Gerchen, Martin Fungisai

Academic Profile

Since December 2020 I am the head of the Research Group Biological Psychology at the Department of Clinical Psychology at the Central Institute of Mental Health (CIMH). My scientific and academic interests are based on my everlasting fascination for the richness and complexity of the processes in the human brain, and for the access modern neuroimaging technologies offer to these processes. My research is dedicated to realizing the potential of these technologies for the investigation of the neurocognitive basis of mental illness and for neuroscientific interventions, with the goal to translate the findings of clinical neuroscience as directly as possible to the treatment of patients with mental disorders.

For achieving this goal, I combine experimental psychological and neuroscientific approaches to address basically three levels in my work: The characterization of clinically relevant neurocognitive processes and functional brain networks in mental disorders, the development and application of modern statistical analysis methods for the assessment of the collected data, and the development of neurofeedback (NF) approaches to make the identified processes accessible for targeted interventions.

The main focus of my work has been on the application of functional magnetic resonance imaging (fMRI) for these aims, with a special emphasis on the development of creative and innovative data analysis approaches that access the inherent richness of information in fMRI data, which is unique in its spatiotemporal properties. For example, I have developed a network-specific analysis approach for assessing dynamics in frontostriatal functional connectivity patterns (Gerchen et al., 2021), implemented a large-scale network functional connectivity approach for NF training (Weiss et al., 2020; Weiss et al., 2022), and introduced equivalence and superiority/inferiority tests for fMRI (Gerchen, Kirsch, & Feld, 2021). With my expertise on fMRI, I am contributing to diverse projects in collaborations inside and outside the CIMH, where I provide extensive counseling on all aspects of fMRI research from specific statistical questions over analysis strategies and methodological approaches, the development of experimental paradigms and study design, to problem solving and trouble-shooting. These collaborations have resulted in numerous publications on diverse topics.

Over the past two years I have further expanded my repertoire of methods to magnetoencephalography (MEG), where I am currently working on the integration of fMRI and MEG through paradigms that are simultaneously adapted to both modalities, a well as on the implementation of a real-time MEG neurofeedback setup at the CIMH.

In my research I put a particular focus on transdiagnostic and cross-disorder mechanisms. For example, a common theme in my work, which thematically comprises the areas of addictive disorders, depression, and schizophrenia, is the function and dysfunction of frontostriatal circuits as a central neural system implementing behavioral control and behavioral regulation. A central aim of my future research is thus the further elucidation of the function of frontostriatal circuits and their role in mental illness, and the translation of the results of this research into novel disorder-specific as well as transdiagnostic neuroscientific intervention approaches.

With respect to my person, what probably characterizes me most as a scientist is my cooperative and interdisciplinary working style. Throughout my entire scientific career at the

Max Planck Institute for Experimental Medicine Göttingen, the Bernstein Center for Computational Neuroscience Heidelberg/Mannheim, and the Central Institute of Mental Health, I have worked in highly interdisciplinary and collaborative research environments at the interface of medicine, psychology, biology, neuroscience, statistics, computational neuroscience, and physics. What I have learned from this work is that recognizing the diverse ways of thinking in the different fields and understanding the divergent scientific languages are very important factors for successful interdisciplinary collaboration. Through my broad background and interdisciplinary experience, I possess this practical knowledge, which allows me to collaborate in an efficient and productive way with colleagues from diverse disciplines.

The already high interdisciplinarity of my work got an additional boost with my admission in 2021 to the young scientist program (WIN-Kolleg) of the Heidelberg Academy of Sciences and Humanities, which is the academy of sciences of the federal state of Baden-Württemberg. As a member of the WIN-Kolleg, I have the chance to participate in the scientific program of the Heidelberg Academy and greatly benefit from its interdisciplinarity that spans from the natural sciences to the humanities. In the context of the WIN program, I acquired competitive third-party funding for conducting an interdisciplinary research project on the neural correlates of beliefs in conspiracy theories, alternative medicine, and paranormal phenomena together with colleagues from the fields of computational neuroscience (Georgia Koppe, CIMH), philosophy (Mathis Lessau, University of Freiburg), and German literature studies (Hans-Christian Riechers, University of Basel). This project allows me to address highly interesting topics that have certain commonalities with mental disorders, but also clear differences, and are of general importance for society.

