Co-funded by
the European Union

WP4.5 Linking Model Activity and Function to Experimental Data (Grün, Jirsa)

T4.5.1

Michael von Papen, N. Voges, P. Dabrowska, S. Grün

12 January 2018

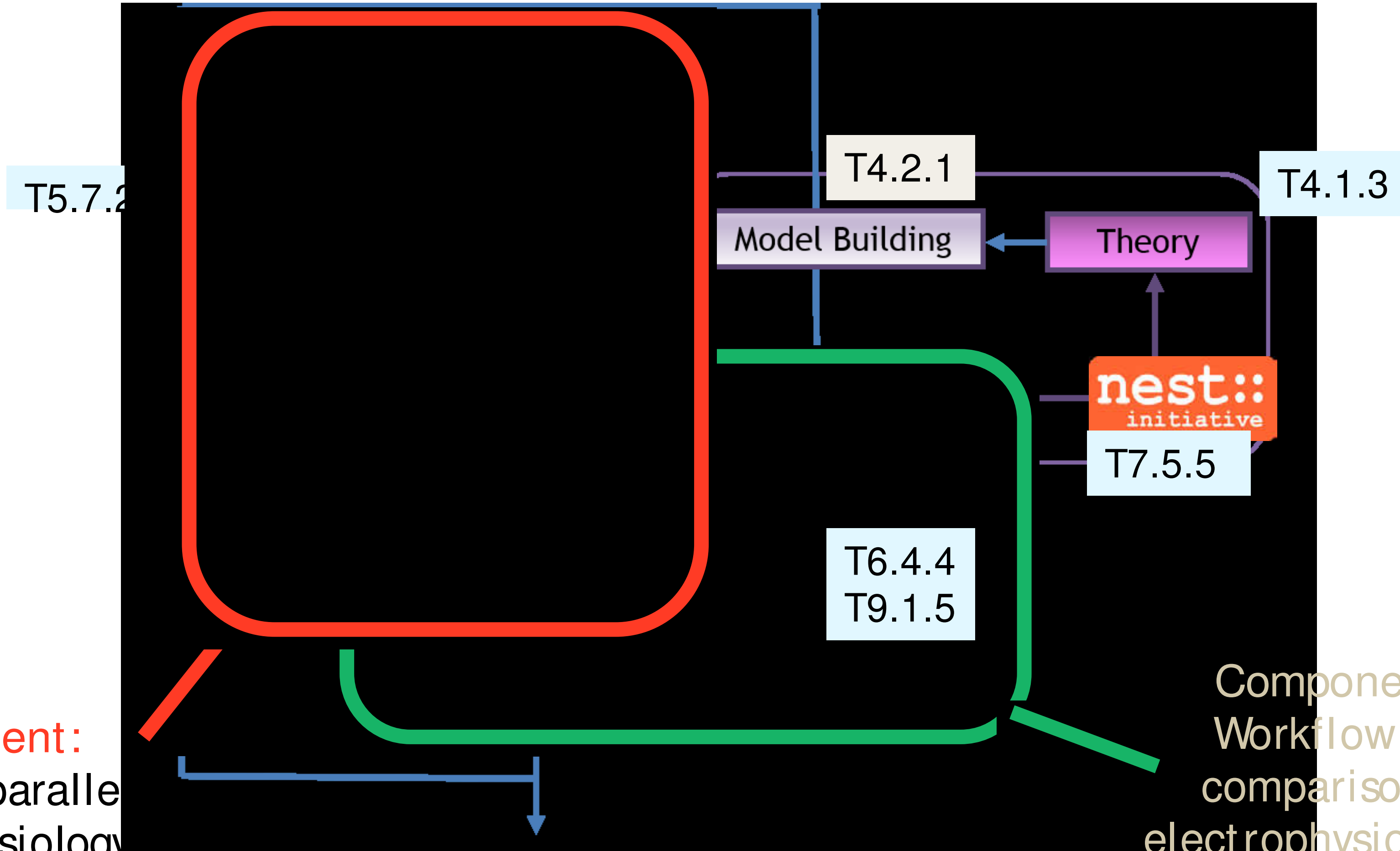
SGA1 T4.5.1 Objectives

Comparing Models with Mouse and Human Brains
(Task leader: Sonja Grün)

