Dr. Lilianne Mujica-Parodi PECASE Award remarks

Transcript of remarks from National Science Foundation ceremony to honor the 21 PECASE recipients for their NSF-funded research

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 US Navy SEAL, identify pathological stress vulnerability in children at risk for clinical anxiety and depression, map neural signatures for schizophrenia that may indicate whether a patient is likely to respond most effectively to one type of drug versus another, 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 lives are complex systems too, with influences arising from many expected and unexpected quarters, some acknowledged, and some covert. Nevertheless, there are several people who had profound influences on my development as a scientist, and I would like to take this opportunity to thank them.

My parents, Mauro and Barbara Mujica-Parodi, provided me with an intellectually nurturing environment from an early age, as well as the emotional and financial support to pursue my education. Martin Kaminar, my uncle as well as a Naval officer and engineer, believed that the ideal activity for a young child was building circuits, and provided me my first introduction to engineering. My first serious mentor was Adrian Parsegian, who generously accepted me at the age of fifteen into his laboratory at the National Institutes of Health, and to this day continues to be one of my closest friends and trusted advisors. I am deeply fortunate to have had an extraordinary thesis advisor, Richard Friedberg, of Columbia University's Department of Theoretical Physics. He taught intellectual courage by example, approaching seemingly-intractable problems in quantum mechanics with transparent analytical reasoning from first principles. Igor Vodyanoy, Brett Giroir, and Ted Conway (of the Office of Naval Research, Defense Advanced Research Projects Agency, and the National Science Foundation respectively) were instrumental in providing funding at critical junctures in my research, which allowed me the luxury of attacking problems with unorthodox approaches; none of this work would be possible without their support. Finally, I thank my husband Helmut Strey, a very talented and accomplished scientist in his own right, for his unwavering belief in the importance of my career, and the dedication to an equal partnership at home that made it possible.