Online Course WS 2026/2027

Digital Brain Twins in Clinical Research

Responsible Person: Prof. Dr. Petra Ritter
Email: petra.ritter@charite.de
Affiliation: Charité, BIH
Office: Robert-Koch Platz 4, Charité Campus Mitte

Official website: https://www.brainsimulation.org/
BCCN website: https://www.bccn-berlin.de/courses-and-modules.html
Charité Promotionsumgebung: https://intranet.charite.de/studium_lehre/promotionskurse
Training type: Webinar
Language: English
Location: Online
Costs: Free
Commercial interests: None
Registration: Online form
Credits: 2 ECTS

Learning Outcomes

After completing this module, participants will know the basic concepts and methods for reproducible biology founded personalized brain network modeling and simulation. Students will gain knowledge about how to construct models, process multimodal imaging data for creating individualized models, run simulations and use supporting neuroinformatics tool such as the Charité/BIH Virtual Research Environment, workflows and build interfaces to related tools via APIs. Students will understand how to run brain simulations to address medical problems and have a good understanding of the open-source neuroinformatics platform The Virtual Brain (TVB; thevirtualbrain.org).

Content

This module provides basic knowledge on digital brain twins in clinical research. Required interdisciplinary methods will be introduced. A focus will be set on the open-source simulation platform TVB.

Course overview:

- Theoretical background of large-scale brain network modeling
- Processing of brain images for individualization of brain network modeling
- Concepts of nonlinear dynamics
- Workflows on high-performance computers
- Parameter optimization and model inference
- Application of brain network modeling for clinical questions
- Introduction to the medical condition targeted through brain simulation

- Visualizations of multimodal brain dynamics, ontologies, machine learning, AI, graph theory
- Making use of digital Research Infrastructures used for data integration and simulation in compliance with the EU general Data Protection Regulations (GDPR)
- Scientific operations maturity

Module Components

Course name	Type	Number	Cycle	SWS
Digital Brain Twins in Clinical Research	VL (lecture)	1	WS & SS	1

Workload and Credit Points

Digital Brain Twins in Clinical Research	Multiplier	Units	Total Units
Attendance	12	2.5	30
Lecture rehearsals / individual studies	12	2.5	30
			60

1unit = 45 min
One ECTS/Credit Point equals 30 units

Total: 2 ECTS

Description of Teaching and Learning Methods
The lecture part consists of virtual teaching using an online web platform. In addition to the presentation of theoretical concepts, it comprises several demonstrations of how to operate workflows, simulation engines, high-performance computers and collaborative platforms. Participants are expected to rehearse content after class, using their class notes, digital jupyter notebooks, video tutorials and recommended literature.

Requirements for Participation and Examination
Mandatory requirements:
- Good English language skills
- Basic programming expertise

Successful module completion will require participation in a written exam. Exam tasks will be provided during the last course session, and results need to be submitted by until one week after.

Module Completion
Type of exam: written exam

Grading: none

Duration of the Module
This module can be completed in 1 semester.

Maximum Number of Participants
50

Registration Procedure
Prior registration is required via this link:
https://us06web.zoom.us/meeting/register/YXWtBVH9QY-tho3az2tZuQ