- Develop strategies, principles, and algorithms allowing comparative assessment of experimental data and model approaches
  - Analysis of single unit activity of experimental and simulated data
  - Point-neuron model of motor-cortical mesocircuit
  - Improvement and validation of the model
  - Provide workflows for CDP4 on visuo-motor integration

- Whole brain network models derived from human and mouse connectome data using neural mass models will also be validated against empirical data (*Viktor Jirsa*)

HBP Components in the Integrative Loop



Component:
Massively parallel electrophysiology data

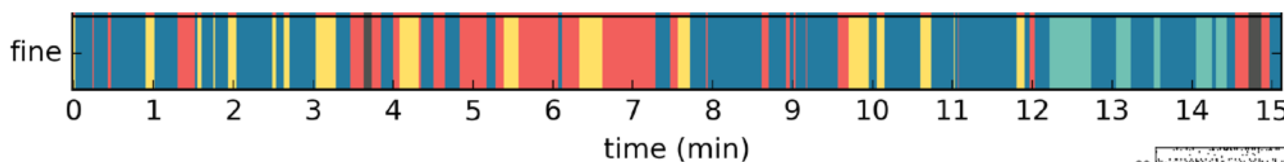
Component:
Workflow for comparison of electrophysiological and simulated data

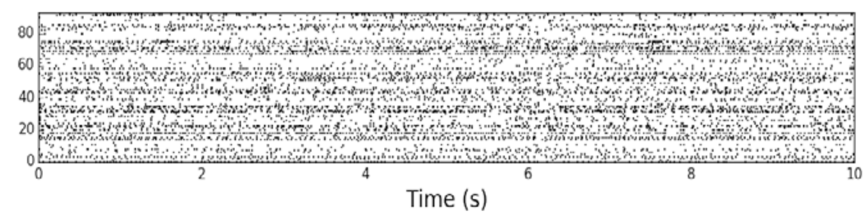
Massively parallel electrophysiology data

- Resting state recordings (no task) of two macaque monkeys
- Microelectrode arrays (96 electrodes) implanted in motor cortex

➢ Available Data: Single unit activity (~140 units), waveforms, LFP

➢ Video recording to identify behavior (rest, sleepiness, body movement, head movements)





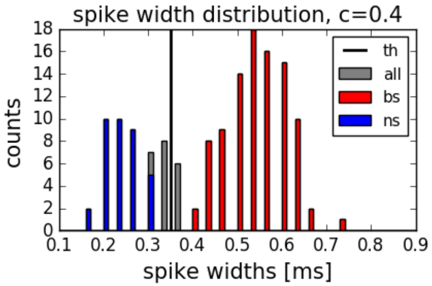
Data available in HBP collaboratory (#2493), to be made available via Neural Activity Resource

Co-funded by the European Union

Analysis Workflow published in HBP Collaboratory

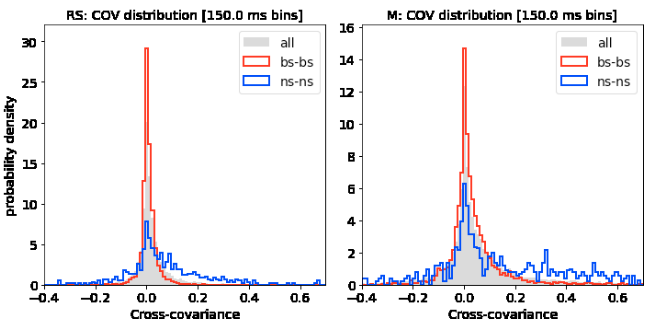
Reproducible analysis following Denker & Grün (2016)

