Learning Dynamic Functional Connectivity Networks from Infant Magnetoencephalography Data

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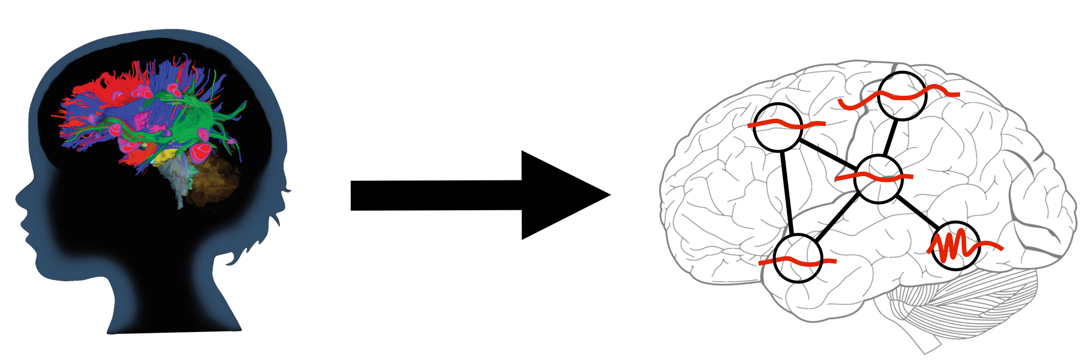
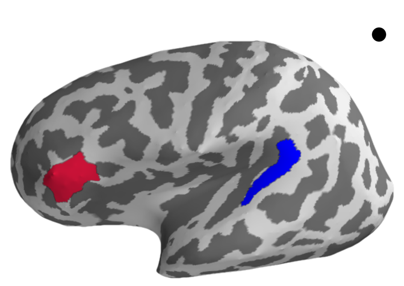
Goal



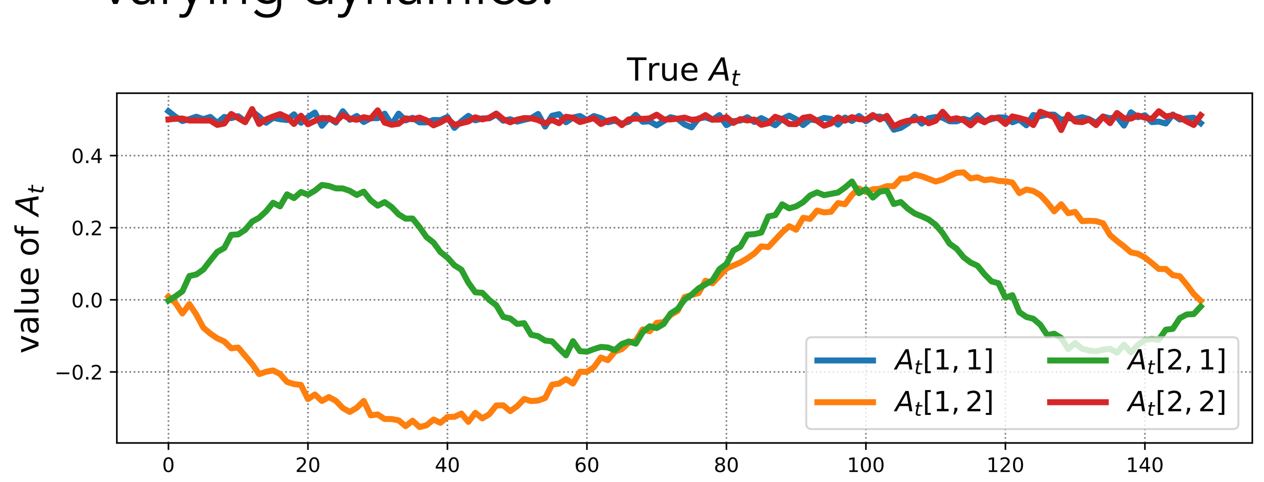
- We present a method for inferring **directed, dynamic functional connections** between brain regions from **magnetoencephalography (MEG)** data.
- Additionally, the method performs **source localization and estimation** of cortical surface signals informed by dynamics.
- We incorporate information from **multiple subjects** to improve estimates of global connectivity.

