WP4 Machine Learning

Georgia Koppe
Central Institute of Mental Health,
Interdisciplinary Center for Scientific Computing,
Heidelberg University

EC Evaluation June 19th

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

WP4 - Staff

Manuel Brenner

Daniel Durstewitz

Georgia Koppe

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

WP4 - Objectives

Two key objectives:

- Simple statistics and visualisations (4.1)
- RNN-based AI models for multimodal (4.2) and big data (4.3) integration and prediction

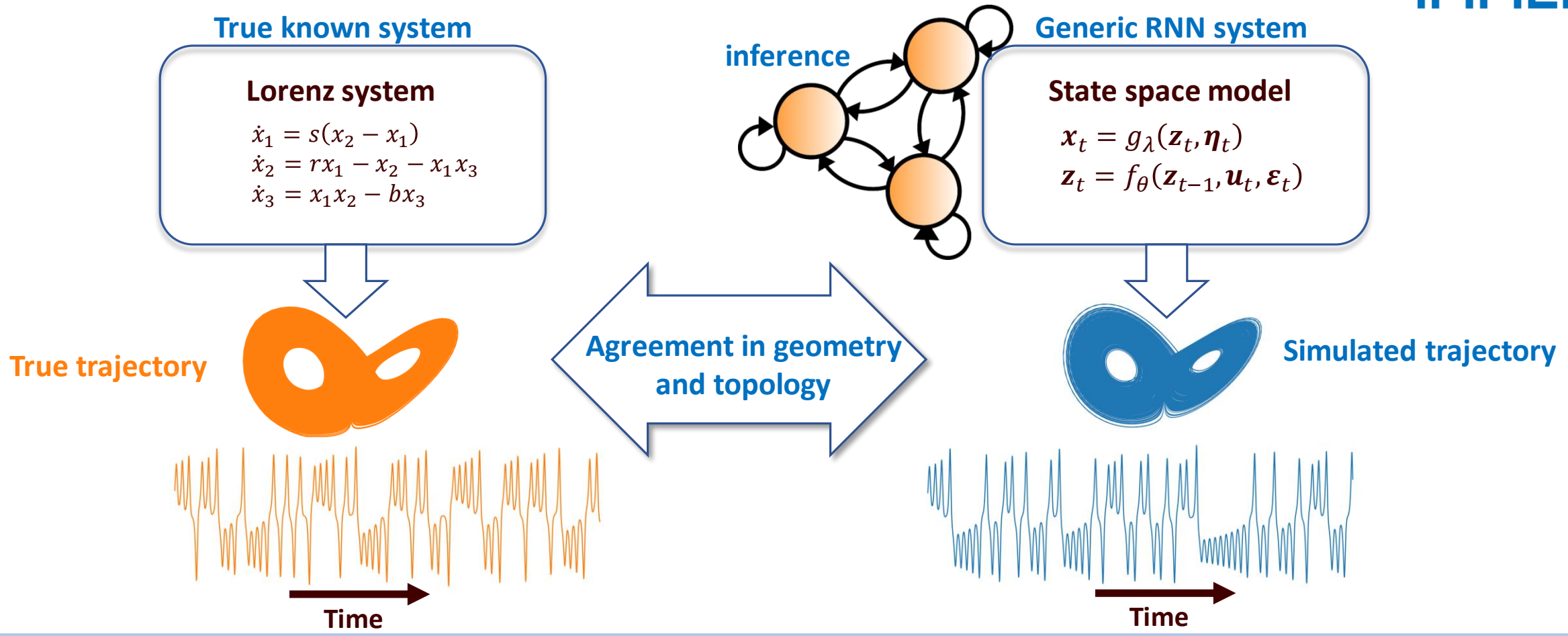
Tasks

- 4.1 Basic data characteristics, robust statistics, and visualization (finalized)
- 4.2 Machine learning for multimodal data integration (finalized)
- 4.3 Development of efficient cross-site big data integration framework (in progress)

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

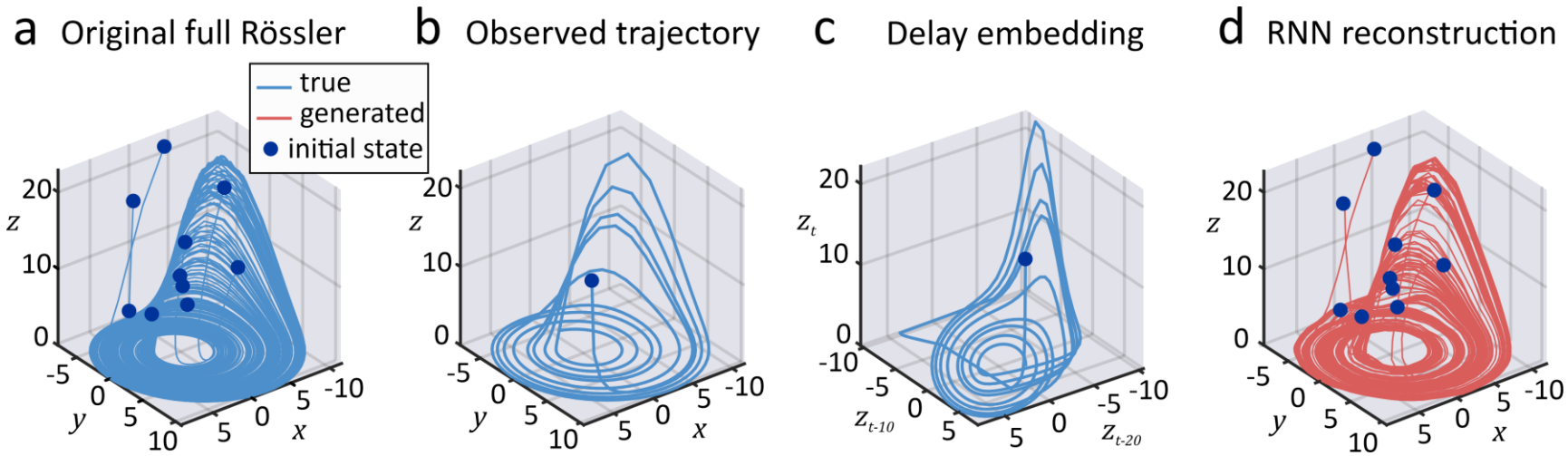
Task 4.2. Machine learning for multimodal data integration

