

Background

To identify effective connectivity maps, various causal models are used which can be characterized in terms of the different kinds of couplings they involve. Recent applications have emerged to model influences in functional brain systems using predefined regions of interest (ROIs). ROI approaches to modeling brain systems assume separate functional regions that influence one another rather than coordinated units of many ROIs that operate to facilitate cognitive functions. A consequence of this may be that certain approaches to effective connectivity impose spatially reductionistic models of brain activity where holistic models are more appropriate. Presented here is a state space model (SSM) approach to integrate dimension reduction of a multivariate ROI BOLD fMRI time series and effective connectivity mapping. This approach allows the researcher to uncover latent time series data via a measurement model and investigate directed influences between those factors in a structural model.

Methods

Participants:

One healthy caucasian male (34 years old, 16 years of education)

BOLD fMRI

- Scanner:
- Siemens 3T Magnetom Trio
- Scanning Parameters
- Axial T1-weighted conventional spin-echo images (in-plane resolution = 0.859 0.859 mm2' TR/TE=450/14 ms, contiguous 5 mm, 256 256 matrix, FOV = 24 24 cm 2, NEX=1)
 - Functional imaging - multislice gradient echo, T2*-weighted images acquired with echoplanar imaging (EPI) method (TE= 30 ms; TR= 2000 ms; FOV = 24 24 cm2; flip angle = 90 ; slice thickness = 5 mm contiguous; 64 64 matrix with an in-plane resolution of 3.75 3.75 mm)

Task

- Subjects were presented with a forced choice stimulus discrimination task using symbols derived from the Symbol Digit Modalities Test

Statistical Analysis

- Preprocessing
- All EPI data were realigned, coregistered to a 150-slice MPAGE, spatially normalized and smoothed.
 - Regions of Interest (ROIs) were selected using the WFUPickAtlas for SP
 - Bilateral anterior cerebellum
 - Bilateral posterior cerbellum
 - Bilateral BA7
 - Bilateral BA8
 - Bilateral BA10

ROI extraction

- All timeseries were extracted using the default settings of the MarsBar toolbox within SPM5

Connectivity modeling

SSM Equations:

Measurement equation: $y_t = \Lambda h_t + e_t$

SSM:

$$h_t = \Lambda \eta_t + \phi_1 \eta_{t-1} + \gamma_0 \mu_t + \gamma_1 \mu_{t-1} + \tau_{11} \eta_{t-1} \mu_{t-1} + \zeta_t$$

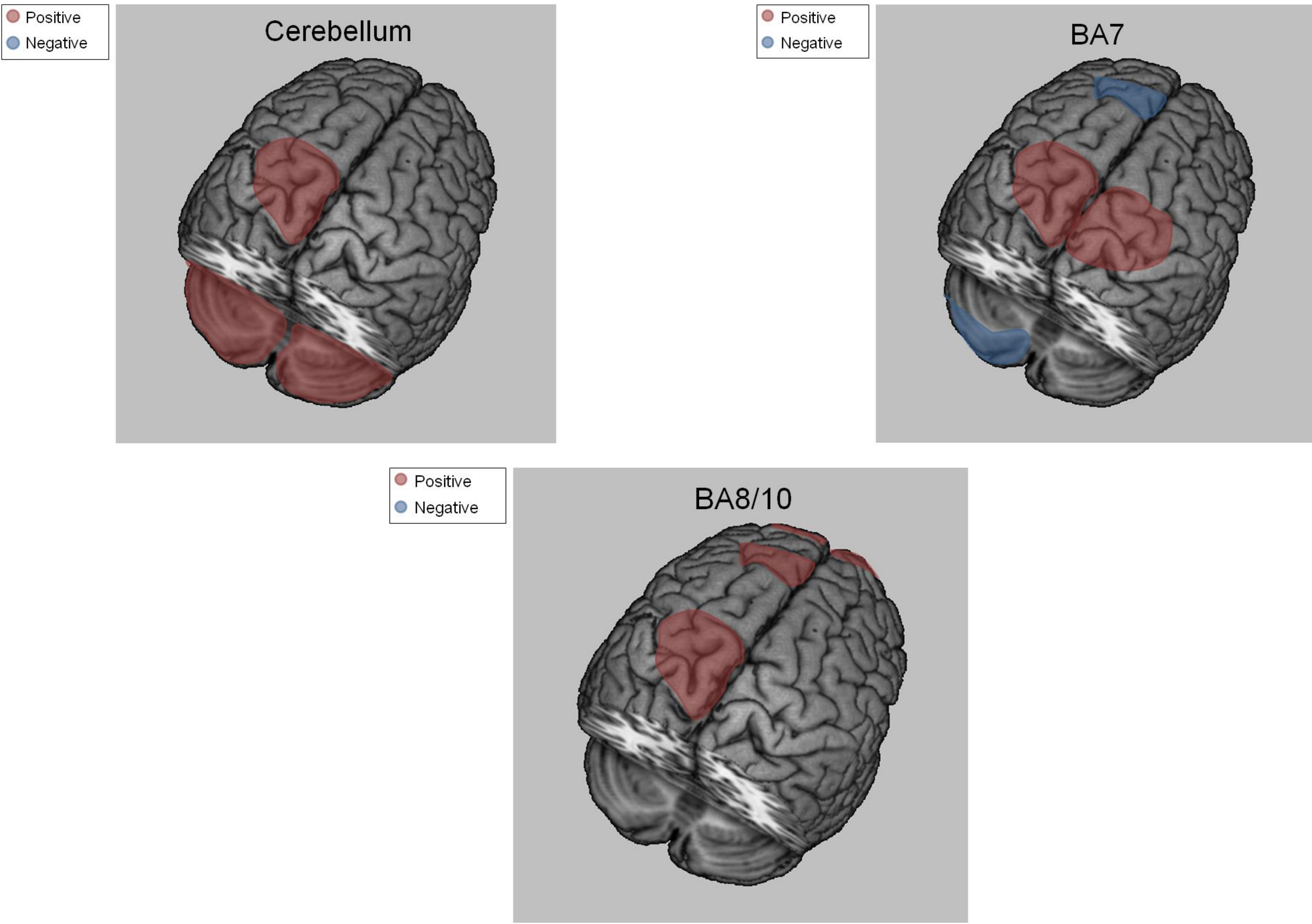
Procedure for model fit via Lisrel:

