Prefrontal cortical microcircuits: from executive control to pathological disruption and back to normal

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Abstract. The prefrontal cortex of the primate brain has a modular architecture based on the aggregation of neurons in mini-columnar arrangements with afferent and efferent connections distributed across many brain regions to represent, select and/or maintain behavioral goals and executive commands. Prefrontal cortical microcircuits are assumed to play a key role in the perception to action cycle that integrates relevant information about environment, and then selects and enacts behavioral responses. Thus, neurons within the inter-laminar cortical microcircuits participate in various functional states requiring the integration of signals across cortical layers and the selection of executive variables. Recent research suggests that executive abilities emerge from cortico-cortical interactions between inter-laminar prefrontal cortical microcircuits, whereas their disruption is involved in a broad spectrum of neurologic and psychiatric disorders such as autism, schizophrenia, Alzheimer's disorder and drug addiction. The focus of this talk is on the structural, functional and pathological facets of prefrontal cortical microcircuits that involve the mechanism of executive control, by looking at normal and disrupted aspects, and discussing technological potential for reversal of such disruption. Based on recent technological progress it has been demonstrated that micro-stimulation of infra-granular cortical layers with patterns of micro-currents derived from supra-granular layers led to an increase in cognitive performance. This suggests that inter-laminar prefrontal cortical microcircuits are playing a causal role in improving cognitive performance. An important reason for the new interest in cortical modularity comes from both the impressive progress in understanding anatomical, physiological and pathological facets of cortical microcircuits and the potential promise of neural prosthetics to partially reverse some of the symptoms in neurological and psychiatric disorders.

Biographical Sketch. Ioan Opris is a Senior Research Scientist in Neuroscience, working in the Department of Physiology and Pharmacology at Wake Forest University School of Medicine. Ioan's academic background is in Physics/ Biophysics and Neuroscience. He received a BS in Physics/ Biophysics and a PhD in Physics with the dissertation on statistical physics aspects of neuronal networks, followed by substantial postdoctoral training in cognitive neuroscience, primate neurophysiology and neural prosthetics at Columbia, Yale and Wake Forest universities. Ioan's current research focusses on neural microcircuits and decision/memory prosthetics. He and his team have provided the first demonstration of inter-laminar columnar processing in prefrontal cortical microcircuits during executive decisions in nonhuman primates and also on the laminar microcircuits in the subfields CA3-CA1 of primate hippocampus. Ioan is also collaborating with Dr. Casanova's team studying autism spectrum disorders in children by applying transcranial magnetic stimulation and neuro-feedback. Moreover, he edits and writes topics on the interface between Physics and Cognitive Neuroscience, having two books (one in press and the other in preparation) for Springer. He initiated a new section in the Frontiers in Neuroscience journal named Frontiers in Neural Technology that is now underway.