INCUBATOR

UCSD

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In this Issue:

Linking Brain, Mind, and Behavior

INC collaboration yields opportunities for advanced research

INC collaborations continue to have a broad impact, resulting in prominent publications and garnering major funding support. Ongoing, INC-based collaborative research at the Schwarz Center for Computational Neuroscience focuses on scientific challenges that pose significant limitations for the field of experiments utilizing EEG technology. Efforts to free neuroscience from the restrictive technologies of cumbersome electronics and conductive gels that pose risks and limits to the study of normal human behavior present substantive obstacles which current research attempts to resolve, while also providing more complex and subtle modes of observation and data analysis.

INC's proposed development of mobile brain / body imaging systems (MoBI) was presented in the *International Journal of Psychophysiology* article, "Linking Brain, Mind and Behavior." Summarizing key issues in the study of "embodied cognition," INC scientists Scott Makeig, Klaus Gramann, Tzyy-Ping Jung, Terrence Sejnowski, and Howard Poizner address the key concepts central to studying natural behavior in changing environments.

By noting the importance of human behavior in cognition, and the role of the environment, imagination, and abstract cognition as a part of body-based behavior and the brain's body image, new approaches and technologies are proposed to contend with the limitations of extant research methods and technologies. (fig a, b) In contrast with typical EEG recording methods, INC scientists have developed MoBI recording

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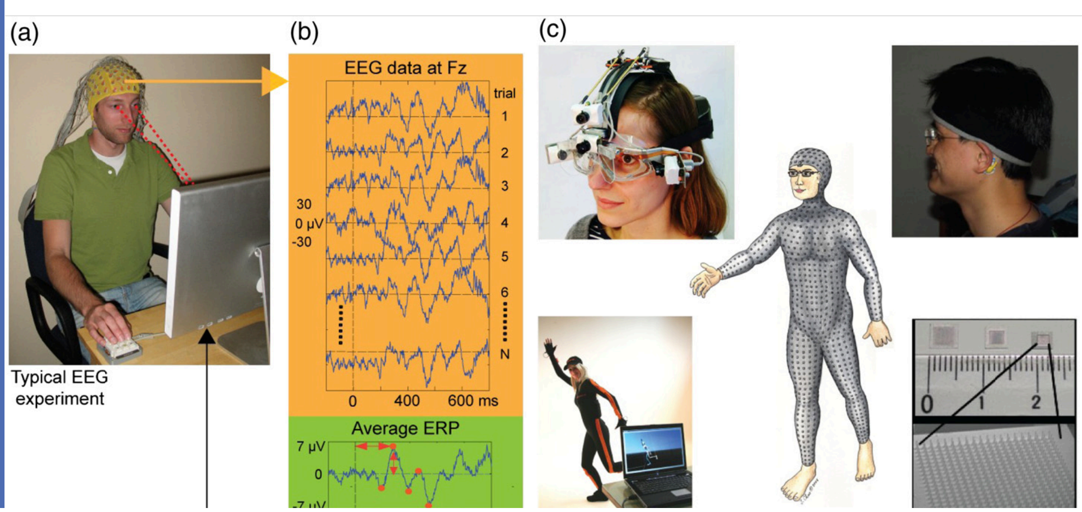

$1.9M EFRI M3C Grant for INC

distributed brain dynamics in motor control

This fall, the NSF Office of Emerging Frontiers in Research and Innovation (EFRI) awarded a $1.9M grant to the project INC proposal, "Distributed Brain Dynamics in Human Motor Control." The grant is a part of EFRI's initiative to support advances in the development of robotics, engineering, and medicine, or Mind, Machines, and Motor Control (M3C).

The project aims to combine cognitive and computational neuroscience, neuro-engineering and system identification towards a transformative understanding of the way distributed brain dynamics interact with motor activity in humans. 3-D body and limbs movement kinematics, eye movements and electro-encephalographic (EEG) spatiotemporal brain data will be recorded simultaneously during motor control and adaptation in healthy and Parkinson's disease patients.

Altered and real world motor tasks will be simulated in 3-D immersive virtual reality technology, with robots which provide proprioceptive interaction and feedback. Large-scale computational models of motor control and adaptation will be designed, based on the anatomy and physiology of the basal ganglia, and constrained by cognitive, behavioral and kinematic data.