- 1) Orthogonal exploratory factor analysis
- 2) Oblique rotation of the solution
- 3) Confirmatory oblique factor analysis
- 4) Fitting of exploratory unified Structural Equation Model (Kim et al., 2007) to the factor loading time series.

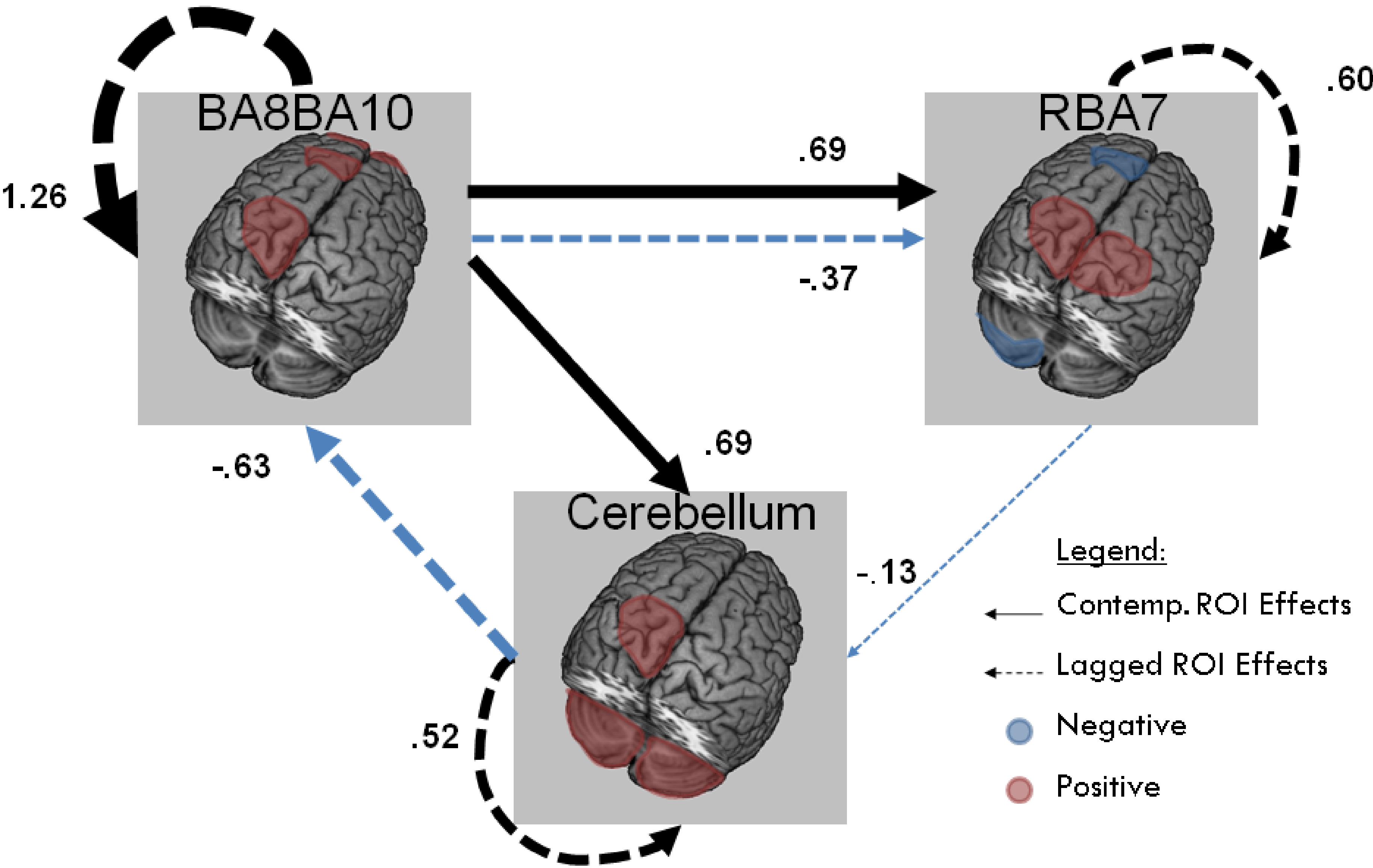
Results:

Factor Loadings

(3 Factor solution: RMSEA= .096, SRMR=.025, NNFI=.95, CFI=.98)



Measurement Model State Space Model



Conclusions

This approach to statistical modeling in systems neuroscience conceptually extends recent innovations (cf. Gates et al., 2010; 2011) and addresses a useful approach to informing theoretical models of information processing in the neural system. Brain systems are nested and may exist on several levels of complexity, and investigations range from the influences between individual neurons to brain-wide neural systems such as statistical parametric maps or seeding approaches to functional connectivity. The current approach to SSM in BOLD data provides a powerful approach for investigators to uncover latent states representative of systems spanning several regions of the brain as well as the contemporaneous and temporally lagged influences between these latent states.

References & Acknowledgements

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