Multimodal Analysis of Neural Signals Related to Source Memory in Young Children

Yuqing Lei[1], John Richards[2], Fengji Geng[3], Tracy Riggins[1]

[1] University of Maryland, College Park
[2] University of South Carolina
[3] Zhejiang University

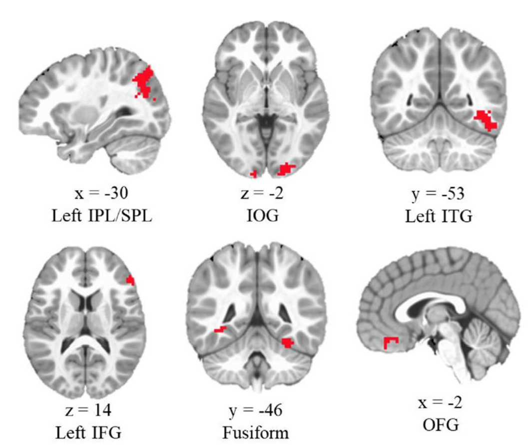
Neurocognitive Development Lab

Introduction

- Both EEG and fMRI studies showed neural signals linking to the performance of source memory (e.g. Ghetti & Bunge, 2012).
- Connections between findings from the two approaches remain unclear.
- The P2 and the late slow wave component (LSW) have been found to be associated with episodic memory, yet their sources and exact functionality is not fully understood.
- We applied source localization to bring the two modalities together. This study sought to understand whether P2 and LSW are localized to to fMRI ROIs obtained from the same children during the same task one week apart (Geng, Redcay, Riggins, 2019).
- Additionally, we predict that sources are significantly different in the medial temporal lobe (MTL) and the surrounding areas, a region long associated with memory feature binding, between source memory correct and source memory incorrect trials.

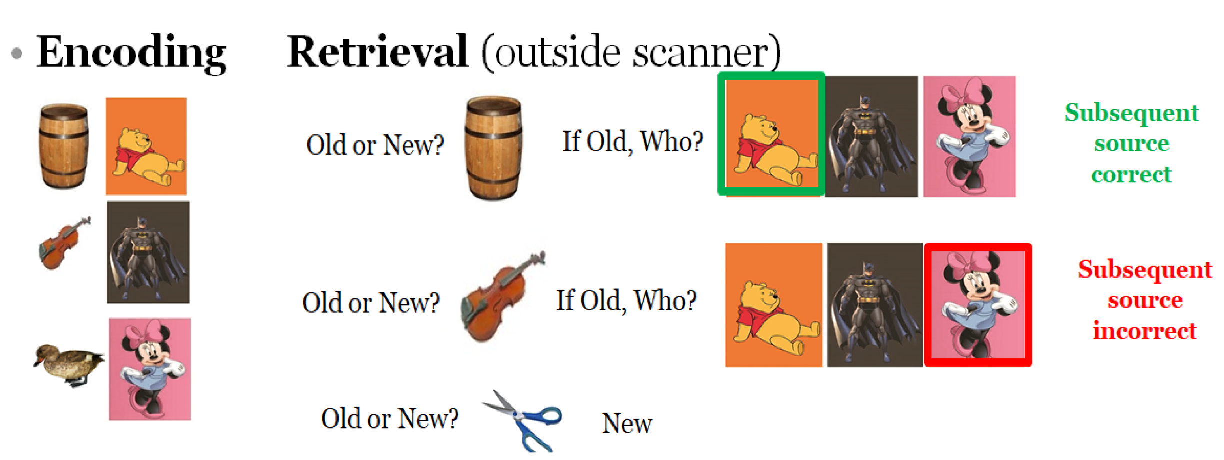
Aims

- Source localization of task-relevant ERPs (P2 and LSW), to identify projected EEG sources that overlap with regions of fMRI activations during the same task (see figure) and areas of MTL.



Neuroimaging Data Collection

Source Memory Task (EEG and MRI)



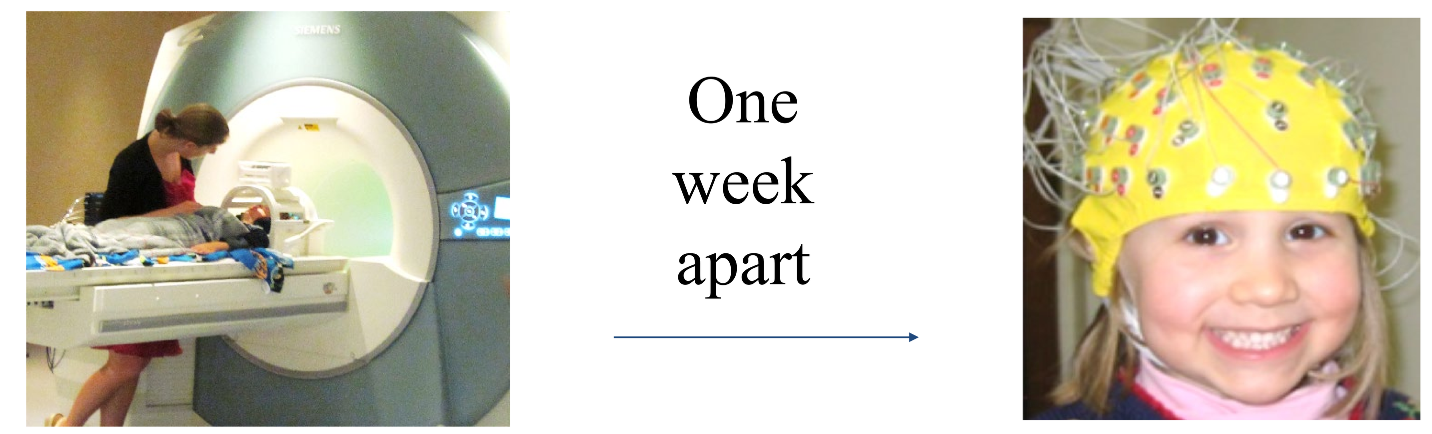
160 images of animals and objects were divided into 4 sets of 40 items and counterbalanced across participants. EEG and fMRI data was collection with different stimuli.