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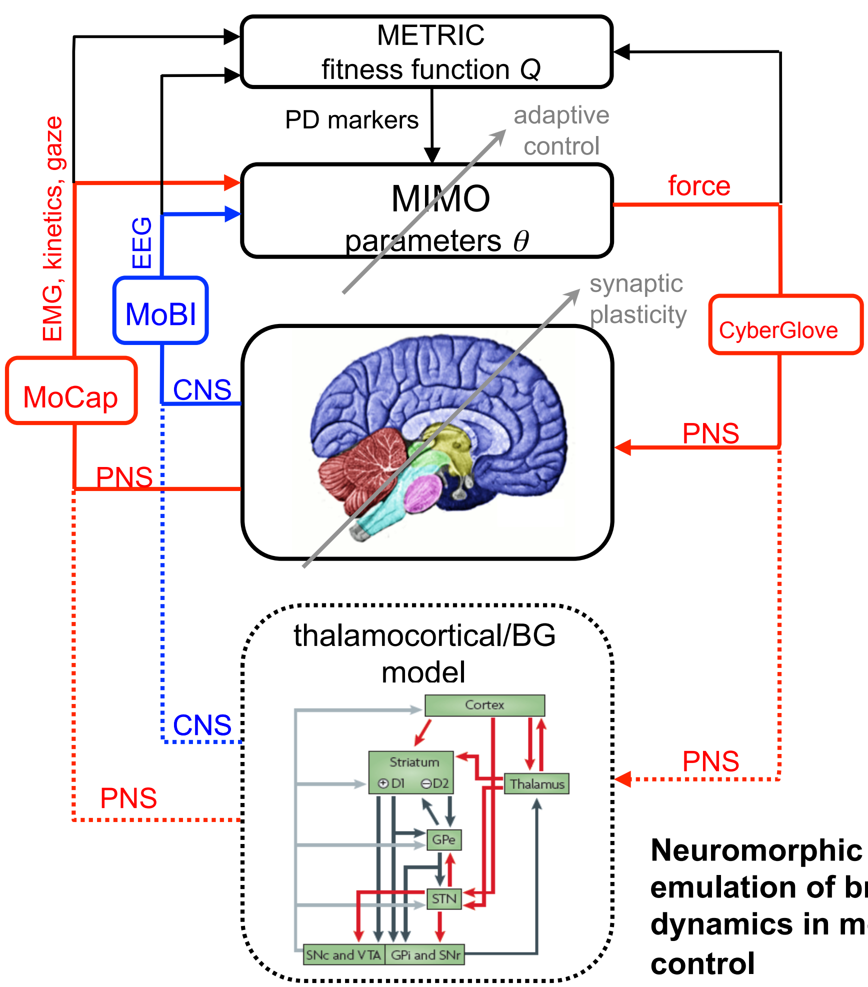

Neuromorphic emulation of brain dynamics in motor control

Diagram: Brain-machine interfaces, prosthetics and telemanipulation

The confluence of cognitive and computational neuroscience, control theory, and wearable bioinstrumentation will provide non-invasive approaches for the treatment and neuro-rehabilitation of patients with Parkinson's disease.

EFRI Grant, cont from page 2

The program team, led by INC Co-director Gert Cauwenberghs, expects the development of new machines for neuro-rehabilitation will result in synergy between engineering and neuroscience. Comprehensive and predictive mathematical models of motor control implemented in neuromorphic hardware are expected to lead to new intelligent neuroprosthetic tools. Human-machine interactions will transform the notion of movement control and provide new contexts to study embodied cognition, resulting in new knowledge in neuroscience and motor control which will accelerate the development of adaptive machines for rehabilitation.

The program will facilitate and supervise increased participation in research for the next generation of scientists and engineers through campus outreach supported by the TDLC and the NSF Research Experience for Undergraduates (REU).

Outcomes of the project, funded through 2015, are expected to have broad impact and applications, leading to the development of a new generation of wireless brain and body activity sensor and adaptive prosthetic devices. This will advance our knowledge of human-machine interactions, stimulate the engineering of new brain/body sensors and actuators, and have a direct influence in diverse areas where humans are coupled with machines, such as brain-machine interfaces, prosthetics and telemanipulation.

Linking Brain, Mind &, Behavior
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methods which allow researchers to record body movement through motion capture suits and prototype technologies to follow and record the gaze. (fig. c) This innovation over the restricted movement of typical EEG experiments constitutes a significant advance in the study of embodied cognition.