Recommended Reading

- Kashyap, Geenjaar, Bey, Dhindsa, Glomb, Plis, Keilholz, Ritter. (2025) Using an ordinary differential equation model to separate rest and task signals in fMRI Nature Communications
- Koller D, Schirner M, Ritter P. Human connectome topology directs cortical traveling waves and shapes frequency gradients Nature Communications
- Schirner, Deco, Ritter (2023) Learning how network structure shapes decision-making for bio-inspired computing. Nature Communications
- Jacobs, … , Ritter,…, Hofmann-Apitius (2026) Selecting medical research data platforms for translational biomedical research: a five tier overview and requirment-weighted assessment framework. Frontiers Digital Health
- Hofsähs, Pille, Kern, Negi, Meier, Ritter (2026) The Virtual Brain links transcranial magnetic stimulation evoked potentials and inhibitory neurotransmitter changes in major depressive disorder. Imaging Neuroscience
- Stasinski, Taher, Meier, Schirner, Perdikis, Ritter (2024) Homeodynamic feedback inhibition control in whole-brain simulations. PLOS Computational Biology
- Johnson, Nguyen, Dichter, Zappulla, Kosma, Gunalan, Halchenko, Neufeld, Ratan, Edwards, Ressl, Heilbronner, Schirner, **Ritter**, Weter, Ghosh, Martone, Pestilli, Yatsenko (2024) SciOps: Achieving Productivity and reliability in Data-Intensive Research arXiv
- Stefanovski, Bülau, Martin, Langford, Palmer, Sacks, Deger, Pille, Schirner, Meier, Neudorfer, Horn, Solodkin, Thirion, Hofmann-Apitius, Jaconbs, Tom Kodamullil, the Alzheimer's Disease Neuroimaging Initiative, Ritter (2025) An Interactive Brain Atlas of Knowledge (biRxiv)
- Them, Deger, Taher, Stasinski, Martin, Meier, Stefanovski, Ritter (2026) Brain network modelling with The Virtual Brain derives pharmacodynamics of ketamine (bioRxiv)
- Martin, Bülau, Pille, Schmitt, Hüttl, Meier, Taher, Perdikis, Schirner, Stefanovski, Ritter (2025) The Virtual Brain Ontology: A Digital Knowledge Framework for Reproducible Brain Network Modeling (BioRxiv)
- Schmitt, Bülau, Martin, Huettl, Schirner, Stefanovski, Ritter (2025) Biological Database Mining for LLM-Drive Alzheimer's Disease Drug Repurposing bioRxiv

- Pille, Martin, Richter, Perdikis, Schirner, Ritter (2025) Fast and Easy Whole-Brain Network Model Parameter Estimation with Automatic Differentiation (bioRxiv)
- Schirner, Domide, Perdikis, Triebkorn, Stefanovski, Pai, Prodan, Valean, Palmer, Langford, Blickensdörfer, van der Vlag, Diaz-Pier, Peyser, Woodman, Zehl, Fousek, Petkoski, Kusch, Hashemi, Marinazzo, Mangin, Flöel, Akintoye, Stahl, Deco, McIntosh, Hilgetag, Morgan, Schuller, Upton, McMurtrie, Dickscheid, Bjaalie, Amunts, Mersmann, Jirsa, Ritter. Brain Simulation as a Cloud Service: The Virtual Brain on the European Research Platform EBRAINS (2022) Neuroimage
- Schirner & Ritter (2024) Virtuelle Forschungsumgebung für Gesundheitsdaten: Virtual Research Environment (VRE) und Health Data Cloud (HDC). Nomos
- Meier, Perdikis, Blickensdörfer, Stefanovski, Liu, Maith, Dinkelbach, Baladron, Hamker, Ritter (2022) Virtual deep brain stimulation: Multiscale co-simulation of spiking basal ganglia model and whole-brain mean-field model with The Virtual Brain. Experimental Neurology
- Schirner, Kong, Yeo, Deco, Ritter (2022) Dynamic primitives of brain network interaction. Neuroimage
- Triebkorn, Stefanovski, Dhindsa, Diaz-Cortes, Bey, Bülau, Pai, Spiegler, Jirsa, McIntosh, Ritter (2022) Alzheimer's Disease Neuroimaging Initaitive. Brain Simulation augments machine-learning-based classification of dementia Alzheimer's and Dementia Translational Research & Clinical Interventions
- Stefanovski, Meier, Pai, Triebkorn, Lett, Martin, Bülau, Hofmann-Apitius, Solodkin, McIntosh, Ritter (2021). Bridging Scales in Alzheimer's disease: Biological framework for brain simulation with The Virtual Brain. Frontiers in Neuroinformatics
- Stefanovski, Triebkorn, Spiegler, Diaz-Cortes, Solodkin, Jirsa, McIntosh, Ritter; for the Alzheimer's Disease Neuroimaging Initiative (2019). Linking molecular pathways and large-scale computational modeling to assess candidate disease mechanisms and pharmacodynamics in Alzheimer's disease. Frontiers Computational Neuroscience
- Schirner, McIntosh, Jirsa, Deco, Ritter (2018) Inferring multi-scale neural mechanisms with brain network modelling. eLife
- Deco, Kringelbach, Jirsa, Ritter (2017) The dynamics of resting fluctuations in the brain: metastability and its dynamical core. Scientific Reports
- Schirner, M., S. Rothmeier, V. Jirsa, A. R. McIntosh and Ritter, P. (2015). An automated pipeline for constructing personalised virtual brains from multimodal neuroimaging data. Neuroimage
- Ritter, P., M. Schirner, A. R. McIntosh and V. K. Jirsa (2013). "The virtual brain integrates computational modeling and multimodal neuroimaging." Brain Connect