Reconstructing dynamical systems via ML



This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

Task 4.2. Machine learning for multimodal data integration

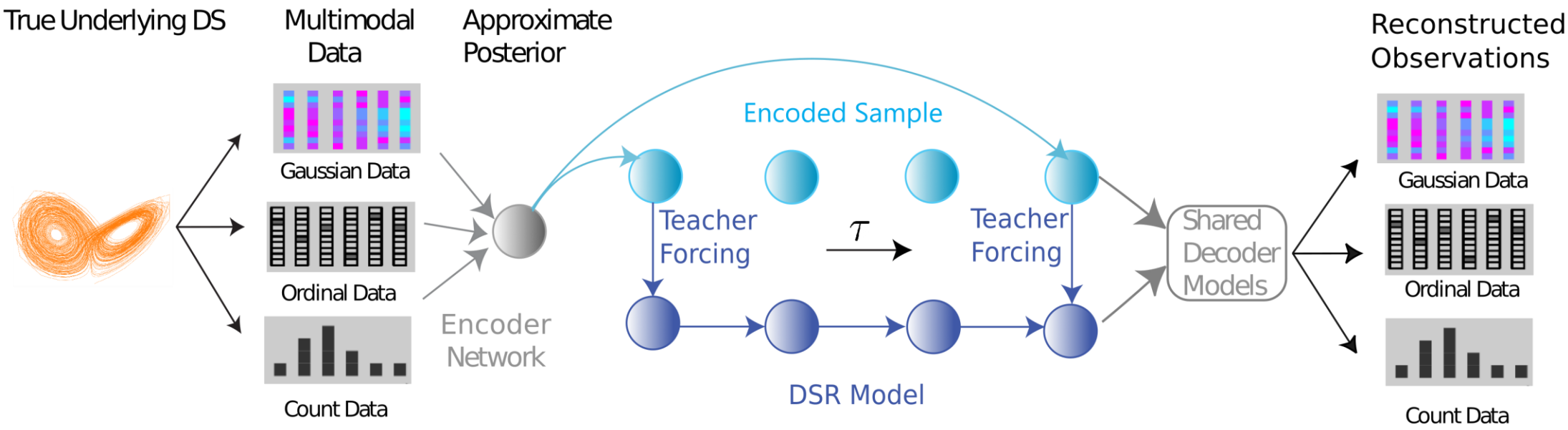


Durstewitz D, Koppe G, Thurm MI (2023) Nat Rev Neurosci

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

Task 4.2. Machine learning for multimodal data integration

Multimodal **V**ariational **A**uto**E**ncoder+ **T**eacher **F**orcing (**MTF**)

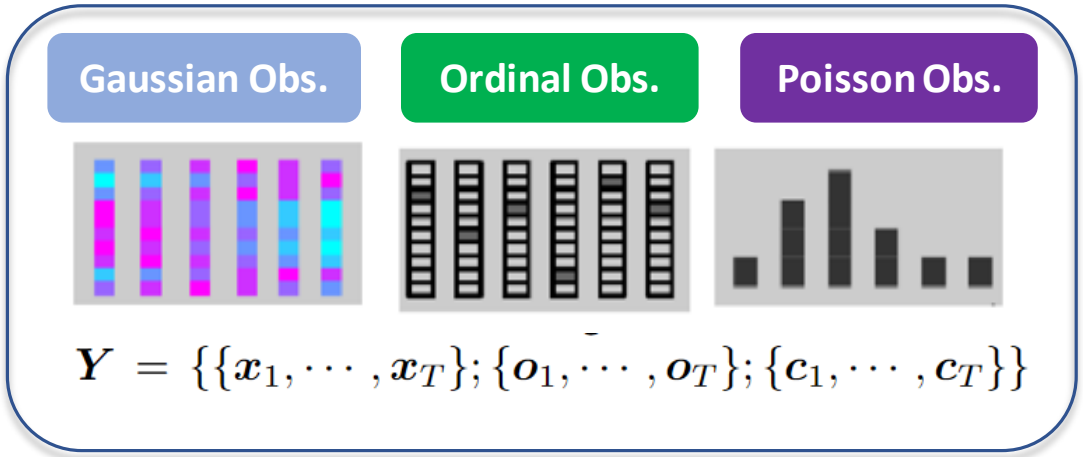


Brenner M, Hess F, Koppe G*, Durstewitz D* (2024) ICML

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

Task 4.2. Machine learning for multimodal data integration

Observed variables



Encoder (CNN)

Approximate posterior

$$q_{\boldsymbol{\phi}}(\tilde{\boldsymbol{Z}}|\boldsymbol{Y}) = \mathcal{N}(\boldsymbol{\mu}_{\boldsymbol{\phi}}(\boldsymbol{Y}), \boldsymbol{\Sigma}_{\boldsymbol{\phi}}(\boldsymbol{Y}))$$

