Research Summary: Lilianne Mujica-Parodi
2010 PECASE Award Winner

Dr. Lilianne Mujica-Parodi's research interests focus on the use of chaos theory to identify emergent properties of nested control circuits in the brain, with neurodiagnostic applications to neurological and psychiatric disorders.

Imagine a network in which every component is itself a network which, in turn, is also comprised of many underlying networks. Imagine, also, that systems are *self-interacting*, such that positive and negative feedback loops ensure that the dynamics at any given point are determined not only by the inputs to that node, but by previously processed outputs. What you're imagining is called a *complex system.*

One interesting feature of complex systems is the existence of emergent properties, in which small causes can have very profound and sometimes astonishingly unexpected effects downstream. Because of this exquisite sensitivity to initial conditions, complex systems can both respond to their environments with a minimum of energy, as well as easily spiral out of control. Some familiar examples of complex systems are stock markets, terrorist networks, viral transmission, and the weather. Economic recessions, violent revolutions, pandemics, and tsunamis are what happen when their dynamics become uncontrollable, which illustrates the power of a complex system gone awry.

Our bodies and, in particular, our brains, are complex systems governed by control circuits embedded within control circuits, and here also, the precarious balance between order and chaos becomes crucial. The brain must be dynamically supple enough to efficiently respond to inputs, but also constrained enough to be able to maintain homeostasis. My research starts from the working hypothesis that imbalance in either direction, caused by problems in network architecture or problems in information transfer, forms the basis for many of our most crippling psychiatric and neurological diseases.

In the laboratory that I head at Stony Brook University, we obtain neural signals non-invasively through imaging by functional MRI, near-infrared spectroscopy, and electroencephalography. We then quantify chaos in neural time-series using a variety of computational techniques adapted from physics, such as power spectrum scale invariance, detrended fluctuation analysis, Hurst and Lyaponov exponents, and approximate entropy. Deviations from the critical degree of chaos can be used diagnostically in conjunction with classification algorithms, to identify risk for illness even before a system has degenerated sufficiently to show onset of symptoms. Application of graph theory and other connectivity techniques can permit us to identify the circuit-wide basis for this dysregulation, which in turn will be used for developing treatment targeted to these specific circuits.

Our research has direct clinical applications, with a focus on development of neurobiologically-based diagnostic instruments. These are designed to:

- Detect exceptional stress resilience in a potential U.S. Navy SEAL,

- Identify pathological stress vulnerability in five-year-old children at risk for clinical anxiety and depression,

- Map neural signatures for schizophrenia that may indicate the drug to which a patient is likely to respond most effectively, and

- Markedly improve neurosurgical outcomes for patients with severe epilepsy, by more accurately identifying the focal points in their brains that trigger their debilitating seizures.

Our engineering work also includes complementary development of:

- Software and algorithm development for near-infrared spectroscopy, an emerging technology with portability, convenience, and low operating costs that make it ideally suited for diagnostics within clinical settings (emergency rooms, doctors' offices, rural and military facilities) that cannot support fMRI,

- Dynamic phantoms for cross-scanner calibration of the blood oxygenated level dependent signal in fMRI, and

- Chemosensory stimuli capable of activating the human limbic system without conscious perception ("human alarm pheromones").

Biography

Lilianne Mujica-Parodi is Director of the Laboratory for the Study of Emotion and Cognition (LSEC), and Assistant Professor at Stony Brook University in the Departments of Biomedical Engineering, Neuroscience, and Psychiatry. She received her undergraduate and graduate degrees from Georgetown University and Columbia University, respectively, studying mathematical logic and physics. After her Ph.D., she completed a three-year National Institutes of Health Training Fellowship in Schizophrenia Research at the New York State Psychiatric Institute. Dr. Mujica-Parodi was subsequently promoted to Assistant Professor of Clinical Neuroscience at Columbia's College of Physicians and Surgeons, where she performed research for two years until being recruited by Stony Brook University. She is the recipient of the National Science Foundation Career Award, the National Alliance for Research in Schizophrenia and Affective Disorder's Young Investigator Award (Essel Investigator), and the White House's Presidential Early Career Award in Science and Engineering.