Impact of data processing on DCM estimates of effective connectivity from task-evoked fMRI

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Introduction

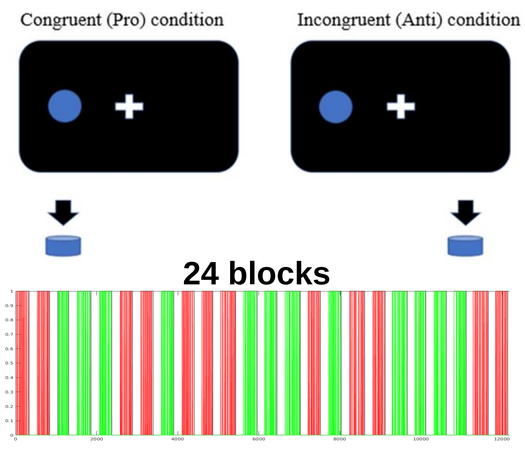
- Effective connectivity (EC) is supposed to estimate directional influences between interacting neuronal populations or brain regions and can be modulated by task stimuli.
- Processing of the functional magnetic resonance imaging (fMRI) data used for EC calculation may impact connectivity estimation.
- However, the optimal data processing for task-evoked EC is still an unresolved problem because of the complexity of EC calculation.
- Therefore, we aim to investigate how task-evoked EC is affected by a selected data processing parameter involving the global signal regression (GSR), task-evoked general linear model (GLM) design, activation contrast, and significance thresholding.

Methods

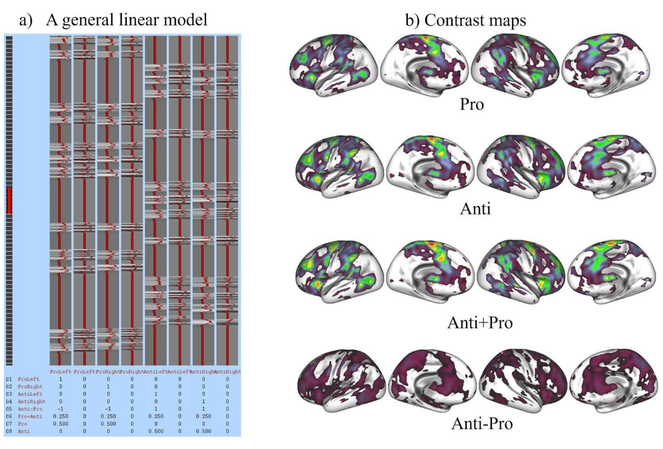
- A stimulus-response incompatibility task (SRC) dataset was used to reconstruct the SRC network with 9 nodes.
- Individual BOLD time series of the SRC network nodes were extracted for every subject in the cohort corresponding to 24 different data-processing conditions involving:
  (a) with/without GSR,
  (b) All-Trials/S-Trials/ Blocks GLM design,
  (c) Incongruent (Anti)/Congurent+Incongruent (Anti+Pro) activation contrast,
  (d) Corrected/Uncorrected significance thresholding.
- A full-connection model was applied, and bilateral intraparietal sulci (IPS) of the SRC network were selected to be the driving-input nodes to estimate EC using dynamic causal modeling (DCM) [1].
- The group-mean task-evoked EC (matrix B) of each considered data-processing condition was calculated using the single-group Parametric Empirical Bayes (PEB) [2] analysis.
- The differences in task-evoked EC between considered conditions of the data processing were evaluated using the between-group PEB analysis.

