Modeling state-dependant communication between brain regions with switching nonlinear dynamical systems

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Modeling multiregion dynamics and communication

- We introduce MR-SDS, a multiregion latent variable model with switching nonlinear dynamics. MR-SDS decomposes global continuous latents into local and cross-region communication components in the latent space, allowing us to quantify messages.
- We applied the model to three simulations, accurately recovering latent states and dynamics, as well as to 2 multiregion datasets.

Multiregion model with switching, nonlinear dynamics and communication

- Multiregion, switching nonlinear dynamical system (MR-SDS) has global discrete latent, per region continuous latents and corresponding emissions.
- Decomposition of continuous latents exposes estimates of messages between brain regions.
- We use a transformer for inference but small feedforward networks for dynamics, thus retaining interpretability of low-D dynamics.

Generative model

- \( x^k_t = f^k_x(x^k_{t-1}) + \sum_{j \neq k} f^j_k(x^j_{t-1}) + f^k_0(u_t) + \epsilon^k_t \)

Inference network

- Local dynamics
- Incoming communication
- Inputs

Simulation: multiregion, switching Lotka-Volterra dynamics

- Lotka-Volterra is a 2d model of interacting predator-prey populations, we treat each population as a brain region. The simulation switched between two sets of nonlinear dynamics. MR-SDS recovered the dynamics and latents.

Simulations: multiregion double-well dynamics

- MR-SDS found distinct dynamical modes across states and information transmission profiles across regions.

Mesoscope imaging of M2, RSC, AM

- MR-SDS found distinct dynamical modes across states and information transmission profiles across regions.

Widefield imaging of 8 brain regions across the cortical surface

- MR-SDS found distinct dynamical modes across states and information transmission profiles across regions.

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