Transcranial Electric Stimulation

This informal mini symposium brings together researchers from City College of the City University of New York and Rutgers University, Newark to discuss recent findings in the field of transcranial electric stimulation.

Rutgers University
Aidekman Research Center
Center for Molecular and Behavioral Neuroscience
197 University Avenue
Newark, NJ 07102

Date: Monday, October 24th, 2011
Time: 1pm - 6pm
Room: Aidekman Seminar Room (first floor)

For more information, please contact Bart Krekelberg: bart@rutgers.edu

Program

Talks are 20 minutes, with ten minutes for discussion.

- **1:00-1:30** – Kohitij Kar – Retinal and cortical effects of transcranial electrical stimulation.
- **1:30-2:00** –David Reato – Oscillatory electrical stimulation modulates coherence and homeostatic downscaling of human slow wave activity
- **2:00-2:30** – Jacek Dmochowski – Optimized multi-electrode stimulation increases focality and intensity at target

--- Coffee Break ---

- **3:00-3:30** – Belen Lafon – Modulation of homeostatic plasticity with electric fields in rat hippocampal slices.
- **3:30-4:00** – Antal Berenyi – Perturbation of neuronal activity by transcranial electrical stimulation and optogenetic tools in animals
- **4:00-4:30** – Asif Rahman – Synaptic pathway and orientation specific modulation of neuronal excitability by weak direct current stimulation.

Abstracts

- Asif Rahman, Davide Reato, Abhishek Datta, Lucas Parra, Marom Bikson (CUNY)

  Synaptic pathway and orientation specific modulation of neuronal excitability by weak direct current

  Transcranial direct current stimulation, a clinical technique explored for noninvasive neuromodulation, is thought to induce polarity-specific lasting change in cortical excitability. However, the mechanisms of DC stimulation are not fully understood and the results of tDCS studies remain highly variable, potentially as a result of the differences in induced electric field direction relative to afferent fibers in the primary motor cortex. Therefore, we describe the acute (during field) effects of transient (1 sec) exposure of weak DC fields (±10 V/m) on synaptic efficacy in rat brain slices to address the effects of DC stimulation in distinct cortical synaptic pathways. Traditionally, therapies are designed to generically "increase excitability" under the anode and "decrease excitability" under the cathode but stimulation results vary across subjects. Our results suggest that a source of the variability observed in tDCS literature may be due to the stimulated synaptic-pathways and direction of the induced electric field in the motor cortex. Because of this variability, it is necessary that in the interpretation and design of clinical tDCS studies and experimental research to distinguish and identify the specific synaptic-pathway and emphasize directionality of the induced field.

- Jacek Dmochowski, Abhishek Datta, Marom Bikson, and Lucas Parra (CUNY)

  Optimized Multi-Electrode Stimulation Increases Focality and Intensity at Target.

  Transcranial direct current stimulation (tDCS) provides a non-invasive tool to elicit neuromodulation by delivering current through electrodes placed on the scalp. The present clinical paradigm uses two relatively large electrodes to inject current through the head resulting in electric fields that are broadly distributed over large regions of the brain. In this paper, we present a method that uses multiple small electrodes and systematically optimize the applied currents to achieve effective and targeted stimulation while ensuring safety of stimulation. We found a fundamental trade-off between achievable intensity (at the target) and focality, and algorithms to optimize both measures are presented. When compared with large pad-electrodes, the proposed approach achieves electric fields which exhibit simultaneously greater focality (80% improvement) and higher target intensity (98% improvement) at cortical targets using the same total current applied. These improvements illustrate the previously unrecognized and non-trivial dependence of the optimal electrode configuration on the desired electric field orientation and the maximum total current (due to safety). Similarly, by exploiting idiosyncratic details of brain anatomy, the optimization approach significantly improves upon prior un-optimized approaches using small electrodes. The analysis also reveals the optimal use of conventional bipolar montages: maximally intense tangential fields are attained with the two electrodes placed at a considerable distance from the target along the direction of the desired field; when radial fields are desired, the maximum-intensity configuration consists of an electrode placed directly over the target with a distant return electrode. To summarize, if a target location and stimulation orientation can be defined by the clinician, then the proposed technique is superior in terms of both focality and intensity as compared to previous solutions and is thus expected to translate into improved patient safety and increased clinical efficacy.

- Belen Lafon, Davide Reato, and Lucas Parra (CUNY)

  Modulation of homeostatic plasticity with electric fields in rat hippocampal slices

Low amplitude electric fields are known to modulate ongoing neural activity. They can also produce long term behavioural effects when incorporated as part of a behavioural training paradigm. Slice and computational models give fairly clear explanations for the underlying mechanisms of the acute effects. However, the long term plastic effects,
which are of paramount clinical relevance remain enigmatic. Here we are particularly interested in the effects of slow-oscillating stimulation during sleep which were shown to boost the benefits of sleep on the consolidation of hippocampus-dependent declarative memory. It has been hypothesized that homeostatic plasticity during sleep is important for the consolidation of behaviors learned during the preceding day. Thus we want to test whether weak electric fields can affect homeostatic rescaling. Since we are interested in the effects of weak-current transcranial stimulation on declarative memory we use hippocampal slices and aim to use sub-threshold fields. We will discuss a novel homeostatic process measured in slices and propose ways to modulate it with low
amplitude fields, thus beginning to understand the underlying mechanisms linking acute and long-term effects.