In addition to new approaches to recording and observation technologies, INC scientists identify the importance of developing and expanding methods and software for processing data derived from both brain and body recording. Preliminary experiments have identified characteristic patterns in EG dynamics and the natural behavior if the body, raising numerous questions and opportunities for further research. Significant attention to coupled observations using and developing MoBI technology are central to future developments in studying open methodological, experimental and theoretical questions.

Further developments and application of MoBI technology and related processing methods have widespread application, including the study of learning and social interaction, as well as the role of embodied cognition in adaptation and navigation.

Citation: "Linking Brain, Mind, and Behavior"
International Journal of Psychophysiology
73 (2009) 95–100

http://www.sciencedirect.com/science/article/pii/S0167876009001032

Staff Spotlight - INC MSO Shelley Marquez

integral team member and top administrator reflects on INC & UCSD

Shelley, you've been recognized as a particularly valuable member of INC as reflected by your being awarded the Betsy Faught Award in 2009 for excellence in academic program management. As you move on to greener pastures, how have INC and the University grown and changed?

I was first hired at UCSD in 1982 in the Institute for Geophysics and Planetary Physics of Scripps Institution of Oceanography (SIO) as a bilingual administrative assistant. I provided administrative support to several researchers working on projects to install seismic and strong motion arrays in Mexico around major faults.

After a series of small earthquakes in the San Diego Bay in 1984, I had a seismometer installed in my backyard for several months to record aftershocks. My house is listed at Caltech Seismological Lab as station Casa de Marquez (CDM) for data collected during that period.

I worked at SIO 13 years and enjoyed learning about seismology and crustal deformation, as well as surfing Scripps Pier every day at lunch.

On my first day at UCSD, I had to type a research proposal on a typewriter. Since they used Greek symbols for their equations, I would have to pause and put a new metal ball on the typewriter for each typeface change, and soon had memorized the locations of DELTA, OMEGA, and EPSILON on my keyboard. To revise a paragraph that had been deleted, I would literally take scissors and cut the paragraph from the page, and then paste the remainder onto a new page to continue typing. (We edited far less frequently in that era before word processors.)

I remember when several of our researchers joined DARPANET, the first computer-based communication system and forerunner of the Internet. Within a year we all had e-mail accounts. My first personal computer at UCSD was an Apple II.

The 90s were a golden age for research as the University began decentralizing authority down to the department level to make getting things done easier (the opposite of what is happening now in this decade of “accountability” and budgetary deficits).

In 1995, I moved to “upper campus” as we at Scripps called the general campus, to work as a business officer in Latin American Studies for a few years before moving into the areas of research that I have managed ever since, in the Center for Research in Language, the Institute for Neural Computation, and the Kavli Institute for Brain and Mind.

Working in these research laboratories, I have received a top-rate education in language, brain development and disorders, psychology, cognitive science, and learning and memory.

When did you join INC?

I joined INC in 2002 becoming one of the first MSOs on campus to manage two separate organized research units. At the time, INC was bringing in about $2M in federal contracts and grants, including a NIH training program in Cognitive Neuroscience and a NSF training program in Computational Neurobiology. It occupied one small wing of the 2nd floor of the Cognitive Science building.

In the past 10 years INC has grown to more than $12M in research funding, and we now occupy one floor of the San Diego Supercomputer Building and space in Atkinson Hall.

Administration is an important part of the university and research. Can you describe some of your responsibilities guiding and coordinating so many different groups?

My personal mission has always been to provide support to the faculty, post-docs and students so that they can successfully accomplish their research and not have to worry too much about the bureaucracy. As MSO of 3 organized research units and Executive Director of one NSF-funded Center I have been a conduit to share information and funding opportunities, and push back against the growing boundaries to doing something exceptional to policy in this new risk-averse environment. Research takes risk.

As someone with a great deal of experience in research at UCSD, how is INC unique?

INC is unique in my opinion because it has grown and thrived for the past 21 years without a significant initial investment by University, government or private sources.

What will you miss about INC?

"The people."

It all began in April 9, 1990 with a name change of the former Institute for Cognitive Science to the Institute for Neural Computation, a $20,000 loan from the Department of Biology, and one office in the Cognitive Science Building.

