INFERENCE ON HIPPOCAMPAL CONNECTIVITY USING MULTI-TRIAL COUNT-VALUED TIME SERIES

Adam Kiehl

HONR 499

5/5/22

INTRO

- Neural inference: interesting and complex
- Source USC study
  - MIMO SGLVM model
- Purpose: demonstrate GLM effectiveness

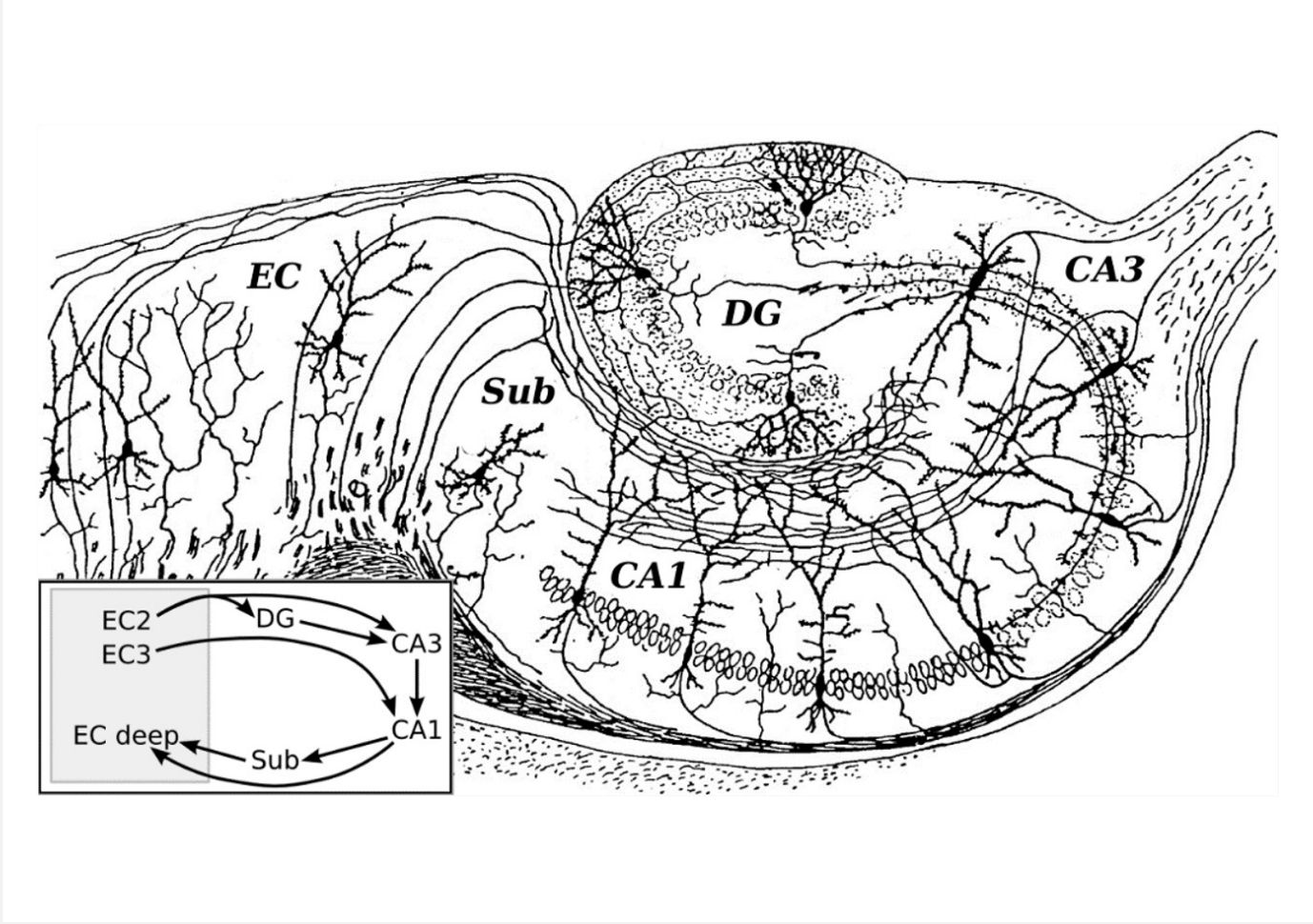
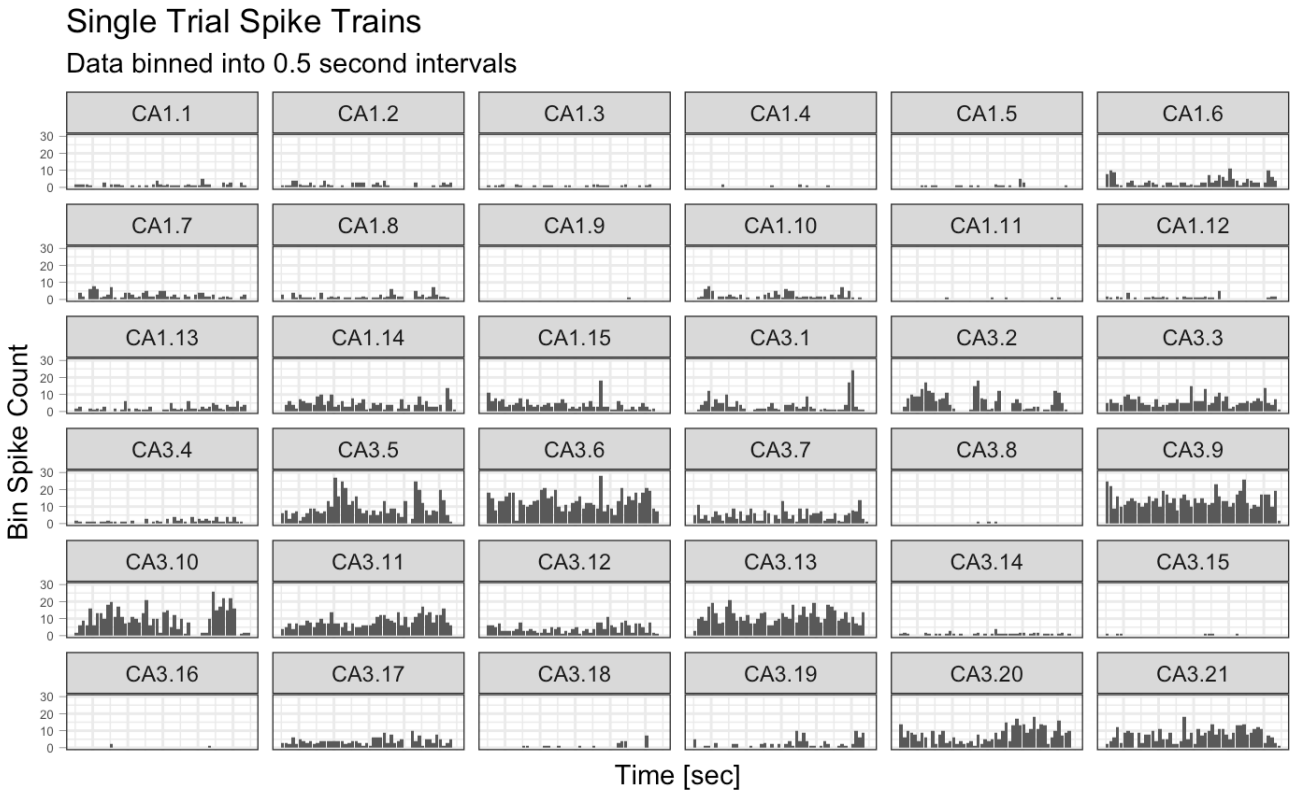