- Antal Berényi, Gyorgy Buzsaki (Rutgers)

Perturbation of Neuronal Activity by Transcranial Electrical Stimulation and Optogenetic Tools in Animals

While transcranial magnetic stimulation (TMS) is an excellent tool to perturb activity of the intact brain, the size of the magnets prevents chronic applications. Transcranial electrical stimulation (TES) has all the major advantages of TMS but requires simple circuits which can be implanted chronically in the skull. We demonstrate how TES stimulation in rats affects neuronal activity in wide areas of the cortex and subcortical areas. Using a brain activity-controlled closed-loop system, we also show that when spike components of generalized seizures are used to trigger TES, appropriate timing of the feedback stimulation can reliably abort seizures. While in many cases, diffuse electrical activity is an advantage, other applications require local perturbation of specific neuronal classes. Combining large-scale recording of unit activity with silicon probes equipped with light guards, localized perturbation of neurons (both excitation and suppression of unit firing) can be achieved by virus-delivered light-sensitive channels. These methods allowed us to demonstrate that phase-distribution of cells assemblies within the hippocampal theta cycles is achieved with precise timing of parvalbumin-containing inhibitory interneurons.

- Kohitij Kar and Bart Krekelberg (Rutgers)

Retinal and cortical effects of Transcranial Electrical Stimulation

Transcranial electric current stimulation (tES) of the human brain is assumed to affect cortical excitability by invoking subthreshold modulation of neuronal activity. This assumption has been used to interpret clinical studies where tES improved stroke recovery, alleviated chronic pain, or treated depression. Our goal is to understand how electrical stimulation leads to changes in brain and behavior. A recent study has shown that application of transcranial alternating current stimulation (tACS) over the visual cortex induces the perception of flashes of light (phosphenes). The claim that these phosphenes were generated cortically has led to considerable debate. We applied tACS over visual cortex with a reference electrode on the vertex; and measured current thresholds for the detection of phosphenes with a Bayesian adaptive method. Then, we shifted the stimulating electrode over to the temporal lobe; away from visual cortex and towards the retina. This simple manipulation enhanced the efficacy of the stimulation as measured by lower current thresholds. The threshold reduction and the stimulation frequency tuning of the induced phosphene were parsimoniously explained by a primate retinal ganglion cell model. This suggests that stimulation of the retina plays a significant part in the generation of phosphenes by tACS. To investigate whether tES induces behavioral changes that are likely caused by direct cortical stimulation, we investigated whether tES could change motion adaptation. We used a standard 40s adaptation design with 4s top-ups, coherent random dots as the adapting stimulus, and dots with varying coherence to measure the strength of the MAE. Our results show that the strength of motion adaptation was reduced by simultaneous stimulation with an alternating current of 1mA at 10Hz over human MT+. Many mechanisms could underlie this effect. But, if tES affected both active (adapting) and inactive (not adapting) cells equally, one would not expect any influence on the MAE. Therefore, our finding suggests that tES could be targeted at cortical neuronal populations in an activity dependent manner.

- Davide Reato, Abhishek Datta, Marom Bikson, Lisa Marshall and Lucas C Parra (CUNY)

  Oscillatory electrical stimulation modulates coherence and homeostatic downscaling of human slow wave activity

  Slow wave activity (SWA) in the 0.5Hz-4Hz frequency range is a predominant pattern of the human electro-encephalogram during sleep. Enhanced SWA has been correlated with a number of beneficial learning effects while reduced SWA is a common correlate of many sleep disorders. Interventions that could enhance SWA are thus of major interest. Surprisingly, SWA can be transiently enhanced by non-invasive electric stimulation with slow-oscillating currents. However, the underlying mechanisms for this enhancement are unknown making the enhancement of SWA an elusive goal. Many of the demonstrated effects of transcranial direct current stimulation (tDCS) are polarity specific, yet cortical folding in the human brain complicates matters as a given stimulation configuration will lead to mixed polarities of the induced electric fields on the cortical surface. To elucidate the effects of such realistic mixed-polarity stimulation on SWA we implemented a parsimonious computational model of SWA. Oscillating fields entrain SWA by incrementally and rhythmically polarizing pyramidal cell membranes following an experimentally validated model of neuronal field-effects. Despite mixed polarity on distinct cortical areas the global SWA entrain to one of the two phases of stimulation. Reanalyzing previously recorded human EEG data during sleep (Marshall, 2006) seems to confirm these observations. The model also predicts that entrainment of the oscillatory activity could affect the homeostatic synaptoc downscaling typical of sleep. The humans data seems to confirm this hypothesis.