing that's remarkable is that the CNBC spans across so much of the campus at two universities and numerous departments, and people mostly just get along and actually work well together. From watching other places, that's apparently quite hard to do, although now that I've been here a long time it just feels natural."

## Marlene Behrmann elected to the National Academy of Sciences

Photo Credit: Trib Total Media

We are pleased to report the election of Marlene Behrmann, Cowan Professor of Cognitive Neuroscience, Professor of Psychology and former Co-director of the CNBC (CMU), to the National Academy of Sciences. Behrmann's election acknowledges the seminal contributions she has made to our understanding of vision, attention, autism, face processing and other fields. Michael Tarr, Head of the CMU Department of Psychology, stated, "Marlene is a world-class scientist and her election to the NAS is well-deserved. She represents the field of Psychology, Carnegie Mellon, and our department with the highest distinction."

Graduate Student Spotlight: **Ying Yang**

On graduating from Peking University, China, Ying Yang was interested in graduate programs that fit her interests in applying computational and quantitative approaches to study the brain. "As an undergraduate, I liked neuroscience and had

some experience with electrophysiological recordings of neurons in the rat brain," she recalls. "Yet, I always hoped to dive into research where I could use more sophisticated mathematical tools to understand the computational principles of the brain." The Program in Neural Computation (PNC) at the CNBC fit her goals perfectly.
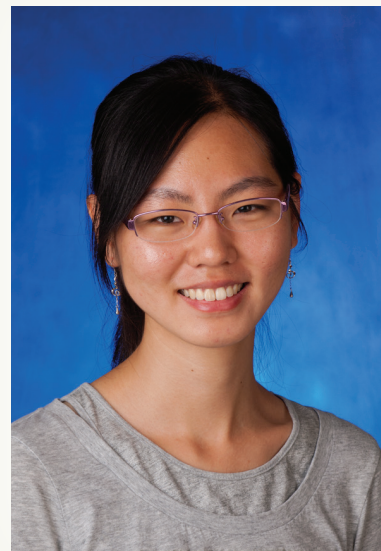
The first year coursework at the PNC in statistics and machine learning allowed Yang to frame her previous mathematical training into a unified perspective. Yang was one of the first students to enroll in the new joint PNC-Machine Learning PhD program, and since 2011, she has been working with Mike Tarr (CMU Psychology and CNBC) and Rob Kass (CMU Statistics, Machine Learning, and CNBC) investigating statistical models for neuroimaging data and computational principles of visual cognition, such as face recognition and scene understanding. "Ying is a remarkable student," Kass observes. "She quickly filled gaps in her computational and statistical background and excelled in all her courses. Her multidisciplinary training allows her to understand problems deeply." Tarr agrees, noting "Ying is a good example of the kind of interdisciplinary student CNBC attracts. Her mastery of empirical and computational approaches allows her to address scientific problems in innovative ways."

Yang's thesis investigates human visual scene processing using magnetoencephalography (MEG) and electroencephalography (EEG). The human visual system has a hierarchical organization where the primary visual cortex extracts low-level features such as edge orientations and the inferior temporal

cortex extracts high-level semantic information to support visual recognition. There remains, however, a gap in detailed understanding of the features processed in mid-level vision. This is complicated by the fact that there is feedback from the higher- to lower-level cortices. To better understand such featural processing, and especially to account for feedback effects, Yang is exploiting the high temporal resolution afforded by MEG and EEG recording methods.

MEG and EEG respectively measure magnetic and electrical signals generated by neural activity. Such recordings can have millisecond temporal resolution of brain activity during behavioral tasks, but they integrate neural signals from all over the brain so their spatial resolution is coarse. An important advance would be to improve spatial resolution by better localizing the source of the measured signals. The problem is that a given MEG or EEG signal is compatible with a number of potential sources of the signal, so improving spatial localization requires solving an "inverse problem": identifying the actual source of the signal.

