Keynote Speaker:

Mikhail Rabinovich

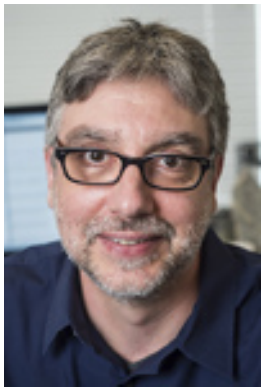
Biocircuits Institute
University of California, San Diego

Sequential information coding in the brain: binding, chunking and episodic memory dynamics

Sequential information coding is a key mechanism that transforms complex cognitive brain activity into a low-dimensional dynamical process based on the sequential switching between finite numbers of localized patterns. The storage size of the corresponding process is large because of the permutation capacity as a function of the signal control in ensembles of these patterns. Extracting low-dimensional functional dynamics from multiple large-scale neural populations is a highly relevant problem both in neuro- and cognitive-sciences. Experimental results in the last decade represent a solid base for the creation of low-dimentional models of different cognitive functions and allow moving towards a dynamical theory of consciousness. We discuss here a methodology to build simple kinetic equations that can be the mathematical skeleton of this theory. Models of the corresponding discrete information processing can be designed using the following dynamical principles: (i) clusterization of the neural activity in space and time and formation of information patterns; (ii) robust sequential dynamics based on heteroclinic chains of metastable clusters; and (iii) sensitivity of such sequential dynamics to intrinsic and external informational signals. We analyze sequential discrete coding based on winnerless competition low-frequency dynamics. Under such dynamics, entrainment and heteroclinic coordination leads to a large variety of coding regimes.

Computational & Systems Neuroscience Symposium

IUPUI, April 27, 2018



Keynote Speaker:

Olaf Sporns

Department of Psychological and Brain Sciences, Indiana University, Bloomington, IN

Network Neuroscience

Modern neuroscience is in the middle of a transformation, driven by the development of novel high-resolution brain mapping and recording technologies that deliver increasingly large and detailed "big neuroscience data". Network science has emerged as one of the principal approaches to model and analyze neural systems, from individual neurons to circuits and systems spanning the whole brain. A core theme of network neuroscience is the comprehensive mapping of anatomical and functional brain connectivity, also called connectomics. In this lecture I will review current themes and future directions of network neuroscience, including comparative studies of brain networks across different animal species, investigation of prominent network attributes in human brains, and use of computational models to map information flow and communication dynamics. I will argue that network neuroscience represents a promising theoretical framework for understanding the complex structure, operations and functioning of nervous systems.

IUPUI, April 27, 2018

Leslie M. Kay

Department of Psychology

Institute for Mind and Biology

University of Chicago

Tracking cognitive modes using dynamical state switches in the mammalian olfactory system

The mammalian olfactory system displays characteristic oscillatory phenomena as measured in the local field potential. Classically, these oscillations were identified as respiratory (theta, 2-12 Hz in rats) and gamma (40-100 Hz in rats), with gamma oscillations initiated at the peak of inhalation. More recently, beta (15-30 Hz) oscillations have been identified and have been shown by my lab and others to be evoked by repeated exposure to high volatility odorants and also by associative learning. Physiological and behavioral analysis of gamma and beta oscillations show that during odor sampling bouts (~450 msec) rats produce 2-4 fast sniffs in which the olfactory bulb (OB) produces gamma oscillations that abruptly switch to beta oscillations later in the sampling bout. The transition and timing is reliable across tasks, odors, and learning context, but the amplitudes of both types of oscillations are independently associated with each of these factors. Modeling results suggest the transition is gated by excitability of local inhibitory interneurons via multiple pathways (sensory and top-down inputs, synaptic strength, neuromodulators). Predictions of the model have now been verified by via pharmacological manipulations. The two states are presumed to encompass early feed-forward sensory processing followed by system-wide engagement during beta oscillations to plan and carry out a response.

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John Beggs
Biophysics,
Indiana University

IUPUI, April 27, 2018

What is criticality, and why might it matter for brain health?

Research over the past decade in animals and humans has accumulated to show that the cortex operates near a critical point. At criticality, the cortex is poised between a phase where activity is damped and a phase where activity is amplified. Experiments and simulations show that information processing is optimized near this critical point, and that deviations from criticality are associated with neurological disorders like epilepsy and depression. Here I will briefly describe the critical point in cortical networks and how it is relevant for human health.