Lecture Notes

Lecture presentations will be made available and published here:
YouTube: https://www.youtube.com/@brainmodes/

Assigned Degree Programs

Students of other courses can take this module if capacity allows.

Miscellaneous
Open-source software The Virtual Brain (thevirtualbrain.org) can be installed on own notebook/computer (runs on MacOS, Linux, Windows) or used via the research infrastructure EBRAINS (requires free registration at https://ebrains.eu/register/).

Course Structure
The courses take place in the summer and winter semester and consist of the following parts:
Lectures and self-study: 2 ECTS

Dates WS 2026/2027:

Nov 12, 2026 – Nov 27,2026

1. Nov 12 16:30-18:30 = 2.5 units á 45 min (Ritter)
2. Nov 13 16:30-18:30 = 2.5 units á 45 min (Martin)
3. Nov 16 16:30-18:30 = 2.5 units á 45 min (Schirner & Sacks)
4. Nov 17 16:30-18:30 = 2.5 units á 45 min (Schirner & Brandt)
5. Nov 18 16:30-18:30 = 2.5 units á 45 min (Stefanovski & da Costa Zemsch)
6. Nov 19 16:30-18:30 = 2.5 units á 45 min (Schirner & Martin)
7. Nov 20 **17:00-19:00** = 2.5 units á 45 min (Pille & Perdikis)
8. Nov 23 16:30-18:30 = 2.5 units á 45 min (Taher & An)
9. Nov 24 16:30-18:30 = 2.5 units á 45 min (Felicetti)
10. Nov 25 16:30-18:30 = 2.5 units á 45 min (Liu & Deger & Bragin)
11. Nov 26 16:30-18:30 = 2.5 units á 45 min (Bülau & Hüttl)
12. Nov 27 16:30-18:30 = 2.5 units á 45 min (Taher & Them & Schmitt)

Total: 30 units á 45 min
Each session has a short bio break of 7 minutes.

Target Group
Master and PhD students with interest in the topic of computational neuroscience and its applications in clinical research.

Course Certificate
Students have to pass a written exam that can be completed at home. The exam tasks are given in the last session of the course and must be solved until one week later. Students who successfully pass the written exam are awarded 2 ECTS.

Program
The order of lectures may change.

Session 1 "**The Virtual Brain - Overview**" Prof. Dr. Petra Ritter

Recommendation for self-study:

- Schirner, Deco, Ritter (2023) Learning how network structure shapes decision-making for bio-inspired computing. Nature Communications
- Koller D, Schirner M, Ritter P. Human connectome topology directs cortical traveling waves and shapes frequency gradients Nature Communications
- Schirner, Domide, Perdikis, Triebkorn, Stefanovski, Pai, Prodan, Valean, Palmer, Langford, Blickensdörfer, van der Vlag, Diaz-Pier, Peyser, Woodman, Zehl, Fousek, Petkoski, Kusch, Hashemi, Marinazzo, Mangin, Flöel, Akintoye, Stahl, Deco, McIntosh, Hilgetag, Morgan, Schuller, Upton, McMurtrie, Dickscheid, Bjaalie, Amunts, Mersmann, Jirsa, Ritter. Brain Simulation as a Cloud Service: The Virtual Brain on the European Research Platform EBRAINS (2022) Neuroimage

Session 2 "Introduction to TVB modeling framework and The Virtual Brain Ontology for reproducible and comparable computational modeling" Leon Martin, MSc.

