CSC-RUB PhD Project Proposal

Title: Neuromodulators' action on brain dynamics

Sector of research: Neuroscience

Degree awarded: PhD in Neuroscience

Keywords: Neuromodulators, cortical processing,

Vision and acting; neurophysiology; cognitive neuroscience, neuromodulators; decoding brain dynamics; optogenetics; optical (2-photon) 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, e-mail: dirk.jancke@rub.de, ORCID ID 0000-0001-8440-6259

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 (including 2-photon), 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.

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

Jancke D, Herlitze S, Kringelberg ML, and Deco G. (2021). Bridging the gap between single receptor type activity and whole brain dynamics. ***FEBS J*** 289, 2064-2089. doi: 10.1111/febs.15855

Summary of research plan

Background:

Dysfunction of neuromodulatory systems plays a central role in the etiology of psychiatric disorders. How single neuronal receptor types influence entire brain dynamics remains unclear. As exemplified by the serotonergic (5-HT) system we recently showed how optogenetic tools can be used to trigger activation of specific 5-HT receptors with associated changes in brain states. Our long-term goal is to find new ways for the diagnosis and treatment of psychiatric disorders associated with malfunction of neurotransmitter systems.

Study objective:

Introducing the concept of the cortical ‘receptome’, we hypothesize that the structural neuronal connectivity backbone and its modulation by a single neurotransmitter system allows access to a rich repertoire of different brain states that are fundamental for flexible behavior (Jancke et al., 2020). The goal of the PhD project is to visualize and quantify changes in brain state through activation of specific modulatory (e.g. 5-HT) receptor types across different cell classes.

Expected Results:

We expect a bidirectional coupling between modulatory neurotransmission and neuronal connectivity hardware exemplified by the impact of single 5-HT receptor types on cortical dynamics. It will be assessed how specific optogenetic activation of different 5-HT receptor types influences cortical processing dynamics and behavior. The used wide-field imaging and optogenetic tools provide ideal access to the analysis and modeling of whole-brain dynamics. We expect therefore publication of our results in highly competitive journals.

Methods:

In the PhD project we study state-dependent changes in brain activity by manipulating serotonergic pathways in the mouse model. The multidisciplinary project combines modern wide-field optical imaging with voltage- and Ca^{2+} indicators, 2-photon imaging, electrophysiology and optogenetics to stimulate and record from specific neuronal circuits during behaviour in virtual reality. In close collaboration with our partner Stefan Herlitze, Ruhr University Bochum, we provide a high quality infrastructure and equipment together with an experienced team of researchers to ensure successful conduction of the outlined PhD project.

Candidate Requirements:

Good English language skills. 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.