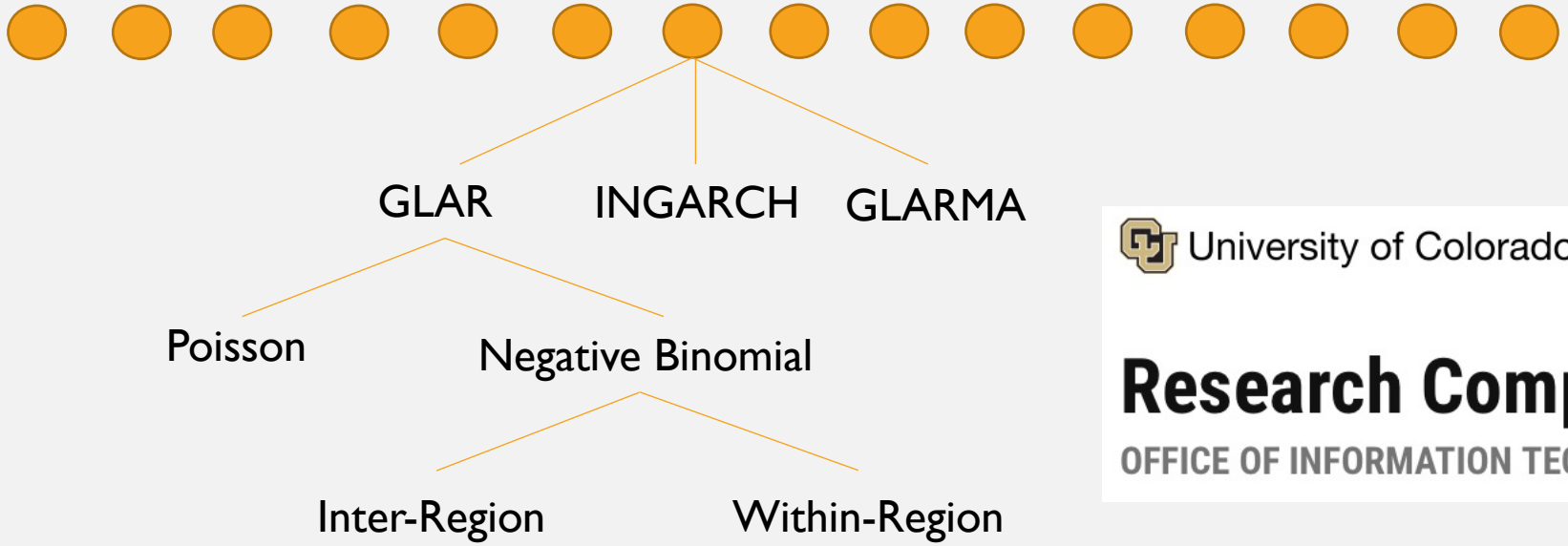
Image: Stanton 2022

DATA

- Collected by USC team
- 3-stage reinforced learning task
- Data preparation:
  - Binned on 0.5 sec intervals
  - Only complete trials
  - Only first day
  - 40/6 split



