Comparing multimodal data integration approaches for simultaneous EEG/fMRI recordings

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Theoretical Background

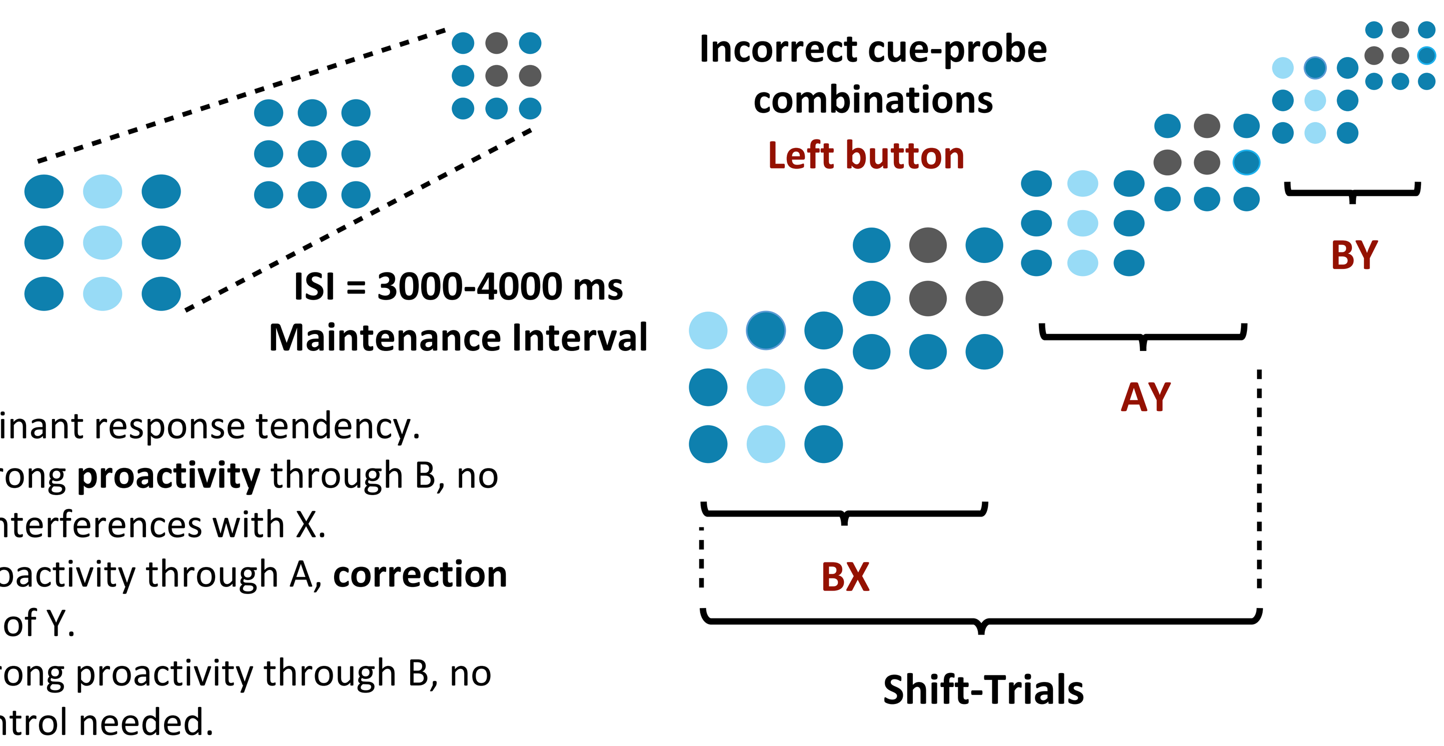
The dynamic exertion of cognitive control in accordance to everyday demands is a key factor in executive functioning and goal directed behaviour. Both active maintenance and flexible updating of context information in working memory constitute efficient behavioural control. Therefore, two distinct modes of control can be identified: **proactive** (i.e. preparatory, context-driven) and **reactive control** (i.e. corrective, stimulus-driven) (1). Past research points to the dorsolateral prefrontal cortex (DLPFC) to be the core structure for both modes (4). While proactive control optimises behaviour in the long-term and should be less demanding in terms of prefrontal resources, it should involve more central and posterior parietal areas (i.e. motor preparation).