To solve the "inverse problem" for visual cognition tasks such as face recognition, Yang has constructed a statistical model that searches for spatially sparse and temporally smooth neural signals and optimizes both their correlation with sensor recordings and their correlation with candidate visual features obtained using computer vision models. The statistical model can provide a spatio-temporal profile of correlation between neural responses with different visual features, and hopefully select the best mid-level features from the candidates. The next step will be to examine whether there is top-down feedback between different levels of processing in light of this profile.

Yang has enjoyed being in the highly collaborative CNBC community. "I can talk to both faculty members and students in different domains—machine learning, computer vision, information theory and signal processing," she observes. "The most important thing I have learned is how to look at problems from different points of views and how to address and solve problems in novel ways."

The Multimodal Neuroimaging Training Program (MNTP): A CNBC Success Story

MNTP Co-Directors Bill Eddy (CMU) and Peter Gianaros (Pitt)

A mainstay of the CNBC has been the Multimodal Neuroimaging Training Program (MNTP), supported by two grants from the National Institute on Drug Abuse (NIDA) totaling four million dollars. MNTP started in 2006 as one of three NIH-sponsored neuroimaging training programs in the nation. When the NIH announced a request for applications for "Training Neuroimaging: Integrating First Principles and Applications," Seong-Gi Kim (formerly Radiology, Neurobiology and Bioengineering, Pitt) and Bill Eddy (CMU Statistics, CNBC) designed a special hands-on training program focused on rigorous physical principles and statistical analyses. On Kim's departure to Korea in 2014, Peter Gianaros (Pitt Psychology, Psychiatry, CNBC) took over as the Pitt MNTP co-director.

The MNTP serves two purposes: providing support for 5-7 CNBC graduate students a year from Pitt and CMU and offering a six-week summer training program in brain imaging. The summer workshop provides an intensive, hands-on experience in the collection, analysis, and interpretation of multimodal brain imaging data. It emphasizes experiments that are executed by a small group of workshop participants working under the mentorship of instructors and teaching assistants. At the same time, the MNTP supports lectures and research colloquia open to the community, delivered by local faculty and external speakers. At the conclusion of the workshop, there is a thematic symposium, with topics rotating from year to year. The theme of the ninth (2015) MNTP training program was Health Neuroscience.

Applications for the training program come from around the world and competition for spots is intense with around 12 students accepted each year from a pool of about 70 applicants. "The program has been amazing. Since 2006, 45 graduate student fellowships have been funded (typically one but potentially two years), and 127 students have taken part in the summer workshops," according to Tomika Cohen, administrative assistant for the program. Participants are introduced to a variety of imaging methods: Magnetoencephalography (MEG), diffusion weighted imaging (DWI), positron emission tomography (PET), functional near infrared spectroscopy (fNIRS), functional magnetic resonance imaging (fMRI), and optical imaging for animal studies. Many CNBC faculty, fellows, teaching assistants, and administrative support staff take part.

The workshop has had a very positive impact on students. "This program took me from knowing almost nothing about MEG to having conducted an experiment and performed the analysis successfully in less than two months," recalls Lauren Hopkins, a PhD student from the University of Wisconsin, Madison. "You're not going to get an experience like that anywhere else." Sarah Lichtenstein, a CNBC graduate student (Pitt Psychology) with Erika Forbes (Pitt Psychiatry, CNBC) agrees. "I learned a huge amount about diffusion imaging in only six weeks," she comments. "This summer, we presented the results of our MNTP project as a poster at the Organization for Human Brain Mapping 2015 meeting and also submitted the manuscript describing our findings for publication."

Both students note that while they focused on specific imaging techniques, the interactions and presentations gave them exposure to other approaches and projects. As Kim notes, "Out-of-town MNTP students live together for six weeks at a dormitory, creating special friendship and networks. This is an additional bonus for young scientists."