ELBO Loss

$$\mathcal{L}(\boldsymbol{\phi}, \boldsymbol{\theta}; \boldsymbol{Y}) = -\mathbb{E}_{q_{\boldsymbol{\phi}}}[\log p_{\boldsymbol{\theta}}(\boldsymbol{Y}|\tilde{\boldsymbol{Z}}) + \log p_{\boldsymbol{\theta}}(\tilde{\boldsymbol{Z}})] - \mathbb{H}_{q_{\boldsymbol{\phi}}}(\tilde{\boldsymbol{Z}} \mid \boldsymbol{Y})$$

Decoder

Observation Models

$$\boldsymbol{x}_t \mid \tilde{\boldsymbol{z}}_t \sim \mathcal{N}(\boldsymbol{B}\tilde{\boldsymbol{z}}_t, \boldsymbol{\Gamma})$$
$$\boldsymbol{o}_t \mid \tilde{\boldsymbol{z}}_t \sim \text{Ordinal}(\boldsymbol{\beta}\tilde{\boldsymbol{z}}_t, \epsilon)$$
$$\boldsymbol{c}_t \mid \tilde{\boldsymbol{z}}_t \sim \text{Poisson}(\lambda(\tilde{\boldsymbol{z}}_t))$$

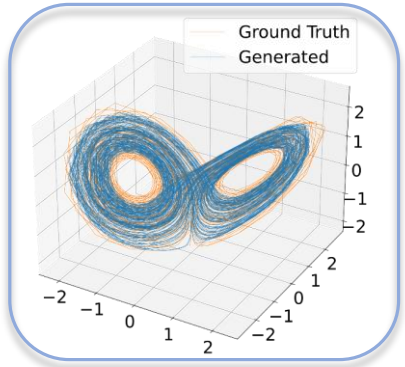
Data Likelihoods

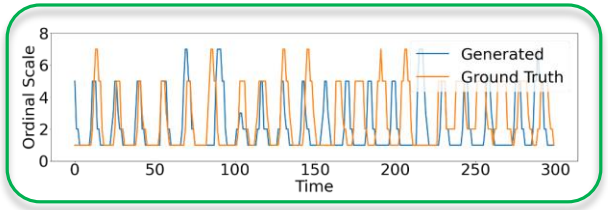
$$\log p_{\boldsymbol{\theta}}(\boldsymbol{Y}|\tilde{\boldsymbol{Z}}) = \sum_{t=1}^{T} (\log p_{\boldsymbol{\theta}}(\boldsymbol{x}_t|\tilde{\boldsymbol{z}}_t) + \log p_{\boldsymbol{\theta}}(\boldsymbol{o}_t|\tilde{\boldsymbol{z}}_t) + \log p_{\boldsymbol{\theta}}(\boldsymbol{c}_t|\tilde{\boldsymbol{z}}_t))$$

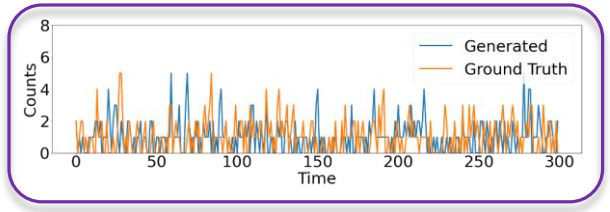
This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