In the WIN-Kolleg I was further elected as the spokesperson of the 8th WIN cohort and participated as a member of the organizational committee in the organization of the interdisciplinary meeting ”Coherence and Disruptions“ in October 2021 in Heidelberg, which provided a discussion forum in which the core concepts of coherence and disruptions were addressed from diverse scientific perspectives.

In addition to interdisciplinarity, the criteria of open and reproducible science are a demand that I put on my work. I am convinced that only rigorous research procedures can ensure the necessary high quality of our science, and ensure the reliable, reproducible, and robust results that are necessary for making contributions that indeed help alleviating the burden of mental disorders for patients.

Besides research, teaching the next generations of students and transferring the knowledge I have acquired is a major part of my self-concept as a scientist. Since 2017 I am giving lectures in biological psychology as a lecturer at the Institute of Psychology at Heidelberg University. In my courses, I always pursue the goal of passing on my own fascination for biological psychology and clinical neuroscience, which is highly appreciated by the students who consistently evaluate my lectures with excellent grades. At the Institute of Psychology, I am also currently doing my habilitation, for which my habilitation thesis focusing on real-time fMRI NF (rtfMRI NF) has been submitted and is currently under evaluation. My habilitation will be finished presumably in November this year.

To provide similar early opportunities to get practically involved in current research as I had in my own education, I regularly supervise Bachelor’s and Master’s theses in which I provide

access to advanced methodology like fMRI and MEG and conduct research on latest research topics. Since 2020 I have supervised 5 theses, and 5 are currently ongoing. Supervising these theses has been among the most rewarding activities in my work, and it is always very impressive to see what excellent students are capable of achieving already in very early stages of their careers.

Very recently in July 2022, the PhD thesis of Franziska Weiss, which was the first PhD thesis that I supervised, was successfully completed. In her acknowledgement she stated that "the fruitful collaboration […] showed me what excellent structuring and great teamwork can achieve", which is probably among the best feedbacks that I could hope for as a first-time PhD supervisor.

Key output of the years 2020-now

Weiss, Zamoscik, Schmidt, Halli, Kirsch, & Gerchen, 2020, Just a very expensive breathing training? Risk of respiratory artefacts in functional connectivity-based real-time fMRI neurofeedback, *NeuroImage*

Weiss, Zhang, Aslan, Kirsch, & Gerchen, 2022, Feasibility of training the dorsolateral prefrontal-striatal network by real-time fMRI neurofeedback, *Scientific Reports*

These papers resulted from the just mentioned PhD thesis of Franziska Weiss. In Franziska's PhD project we worked on connectivity-based rtfMRI NF and implemented several methodological advancements. Particularly, we developed an efficient network-based NF approach that makes it possible to use several hundreds of brain regions and use high-level feedback signals like graph-theoretical properties of brain networks. Based on brain network alterations in Schizophrenia, we used our methodology to upregulate frontostriatal networks and tested it in two double-blind randomized controlled studies with healthy controls. In the first study we identified major respiratory artefacts in the functional connectivity-based feedback signal and then used the data to identify and implement an online correction approach for these artefacts. In the second study we tested this procedure and demonstrated the feasibility of our approach to modulate frontostriatal networks, which now requires further testing in a well-powered confirmatory study. These papers are exemplarily showing how the development of cutting-edge NF approaches can go hand in hand with addressing the inherent challenges of rtfMRI NF in a stepwise procedure, and have acquired much attention in the field.