Indeed, this interaction among participants is echoed in the interaction of the instructors drawn from both Pitt and CMU. Gianaros adds, "The MNTP is a one-of-a-kind resource and an excellent example of a joint Pitt-CMU effort."

Sadly, the grant is coming to an end. The last MNTP summer workshop will be held in 2016 and support for graduate trainees terminates in August, 2016. The funding

mechanisms that support the graduate training program and summer workshop no longer exist, and supporting grants cannot be renewed. Peter Gianaros and the CNBC
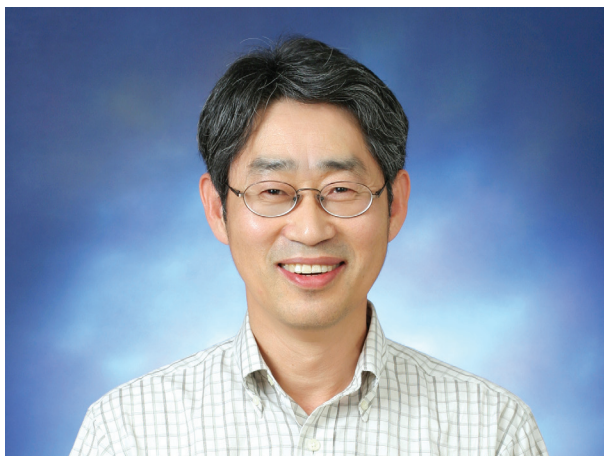
Seong-Gi Kim

leadership are seeking members of the CNBC community who are interested in being involved with a continuation effort of this valuable program by modifying and updating the existing MNTP grant applications. CNBC supporters interested in getting involved should contact Peter Gianaros at gianaros@pitt.edu.

Faculty Recent Awards

Ahmari

Cohen

Suzanne Ahmari & Marlene Cohen have been awarded the McKnight Scholar Award from the McKnight Endowment Fund for Neuroscience.

Ahmari's group (Pitt Psychiatry) investigates the underlying circuitry that is the basis of compulsive behaviors and anxiety disorders with focus on circuit changes and dynamics as potential causes. Recent work has focused on the connections between prefrontal cortex and the basal ganglia.

Cohen's group (Pitt CNUP) works on visual processing, attention and decision making, drawing on

single and multi-electrode electrophysiology and computational approaches. An important goal is to understand the activity of groups of neurons as the basis of the animal's cognitive state and behavioral performance.
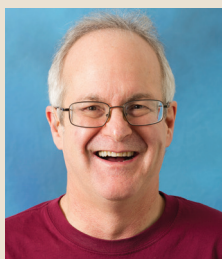
Bard Ermentrout (Pitt Mathematics) has been awarded a $100,000 Mathematical Neuroscience Prize for 2015 from Israel Brain Technologies. The prize recognizes Ermentrout's important contributions to understanding the brain using mathematical analysis and modeling. Ermentrout's group uses approaches from nonlinear dynamics and applied mathematics to get at mechanisms underlying how spatio-temporal patterns are formed in the brain.

CNBC

CENTER FOR THE NEURAL BASIS OF COGNITION

Carnegie Mellon University

5000 Forbes Avenue

Pittsburgh, PA 15213

www.cnbc.cmu.edu

Honors & Awards

Faculty

Marlene Behrmann was named a Fellow of the Cognitive Science Society.

Marlene Cohen was awarded the 2015 Chancellor's Distinguished Research Award from the University of Pittsburgh and a grant from the Simons Collaboration on the Global Brain.

Brent Doiron was awarded a grant from the Simons Collaboration on the Global Brain.

Kirk Erickson was awarded the 2015 Chancellor's Distinguished Research Award from the University of Pittsburgh and the 2014 Senior Beckman Fellowship from the University of Illinois.

Avniel Ghuman received The Biobehavioral Research Award for In-novative New Scientists from the National Institute of Mental Health.

Karl Kandler was appointed as the UPMC Endowed Chair for Auditory Development and Plasticity.