Task 4.2. Machine learning for multimodal data integration

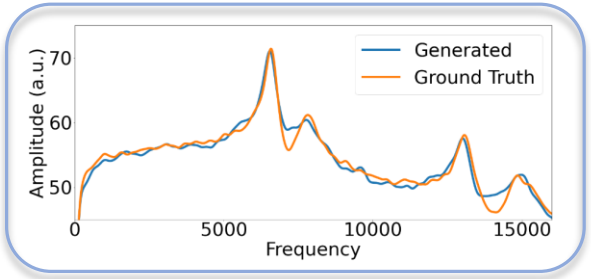
Geometric agreement

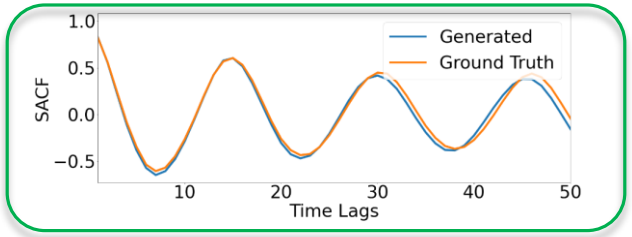


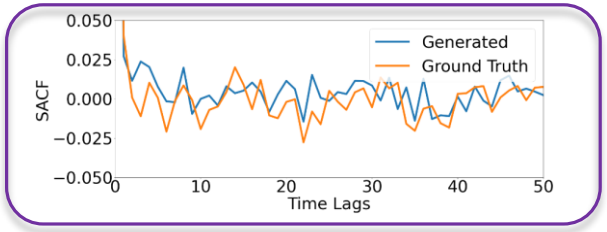




Temporal agreement



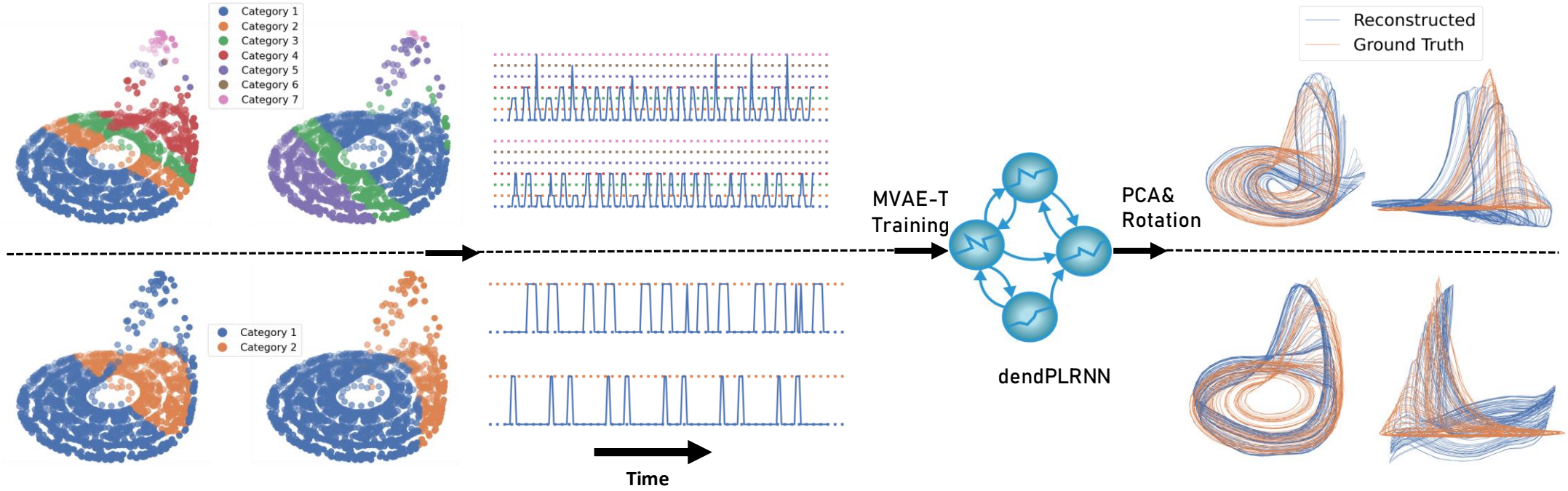




This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

Task 4.2. Machine learning for multimodal data integration

Reconstructed dynamics from ordinal discretization

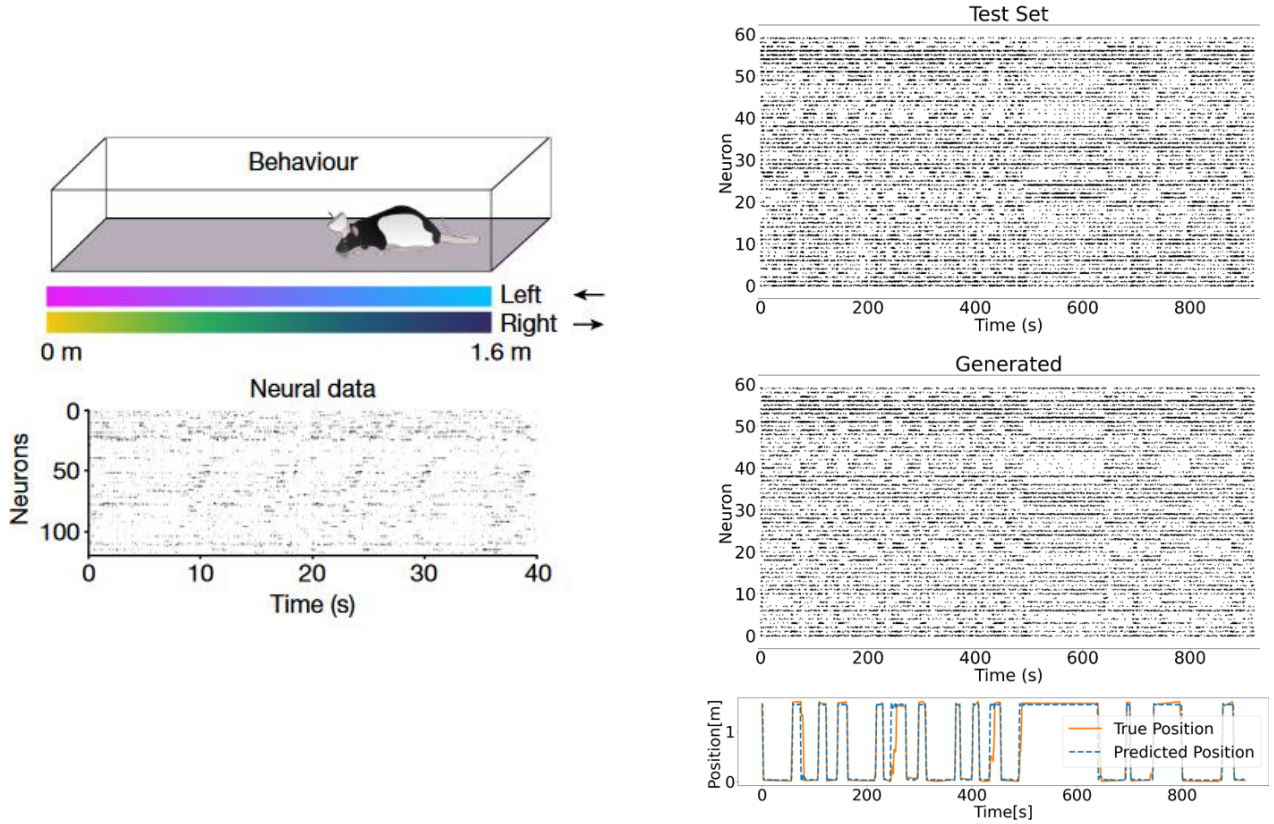


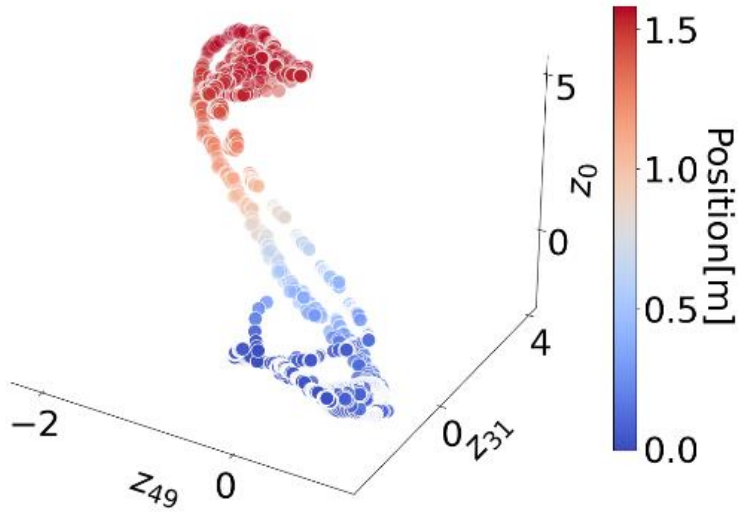