Results of Resting State Analysis

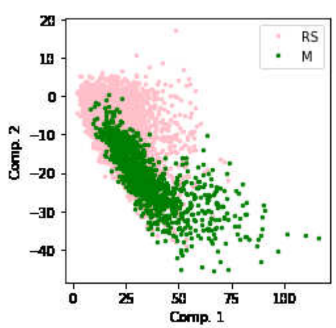


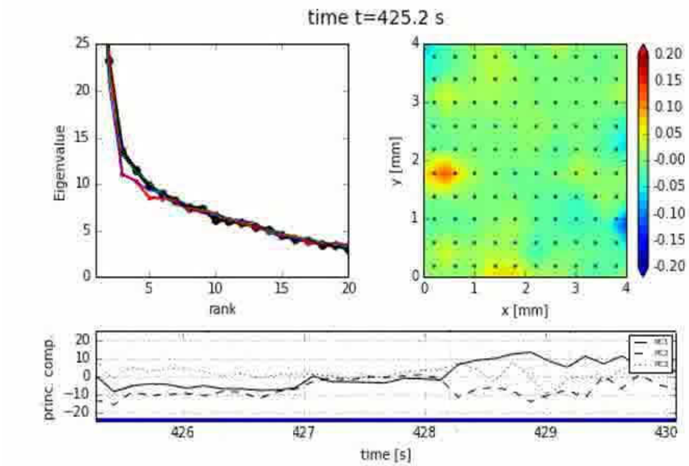
Separation of putative inhibitory/ excitatory units

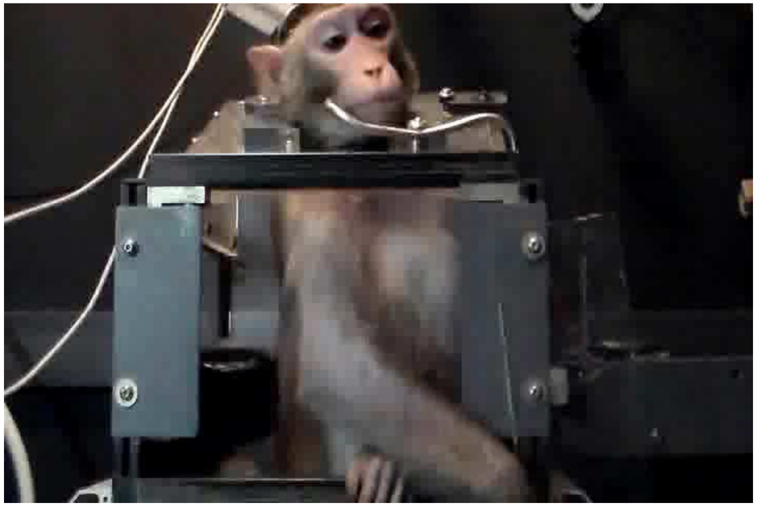
Extraction of neuron type-specific covariance structure (with T4.1.3)



