CSC-RUB PhD Project Proposal

Title: "I-SEE" - Developing intracortical visual prostheses

Sector of research: Neuroscience

Degree awarded: PhD in Neuroscience

Keywords: Neuromodulators, cortical processing

Vision and acting; neurophysiology; decoding brain dynamics; cognitive neuroscience, optogenetics; optical imaging *in vivo*; perception; learning; neuronal plasticity.

Supervisor of PhD project:

PD Dr. Dirk Jancke, Optical Imaging Group, Institute for Neural Computation, Ruhr University Bochum, Germany.

Research focus of supervisor:

My lab focusses on brain function with respect to neuronal dynamics, perception, behavior, and neurophysiological disorders. In this framework we explore the brain's capacities for plastic reorganization, learning, and its potential to interact with brain-machine-interfaces. As major methods we use state-of-the-art optical imaging techniques, optogenetics, and electrophysiology. Our wide-field optical imaging approach is unique in its capability of capturing highly resolved activity of millions of neurons at once (for a review see "VSDI: a new era in functional imaging of cortical dynamics" and our contribution therein). In combination with optogenetic stimulation and recordings of target neurons and neuronal subnetworks our approach provides direct access to theoretical and experimental questions dealing with the computational power of activity patterns across the brain (see our website https://jancke-lab.de/)

Publications: {selection of five relevant papers}

Jancke D, Chavane F, Naaman S, and Grinvald A (2004). Imaging cortical correlates of illusion in early visual cortex. ***Nature*** 428: 423-426.

Pallagina G, Eysel UT, and Jancke D (2009). Strengthening of lateral activation in adult rat visual cortex after retinal lesions captured with voltage-sensitive dye imaging in vivo. ***Proc Natl Acad Sci U. S. A*** 106, 8743-8747.

Kozyrev V, Eysel UT, and Jancke D (2014). Voltage-sensitive dye imaging of transcranial magnetic stimulation-induced intracortical dynamics. ***Proc Natl Acad Sci U. S. A*** 111, 13553-13558.

Kozyrev V, Staadt R, Eysel UT, and Jancke D (2018). TMS-induced neuronal plasticity enables targeted remodeling of visual cortical maps. ***Proc. Natl. Acad. Sci. U. S. A*** 115, 6476-6481.

Azimi Z, Barzan R, Spoida K, Surdin T, Wollenweber P, Mark MD, Herlitze S, and Jancke D (2020). Separable gain control of ongoing and evoked activity in the visual cortex by serotonergic input. ***Elife*** 9, e53552.

Summary of research plan

Background:

With more than 40 million legally blind individuals worldwide, there is growing pressure to provide a viable solution that would at least partially restore visual abilities and improve patients' quality of life. Modern technological advances provided examples of successful treatment of lost sensory function using implantation of electrical circuits. The aim of our international consortium is to improve the ability of cortical prostheses to 'mimic' the language of the brain and increase the safety and longevity of visual prosthetic devices.

Study objective:

The multidisciplinary project brings together scientists from different fields and complementary experimental and theoretical know-how. Using optical imaging the goal of the PhD project is to "listen" to the brain's background activity and including it in spatial and temporal modes for cortical stimulation. To this aim, we will develop neuro-computational models, which use the optical recordings to learn patterns of neural activity related to specific visual features.

Expected Results:

The main idea is to reshape ongoing activity patterns by a weak, subthreshold (multi-site) stimulation such that they approximate activation pattern one would observe when presenting a particular visual stimulus. For performing meaningful stimulation we scrutinize how spontaneous states are related to the stimulus-driven neuronal response characteristics. This hypothesis will be tested experimentally in mice in combination with modeling and data analysis. The used wide-field imaging of intrinsically expressed fluorescent voltage- and Ca^{2+} indicators provide unique access to state-of-the-art recordings and stimulation of the brain's ongoing dynamics. We expect therefore publication of our results in highly competitive journals.

Methods:

The project part of the PhD position comprises micro electrical stimulation in the mouse brain combined with cutting-edge optogenetic voltage imaging techniques. Thus, the multidisciplinary project combines modern wide-field optical imaging, electrophysiology and optogenetics to stimulate and record from specific neuronal circuits. In close collaboration with our partner Thomas Knöpfel, Imperial College London, UK, we provide

first-hand knowledge and equipment together with an experienced team of researchers to ensure successful conduction of the outlined PhD project.

Candidate Requirements:

Required is an excellent university degree in Biology, Medicine, Physics, or a related discipline. Successful candidates should have a strong background in neuroscience, expertise in electrophysiology, and programming skills (Matlab/Python) applicable to complex data recordings, analysis, and mathematical concepts. The willingness to work within integrative frameworks is highly desirable. Good communication skills, creative and independent thinking and fluent English are mandatory.

Motivation for CSC application (max 250 words):

As a member of the IGSN Study- and PhD- Commissions, I have intensely participated in all aspects of education and training of PhD scholars during the recent decades. Regarding my own laboratory I have always put special emphasis on forming a group with international students of diverse backgrounds in order to contribute also to the development of modern societies. Thus, besides training in the mentioned spectrum of methods, the candidate can expect to be integrated in well-organized working group of international students that care about each other.

Besides participation in the PhD program of the IGSN the candidate will obtain additional offers to soft-skill training organized by the Ruhr University Research School that addresses students across all scientific disciplines. Finally, the candidate will profit from in-person meetings with researchers of a wide range of topics in neuroscience, as our lab actively collaborates since many years with various groups of the vibrant research community across Ruhr University Bochum.