Melissa Libertus received the Early Career Award from the Inter-national Mind, Brain and Education Society.

Susan Perlman received the NIMH Biobehavioral Research Award for Innovative New Scientists (BRAINS).

David Touretzky was named a Senior Member of the Association for the Advancement of Artificial Intelligence.

Tim Verstynen's book *Do Zombies Dream of Undead Sheep* won the 2014 American Publishers Professional and Scholarly Excellence (PROSE) Award for Biomedicine & Neuroscience.

Postdoc

Layla Banihashemi received a K01 from NIMH.

Jordan Williams was awarded an NIH/NINDS Ruth L. Kirschstein National Research Service Award (NRSA) postdoctoral fellowship.

Current Students

Adeetee Bhide won the 2015 Grad Expo Outstanding Presenter.

Erin Crowder received the University of Pittsburgh School of Medicine Department of Ophthalmology's Interdisciplinary Visual Sciences Training Grant.

Mary Gilliam was awarded a 2015 Bassell Student Publication Award by the Clinical Psychology Program, Pitt.

Matthew Golub received the A.G. Milnes Best Thesis Award from Electrical and Computer Engineering at CMU.

Susan Kuo was awarded the Doctoral Foreign Study Award from the Canadian Institutes of Health Research.

Matt Lehet was awarded the Raymond H. Stetson Scholarship in Phonetics and Speech Production from the Acoustical Society of America and 2015 McDonnell Summer Institute in Cognitive Neuroscience Fellowship.

Tina Liu received an NSF Center for Brains, Minds, and Machines 2014 Summer School Fellowship.

Kimberly Lockwood received a National Science Foundation Graduate Research Fellowship.

Sweyta Lohani was awarded an MNTP Fellowship for 2014-2016.

Joe McCaffrey received an external fellowship from the Josephine De Karman Fellowship Trust.

Nicole Rafidi received a Merit Award for her abstract at the Organization for Human Brain Mapping annual meeting.

Dylan Royston received the Best Rehabilitation Research award by a Pre-Doc Student from the Rehabilitation Institute Research Day.

Alba Tuninetti received a 2014-15 Language Learning Doctoral Dissertation Grant, a Provost's Development Fund Fellowship, and an NSF Doctoral Dissertation Improvement Grant.

Ya Zhang was named 2015 AERA Division D In-Progress Research Gala Winner.

Recent Doctoral Graduates

Amy Byrd, Pitt Psychology (Pardini)
Santosh Chandrasekaran, CMU Biological Sciences (Barth & Urban)
Lacey Cirinelli, Pitt Bioengineering, (Davidson)
Alan Degenhart, Pitt Bioengineering (Wang)
Michelle Failla, Pitt CNUP (Wagner)
Alona Fyshe, CMU Machine Learning (Mitchell)
Matthew Golub, CMU Electrical & Computer Engineering (Yu & Chase)
Agnes Haggerty, Pitt Bioengineering (Oudega)
Erin Kirschmann, Pitt CNUP (Thiels)
Marvin Leathers, Pitt CNUP (Olson)
Shuang Li, Pitt CNUP (Tzounopoulos)
Ran Liu, CMU Psychology (Holt)
Xiaonan Liu, CMU Psychology (Reder)
Jungaa Moon, CMU Psychology (Anderson)
Michael Palazzolo, Pitt Bioengineering (Schwartz)
Kristin Quick, Pitt Bioengineering (Batista)
Merissa Remus, CMU Biological Sciences (Thiels)
Brad Rocco, Pitt CNUP (Fish)
Patrick Sadtler, Pitt Bioengineering (Batista)
Suchitra Ramachandran, CMU Biological Sciences (Olson)
Daniel Simmonds, Pitt CNUP (Luna)
Adrienne Taren, Pitt Neuroscience (Tarr)
Leila Wehbe, CMU Machine Learning (Mitchell)