Results

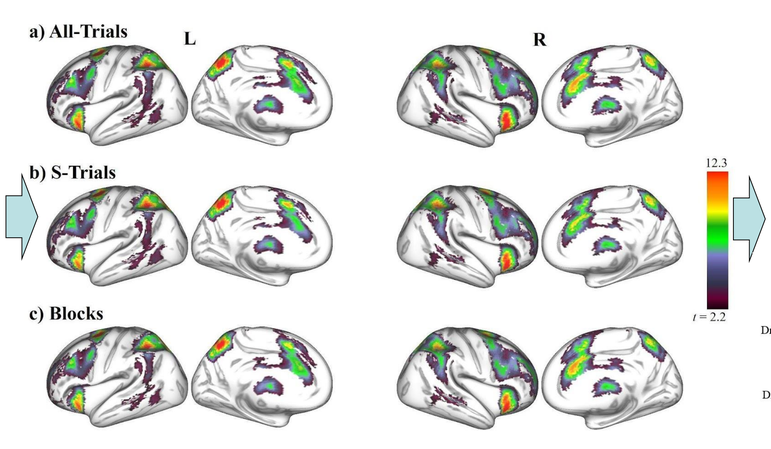
SRC paradigm



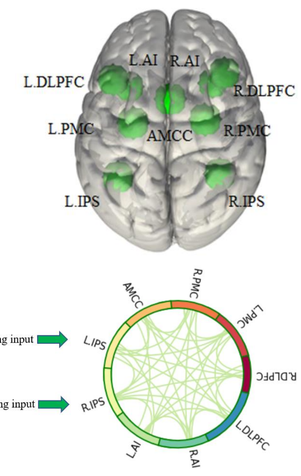
Individual activation contrast



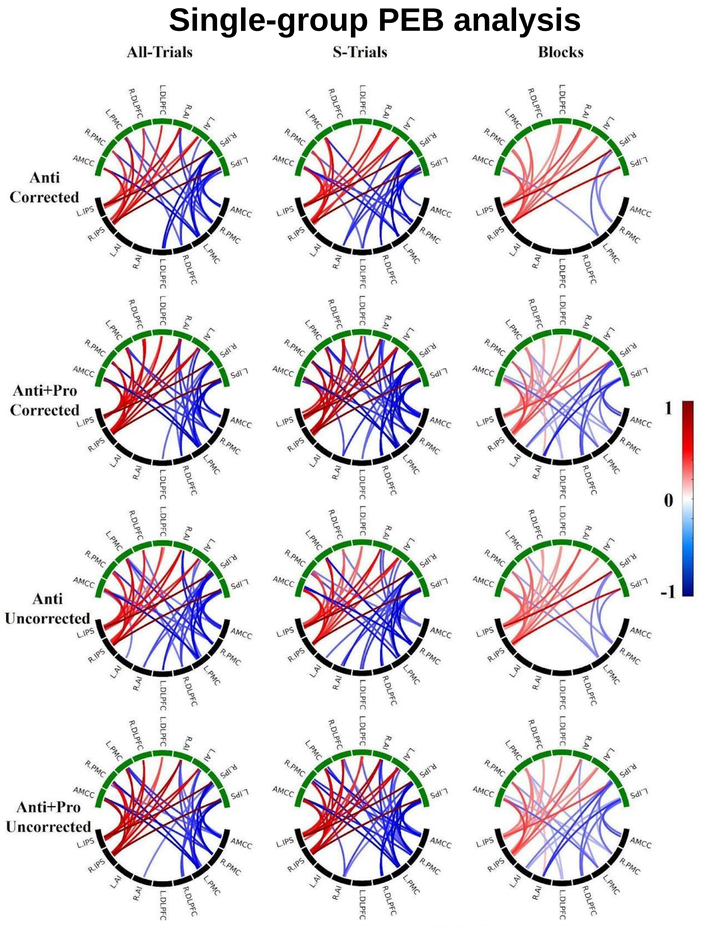
Second-level activation contrast



SRC nodes and model



Single-group PEB analysis



- **Group-mean task-evoked EC based on each data-processing condition.**

Subject cohorts and significant EC after single-group PEB

Sample sizes for different conditions of the data processing with GSR.

	All-Trials		S-Trials		Blocks	
	Corrected	Uncorrected	Corrected	Uncorrected	Corrected	Uncorrected
Anti	152/152	208/204	143/143	204/201	163/161	222/215
Anti+Pro	163/161	219/215	156/154	208/203	168/166	227/222