Brenner M, Hess F, Koppe G*, Durstewitz D* (2024) ICML

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

Task 4.2. Machine learning for multimodal data integration

Validation on neuroscientific data



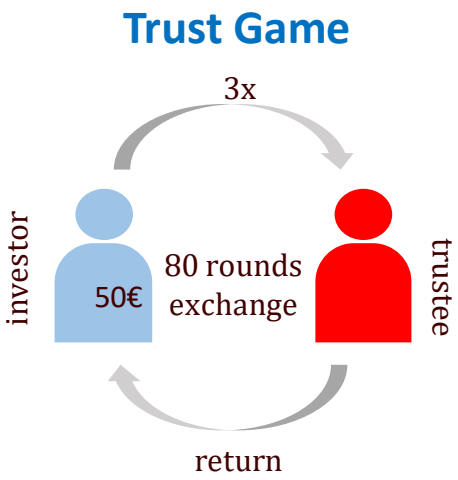


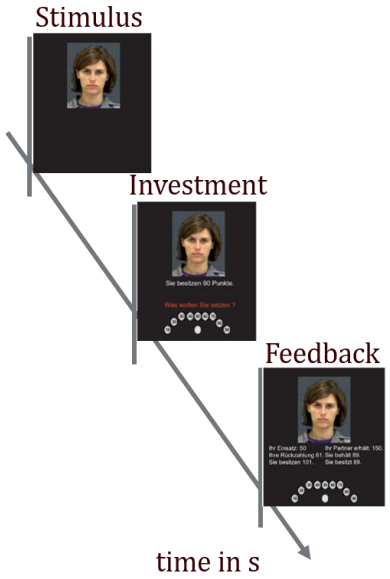
Brenner M, Hess F, Koppe G*, Durstewitz D* (2024) ICML

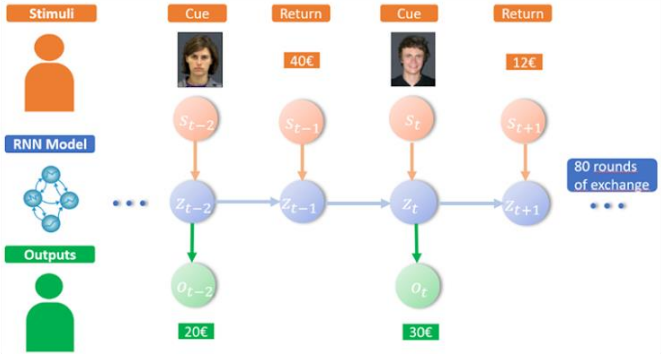
This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

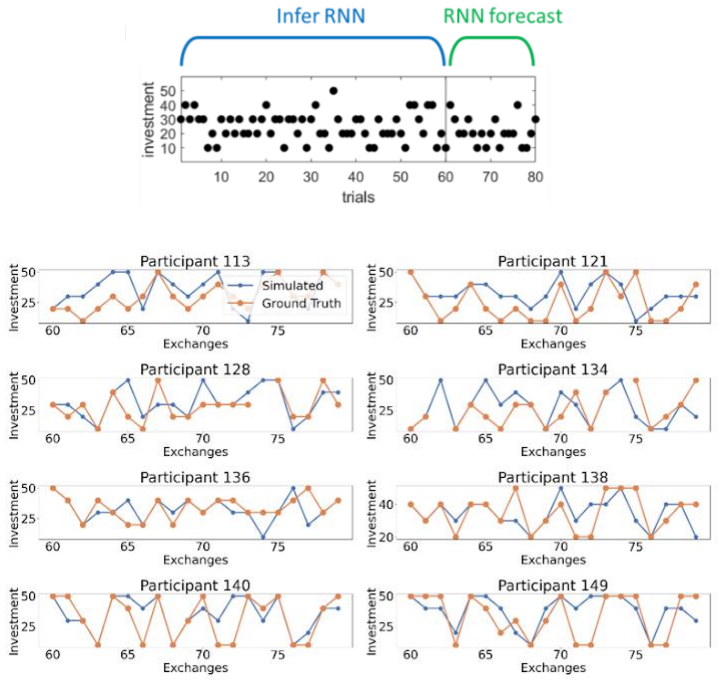
Task 4.2. Machine learning for multimodal data integration