Behavior separable in rate space



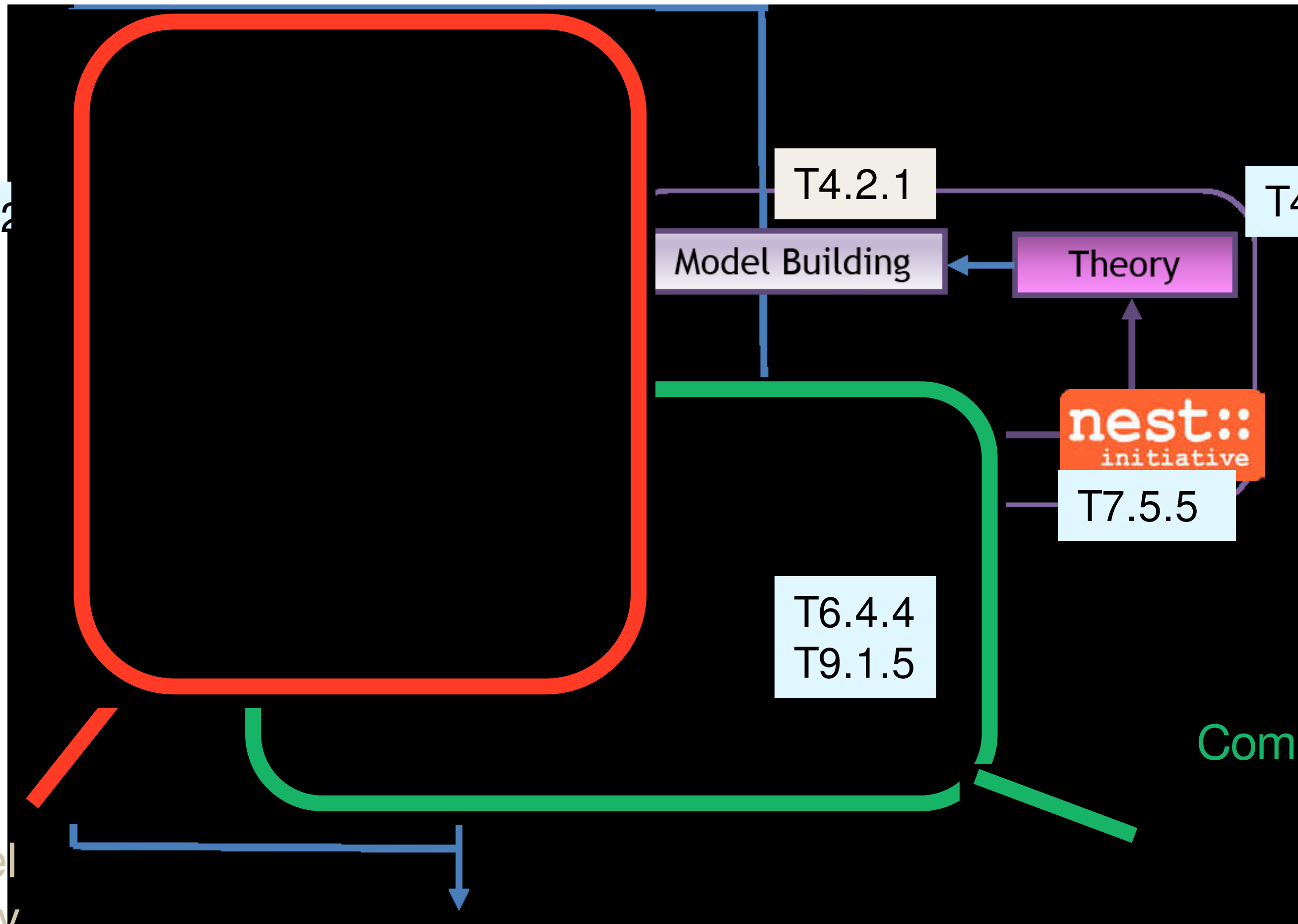




- PCA of single units spike count
- Continuous analysis with sliding window
- Loadings on Utah array
- dimensionality reduced during movement (see Mazzucato et al., 2016)

von Papen, Voges, Dabrowska, Gruen et al., in prep.