INC's inaugural research mission was to gain an "understanding of how nervous systems function through direct observation, experimental investigation, and modeling of neural structures. It extends into the field of psychology where it seeks to uncover cognitive principles through psychological experimentation and parallel-distributed processing models. It will apply these principles of neural computation toward the solution of diverse technological and scientific problems, particularly the building of a new generation of massively parallel computers." [from the first UCSD catalog copy entry, 1990].

Now, if you look at this newsletter and our website, you can see all of the interesting stuff we are doing.

As you look forward to more of time to pursue personal interests, how will you be spending your time?

Sleeping in, yoga and pilates, travel, and studying foreign languages. I look forward to forgetting all the administrative acronyms that have cluttered my brain for the past 30 years, such as eRAP, ECERT, EPET, NPET, RES form, etc. and especially, anything to do with "Marketplace."

What will you miss about INC?

The people.

Faculty Spotlight - Todd Coleman Joins INC

new affiliated faculty brings leading edge research

Newsletter editor Chanda Carey sat down with Todd Coleman, director of the Neural Interaction Laboratory, who recently joined the faculty of Bioengineering as an Associate Professor. Todd is also affiliated with INC, and we had a chance to learn more about his research and diverse scholarly interests.

Would you tell us a bit about the path that brought you here to San Diego?

I was originally trained as an electrical engineer through my Bachelors degree at Michigan, all the way to my PhD at MIT. Then, I did a postdoc in something very different, neuroscience, and I subsequently went to the University of Illinois and spent 5 years on the faculty there in the EE department, as well as the neuroscience program.

That's where I began to work on projects at the intersection of neuroscience and engineering. It began to be quite a bit of fun, a fascinating situation where the science underlying neuroscience helped me formulate new engineering and theoretical questions. Moreover, I used a lot of these theoretical tools to understand brain function. So, it was a very synergistic interplay between the two disciplines.

Then, I was recruited here from Illinois. San Diego has an incredible neuroscience tradition, both on campus as well as across the street at the Salk Institute. Secondly, there's a great medical school and the engineering tradition is very strong. Take that, as well as the weather into consideration and it wasn't too difficult of a decision to make.

You're affiliated faculty with INC. How does that enhance your research?

It's great. You take a look at the people who are at INC, we synergize extremely well. For example, one of the things I'm working on here, which started at Illinois, is developing brain-machine interfaces where we put signals and monitor human brain activity on the surface of their head and couple that to some external device. So, at the end system, the user and the device can accomplish some goal more efficiently than could be done individually.

Contributing research:

"themes that might be of use to INC"

1) flexible, ultra-thin bio-electronics

2) dynamic neural signal processing algorithms

3) control theory algorithms for BCI

4) interpretation of BCI data

Scott Makeig and Tzzy-Ping Jung have both developed lots of technology and algorithms for these paradigms and I think the viewpoint we're providing, from the perspective of team decision theory, feedback information theory, and control theory is quite complimentary to their neural signal processing algorithms. As such, I think brain-machine interface research is improved by my presence. We've been in discussion and are in the process of writing a proposal.

Secondly, some of the quantitative approaches that we've developed to understand brain function are being used in collaboration with Howard Poizner, in some of his research into Parkinson's Disease.

We're attempting to understand how the dynamic interactions between neural processes are different when someone with Parkinson's tries to accomplish a motor task, as compared to a normal control subject. It's very applicable, and we share a postdoc.

Gert Cauwenberghs, one of the co-directors of the institute, is one of my colleagues in bioengineering. We have many overlapping research interests. We're actively working towards collaboration. Lastly, Terry Sejnowski is one of my heroes. He is a unique embodiment of quantitative understanding in its own right in the area of machine learning, decision making, and those fields to which he has made distinguished contributions, using these principles to understand brain function, both at the level of experiments, as well as quantification. The fact that he is one of the co-founders of INC makes me honored to be a member.

Are there any key projects you're bringing to campus, or perhaps these collaborations with INC you'd like to tell our readers about?