Validation on ordinal behavioral data







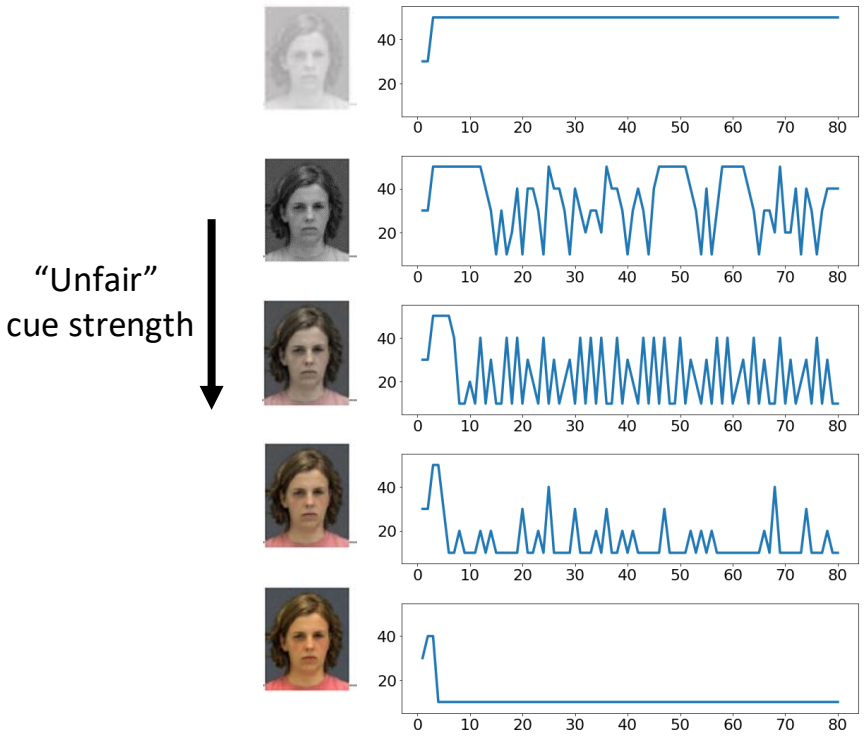


This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

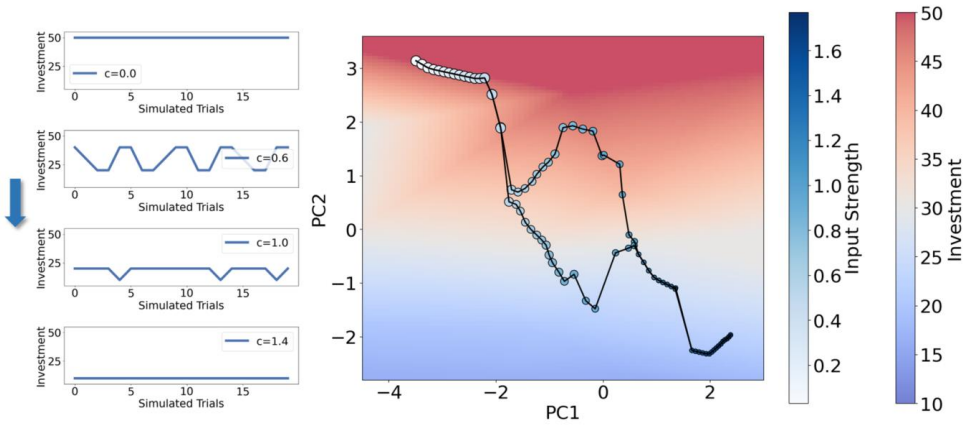
Task 4.2. Machine learning for multimodal data integration

Validation on ordinal behavioral data

Simulating investment dynamics



Bifurcations in investment dynamics



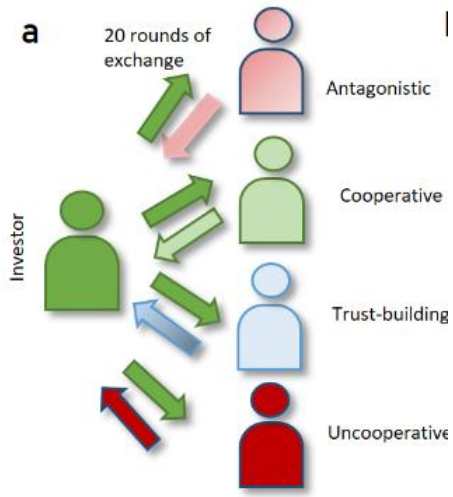
Brenner et al, in prep

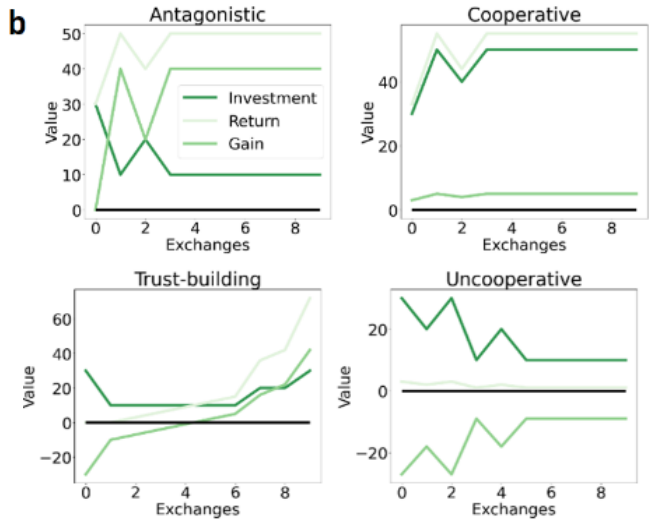
This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