METHODOLOGY



University of Colorado **Boulder**

Research Computing

OFFICE OF INFORMATION TECHNOLOGY

Image: Research Computing User Guide

MODELS

- GLAR(p)
  - Simplest, observation-driven
- INGARCH(p, q)
  - Extends GLAR
- GLARMA(p, q)
  - Parameter-driven

$$\nu_t = \beta_0 + \sum_{i=1}^{p} \beta_j log(Y_{t-i} + 1) + \boldsymbol{\eta^T X_t}$$

$$\nu_t = \beta_0 + \sum_{i=1}^{p} \beta_j log(Y_{t-i} + 1) + \alpha \nu_{t-q} + \boldsymbol{\eta}^T \boldsymbol{X}_t$$

$$e_t = \frac{Y_t - \mu_t}{\sigma_t}$$

$$Z_t = \sum_{i=1}^{p} \phi_i Z_{t-i} + \sigma_t e_{t-1} + \theta e_{t-1-q}$$

$$\nu_t = O_t + Z_t + \boldsymbol{\eta^T X_t}$$

MODEL OPTIMIZATION

- Blocked cross-validation for MSE
  - AIC used for GLARMA models
- Forward variable selection
- Model tuned with p, q=1,…,5

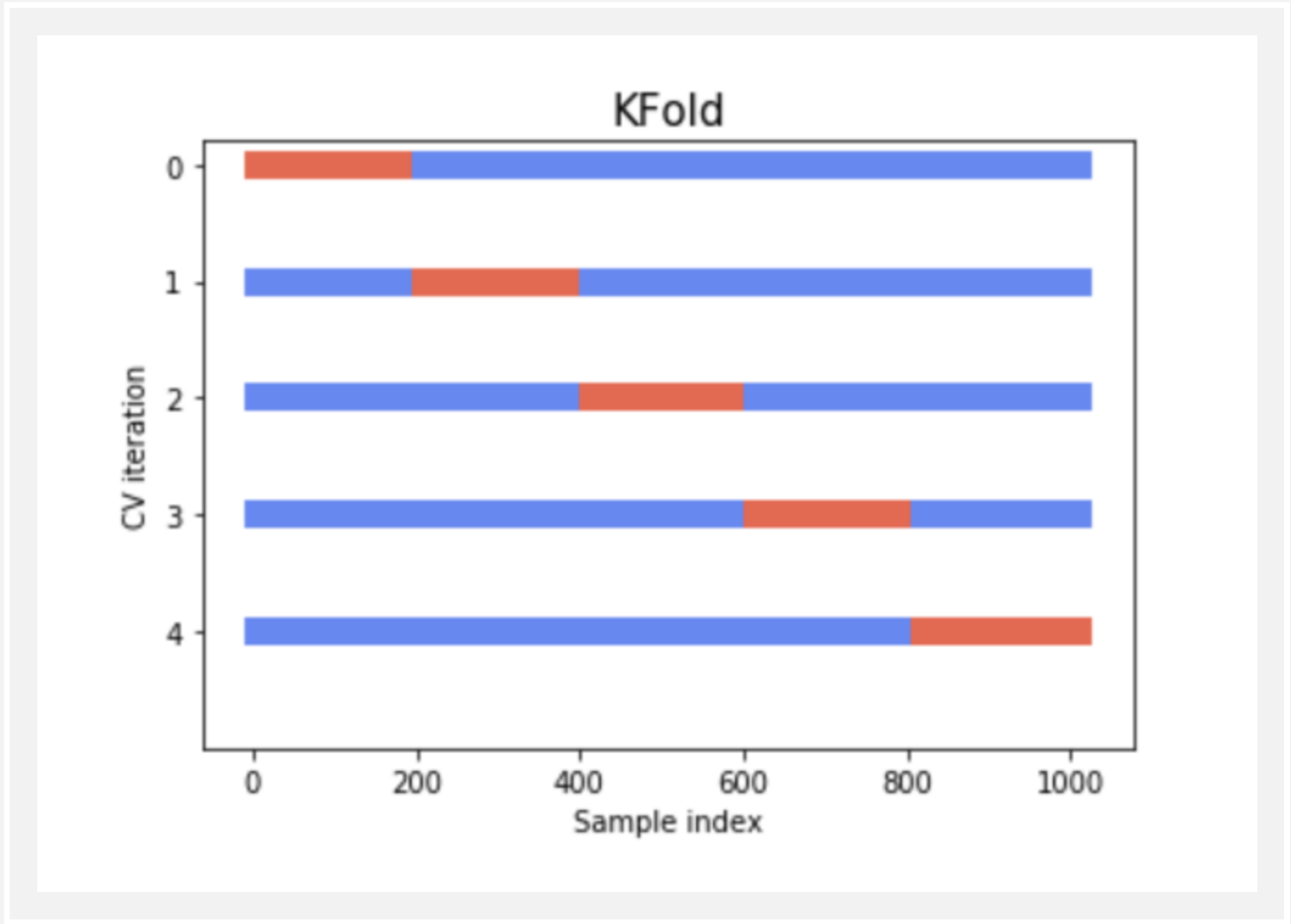
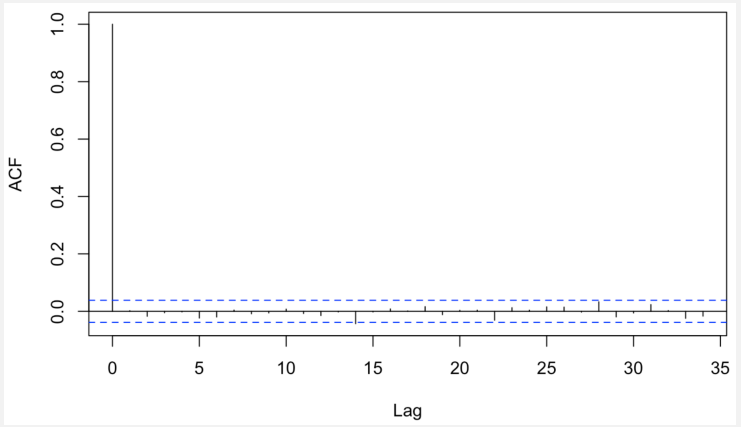
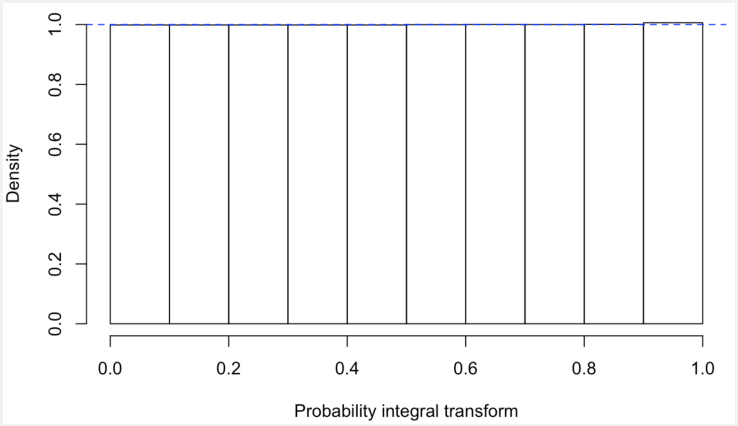
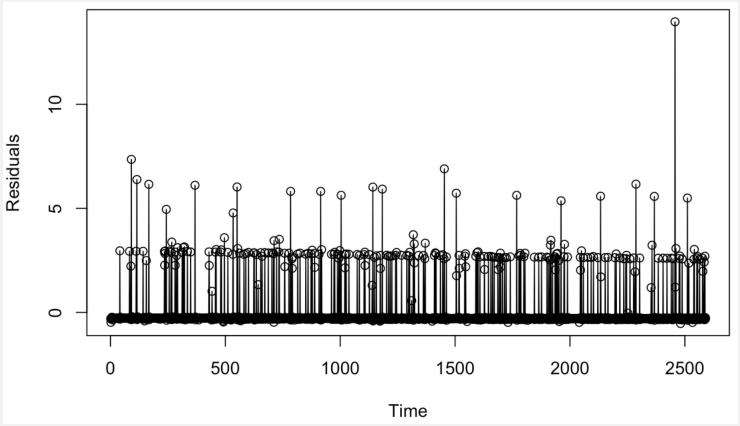


