



Delft University of Technology

Document Version

Final published version

Citation (APA)

Jafarian, M. (2026). Data-driven mechanisms of cortical memory networks in cognition. In G. Bianchin, J. Hendrickx, & R. Jungers (Eds.), *45th Benelux Meeting on Systems and Control: Book of Abstracts* (pp. 230). Katholieke Universiteit Leuven.

Important note

To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright

In case the licence states "Dutch Copyright Act (Article 25fa)", this publication was made available Green Open Access via the TU Delft Institutional Repository pursuant to Dutch Copyright Act (Article 25fa, the Taverne amendment). This provision does not affect copyright ownership.
Unless copyright is transferred by contract or statute, it remains with the copyright holder.

Sharing and reuse

Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy

Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

This work is downloaded from Delft University of Technology.

Data-driven mechanisms of cortical memory networks in cognition

Matin Jafarian

Delft University of Technology

Email: m.jafarian@tudelft.nl

1 Introduction

The importance of understanding human memory functioning is evident from its central role in cognitive processes and its influence on the development of artificial memory networks. Simply put, memory is acquired information that is stored, processed, recalled, or forgotten. Its dynamics range from the connection of two cells [1] to networks of integrated cells and populations across spatial and temporal scales, including short-term and long-term processes [2–5].

The neuronal dynamics of memory have been understood via detailed bio-physical, or phenomenological, abstract [2] or purely data-driven approaches. While detailed biophysical models are mainly relevant to the cell level [1] and networks of cells, they are less useful in cortical representations. They simply have too much parameters to be identified, rapidly scale in complexity and being computationally demanding.

Cortical memory dynamics of human brain are relevant in studying the process of memory consolidation as well as the interplay of memory with higher order cognitive tasks, such as attention regulation, decision making, and the interplay with emotions. To reveal these mechanisms, mainly data analysis techniques have been employed, and partly phenomenological models. In addition to mechanistic understanding, regulation and control is a new focus in brain science owing to the advancement of measuring and intervention technology.

In this talk, we present some examples of our recent work on data-driven mechanistic understanding of memory, discuss the challenges, contributions, and perspectives.

2 Identification of memory dynamics

We focus on data-driven modeling, informing the models with no or with only some high-level biological hypotheses. We consider two experiments using fMRI and MEG recordings of several brain regions whose states are stacked in vector $\mathbf{x} \in \mathbb{R}^n$. In the fMRI study, we consider an associative memory encoding task in which the interplay of emotions and memory was examined. We consider a general nonlinear dynamics with inputs, in the form,

$$\dot{\mathbf{x}} = f(\mathbf{x}, u, \theta),$$

where the function f , its relation with the exogenous input u , and its corresponding parameters are to be identified. Using

the dynamic casual modeling framework, we show that a stochastic bilinear model best describes the data [4].

In the MEG study, we consider a task of working memory in which the interplay of attention and memory was examined. We propose the following oscillatory network model [5]

$$\dot{\mathbf{x}} = f(\mathbf{x}, \theta_f) + \lambda g(\mathbf{x}),$$

where the function f is assumed known with unknown parameters, function g which represents the attention mechanism, $\lambda \in \{0, 1\}$, is to be identified. For the latter, We use universal differential equations (UDEs) [5].

3 Results and Discussion

Our focus will be devoted to the identified dynamics, their level of complexity compared with biophysical and abstract models. We discuss the results, their utilization in neuroscience and medical research. We also discuss how analytical tools from systems and control theory could enhance revealing, analyzing and regulating these mechanisms.

References

- [1] Würzbauer, V., Kerstin L., and M. Jafarian. *Astrocytic gliotransmission as a pathway for stable stimulation of post-synaptic spiking: Implications for working memory*. IFAC-PapersOnLine 56.2 (2023): 488-493.
- [2] M. Jafarian, D., Huerta, G., Villani, A., Lansner, and K.H., Johansson. *Cluster Synchronization as a Mechanism of Free Recall in Working Memory Networks*. IEEE Open Journal of Control Systems, 2023.
- [3] S. Bakels, M. van de Ruit, and M. Jafarian. *Accurate linear state-space model of EEG-Based cortical activity during a passive motor task with exogenous input: Perspective for control*. arXiv, 2025.
- [4] W. Dziarnowska, M. Orhun, Y. Zhu, N. Kohn, G. Fernandez, and M. Jafarian. *Associative emotional memory encoding: Insights from network stability analysis of an fMRI-driven bilinear dynamics*. bioRxiv, 2026.
- [5] S.M. Ohkawa, S. Haegens, and M. Jafarian. *A novel data-driven approach for identifying causal interplay of working memory and attention using MEG data*. 2026.