Do ERP and fMRI signals explain different sources of individual variability in memory during childhood?

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Introduction

- Decades of research have explored neural correlates of memory development using Electroencephalography (EEG) and functional magnetic resonance imaging (fMRI). However, connections between findings from the two approaches remain unclear.
- Studies using both EEG and fMRI have shown neural signals linking to the performance of source memory (e.g. Ghetti & Bunge, 2012).
- We explored two methods to bring the two modalities together: structural equation modeling (SEM) and EEG source localization. This study sought to understand whether event related potentials (ERPs) and fMRI activation obtained from the same children (1 week apart) explain different variability in and identify different brain regions related to young children's episodic.

Aims

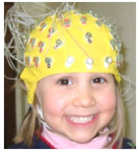
SEM:
1) Explore latent neural construct underlying EEG and fMRI signals.
2) Identify shared and unique variances in memory construct explained by EEG and fMRI.

Source Localization:
1) Source localization of task-relevant ERPs, to identify projected EEG sources that overlap with regions of fMRI activations;
2) fMRI-informed source localization of EEG sources that include a priori regions of interests extracted from fMRI activations.

Participants

- 200 children, 4-8 years (M_{age} = 6.21 years, SD=0.107) participated as part of a larger longitudinal study examining the development of episodic memory.
- 179 children provided useable structural MRI data, 44 provided task fMRI data. 86 provided task EEG data. 22 provided data for all three domains.

One week apart

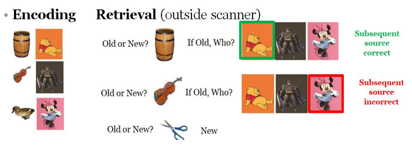


Behavioral Measure

Memory Score: A composite memory measure (Canada et al., 2018) was estimated from four separate memory tasks, fitted through a second-order latent growth models (Hancock et al., 2001).

Neuroimaging Data Collection

Source Memory Task (EEG and MRI)



160 images of animals and objects were divided into 4 sets of 40 items and counterbalanced across participants. EEG and fMRI data was collection with different stimuli.

MRI Data (Siemens 3T scanner, 32-channel coil)
- A T1-weighted structural MRI scan (.9 mm^3)
- A task-based T2*-weighted gradient echo-planar imaging sequence (3 mm^3) was obtained during encoding.

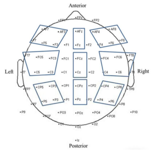
Task EEG Data (BioSemi Active 2, 64 channels)
- EEG was continuously recorded during encoding. Bad channels were interpolated and ocular artifacts were corrected.

Structural Equation Modeling

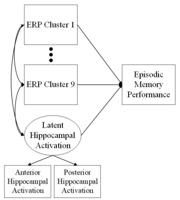
SEM model was built with previously-identified memory-related neural signals (Riggins, 2018; Riggins, 2019), including two hippocampal ROI from fMRI data and Latent Slow Wave (LSW) ERP data.

- Exploratory factor analysis (EFA) was performed to investigate latent structures within domains. **A latent structure was identified between fMRI anterior and posterior hippocampal ROIs**, but not in LSW amplitudes.
- SEM model converged **13 out of 30 with random starting values**. Converged runs showed good model fit (CFI=1.00, RMSEA=.00, 90% CI=[.00, .20]; SRMR=.02).
- Latent hippocampal activation factor was negatively associated with children's composite memory score (β=-.39, p<.05). Several clusters of LSW signals were associated with memory score (left-frontal: β=.81, p<.01; left-central: β=-.57, p< .01; left-posterior: β=.30, p<.05; medial-central: β=1.08, p<.001, medial posterior: β=-.51, p<.02).
- **No significant covariance between the latent hippocampal activation and LSW amplitudes**.

EEG channel clusters



Memory Model



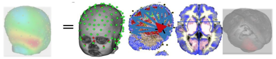
Discussion

- SEM results were unstable due to small sample size and high collinearity among LSW data. Future analyses will explore resting state EEG and resting fMRI data with a larger sample from the same study.
- The SEM results provided an initial step in moving beyond examining the complex relation of the brain and cognition using single measures of neural evidence and memory ability.
- Source localization provides an alternative approach for multimodal analysis, especially with smaller sample sizes.

Source Localization

- Currently adopting EEG source localization to identify the brain sources that are responsible for memory-related ERP signals. The process includes the forward model and inverse model to estimate cortical EEG sources.

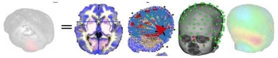
Forward Model



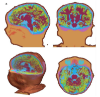
- Models the expected scalp EEG signals from given sources.
- Requires segmented head model
- Calculates lead field matrices combining EEG channel locations, head model and sources.

Inverse Model

- Recovers EEG sources from the scalp to the putative locations of the cortical surfaces, using the mathematical inverse of the lead field matrices.



- **Head Segmentation**



- We will compare the estimated cortical sources of EEG with fMRI activations to identify overlapping and non-overlapping memory-related brain regions.

Figures adapted from Conte & Richards, 2022.

Take-Home Message

Multimodal analysis brings together literature on EEG and fMRI to better understand the neural sources underlying memory development. Source localization is out next step.

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