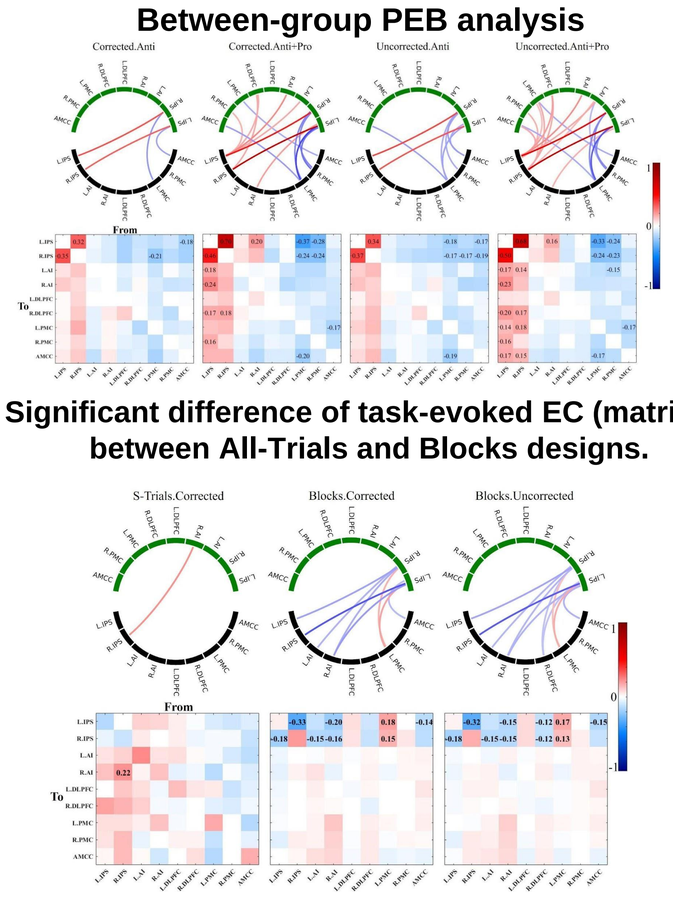
The two subject numbers given in each table cell correspond to the subject cohorts qualified for BOLD signal extraction for SRC network nodes of individual subjects/explained variance criterion of DCM.

Numbers of the group-level significant edges of task-evoked EC (matrix B)

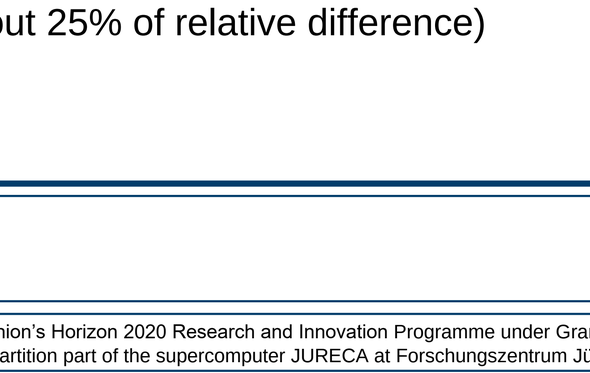
	All-Trials		S-Trials		Blocks	
	Corrected	Uncorrected	Corrected	Uncorrected	Corrected	Uncorrected
Anti	32	40	30	39	18	22
Anti+Pro	35	36	41	42	30	32

All task-evoked EC exceeded the 95% posterior probability threshold (excluding self-connections) and was calculated by the single-group PEB analysis for the considered conditions of the data processing with GSR.

Between-group PEB analysis



- **Significant difference of task-evoked EC (matrix B) between All-Trials and Blocks designs.**



- **Significant difference of task-evoked EC (matrix B) between Anti+Pro and Anti contrasts.**

Conclusions

- Different choices of data-processing parameters substantially affected task-evoked EC.
- Event-related designs showed stronger positive and negative task-evoked modulation of EC than block-based designs.
- Block-based designs seem to be more sensitive to the selection of the activation contrasts than event-related designs.
- The addition of GSR may not impact within-network task-evoked EC, which was also reported in the resting-state paradigm [3].
- The significance thresholding at the signal extraction also appeared to have a weak and nonsignificant influence on EC in spite of very different sample sizes (about 25% of relative difference)

References:

1. Friston, K. J. (2011). Functional and Effective Connectivity: A Review. *Brain connectivity*, *1*(1), 13-36
2. Zeidman, P., Jafarian, A., Seghier, M. L., Litvak, V., Cagnan, H., Price, C. J., & Friston, K. J. (2019). A guide to group effective connectivity analysis, part 2: Second level analysis with PEB. *Neuroimage*, *200*, 12-25.
3. Almgren, H., Van de Steen, F., Razi, A., Friston, K., & Marinazzo, D. (2020). The effect of global signal regression on DCM estimates of noise and effective connectivity from resting state fMRI. *Neuroimage*, *208*, 116435.

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