Concerning Event-Related Potentials (ERPs), late fronto-parietal positivity associated with working memory updating and maintenance (i.e. P3b, Late Positive Potentials) should relate to the processing of predictive context cues and increased efforts to integrate new information into behavioural plans.

These findings have been observed in the past, but mostly isolated from one another. The aim of this study was the identification of **joint and distinct signal sources** characterising modes of control in multimodal data integration approaches. These vary in how much information they utilise, whether they are performed on the subject or trial level, which specific measures of fMRI or EEG are entered and in the physiological or statistical assumptions they make.

Paradigm

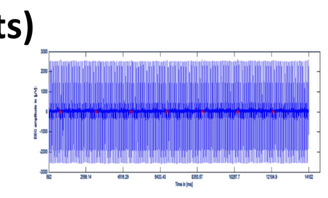
Right button
Correct cue-probe combination AX



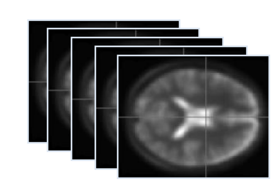
- AX – 65% = Dominant response tendency.
- BX – 11.6 % = Strong **proactivity** through B, no correction, but interferences with X.
- AY – 11.6 % = proactivity through A, **correction** needed because of Y.
- BY – 11.6 % = Strong proactivity through B, no correction or control needed.

Experimental Setup and Design

EEG Data (11 Subjects)
T timepoints
C electrodes
M trials
T*C by M matrix

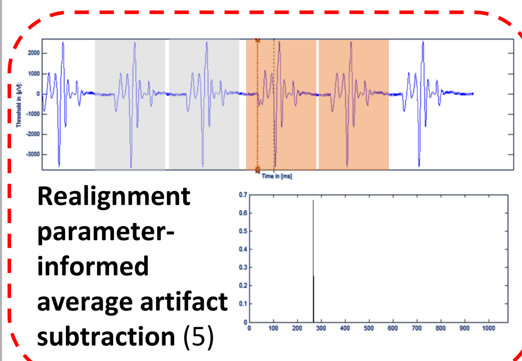


fMRI Data (11 Subjects)
T timepoints
X voxels
M trials
T*X by M matrix



Realignment

Realignment Parameters

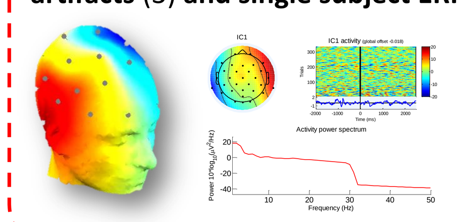


Hemodynamic lag, temporally unmatched

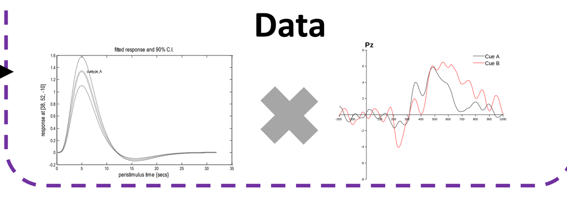
Alignment of temporal resolution with HRF

Hemodynamic Response Function

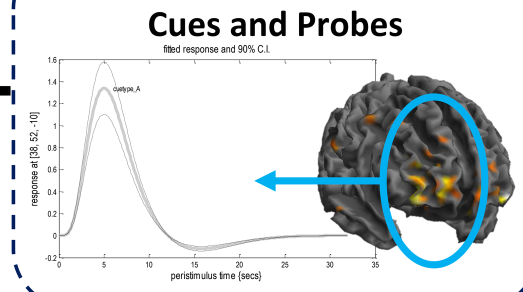
ICA correction of cardioballistic artifacts (3) and single subject ERPs



Convolution of single subject EEG Data

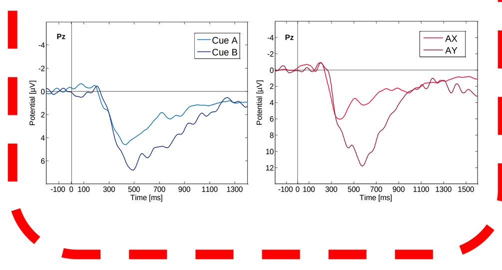


First Level Contrasts Cues and Probes



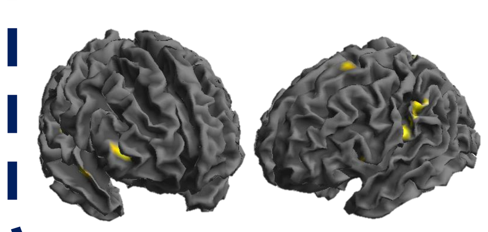
Joint Data Space
[T*C + T*X] by M
for sample N of both data modalities