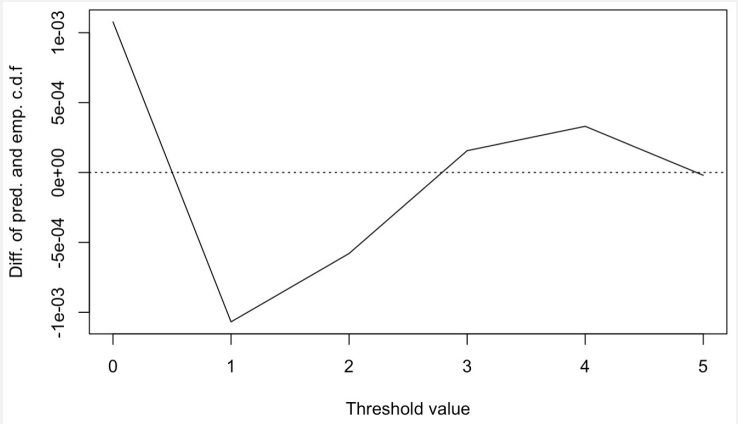
Image: Shrivastava 2020

MODEL DIAGNOSTICS



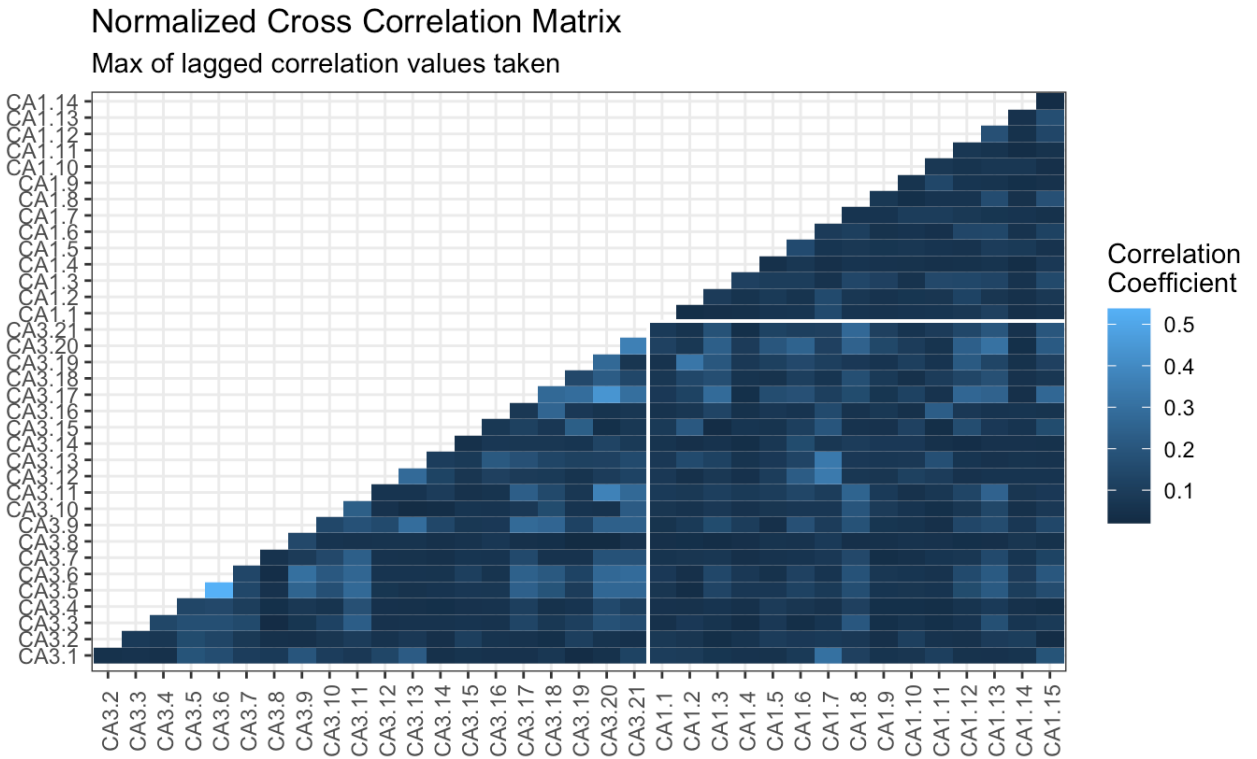






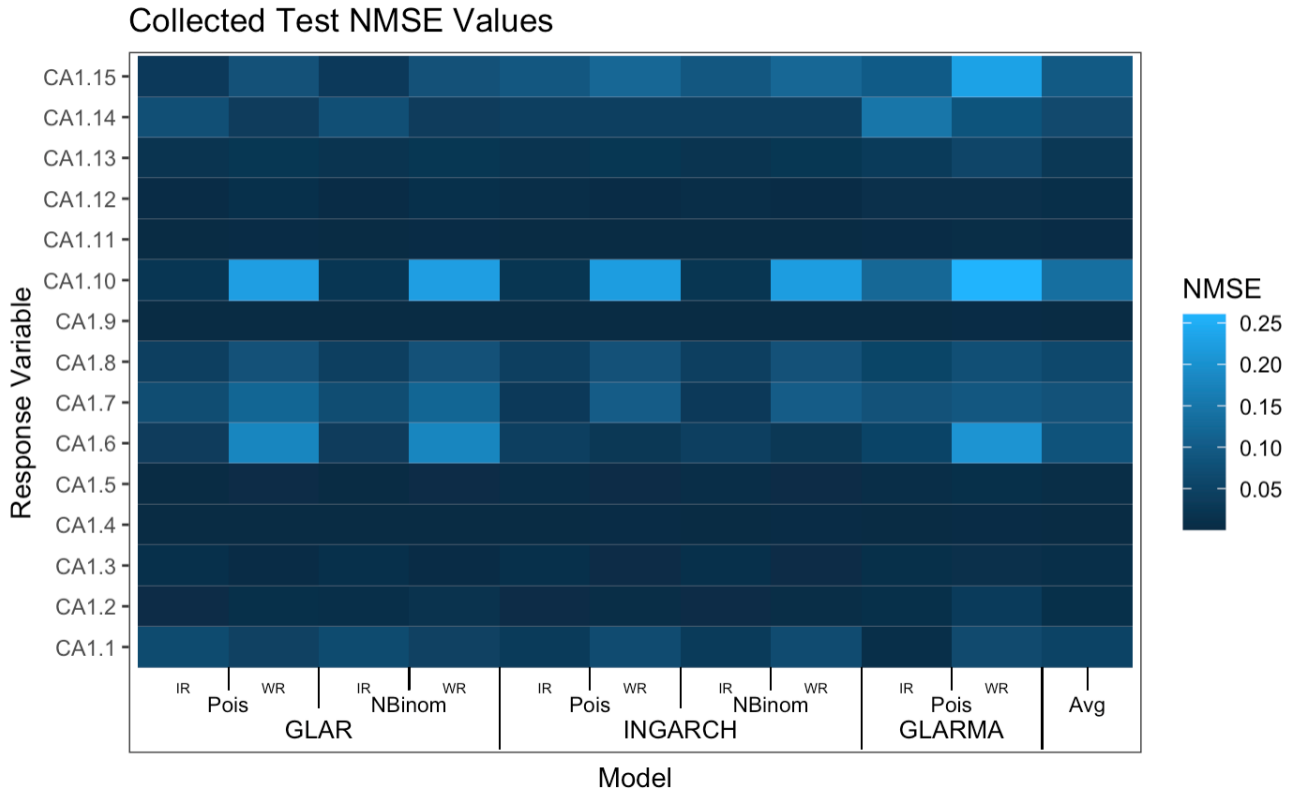
CORRELATION MATRIX

- Experimental detection of connections
- Inter-region vs. within-region correlations