Task 4.2. Machine learning for multimodal data integration

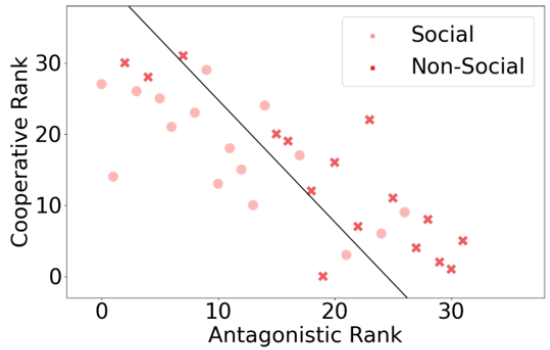
Validation on ordinal behavioral data

Out-of-domain simulations





Out-of-domain generalization

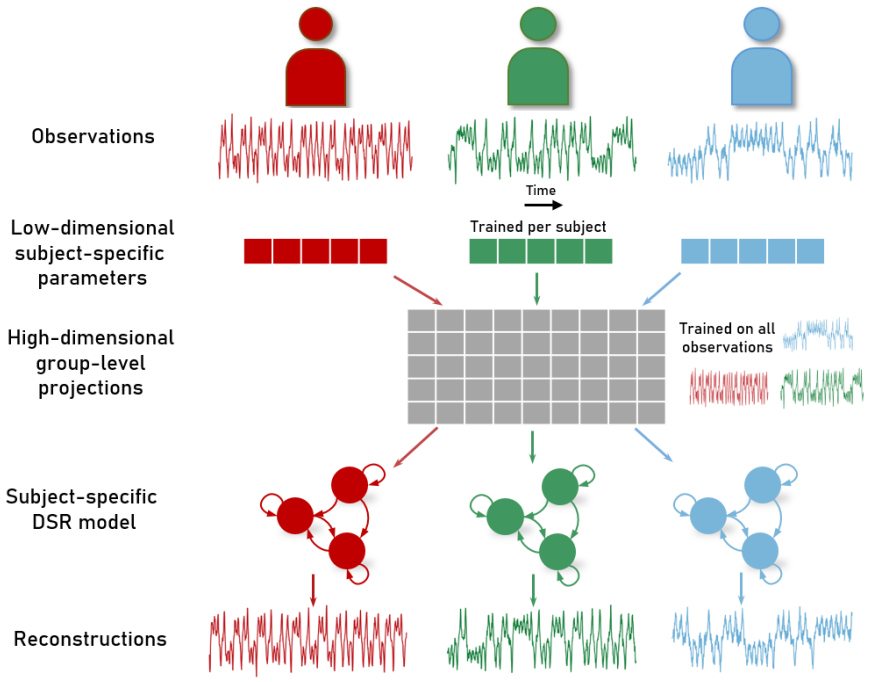


classification accuracy ~80%

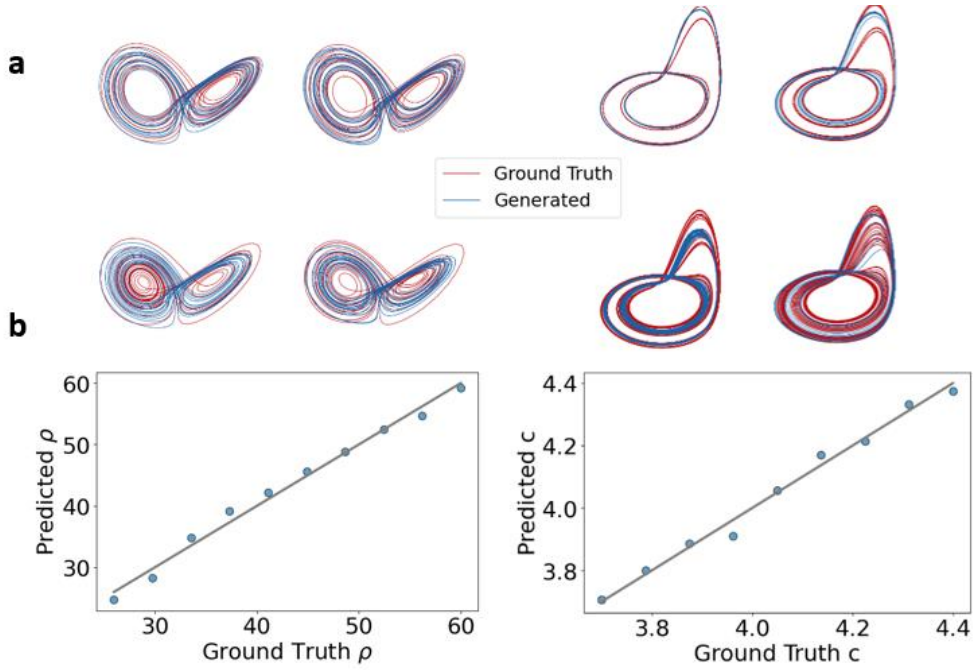
This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