Recommendation for self-study:

- Martin, Bülau, Pille, Schmitt, Hüttl, Meier, Taher, Perdikis, Schirner, Stefanovski, Ritter (2025) The Virtual Brain Ontology: A Digital Knowledge Framework for Reproducible Brain Network Modeling (BioRxiv)
- Sanz-Leon, P., Knock, S. A., Spiegler, A., & Jirsa, V. K. (2015). Mathematical framework for large-scale brain network modeling in The Virtual Brain. *Neuroimage, 111*, 385-430. doi: 10.1016/j.neuroimage.2015.01.002
- Ritter, P., M. Schirner, A. R. McIntosh and V. K. Jirsa (2013). "The virtual brain integrates computational modeling and multimodal neuroimaging." Brain Connect

Session 3 "Secure Processing Environment, containers and reproducible processing" Dr. Michael Schirner, Marc Sacks, MSc.

Recommendation for self-study:

- Schirner, Domide, Perdikis, Triebkorn, Stefanovski, Pai, Prodan, Valean, Palmer, Langford, Blickensdörfer, van der Vlag, Diaz-Pier, Peyser, Woodman, Zehl, Fousek, Petkoski, Kusch, Hashemi, Marinazzo, Mangin, Flöel, Akintoye, Stahl, Deco, McIntosh, Hilgetag, Morgan, Schuller, Upton, McMurtrie, Dickscheid, Bjaalie, Amunts, Mersmann, Jirsa, Ritter. Brain Simulation as a Cloud Service: The Virtual Brain on the European Research Platform EBRAINS (2022) Neuroimage
- Jacobs, … , Ritter,…, Hofmann-Apitius (2026) Selecting medical research data platforms for translational biomedical research: a five tier overview and requirment-weighted assessment framework. Frontiers Digital Health
- Schirner & Ritter (2024) Virtuelle Forschungsumgebung für Gesundheitsdaten: Virtual Research Environment (VRE) und Health Data Cloud (HDC). Nomos

- Schirner, Domide, Perdikis, Triebkorn, Stefanovski, Pai, Prodan, Valean, Palmer, Langford, Blickensdörfer, van der Vlag, Diaz-Pier, Peyser, Woodman, Zehl, Fousek, Petkoski, Kusch, Hashemi, Marinazzo, Mangin, Flöel, Akintoye, Stahl, Deco, McIntosh, Hilgetag, Morgan, Schuller, Upton, McMurtrie, Dickscheid, Bjaalie, Amunts, Mersmann, Jirsa, Ritter. Brain Simulation as a Cloud Service: The Virtual Brain on the European Research Platform EBRAINS (2022) Neuroimage
- Schirner, M., S. Rothmeier, V. Jirsa, A. R. McIntosh and Ritter, P. (2015). An automated pipeline for constructing personalised virtual brains from multimodal neuroimaging data. Neuroimage
- https://www.youtube.com/watch?v=vFsi7L9zPdk&t=8s

Session 4 "**Digital Twins, Intelligence & Plasticity**" Dr. Michael Schirner & Luca Brandt, MSc.