Grand Averages
cue- and probe-locked

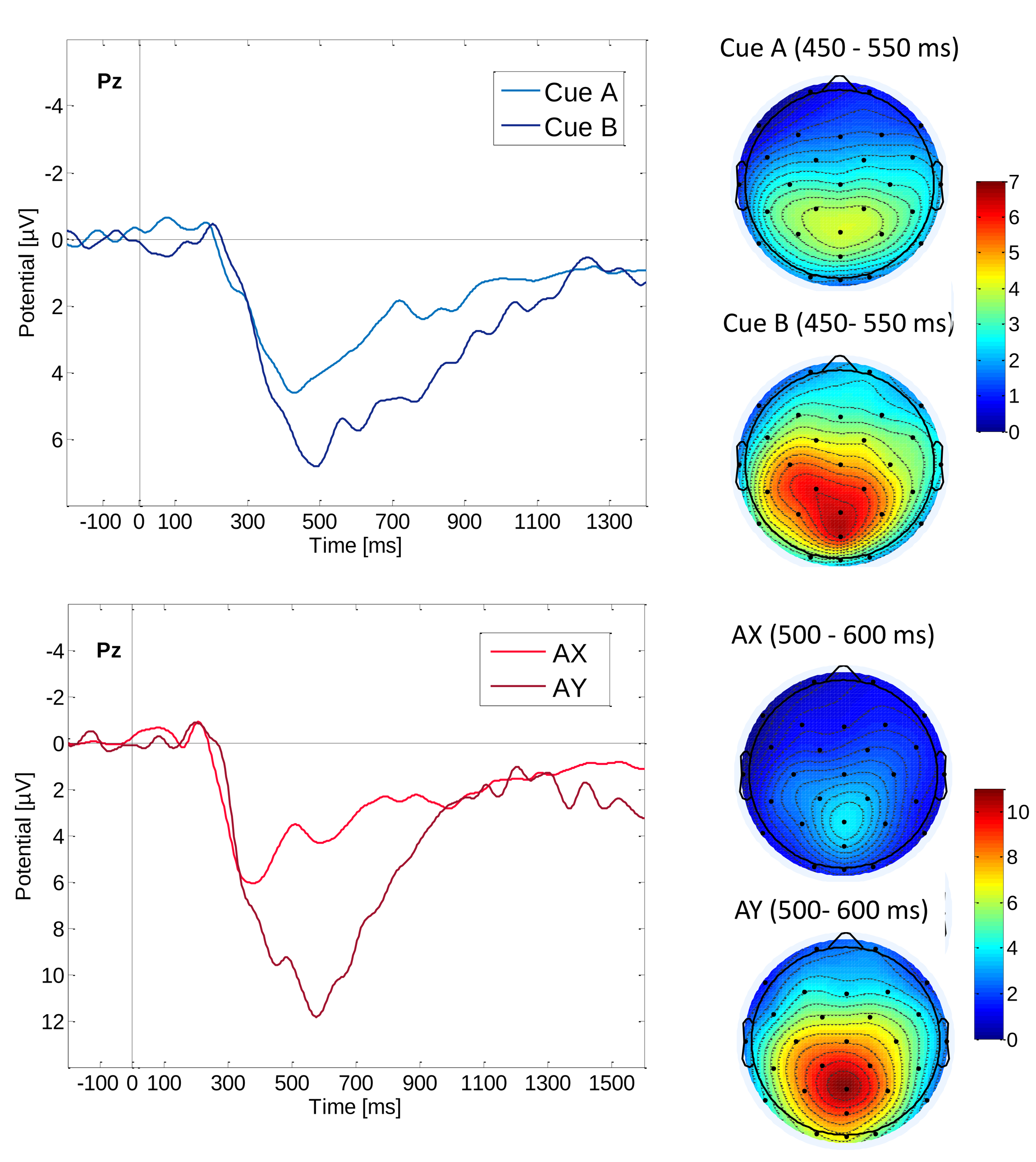


Joint Independent Component Analysis (jICA): Extraction of shared component weights matrix with complementary components [2]