Task 4.3. Efficient big data integration framework

Conceptual idea



Benchmark validation

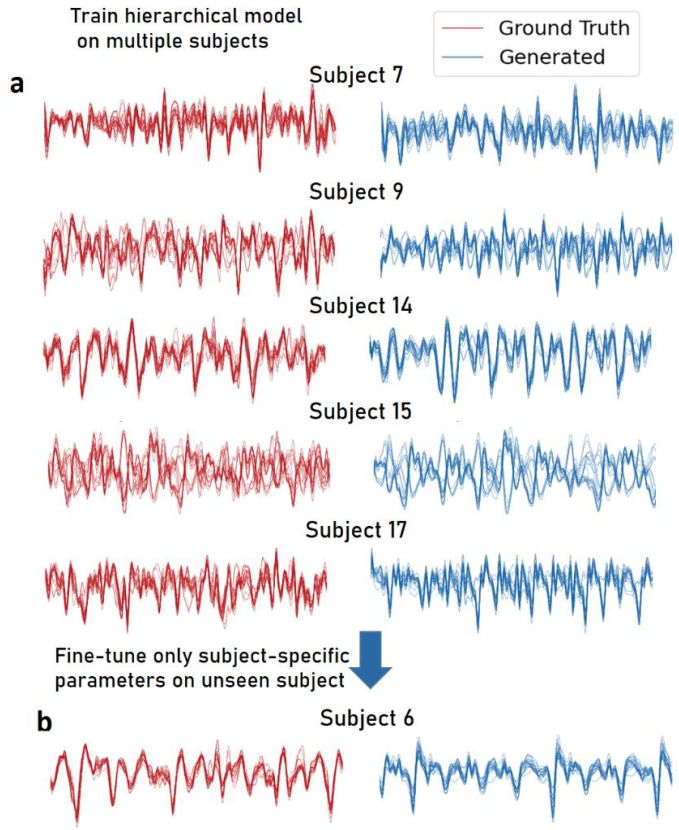


Brenner M et al, in prep

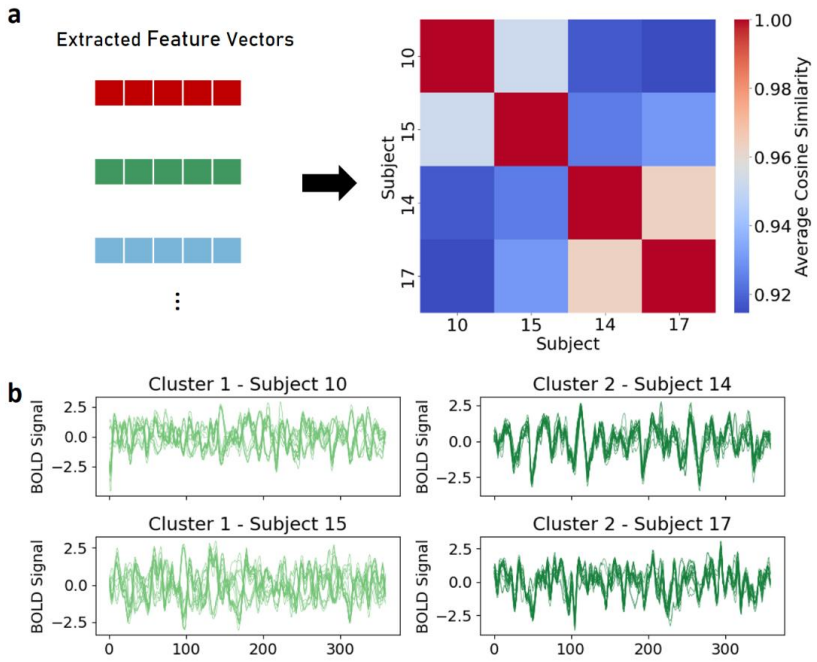
This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

Task 4.3. Efficient big data integration framework

Data validation



Extraction of interpretable structure



Brenner M et al, in prep

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

WP4 – Deliverables & Milestones

Milestone / deliverable	Title	Original deadline	Status
D4.1	Set of basic statistics for direct implementation and visualization	Month 9	✓
MS14	Identification of interpretable behavioral traits and contingencies in personalized DTSM models	Month 24	✓
D4.2	Algorithms and software environment for DTSM-based multimodal big data integration	Month 36	✓
MS18	Development of multi-site big data approach for ESM and DTSM models	Month 30	✓
MS24	Cross-site validation of big data approach	Month 40	(✓) under evaluation
D4.3	Software for identification, visualization, and feedback of behavioral contingencies	Month 48	Ongoing

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

WP4 – Challenges, delays, and solutions

Challenges:

- Funding ran out

Solutions:

- Manuel Brenner has raised his own funds until end of 2024 and has agreed to finalize D4.3.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

WP4 – Dissemination

June 2024: Dynamics and control for mental health applications, IWR Heidelberg

June 2024: Creating digital twins of social Interaction partners, ML Galore, IWR Heidelberg

December 2023: Poster on Integrating Multimodal Data for Joint Generative Modeling of Complex Dynamics, CIMH Mannheim Retreat

October 2023: Using AI to Predict the Dynamics of Mental Health, article on the IMMERSE blog

October 2023: Using Recurrent Neural Networks to Mimic Human Social Interaction Dynamics, Workshop HI meet AI, Structures Cluster of Excellence Heidelberg

October 2023: Poster on Integrating Multimodal Data for Joint Generative Modeling of Complex Dynamics, AIH InScide Out Unconference, EMBL Heidelberg

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

WP4 – Conferences

June 2024: Integrating Multimodal Data for Joint Generative Modeling of Complex Dynamics, 41st International Conference on Machine Learning

July 2023: A Guide to Reconstructing Dynamical Systems from Neural Measurements Using Recurrent Neural Networks, CNS 2023, Leipzig

February 2023: Multimodal Teacher Forcing for Reconstructing Nonlinear Dynamical Systems, Presented at AAAI 2023.

July 2022: Tractable Dendritic RNNs for Reconstructing Nonlinear Dynamical Systems, Presented at ICML 2022.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)

WP4 – Next steps

- Finalizing the evaluation of the big data integration framework (incl. publication)
- Setting up software tutorial/ workshop using IMMERSE data to educate fellow researchers on model usage and provide examples

Thank you for your attention.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 945263 (IMMERSE)