Joaquin Goni
Industrial Engineering and Biomedical Engineering,
Purdue University

The quest for identifiability in human functional connectomes

The evaluation of the individual "fingerprint" of a human functional connectome (FC) is becoming a promising avenue for neuroscientific research, due to its enormous potential inherent to drawing single subject inferences from functional connectivity profiles. Here we show that the individual fingerprint of a human functional connectome can be maximized from a reconstruction procedure based on group-wise decomposition in a finite number of brain connectivity modes. We use data from the Human Connectome Project to demonstrate that the optimal reconstruction of the individual FCs through connectivity eigenmodes maximizes subject identifiability across resting-state and all seven tasks evaluated. The identifiability of the optimally reconstructed individual connectivity profiles increases both at the global and edgewise level, also when the reconstruction is imposed on additional functional data of the subjects. Furthermore, reconstructed FC data provide more robust associations with task- behavioral measurements. Finally, we extend this approach to also map the most task-sensitive functional connections. Results show that is possible to maximize individual fingerprinting in the functional connectivity domain regardless of the task, a crucial next step in the area of brain connectivity towards individualized connectomics.

Robert Rosenbaum

Dept. of Applied and Computational Mathematics and Statistics,
Notre Dame

A reservoir computing model of motor learning with parallel cortical and basal ganglia pathways

Reservoir computing is a biologically inspired class of learning algorithms in which the intrinsic dynamics of a recurrent neural network are mined to produce target time series. Most existing reservoir computing algorithms rely on fully supervised learning rules, which require access to an exact copy of the target response, greatly reducing the utility of the system. Reinforcement learning rules have been developed for reservoir computing, but we find that they fail to converge on complex motor tasks. Current theories of biological motor learning pose that early learning is controlled by dopamine modulated plasticity in the basal ganglia that trains parallel cortical pathways through unsupervised plasticity as a motor task becomes well-learned. We developed a novel learning algorithm for reservoir computing that models the interaction between reinforcement and unsupervised learning observed in experiments. This algorithm converges on simulated motor tasks on which previous reservoir computing algorithms fail, and reproduces experimental findings that relate Parkinson's disease and its treatments to motor learning. Hence, incorporating biological theories of motor learning improves the effectiveness and biological relevance of reservoir computing models.

Leonid Rubchinsky
Department of Mathematical Sciences,
IUPUI
Indiana University School of Medicine,
Stark Neurosciences Research Institute

IUPUI, April 27, 2018

Dynamics of intermittent neural synchronization: observations, mechanisms, and functions

Synchronization of neural activity in the brain is involved in a variety of brain functions including perception, cognition, memory, and motor behavior. Excessively strong, weak, or otherwise improperly organized patterns of synchronous oscillatory activity may contribute to the generation of symptoms of different neurological and psychiatric diseases. However, neuronal synchrony is frequently not perfect, but rather exhibits intermittent dynamics. The same synchrony strength may be achieved with markedly different temporal patterns of activity. I will discuss methods to describe these phenomena and will present the application of this analysis to the neurophysiological data in healthy brain, Parkinson's disease, and drug addiction disorders. I will finally discuss potential cellular mechanisms and functional advantages of some of the observed temporal patterning of neural synchrony.

Christopher Lapish
Neuroscience Program
Department of Psychology, IUPUI

Intention signals in prefrontal cortex and compulsive drinking

The prefrontal cortex is a brain region that plays a central role in controlling complex behaviors and decisions. Evidence suggests that prefrontal cortex function is altered in alcohol use disorders, however the specific computational processes that are negatively impacted by alcohol use remain to be determined. In this talk, I will explore how computation is altered in the prefrontal cortex of a rodent model of compulsive drinking. The results of our work indicate that signals related to the intention to drink alcohol are blunted in the prefrontal cortex of rats that drink alcohol compulsively. These data indicate that once drinking progresses to a compulsive stage that the decision to drink may be relegated to brain regions other than prefrontal cortex, and thus may underlie the inability to abstain from using alcohol.

Alexey Kuznetsov
Department of Mathematical Sciences,
IUPUI

Circuit-level mechanisms of alcohol influence on dopamine system

A large body of experimental data has paved the way towards a clearer understanding of the specific molecular targets through which ethanol (EtOH) acts on brain circuits. Yet how these multiple mechanisms interact to result in dysregulated dopamine (DA) release under alcohols influence remains unclear. In this report, we delineate potential circuit-level mechanisms responsible for EtOH-dependent increase and dysregulation of DA release from the ventral tegmental area (VTA) into its projection areas (e.g. nucleus accumbens, NAc). For this purpose, we constructed a circuit model of the VTA composed of DA and GABAergic neurons, that integrate external Glutamatergic (Glu) inputs to result in DA release. In particular, we reproduced the concentration-dependent effects of EtOH on DA neuron activity, where an increase in firing at small to intermediate concentrations is replaced by decrease in firing at high concentrations. Our simulations predict that a certain level of synchrony in Glu afferents to VTA is necessary for the firing rate increase produced by EtOH. Moreover, EtOH's effect on the DA neuron's firing rate and, consequently, DA release, can reverse depending on the average activity level of the Glu afferents. Further, we propose a mechanism for the emergence of transient (phasic) DA peaks and the increase in their frequency following EtOH. Phasic DA transients result from DA neuron population bursts, and these bursts are enhanced in EtOH. These results outline a critical role for synchrony and activity level of Glu afferents to VTA in shaping phasic and tonic DA release under the acute influence of EtOH and in normal conditions.