Problem Setup

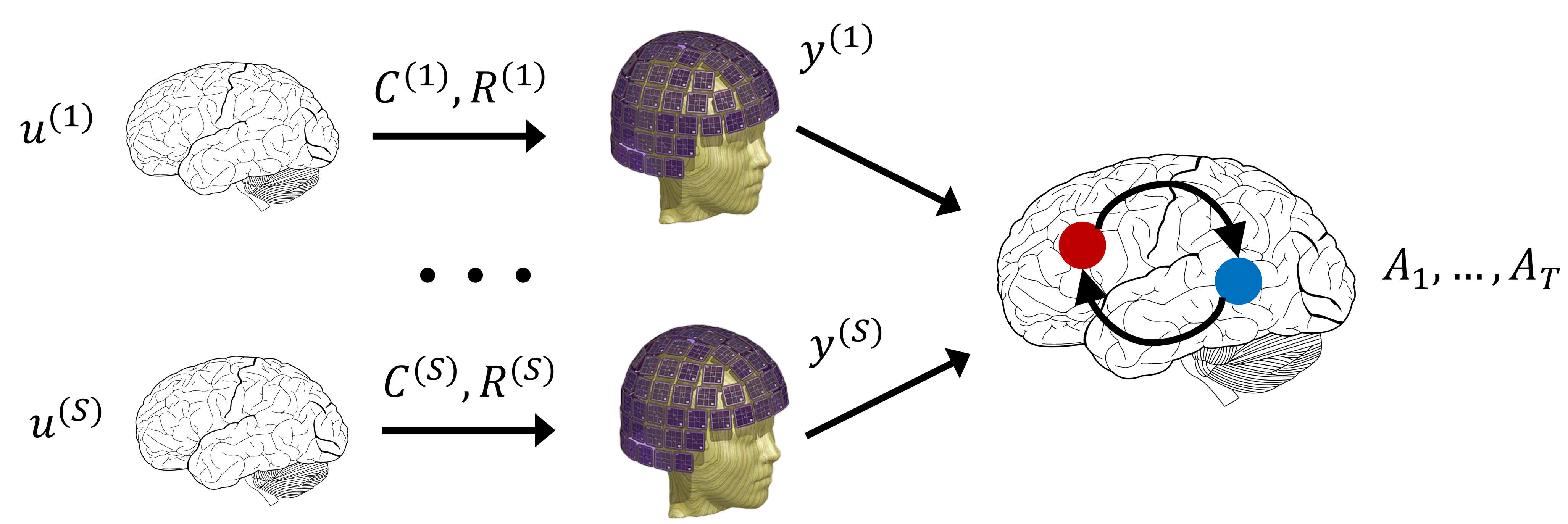
- We are using existing structural information from 2 adult and 2 infant subjects.



- The regions of interest (ROIs) are predefined, both in the left hemisphere, one posterior and one anterior.
- The sensor recordings are simulated from a linear dynamical system with known, time-varying dynamics.



Description of model



ROI model: $u_{n,t}^{(s)} = A_t u_{n,t-1}^{(s)} + \epsilon_{n,t}^{(s)} \qquad \epsilon_{n,t}^{(s)} \in \mathbb{R}^R \sim \mathcal{N}(0, Q)$

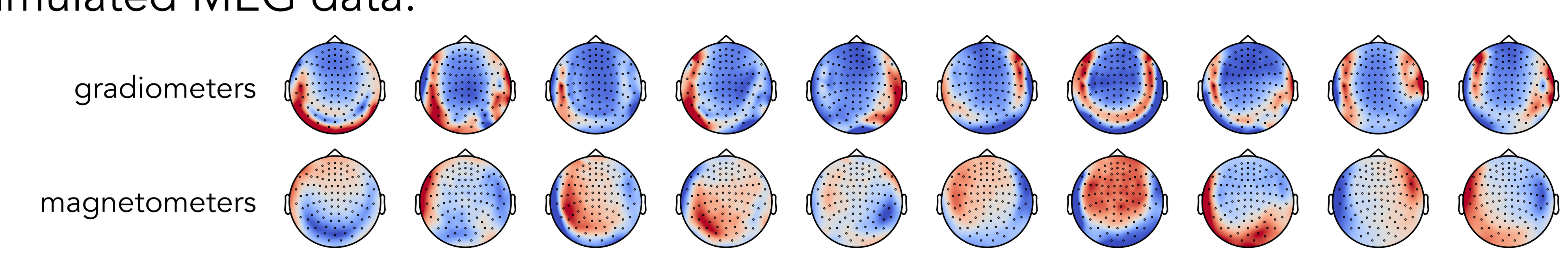
Sensor model: $y_{n,t}^{(s)} = C^{(s)} u_{n,t}^{(s)} + \eta_{n,t}^{(s)} \qquad \eta_{n,t}^{(s)} \in \mathbb{R}^D \sim \mathcal{N}(0, R^{(s)})$

- The sensor values y, forward model C, and noise covariance R are subject-specific; y and C are known, R contains known and unknown components.
- The source-space noise Q and dynamics $A_{1:T}$ are global and unknown, learned from data using an EM algorithm.
- The entries of $A_{1:T}$ give the strength of directed connections at all timepoints.