Markett, Jawinski, Kirsch, & Gerchen, 2020, Specific and segregated changes to the functional connectome evoked by the processing of emotional faces: A task-based connectome study, *Scientific Reports*

In this cooperation project with Prof. Sebastian Markett (Humboldt University Berlin), we applied whole-brain PPI, an fMRI analysis approach that I developed in my PhD thesis (Gerchen et al., 2014; Gerchen & Kirsch, 2017), to assess changes in large-scale brain networks during the processing of emotional faces in a large sample of N=843 participants from the Human Connectome Project data collection. The results are in line with both, the theory of constructed emotions assuming distributed processes as well as the primary emotion theory assuming localized processing during affective processing, and are thus offering a potential approach for developing a unified perspective on these conflicting theories.

Gerchen, Weiss, Kirsch, Rentsch, Halli, Kiefer, & Kirsch, 2021, Dynamic frontostriatal functional peak connectivity (in alcohol use disorder), *Human Brain Mapping*

This paper describes the methodological advancement of an analysis approach for frontostriatal connectivity patterns I introduced recently (Gerchen et al., 2019). The approach is based on the gradient model of frontal cortex-basal ganglia-thalamus-frontal cortex loops, which was mainly informed by animal tract-tracing studies, and allows to identify dynamic changes in these circuits with fMRI. Thus, this research aims at bridging the gap between fMRI and anatomical circuit models by applying fMRI analyses in a way tailored to a specific brain system. To demonstrate its applicability and clinical relevance, the approach was applied to data from patients with Alcohol Use Disorder (AUD), where clinical associations with the functional dynamics of frontostriatal projections were detected, thus providing novel insights into the underlying pathology of alcohol addiction.

Gerchen, Kirsch, & Feld, 2021, Brain-wide inferiority and equivalence tests in fMRI group analyses: Selected applications, *Human Brain Mapping*
***GitHub* repository https://github.com/Fungisai/g_ci_spm**

Standard null hypothesis significance testing (NHST) with strict thresholding in mass-univariate settings like fMRI provides only a very limited perspective on the effects in a data set. In this paper, we introduced the modern statistical concepts of equivalence, superiority, and inferiority tests into the field of fMRI. As a prerequisite to implement these tests, I derived the generalized form of the standardized effect size Hedges' g and its confidence interval for the general linear model used in fMRI analyses and made the code openly available in a Github repository. These procedures now allow to formally compare virtually all effects within and between fMRI data sets, and even across modalities, for example between behavior and fMRI, broadening the insight that can be obtained into fMRI data.

Eckstein*, Stößel*, Gerchen*, Bilek, Kirsch, & Ditzen, 2022, Neural responses to instructed positive couple interaction: An fMRI study on compliment sharing, Preprint, *bioRxiv* (*equally contributing first authors)

In this study that was conducted in cooperation with Prof. Beate Ditzen and Dr. Monika Eckstein (Heidelberg University) we assessed romantic couples who were giving each other compliments while both partners were scanned simultaneously in two scanners. We found that the dopaminergic reward system is specifically activated by choosing a compliment for the partner in contrast to receiving compliments. This paper is providing important insight into the behavior that activates brain processes which are associated with maintaining romantic relationships. In this project I contributed the analyses of the complex fMRI data set.

Winkelmeier, Filosa, Hartig, Scheller, Sack, Reinwald, Becker, Wolf, Gerchen, Sartorius, Meyer-Lindenberg, Weber-Fahr, Clemm von Hohenberg, Russo, & Kelsch, 2022, Striatal hub of dynamic and stabilized prediction coding in forebrain networks for olfactory reinforcement learning, *Nature Communications*

To this complex and interdisciplinary paper on olfactory reinforcement learning in mice by the group of Wolfgang Kelsch I contributed with my expertise in fMRI analysis strategies and

imaging statistics. This paper is an excellent example of my fruitful interdepartmental collaborations at the CIMH.