Predicting individual differences from task-evoked effective connectivity

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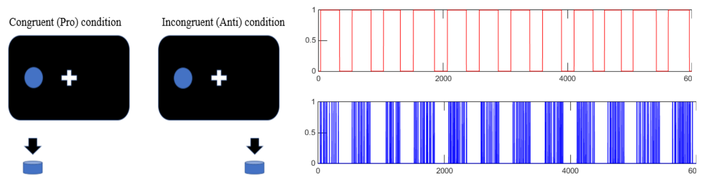
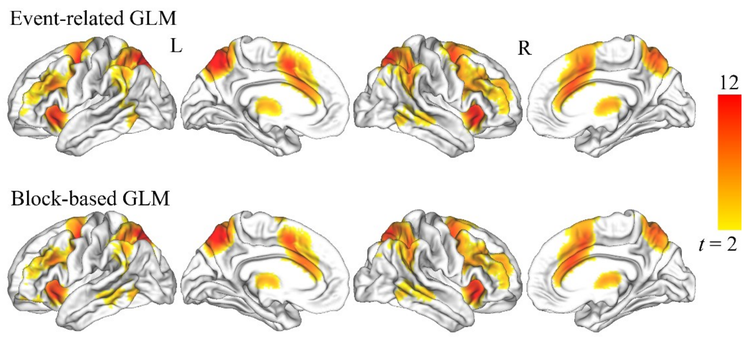
Introduction

- How different modalities of task-evoked effective connectivity (EC) can be used to predict individual behavior?
- Consider reaction time (RT) of the stimulus-response compatibility (SRC) task and age as prediction target scores.
- Features from DCM EC of SRC task-fMRI data of both intrinsic EC (I-EC, calculated at baseline, matrix A of DCM) and task-modulated EC (M-EC, induced by experimental conditions, matrix B of DCM).
- Various data-processing conditions: event-related and block-based GLM/DCM, cross-validation schemes (CV), machine-learning models, Bayesian model reduction (BMR).
- Comparing with task-evoked functional connectivity (FC).

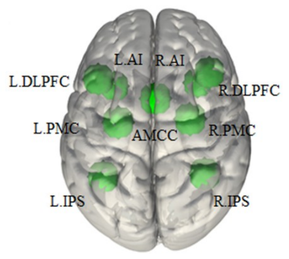
Methods

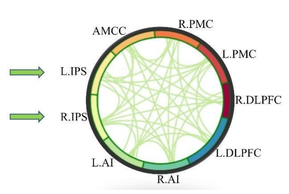


- Stimulus-response compatibility task (**SRC**)
- **GLM designs:** **Block-based** – entire blocks; **Event-related** – consider every trial



- Incompatibility task effects (Anti > Pro) estimated from the second-level analysis for the two GLM designs [1]
- 271 subjects (123 females), 1000BRAINS project [2].