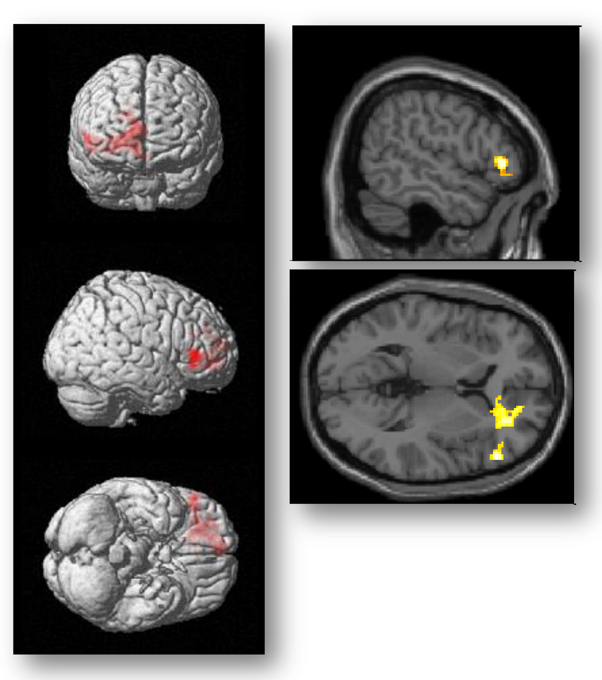
Second Level Contrasts cues and probes



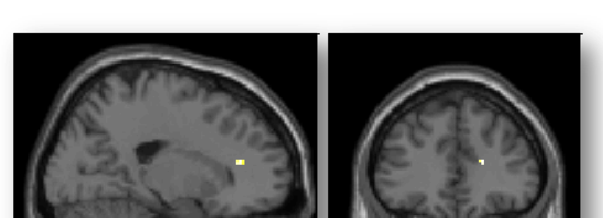
Results



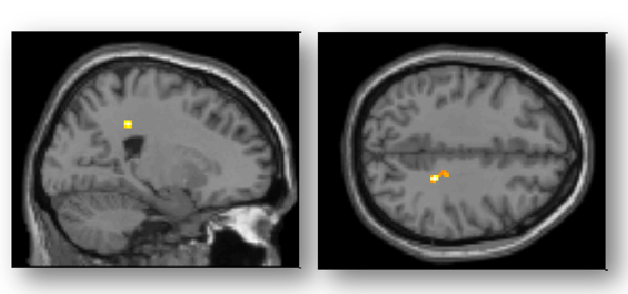
ROI analysis, Contrast **A>B,** p < .05 (FWE-corr.)