Recommendation for self-study:

- Schirner, Deco, Ritter (2023) Learning how network structure shapes decision-making for bio-inspired computing. Nature Communications
- Schirner, Kong, Yeo, Deco, Ritter (2022) Dynamic primitives of brain network interaction. Neuroimage
- Schirner, McIntosh, Jirsa, Deco, Ritter (2018) Inferring multi-scale neural mechanisms with brain network modelling. eLife
- Fauth, … Ritter,… Schirner,… Stefanovski, … Vlachos (2026) Rewiring of adult neural networks – learning from structural plasticity across multiple scales bioRxiv
- Roy, D., R. Sigala, M. Breakspear, A. R. McIntosh, V. K. Jirsa, G. Deco and P. Ritter (2014). "Using the Virtual Brain to Reveal the Role of Oscillations and Plasticity in Shaping Brain's Dynamical Landscape." Brain Connect 4(10),791-811

Session 5 "Integrating biological knowledge in brain network models & modeling neurodegeneration and mental disprders" Dr. Leon Stefanovski & Luise da Costa Zemsch, MSc.

Recommendation for self-study:

- Stefanovski, Bülau, Martin, Langford, Palmer, Sacks, Deger, Pille, Schirner, Meier, Neudorfer, Horn, Solodkin, Thirion, Hofmann-Apitius, Jaconbs, Tom Kodamullil, the Alzheimer's Disease Neuroimaging Initiative, Ritter (2025) An Interactive Brain Atlas of Knowledge (biRxiv)
- https://www.youtube.com/watch?v=QzEyD-9HOw8&t=5s
- https://www.youtube.com/watch?v=UyS7Tt3oVuE
- Stefanovski, Triebkorn, Spiegler, Diaz-Cortes, Solodkin, Jirsa, McIntosh, Ritter; for the Alzheimer's Disease Neuroimaging Initiative (2019). Linking molecular pathways and large-scale computational modeling to assess candidate disease mechanisms and pharmacodynamics in Alzheimer's disease. Frontiers Computational Neuroscience

- Triebkorn, Stefanovski, Dhindsa, Diaz-Cortes, Bey, Bülau, Pai, Spiegler, Jirsa, McIntosh, Ritter (2022) Alzheimer's Disease Neuroimaging Initaitive. Brain Simulation augments machine-learning-based classification of dementia Alzheimer's and Dementia Translational Research & Clinical Interventions

Session 6 "**Scientific Operations Maturity: Automation and artificial intelligence**" Dr. Michael Schirner & Leon Martin, MSc.

Recommendation for self-study:

- Johnson, Nguyen, Dichter, Zappulla, Kosma, Gunalan, Halchenko, Neufeld, Ratan, Edwards, Ressl, Heilbronner, Schirner, Ritter, Weter, Ghosh, Martone, Pestilli, Yatsenko (2024) SciOps: Achieving Productivity and reliability in Data-Intensive Research arXiv, Major revision Nature Methods

Session 7 **"Brain network model optimization and multiscale co-simulation"** Marius Pille, MSc. & Dr. Dionysios Perdikis

Recommendation for self-study:

- Pille, Martin, Richter, Perdikis, Schirner, Ritter (2025) Fast and Easy Whole-Brain Network Model Parameter Estimation with Automatic Differentiation (bioRxiv)
- TVB advanced tutorials https://training.incf.org/course/virtual-brain-node-6-workshop
- Schirner, Domide, Perdikis, Triebkorn, Stefanovski, Pai, Prodan, Valean, Palmer, Langford, Blickensdörfer, van der Vlag, Diaz-Pier, Peyser, Woodman, Zehl, Fousek, Petkoski, Kusch, Hashemi, Marinazzo, Mangin, Flöel, Akintoye, Stahl, Deco, McIntosh, Hilgetag, Morgan, Schuller, Upton, McMurtrie, Dickscheid, Bjaalie, Amunts, Mersmann, Jirsa, Ritter. Brain Simulation as a Cloud Service: The Virtual Brain on the European Research Platform EBRAINS (2022) Neuroimage
- Stefanovski, Meier, Pai, Triebkorn, Lett, Martin, Bülau, Hofmann-Apitius, Solodkin, McIntosh, Ritter (2021). Bridging Scales in Alzheimer's disease: Biological framework for brain simulation with The Virtual Brain. Frontiers in Neuroinformatics
- Schirner, McIntosh, Jirsa, Deco, Ritter (2018) Inferring multi-scale neural mechanisms with brain network modelling. eLife

Session 8 "**Understanding principles of brain function in the computational macaque and mouse model**" Halgurd Taher, MSc & Jeehye An, MSc

Recommendation for self-study:

- Munoz Lagunas, An, Stefanovski, Ritter (2025) From Ions to Chaos: exploring a whole-brain modelling framework in the mouse (bioRxiv)

Session 9 "**In silico optimization of brain stimulation**" Tiago Felicetti, MSc.