- Moderate agreement with variable selection



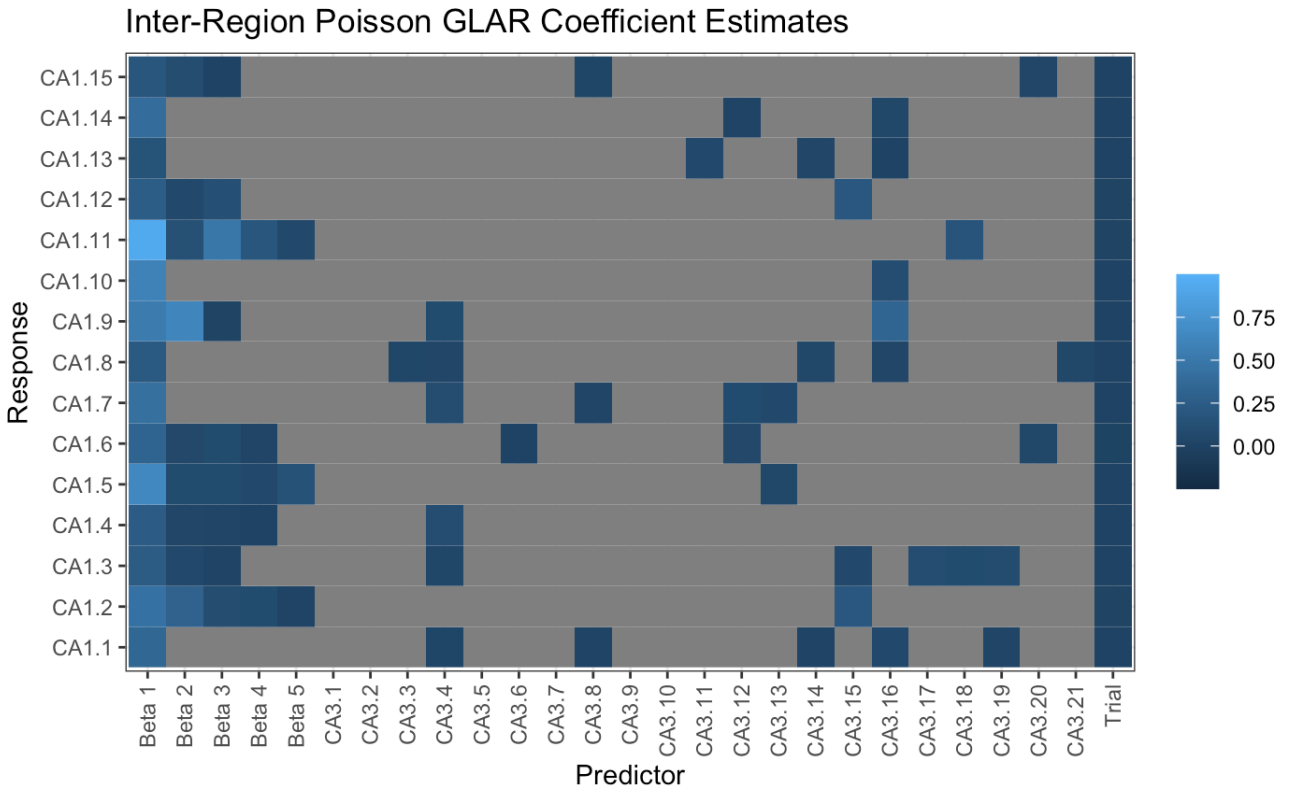
MODEL EVALUATION

- Test NMSE for evaluation
  - Model frameworks
  - Distribution assumptions
  - Region methods
- Variability from response neuron