HBP Components in the Integrative Loop

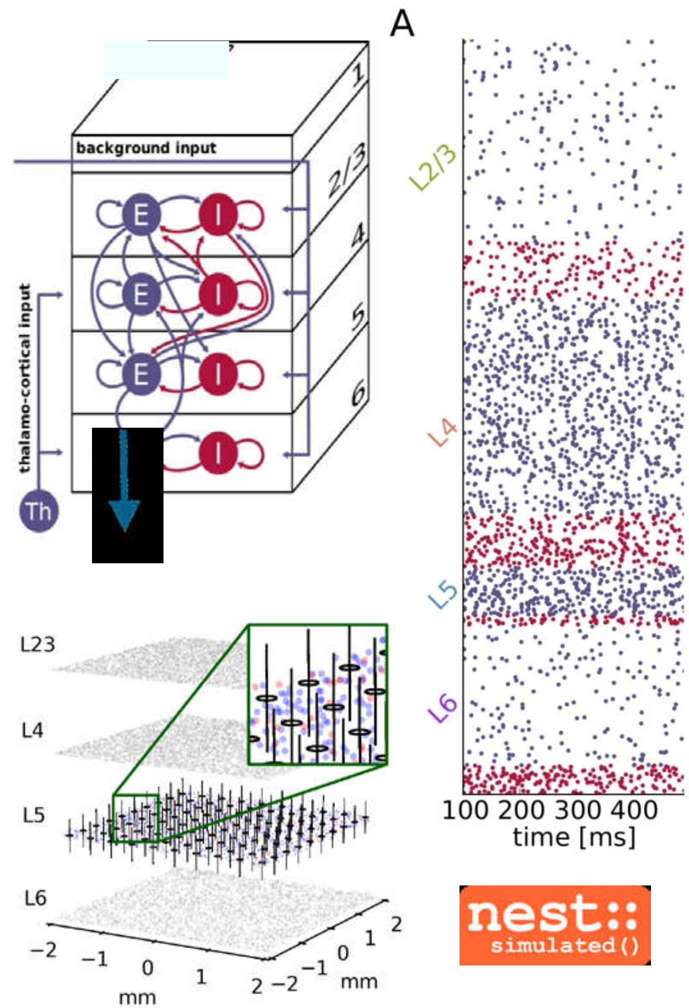


T5.7.

Component:
Massively parallel
electrophysiology
data

Component:
flow for
arison of
hysiological
and simulated data

Cortical Mesocircuit Model



Mesocircuit model:

- Extension of Potjans & Diesmann (2014) microcircuit (T4.2.1) to 4x4mm^2
- Distance dependent connectivity
- 1.2 million LIF point neurons
- 6 billion current-based synapses
- 2 neuron populations (E,I) in 4 layers
- Layer & type specific random connectivity

❖ E. Hagen, J. Senk, S. van Albada, M. Diesmann

Aim: Understand network dynamics of resting state

Problem: Not yet tailored to motor cortex

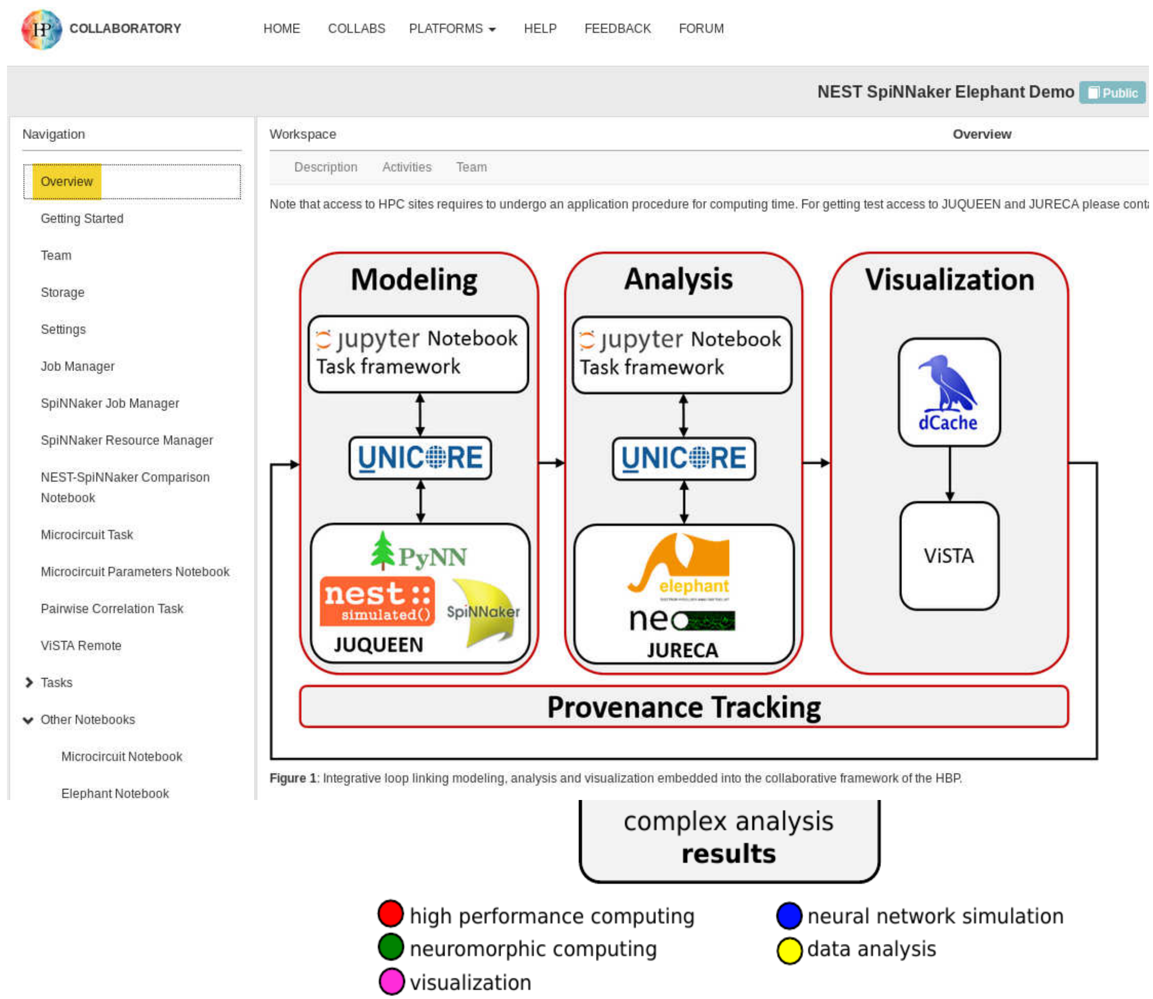
➢ 1st step: Parameter space confinement using mean field-theoretic approach (Dahmen et al., 2016; T4.1.3)