Recommendation for self-study:

- Hofsähs, Pille, Kern, Negi, Meier, Ritter (2026) The Virtual Brain links transcranial magnetic stimulation evoked potentials and inhibitory neurotransmitter changes in major depressive disorder. Imaging Neuroscience
- Meier, Perdikis, Blickensdörfer, Stefanovski, Liu, Maith, Dinkelbach, Baladron, Hamker, Ritter (2022) Virtual deep brain stimulation: Multiscale co-simulation of spiking basal ganglia model and whole-brain mean-field model with The Virtual Brain. Experimental Neurology

Session 10 "**Modeling mechanisms of consciousness**" Dr. Qin Liu & Lion Deger, MSc. & Valery Bragin, MSc.

Recommendation for self-study:

- Lee, Liu, Dadgar-Kiani (2022) Solving brian circuit function and dysfunction with computational modeling and optogenetic fMRI. Science
- Liu, Ulloa, Horwitz (2022) The spatiotemporal neural dynamics of entersensory attention capture salient stimuli: a large-scale auditory-visual modeling study. Frontiers Comp Neurosci
- Liu, Ulloa, Horwitz (2017) Using a Large-scale Neural Model of Cortical Object Processing to investigate the Nerual Substrate for Managing Multiple Items in Short-term Memory. J Cogn Neurosci

Session 11 "**Modeling mechanisms of psychosis**" Dr. Konstantin Bülau & Christoph Hüttl

Recommendation for self-study:

- Costa Klein, Ettinger, Schirner, Ritter, Rujescu, Falkai, Koutsouleris, Kambeitz-Ilankovic, Kambeitz. (2020) Brain Network Simulations Indicate Effects of Neuregulin-1 Genotype on Excitation-Inhibition Balance in Cortical Dynamics. Cerebral Cortex.
- Domingo-Fernández, D., Kodamullil, A. T., Iyappan, A., Naz, M., Emon, M. A., Raschka, T., . . . Hofmann-Apitius, M. (2017). Multimodal mechanistic signatures for neurodegenerative diseases (NeuroMMSig): a web server for mechanism enrichment. *Bioinformatics, 33*(22), 3679-3681. doi: 10.1093/bioinformatics/btx399

Session 12 "**TVB-Positron Emission Tomography & In silico drug discovery and testing**" Dr. Halgurd Taher & Jennifer Them, MSc. & Rico Schmitt

Recommendation for self-study:

- Stasinski, Taher, Meier, Schirner, Perdikis, Ritter (2024) Homeodynamic feedback inhibition control in whole-brain simulations. PLOS Computational Biology
- Them, Deger, Taher, Stasinski, Martin, Meier, Stefanovski, Ritter (2026) Brain network modelling with The Virtual Brain derives pharmacodynamics of ketamine (bioRxiv)
- Schmitt, Bülau, Martin, Huettl, Schirner, Stefanovski, Ritter (2025) Biological Database Mining for LLM-Drive Alzheimer's Disease Drug Repurposing bioRxiv
- Stefanovski, Triebkorn, Spiegler, Diaz-Cortes, Solodkin, Jirsa, McIntosh, Ritter; for the Alzheimer's Disease Neuroimaging Initiative (2019). Linking molecular pathways and large-scale computational modeling to assess candidate disease mechanisms and pharmacodynamics in Alzheimer's disease. Frontiers Computational Neuroscience