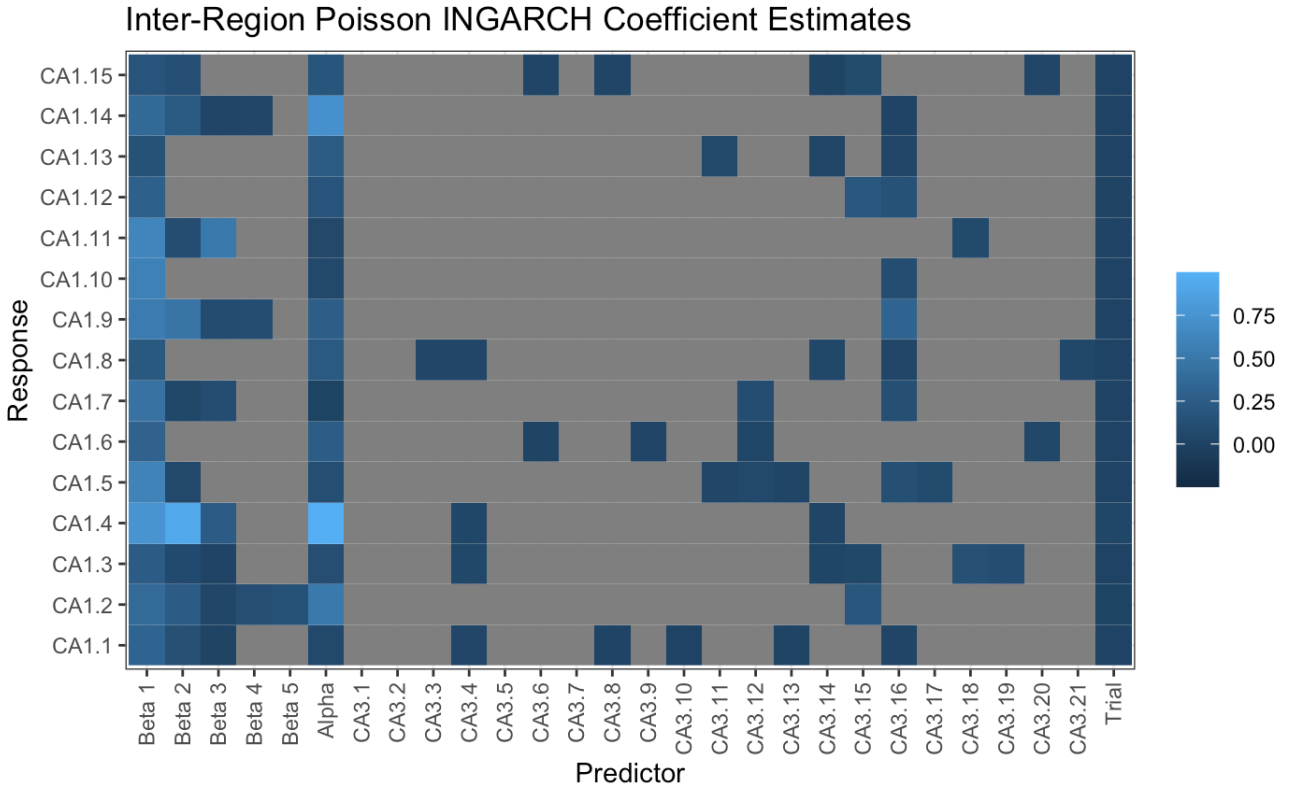
RESULTS I

- Simulated degree of connectivity
  - Within-model estimate comparisons
- Neural connectivity maps
- Poisson vs. Negative Binomial