Workflow for comparison of electrophysiological and simulated data

Compare spiking network model to experimental data

Based on NEST-Spinnaker comparison workflow (Senk et al., 2016), see collab #507

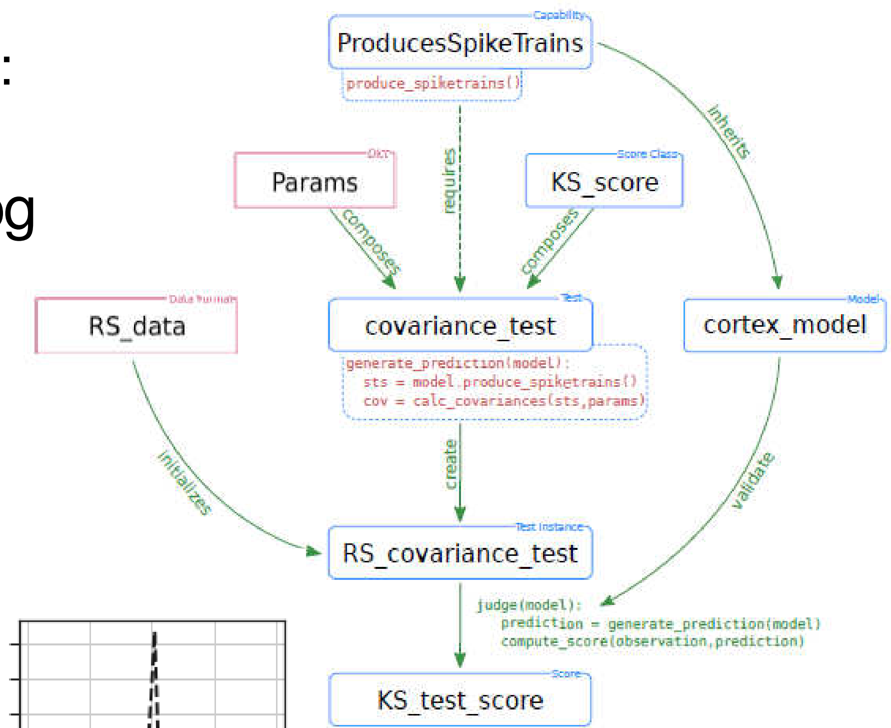
1. Simulation run on HPC cluster within HBP Collaboratory (UNICORE)
2. Extract and analyse statistical properties in collab
3. Validate model using python module *SciUnit* (within Validation Framework, T6.4.4)