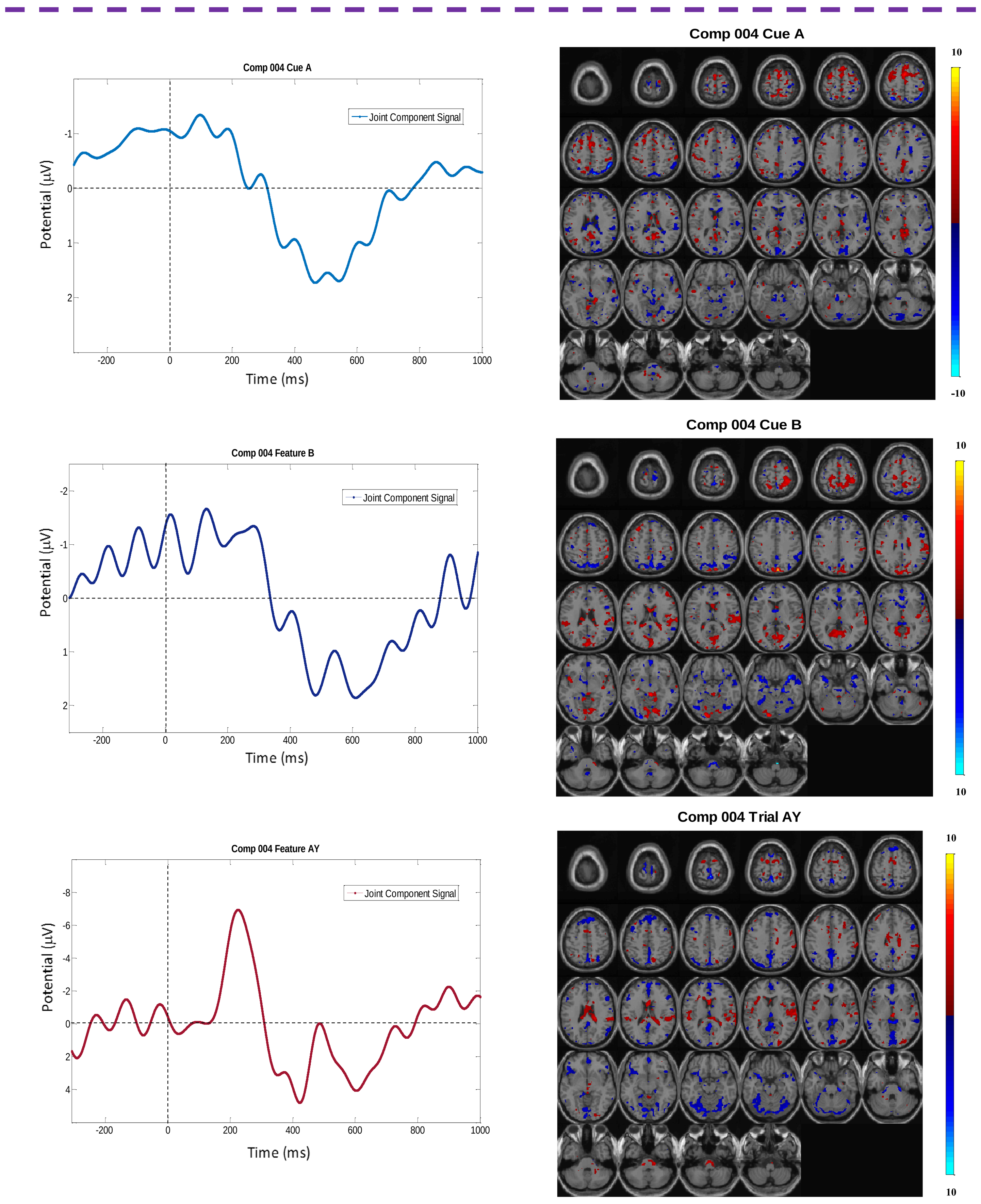


ROI analysis, Contrast **AY>AX,** p < .05 (FWE-corr.)



ROI analysis, Contrast **BX>BY**, p < .05 (FWE-corr.)





Selected joint components for EEG and fMRI data (cue- and probe-locked), marked voxels exceed z-value thershhold of 1.5

Each time point in the ERP time course is assigned a combination of the associated fMRI voxels

Conclusions

- Further evidence for fonto-parietal structures (i.e. DLPFC, central parietal cortex) underlying cognitive control functioning in working memory: 1) More prefrontal and less posterior parietal activity for ambiguous as opposed to predictive cues 2) Higher late positive potentials (P3b, LPPs) for reactive control correcting behaviour as opposed to early behavioural optimisation (i.e. goal maintenance).
- Multimodal Data Integration (i.e. jICA) as a way of examining shared information between features in a joint data space.
- Otherwise lost information in means, isolated contrasts or grand averages can be extracted.
  - Means to observe simultaneous variation in data signals when investigating temporal and spatial dynamics of cognitive control functioning.
- Joint ICA as a tool for multimodal data fusion is limited by:
  - Assumption of exclusively linear associations
  - Decomposition is constrained to identical modulation of data sources across subjects
  - Implemented as second level analysis, usage of higher order statistics

Literature

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(4) Lopez-Garcia, P., Lesh, T. A., Salo, T., Barch, D. M., MacDonald III, A. W., Gold, J. M., ... & Carter, C. S. (2016). The neural circuitry supporting goal maintenance during cognitive control: a comparison of expectancy AX-CPT and dot probe expectancy paradigms. *Cognitive, Affective, & Behavioral Neuroscience, 16*(1), 164-175.

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