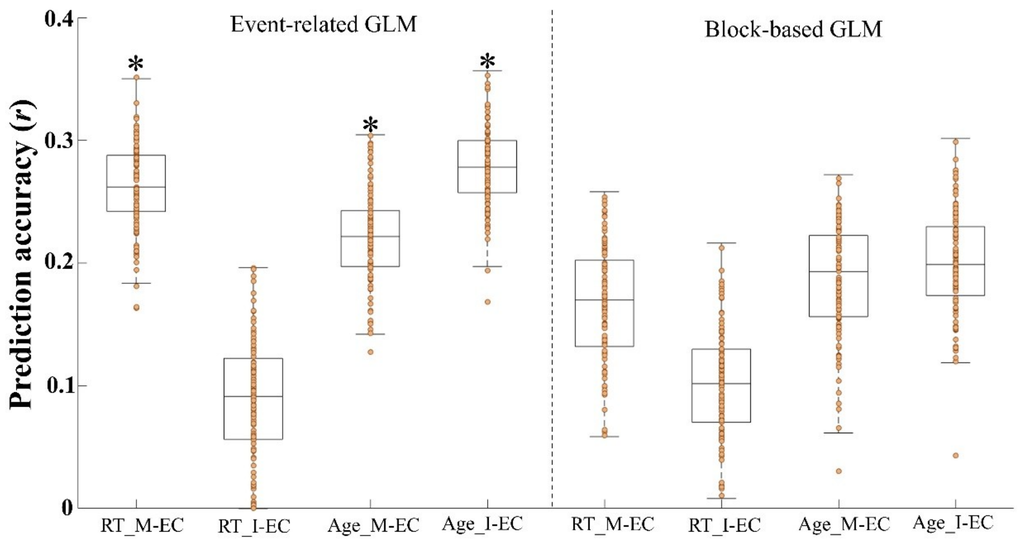


SRC network: **DLPFC** - dorsolateral prefrontal cortex; **PMC** - premotor cortex; **IPS** - intraparietal sulcus; **AI** - anterior insula; **AMCC** - anterior midcingulate cortex

- Example of the SRC network of 9 nodes (5-mm radius ROIs) for the Block design [1].
- Extract individual BOLD time series of SRC network (Anti contrast) for DCM [1,3].
- Full model was used for individual DCM (input nodes: bilateral intraparietal sulci).
- Parametric Empirical Bayes (PEB) [4,5] was employed for the I-EC and M-EC feature extraction (two-column design, RT and age).
- LASSO and ridge linear regression machine-learning models at 5-fold, 10-fold and leave-one-out CV with 100 split repetitions.
- Prediction accuracy: Pearson correlation *r* between empirical and predicted scores.
- Full task-evoked and task-residual FC was also used for prediction of RT and age for comparison.