I'd say there are three themes that might be of use to INC, notably, developing new core technology. One of things we're working on is flexible skin-mounted electronics that can sense bodily signals, literally as thin as a temporary tattoo, so you don't feel it on the body and the observers can't see the electronics, which can monitor brainwaves, also record interesting behavioral signals, which people like Howard Poizner would be interested in. We can record motor kinematics, we can record brainwaves, in a manner

which is extremely thin and minimal, which can transmit these bodily signals wirelessly to researchers, or medical personnel, or even your cell phone. We think this technology could be extremely useful for a lot of the research teams at INC. For example, MoBI Lab, attempts to monitor people's behavior and their brain signals in very natural, mobile environments. The technology that we are developing is completely in synergy with that -- likewise, for the NSF Temporal Dynamics of Learning Center.

Secondly, in some of the quantitative approaches that we're developing in terms of receiving signals, we're attempting to understand the way in which all of these signals are interacting with one another. It's quite common in neuroscience now to have technology that enables one to simultaneously acquire an overabundance of bodily signals; but how do we take these time series and understand function? This "data deluge" problem is not only a problem for neuroscience, but for Google, and almost any company that's trying to make sense out of data. In neuroscience this is increasingly the norm, and we are

Epidermal electronics open up vast possibilities for applications from medicine to consumer electronics

developing some succinct quantitative graphical models in terms of directed graphs that are describing the fundamental interaction structure between neural processes and are closer to understanding the causal relationships between things. So, rather than only being able to understand these two things are associated with each other, we can start to understand what caused the other. We're developing a framework to develop these models that are applicable to many modalities, not just one.

Would you elaborate on the real world applications of the core technology, like the 'temporary tattoo' sensor?

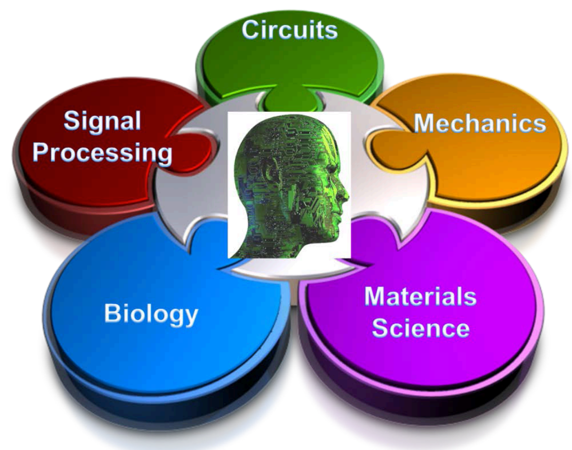
I recently presented on this topic to the corporate advisory board of the School of Engineering, addressing clinical applications, as well as general-purpose consumer products applications. I think on the clinical side, the ability to have continuous monitoring of someone's physiological signals in a manner that does not disturb the way they naturally interact with the environment is something that has been the gold standard for clinicians, but hasn't been achieved as of yet. When we attempt to develop continuous monitoring sensors they tend to be somewhat big and bulky, making the experience somewhat unnatural.

Potential advances with the technology that we're developing with some clinicians here in San Diego, open new possibilities. Instead of saying, "Take two of these and call me in the morning," they will be in a position to say, "Wear this and I'll call you if there's a problem." We're pushing hard to get this in the hands of the clinicians at the medical school to see if this can transform neurological care, in particular. In terms of consumer products, we are also thinking about athletes and performance monitoring. Imagine if I'm wearing some clothing that has some of these flexible electronics in it and it can sense your kinematics, your heartbeat, and a number of other signals of interest, and afterwards be able to understand so much about the effects and conditions of training in ways you wouldn't be able to otherwise. You could use this information to optimize diet, training regimen, maybe even change the way you throw a football. Then you could throw a football more like Eli Manning. We're envisioning many applications beyond significant contributions to the health care and clinical space which could be achieved with this technology.

"In some of our research in brain-computer interfaces, we're able to do very sophisticated things that one could not do otherwise. We think this has implications not only for someone who uses a brain-computer interface with a special need or deficit, but also facilitating the search process."

--Todd Coleman

When we first published our paper on the tattoo electronics in *Science* in August, it got picked up by CNN and other places. We would periodically look at blog entries and it's unbelievable some of the applications that people have come up with that we have not even thought about. One thing that's great about the interconnected world of social media is that we can outsource ideas and applications from the creativity of the social world.



What was one of the most interesting ideas?

