Multiple functionally connected networks revealed for verbal working memory using constrained principal component analysis

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Aims:

- To determine load sensitive functionally connected networks involved in the retention of verbal information across the short term.
- To reconcile the discrepancy between Single Subject (SS) and spatially normalized group-averaged (SNGA) univariate analyses of the same data set (Feredoes & Postle, 2007; Feredoes et al. 2007).

Constrained Principal Component Analysis (cPCA)

- Method for structural analysis of multivariate data (Hunter & Takane, 2002). Applied to fMRI data, cPCA can identify components directly relevant to experimental conditions of interest by intergrating this information prior to computation of components.

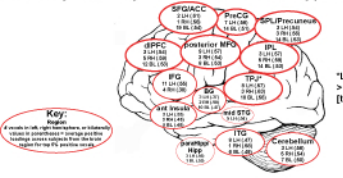
SS cPCA

- N = 26 (from Feredoes et al. 2007).
- Constrained to detect load sensitive (5 letters vs. 2 letters) delay period functionally connected neural system/s. cPCA performed on each subject's data separately.

Results:

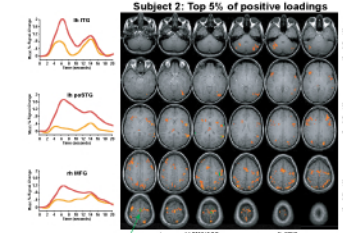
- One component extracted for each subject.
- All regions detected with a SS univariate analysis (Feredoes et al. 2007) identify in this analysis as part of a broader fronto-cingulo-parietal network.

Across-subjects summary of nodes in a load sensitive delay period functional network



*Loadings in lh TPJ > than dlPFC [t(16)=2.74; p<.05]

Subject 2: Top 5% of positive loadings

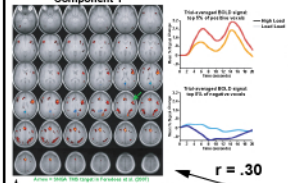


Load-sensitive voxels from SS univariate analysis

Spatially normalized group-averaged cPCA

- N = 25 (from Feredoes et al. 2007).
- Constrained to detect load sensitive (5 letters vs. 2 letters) delay period functionally connected neural system/s.
- 3 significant components extracted:

Component 1

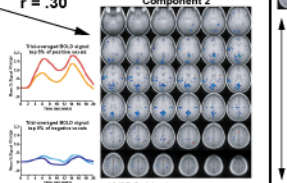


- 22/25 Subjects
- Accounts for 40.21% of variance that can be explained by the model.
- Primarily fronto-cingulo-parietal regions.

r = .30

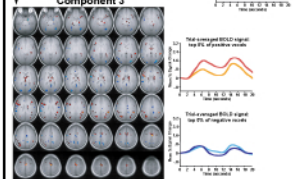
r = -.12

Component 2



- 18/25 Subjects
- Accounts for 30.41% of variance that can be explained by the model.
- Primarily suppression of default network and primary sensory (auditory, visual & motor) cortices.

Component 3



- 18/25 Subjects
- Accounts for 31.75% of variance that can be explained by the model.
- Activation in fronto-parietal + subcortical regions; suppression in primary sensory cortices.

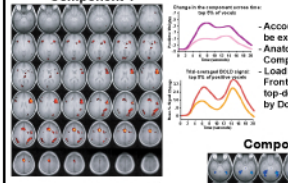
Summary

- Considerable agreement between SS components and SNGA Component 1 & 3 results.
- ***BOLD time courses extracted from delay period brain regions do not take into account any correlations that may exist between voxels for any of the time points outside of the modeled period (middle of delay period). What are the time courses of correlated neural systems?***

Finite impulse response function-based cPCA

- N = 24 (from Feredoes et al. 2007).
- 11 FIR basis functions (for each time point in a trial).
- FIR-based cPCA reveals neural systems that also correlate across across the trial. Predictor weight for each time point in a trial = averaged, correlated BOLD signal.

Component 1

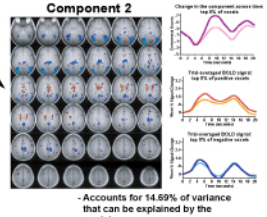


- Accounts for 72.40% of variance that can be explained by the model
- Anatomical network identical to Component 1 from delay period load cPCA.
- Load sensitive throughout entire trial: Fronto-parietal and cingulo-opercular top-down control networks as described by Dosenbach et al. 2008?

r = .32

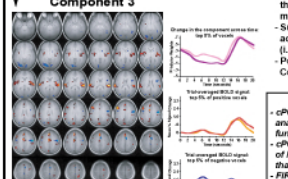
r = -.50

Component 2



- Accounts for 14.69% of variance that can be explained by the model.
- Subcortical delay period load sensitive activity = storage support (i.e., rehearsal) network?
- Positive correlation: active when Component 1 system is active.

Component 3



- Accounts for 15.32% of variance that can be explained by the model.
- Late-peaking activity in BL primary auditory cortex during probe period = post-response evaluation processes?
- Negative correlation: suppressed when Component 1 system is active

Conclusions

- ***cPCA revealed multiple large scale anatomically distributed delay period functional networks.***
- ***cPCA is more sensitive for the detection of load-sensitive delay period activity than SS & SNGA univariate analyses.***
- ***FIR-based cPCA extracted components that also correlate across an entire trial allowing visualization of the temporal dynamics of functional networks.***
- ***Component 1 explains the most variance (for both cPCA methods); it appears to involve top-down control regions.***
- ***FIR-based Component 2 is a good candidate for a (delay period) storage support system. Additionally, primary sensory regions are suppressed during the delay period.***

Supported by Bil Wentz Health & Addiction Services (E.F.); MSPH Research Scholar Award (T.S.W.); NIH MH080466 (B.R.P.)