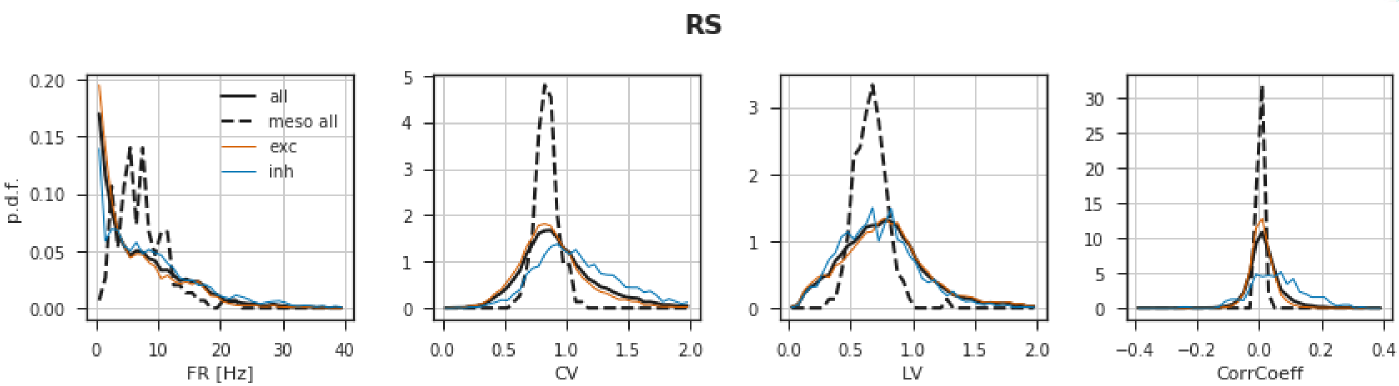


Senk et al., 2016

Results of Model / Experiment Comparison

- Prototype workflow for validation using microcircuit
- Python module for quantitative comparison: NetworkUnit (T6.4.4, T9.1.5)
- Microcircuit implemented in model catalog
- Preliminary statistics of mesocircuit
  - Qualitatively but not quantitatively
  - Lack of low firing rates, more regular less correlated





Conclusions T4.5.1

- **Key results: What went according to plan?**
  - Use-case (resting state analysis) identified: obtained experimental data and suitable model [MS4.5.1✓]
    - Mesocircuit model with distance dependent connectivity
    - Workflow published for data analysis (collab #2493)
  - Comparison of simulated and experimental results [MS4.5.4✓]
    - Groundwork: workflow published for statistical comparison (Senk et al., 2016; collab #507)
    - Prototype workflow for validation of mesocircuit and CDP4
  - Intense interaction with other WP's and SP's (WP4.1, WP4.2, SP5, SP6, SP7, SP9)
- **Where are we behind? What's left?**
  - Not yet implemented in Neural Activity Resource (T5.7.2)
  - Paper publication of resting state analysis
  - Model parameters to be adapted to motor cortex
  - Mesocircuit model to be implemented on platforms

Milestones

MS4.5.1 Overview of available brain activity data and model pairings, including the type of data, and identified first use cases for the comparison of activity data and model simulations✓

MS 4.5.4 Comparison of models with mouse and human brains ✓

Thanks to all people involved at FZ Juelich:
P. Dabrowska, D. Dahmen, M. Denker, L. Deutz, R. Gutzen, M. Helias, J. Senk, N. Voges

Appendix

T4.5.1 Dissemination

What audience do I want to reach to?

- neuroscientists and computational neuroscientists inside and outside the HBP

What information do I want to share with them?

- Workflows adaptable to their own scientific question

Why do I want to share that specific result with them?

- deliver basic parameters for model building
- get an understanding of the difference of structural and functional correlation
- community can make use of reproducible analysis

What channels do I want to use for that?