One that came up that we're exploring with the clinicians is monitoring neurological function in babies. Babies have very unique qualities, in that their skull is not nearly as thick, so we might be able to sense all different kinds of function much deeper in the brain than we could adults. Secondly, babies' heads are covered with much less hair, so we can cover more of the head with the tattoo technology and get very thorough understand of brain function over a baby's head. Lastly, this led us to think about pregnancy monitoring, because our electronics are flexible. There's a lot that could be learned, and multiple health applications possible in observing a woman's pregnancy. That comes from one of these ideas that we've mined and expanded upon through social media.

A third project that we're thinking about is our viewpoint on brain-computer interfaces, which is another important area that compliments the work going on at INC. The viewpoint that we're developing is the sensor, how you get the signal. Another value-addition that we're providing is the interpretation of a brain computer interface, or even any human-computer interface, as a coupling between two interacting decision-making systems. One decision-making system is the brain and the other is a device, like your smart phone, or this computer that's acquiring your brain signals and giving you feedback. One of the values that were trying to espouse is that people need to spend more time thinking about is, how does this device, which is acquiring noisy signals of your intent – how does it take these noisy signals and provide you the most minimal, "Steve Jobs-type" form factor? So, we develop new theory to address that. In some of our research in brain-computer interfaces, we're able to do very sophisticated things one could not do otherwise. We think this has implications not only for someone who uses a brain-computer interface with a special need or deficit, but also facilitating the search process. Thinking about a variety of different scenarios in the future, by us being coupled with an external device our daily lives can be enhanced via this process. So, that's the bet that we're placing.

You've been talking about users coming to these new technologies in the context of smart phones, and referred to design conscious approaches like those associated with Steve Jobs. You're planning to work on possibilities for understanding and advancing creativity with interdisciplinary faculty across campus, centered in digital media and arts. Could you share a bit more about how those activities relate to your current and past research?

I think the best example for me of that in developing the flexible electronics required interaction between people in many different disciplines. We had to understand the physiology of skin, mechanics, electrical engineering and chemistry. Then we had to combine all these things together over a space of three years to come up with this tattoo technology solution. I think that's a great example of interdisciplinary collaboration. I think to solve the world's problems in this century it's going to require people of many different disciplines coming together. If you look at the 20th century, many people might argue it was the century of physics. Many of society's problems were addressed from the perspective of the sciences by having one pillar and people pushing the frontiers of physics. I think if we take a look at the world's problems as they stand today, in terms of energy, social conflict, the world expanding, understanding the brain and biological systems, it's going to take people from many different disciplines and creativity is going to have a very special place, particularly with the human factors there.

If you look at the world's most successful company Apple, one could argue that a major part of its success comes from its founder's deep appreciation for creativity, and the artistic human experience that is common to all of us. I resonate with that and try hard to follow and expand on that insight.

Our research group is very interdisciplinary and we enjoy interacting with people from all different parts of campus, throwing them in a Petri dish and watching what new life forms emerge afterwards. My gut tells me the important challenging problems we're currently facing in society are going to require creativity and interaction from very different disciplines.

That's the bet that I'm making.

Neural Interaction Lab http://coleman.ucsd.edu/

Citation

Epidermal electronics Kim et al., Science, 333 (6044): 838-843

http://www.sciencemag.org/content/333/6044/838.abstract

Additional commentary

An Electronic Second Skin Zhengquiang Ma, Science, 333 (6044): 830-831

http://www.sciencemag.org/content/333/6044/830.summary

Full coverage (via Neural Interaction Lab)

Science Online – “Epidermal Electronics”

Science Perspectives (Commentary) – “An Electronic Second Skin”

CNN News – “Tattoos good for your heart?”

New York Times – “Tracking Vital Signs, Without the Wires”

TIME Healthland – “Can a Tiny Electronic Tattoo…”

BBC News – “Electronic Tattoo”

NBC 7 San Diego News – “Electronic Skin Monitors Patients”

Financial Times – “Smart Skin”

Nature News – “Electronic Skin”

Popular Science – “Epidermal Electronics”

Technology Review – “Stick-On Electronic Tattoos”

University of Illinois News – “Smart Skin”

Daily Illini – “New technology provides interface between humans, computers”

UCSD Jacobs School News – “Wearable Electronics”

ZDNet – “A Better Wearable …”

Electronics Weekly – “Electronics Stretch Like Skin”

io9 Science Blog – “Electronic Circuits”

Gizmag – “Skin Mounted Electronics”