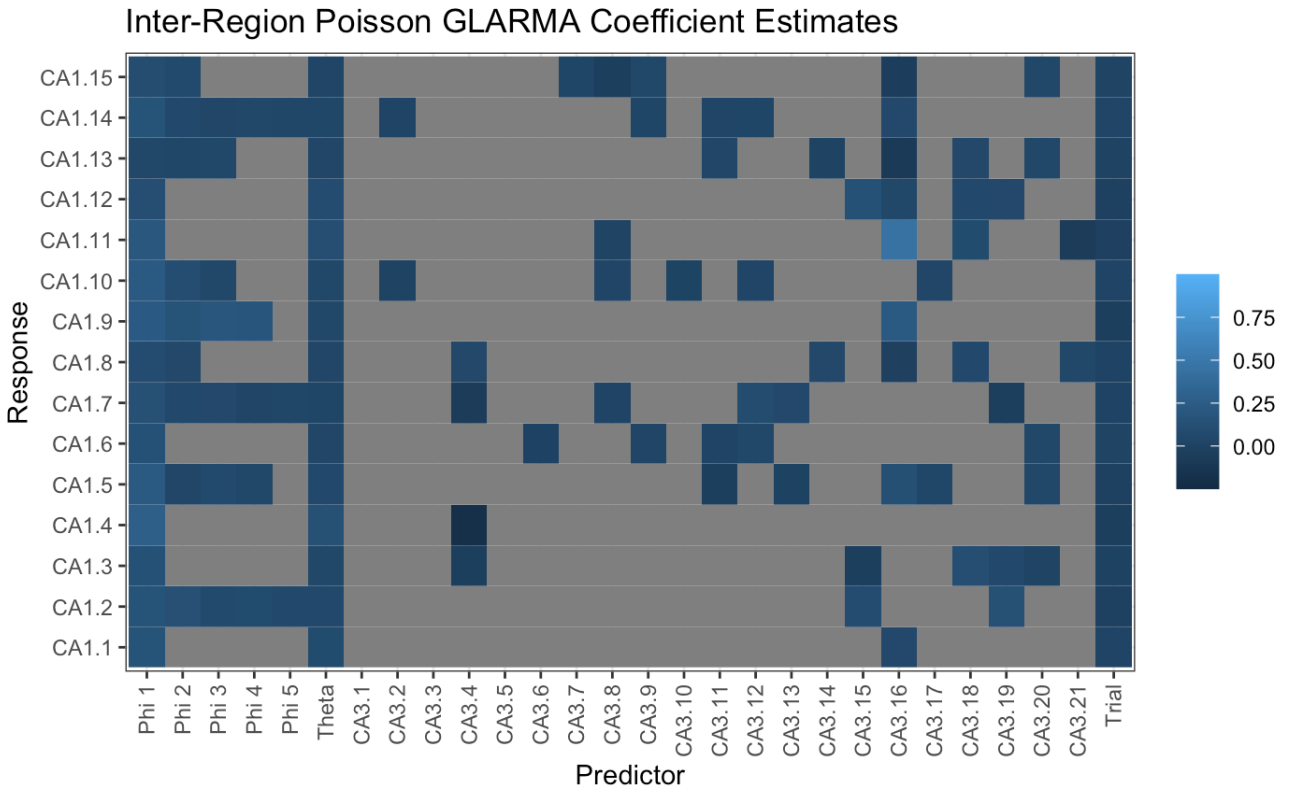
RESULTS II

- Estimates like GLAR
- Diminishing lag estimates
  - Phase effect of task
  - Conditional mean



RESULTS III

- Differs from GLAR/INGARCH
- Connectivity ≠ predictivity
- Trial inconsequential



DISCUSSION

LIMITATIONS

- Local connectivity interpretation
  - Small signal sizes -> NMSE
- Resolution of analysis
  - Measurement
  - Bin size

FUTURE RESEARCH

- GARMA, Bayesian INLA
- Dimension reduction
- Relation to phase of task

REFERENCES

Action potentials and synapses. (2017). https : / / qbi . uq . edu . au / brain - basics/brain/brain-physiology/action-potentials-and-synapses.

Anomaly.io. (2016). Detecting correlation among multiple time series [Ac- cessed: 4/10/2022]. https://anomaly.io/detect-correlation-time-series/ index.html.

Chen, Z., & Yang, Y. (2004). Assessing forecast accuracy measures. Iowa State University.

Davis, R., Dunsmuir, W., & Streett, S. (2001). Modeling time series of counts. Columbia Statistics.

Davis, R., Fokianos, K., Holan, S., Joe, H., Livsey, J., Lund, R., Pipiras, V., & Ravishanker, N. (2021). Count time series: A methodological review. Journal of the American Statistical Association.

Dunsmuir, W. T. M., & Scott, D. J. (2015). The glarma package for observation- driven time series regression of counts. Journal of Statistical Software.

How to measure brain activity in people. (2018). Queensland Brain Insti- tute. https://qbi.uq.edu.au/brain/brain-functions/how-measure-brain- activity-people.

Liboschik, T., Fokianos, K., & Fried, R. (2017). Tscount: An R package for analysis of count time series following generalized linear models. Journal of Statistical Software.

McCullagh, P., & Nelder, J. A. (1989). Generalized linear models (2nd ed.) Chapman and Hall.

Research computing user guide. (n.d.). University of Colorado Boulder. https://curc.readthedocs.io/en/latest/index.html.

Rey, H. G., Pedreira, C., & Quiroga, R. Q. (2015). Past, present and future of spike sorting techniques. Brain Research Bulletin.

Salles, R., Assis, L., Guedes, G., Bezerra, E., Porto, F., & Ogasawara, E. (2022). A framework for benchmarking machine learning methods using linear models for univariate time series prediction. Journal of Statistical Software.

Shrivastava, S. (2020). Cross validation in time series [Accessed: 4/10/22]. Medium. https://medium.com/@soumyachess1496/cross-validation-in- time-series-566ae4981ce4.

Song, D., Harway, M., Marmarelis, V. Z., Hampson, R. E., Deadwyler, S. A., & Berger, T. W. (2014). Extraction and restoration of hippocampal spatial memories with non-linear dynamical modeling. Frontiers in Systems Neuroscience.

Stanton, G. (2022). Neural data and models [Presentation].

Trapletti, A., & Hornik, K. (2022). Tseries: Time series analysis and computational finance. Journal of Statistical Software.