- collaboratory and other repositories
- lectures and tutorials on international courses

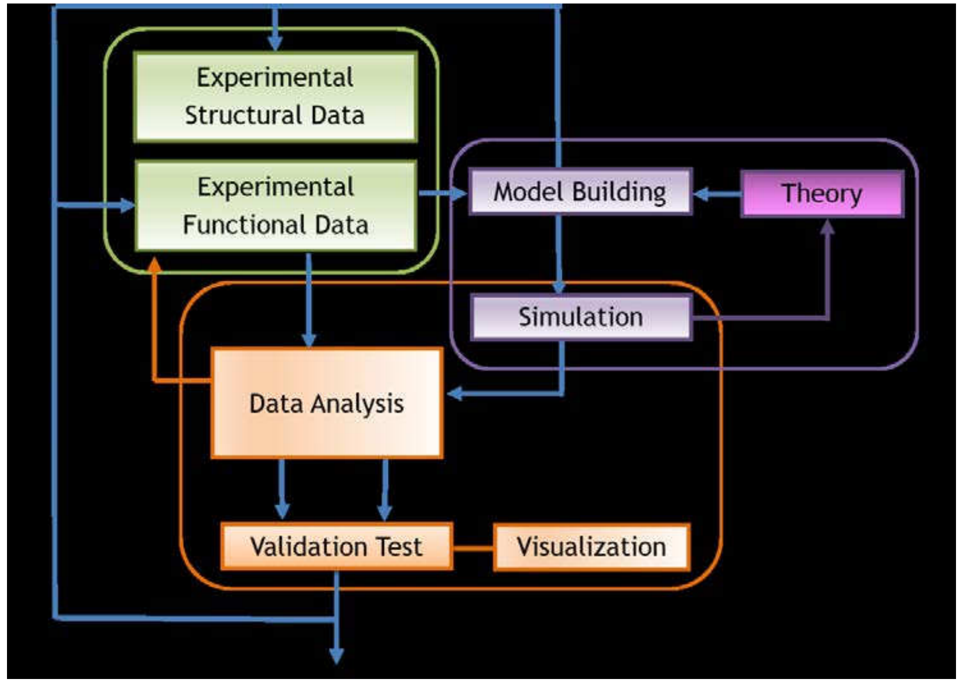
How can I verify the impact that dissemination has had on my targeted audience?

- By number of citations of papers
- By number of access and users of collaboratories (statistics needed!)

T4.5.1 Summary

T4.5.1: Comparing Models with Mouse and Human Brains

- Description: The task provides workflows for the analysis of neural activity data and for the quantitative comparison of simulated and experimental data. These workflows are used to further develop models of visuo-motor integration and motor-cortical mesocircuit.



- Status report:
  - SGA1 Milestones achieved
  - Workflows published in collab (#507, #2493) and in print (Denker & Grün, 2016; Senk et al., 2016)

T4.5.1 Publications

- Denker, M. and Grün, S. (2016) 'Designing workflows for the reproducible analysis of electrophysiological data', in Amunts, K. et al. (eds) Lecture Notes in Computer Science. Springer, pp. 58–72. doi: 10.1007/978-3-319-50862-7.
- Hagen et al. (2016). Hybrid scheme for modeling local field potentials from point-neuron networks. Cerebral Cortex 26:4461–4496. DOI: 10.1093/cercor/bhw237.
- Senk, J. et al. (2016) 'A collaborative simulation-analysis workflow for computational neuroscience using HPC', in Di Napoli, E. et al. (eds) Lecture Notes in Computer Science. Springer, pp. 243–256. doi: 10.1007/978-3-319-53862-4.
- Torre et al. (2016). ASSET: analysis of sequences of synchronous events in massively parallel spike trains. PLOS Computational Biology 12:e1004939. DOI: 10.1371/journal.pcbi.1004939.
- Torre et al. (2016). Synchronous spike patterns in macaque motor cortex during an instructed-delay reach-to-grasp task. Journal of Neuroscience 36:8329–8340. DOI: 10.1523/JNEUROSCI.4375-15.2016.
- Zehl et al. (2016). Handling metadata in a neurophysiology laboratory. Frontiers in Neuroinformatics 10. DOI: 10.3389/fninf.2016.00026.
- Denker et al. (2017). LFP beta amplitude is predictive of mesoscopic spatio-temporal phase patterns. arXiv:1703.09488.
- Rostami et al. (2017). [Re] spike synchronization and rate modulation differentially involved in motor cortical function. Rescience 3. DOI: 10.5281/zenodo.583814.