INCEVENTS

SEMINARS

NEUROENGINEERING SEMINAR SERIES

07/18/11 **Sergio Davies**
Francesco Gallupi The SpiNNaker System: A Universal Spiking Network Architecture
09/26/11 **Ratnesh Lal**
Atomic force microscopy and molecular nanotechnology for systems neuroscience and neuroengineering
09/26/11 **Mohsen Mollazadeh** Integrated cortical interfaces for analysis and control of hand movements
01/17/12 **Charles Unsworth** Patterning human neurons and astrocytes on silicon chip
01/23/12 **Mustafa Culha** Nanoplasmonics in biomedical sciences and medicine

COMPUTATIONAL NEUROSCIENCE SEMINAR

10/20/11 **Terrence Sejnowski** Suspicious coincidences in the brain

BIOENGINEERING SEMINAR SERIES

08/25/11 **Barbara Hanna** Cortically coupled image search: a practical system
07/20/11 **Emre Neftci** Toward VLSI Spiking Neuron Assemblies as General Purpose Processors

CHALK TALKS

03/10/11 **Bill Kristan** Leech electrophysiology and functional connectivity
09/22/11 **Todd Coleman** A team decision theory approach to the design of brain-machine interfaces
10/06/11 **Christopher Rozell** Sparse coding and compressed sensing in neural systems
10/20/11 **Joe Snider** EEG in an immersive environment with free movement: object recognition and theta auto correlation
11/03/11 **Samat Moldakarimov** Feedback model of visual perception learning
11/17/11 **Tim Gentner** Learning-dependent modification of auditory responses across forebrain networks
12/08/11 **Mikhail Rabinovich** Cognitive information dynamics
01/19/12 **Lars Kai Hansen** Sparse non-linear denoising of fMRI data
01/26/12 **Claudia Lainscesk** Probing epilepsy in human cortex with delayed differential equations

For more information on current events,
please contact **Kristen Michener** kmichener@ucsd.edu

INCEVENTS

KIBM Workshops

01/18/12 **Jean-Pierre Changeux** The neurobiology of consciousness

02/01/12 **Ann-Shyn Chiang** Connectomics mapping of memory circuits in the drosphila brain

INC Talks

04/13/11 **Surya Ganguli** Compressed sensing and memory traces in neural networks

04/15/11 **John Doyle** Network architecture and its discontents

08/10/11 **Yoram Boram** Augmented reality for gait improvement

08/12/11 **Yoram Boram** Chaotic multiplexity in synaptically modulated neural firing

TDLC Special Speaker Series

01/27-28/12

David Poeppel The architecture of speech and its temporal foundations

Daniel Feldman Time scales and inhibitory circuit mechanisms for cortical sensory coding and plasticity

Uri Hasson Topographic mapping of a hierarchy of temporal receptive windows using natural stimuli

Awards, Honors, and Collaborations

Tzyy-Ping Jung

-- awarded $97K by Nissan Motor Corp to study,

"The Effects of Distraction on Driving Performance and EEG Dynamics"

"Highlights of 2011" -- "A cell-phone-based brain-computer interface for communication in daily life," published in Journal of Neural Engineering, has been selected as one of the journal's highlights, and downloaded more than 1290 times. The article and INC researcher Tzyy-Ping Jung were featured in the Spring 2011 issue of INCubator.

INC Research Groups and staff

Institute for Neural Computation (INC)
http://www.inc.ucsd.edu
Terrence Sejnowski and Gert Cauwenberghs, Co-Directors
Shelley Marquez, Executive Director

Swartz Center for Computational Neuroscience at INC
http://www.sccn.ucsd.edu
Scott Makeig and Tzyy-Ping Jung, Co-Directors

Machine Perception Laboratory at INC
http://mplab.ucsd.edu/
Javier Movellan, Marian Stewart Bartlett, and Glen Littlewort, Principal Investigators

Temporal Dynamics of Learning Center (TDLC) Motion Capture/Brain Dynamics Facility at INC
http://inc.ucsd.edu/~poizner/motioncapture.html
Howard Poizner and Scott Makeig, Co-Directors

Office of Naval Research (ONR) Multidisciplinary University Initiative (MURI) Center
http://inc.ucsd.edu/~poizner/onr_muri/
Howard Poizner, UCSD (PI); Gary Lynch, UCI (Co-PI); Terrence Sejnowski, Salk Institute/UCSD (Co-PI)

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