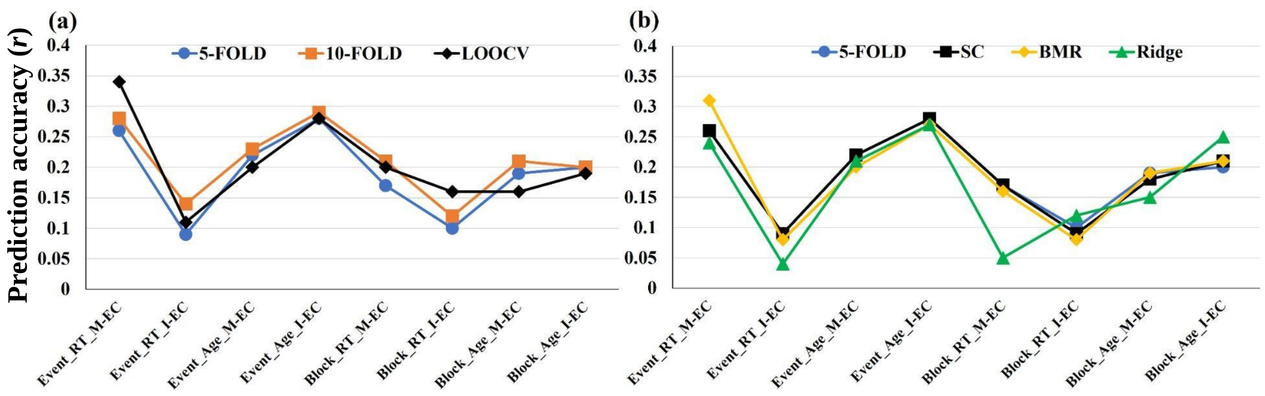
Results

RT and age prediction by task-evoked EC

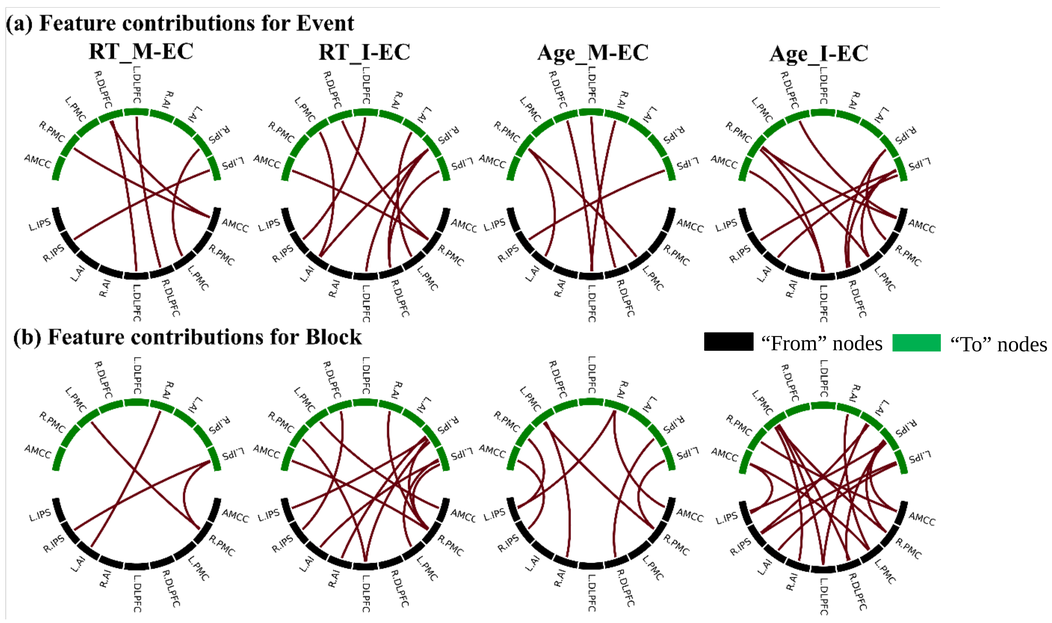


- Event-related GLM/DCM: Significant prediction results for RT by M-EC and age by M-EC and I-EC (against permutation tests).
- RT can be better predicted by M-EC, while I-EC performs better for age.
- Block-based GLM/DCM: All results are weak and non-significant.

Impact of data processing and modeling conditions on prediction results



SRC sub-networks for RT and age prediction



- Features (EC edges) frequently selected (> 80%) by PEB (PP > 95%) at the model training and prediction across all CV instances.
- Different SRC sub-networks were participating in RT and age prediction by M-EC (sparse) and I-EC as well as for event-related and block-based GLM/DCM designs.
- These sub-networks can be used for investigation of the relationships between the SRC task-evoked EC and behavior (RT) or phenotype (age).

RT and age prediction by task-evoked FC

GLM design	Event-related		Block-based	
Type of FC	Full	Residual	Full	Residual
RT	$r = 0.19 \pm 0.02$	$r = 0.22 \pm 0.02$	$r = 0.12 \pm 0.02$	$r = 0.2 \pm 0.02$
age	$r = 0.34 \pm 0.01$	$r = 0.36 \pm 0.01$	$r = 0.37 \pm 0.01$	$r = 0.37 \pm 0.01$

Discussion

- We investigated and compared the performance of intrinsic and task-modulated EC of DCM from the task-evoked fMRI for predicting RT and age.
- We adopted a CV-based PEB analytical strategy to extract I-EC and M-EC parameters as predictive features.
- We compared the prediction results for the event-related and block-based GLM/DCM designs of task fMRI processing and EC estimation.
- The event-related GLM/DCM design performed better at predicting RT and age than did the block-based design.
- M-EC led to a higher prediction accuracy (correlation) for RT prediction, while I-EC was better for the age prediction.
- A variety of tested conditions (CV schemes, BMR, including self-connectivity, ridge regression) did not largely affect the prediction accuracy.
- Task-evoked FC performed relatively well in age prediction and outperformed EC, but succeeded less in RT prediction and was outperformed by M-EC for the event-related case.
- The task-evoked I-EC, M-EC and FC may capture different behavioral/phenotypical attributes.
- The presented results can contribute to a better applicability of the task-evoked brain connectivity to investigation of inter-individual variability of brain-behavior relationships.

References:

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