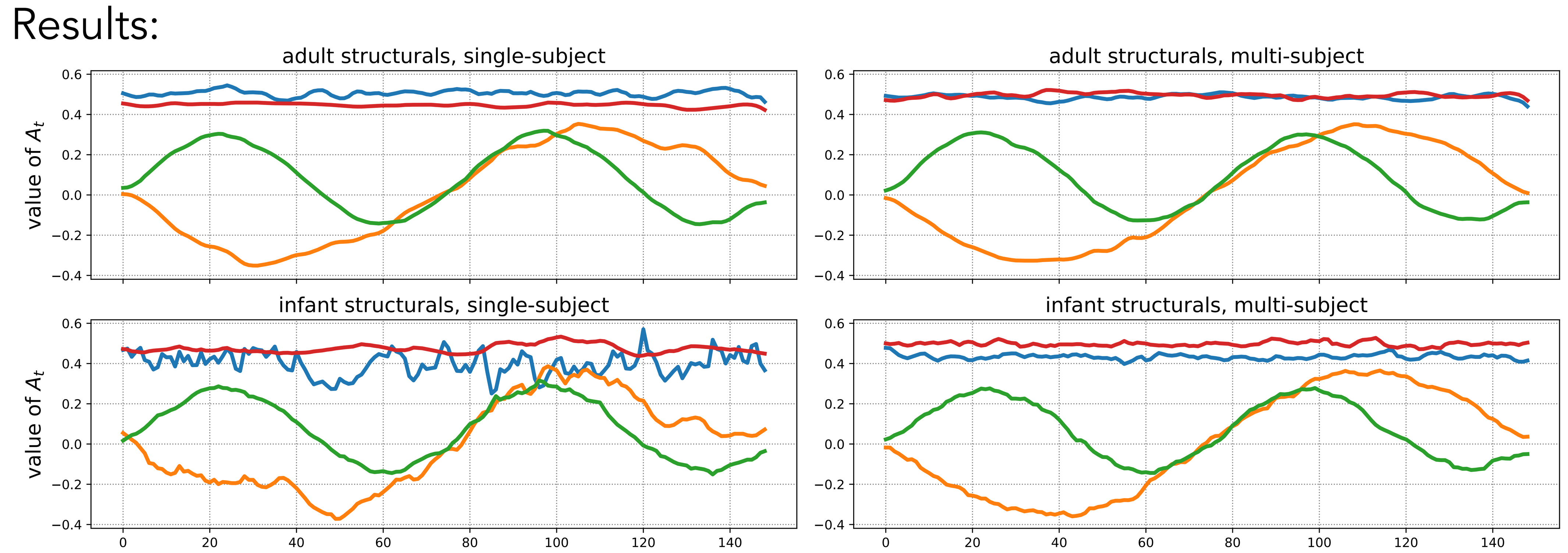
Simulation Experiments

Goal: Assess the effect of structural information quality on inferring connectivity.

Simulated MEG data:



Results:



Discussion

- Single-subject experiments demonstrate that **infant structural information is noisier** than adult structurals.
- Multi-subject results show improved performance, highlighting the **importance of sharing information across subjects** even with different structural information.
- Infant results motivate the need to augment the model to **capture uncertainty in infant structural information**.
- We plan to apply the model to **real infant MEG data** from a music intervention study.

Future Directions

- We could expand upon the current method to develop a **hierarchical model** that shares information but also allows for **inter-subject variability** in learn connections.
- Uncertainty in the structurals could be captured by **allowing regions of interest to be learned from data** rather than predefined.

References

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P. C. Hansen, M. L. Kringelbach, and R. Salmelin. *MEG: An Introduction to Methods.* Oxford University Press, 2010.

Y. Yang, E. M. Aminoff, M. J. Tarr, and R. E. Kass. A state-space model of cross-region dynamic connectivity in MEG/EEG. *30th Conference on Neural Information Processing Systems*, 2016.

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