# SFB 910 Symposium
# “Control of Neural Dynamics”

**Friday, 11th February 2022, 15:00 s.t.**
**via Zoom**
For information on how to access the event, please contact:
henning.reinken@itp.tu-berlin.de

Technische Universität Berlin
Straße des 17. Juni 135, 10623 Berlin

**15:00** **A network perspective on cognitive effort**
Danielle Bassett *(University of Pennsylvania, Philadelphia, USA)*

**15:50** **Experimental control of neural dynamics using transcranial brain stimulation**
Ivan Alekseichuk *(University of Minnesota, Minneapolis, USA)*

**16:30** **Nonlinear optimal control of neural populations**
Lena Salfenmoser *(TU Berlin)*

Guests are welcome!

Sabine Klapp Andreas Knorr Klaus Obermayer

http://www.itp.tu-berlin.de/sfb910/

# Abstracts

## A network perspective on cognitive effort

Danielle Bassett *(University of Pennsylvania, Philadelphia, USA)*

Cognitive effort has long been an important explanatory factor in the study of human behavior in health and disease. Yet, the biophysical nature of cognitive effort remains far from understood. In this talk, I will offer a network perspective on cognitive effort. I will begin by canvassing a recent perspective that casts cognitive effort in the framework of network control theory, developed and frequently used in systems engineering. The theory describes how much energy is required to move the brain from one activity state to another, when activity is constrained to pass along physical pathways in a connectome. I will then turn to empirical studies that link this theoretical notion of energy with cognitive effort in a behaviorally demanding task, and with a metabolic notion of energy as accessible to FDG-PET imaging. Finally, I will ask how this structurally-constrained activity flow can provide us with insights about the brain's non-equilibrium nature. Using a general tool for quantifying entropy production in macroscopic systems, I will provide evidence to suggest that states of marked cognitive effort are also states of greater entropy production. Collectively, the work I discuss offers a complementary view of cognitive effort as a dynamical process occurring atop a complex network.

## Experimental control of neural dynamics using transcranial brain stimulation

Ivan Alekseichuk *(University of Minnesota, Minneapolis, USA)*

Single neurons and neural circuits exhibit an intricate repertoire of neural signals, creating multiscale neural dynamics. These dynamics are essential for all functions of the neural system and, thus, attract an immense interest both from the fundamental and applied standpoint. Experimental methods to control neural communications in a human brain are currently under active development, and our understanding of the capabilities of transcranial brain stimulation is rapidly evolving. This talk will cover the latest advances in the translational and applied aspects of two primary technologies in the space of non-invasive neuromodulation. Transcranial alternating current stimulation (tACS) aims to manipulate the neurons via steering the local field potentials. TACS exploits the ephaptic coupling between the neural action potentials and electric fields in a neural population. The resulting changes in the spike timing and phase of the local fields, although mild, can have profound implications for brain functions. Transcranial magnetic stimulation (TMS) induces direct neural action potential via a strong electromagnetic perturbation. The latest advances in this area include a brain state-controlled TMS. For such applications, we combine the stimulation with the real-time imaging method, like electroencephalography. State-controlled TMS can inhibit or excite the local neural circuit and potentially provides a tool to verify several theoretical predictions regarding the neural dynamics.

## Nonlinear optimal control of neural populations

Lena Salfenmoser *(TU Berlin)*

We apply the framework of nonlinear optimal control to a biophysically realistic neural mass model, which consists of two mutually coupled populations of deterministic excitatory and inhibitory neurons. External control signals are realized by time-dependent inputs to both populations. Optimality is defined by two alternative cost functions that trade the deviation of the controlled variable from its target value against the ”strength” of the control, which is quantified by the averaged 1- and 2-norms of the control signal. We focus on a bistable region in state space where one low- (”down state”) and one high-activity (”up state”) stable fixed point coexist. With methods of nonlinear optimal control we search for the most cost-efficient control function to switch between both activity states. For a broad range of parameters, we find that cost-efficient control strategies consist of a pulse of finite duration to push the state variables only minimally into the basin of attraction of the target state. We compare two types of control signals, which mimic either the ion flow across a neuron’s cell membrane ("current control"), or synaptic inputs from other connected neurons ("rate control"). Penalizing control strength via the averaged 1-norm (2-norm) yields finite control inputs along one (vs. several) input channels, as expected. Our study highlights the applicability of nonlinear optimal control to understand neuronal processing under constraints better.