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.

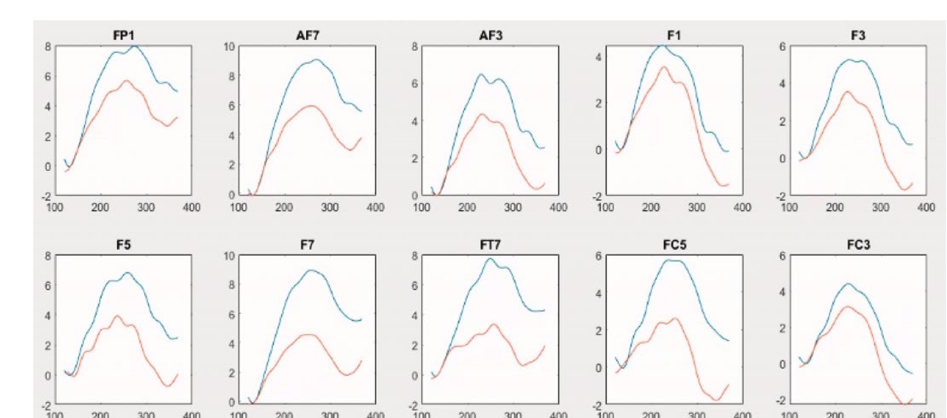
Participants

- 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.

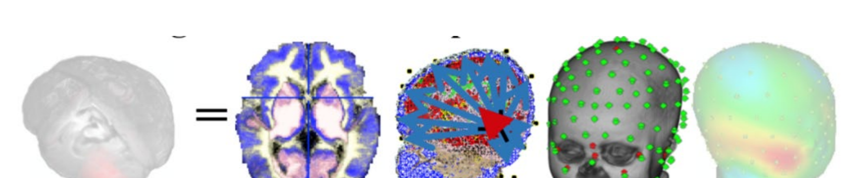


Methods

- General linear modeling was applied to identify EEG channels that showed significant differences between memory conditions. A cluster of EEG channels were identified in the left-frontal area.
  - Grand average P2 in left frontal channels, source correct (blue) v.s source incorrect (red).



- These channels were used to identify peak P2 and time window of LSW. Data was re-epoched and baseline corrected to create 150ms sections of P2 (175 - 325 ms) and LSW (975ms - 1125 ms) components.
- P2 and LSW were source localized using finite element modeling (FEM) and eLORETA methods. Head models were built and segmented from individual T1 images.

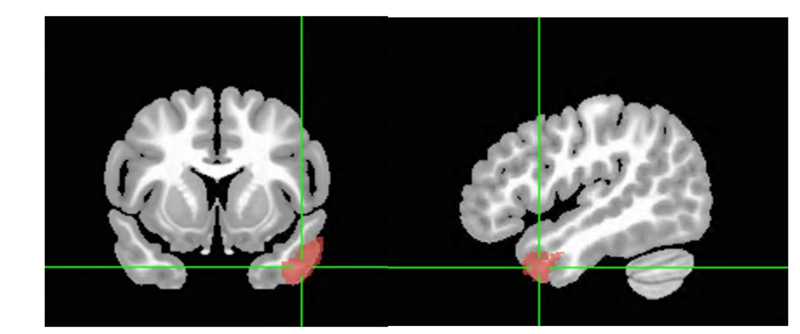


Figures adapted from Conte & Richards, 2022.

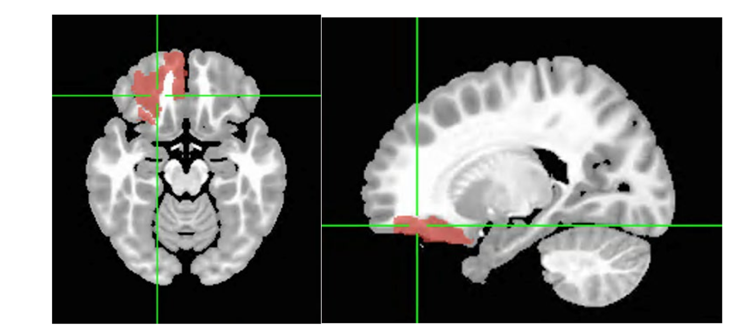
- LSW and P2 source scores were compared area by area (using Brainnetome atlas) between memory conditions using paired t-tests. Multiple comparison correction was conducted using the Benjamini & Hochberg method. Right and left hemispheres were tested and corrected separately.

Results

- P2 sources showed trends of differences, while insignificant, between source correct and source incorrect conditions after correction (ps <0.07; areas in left and right ORG, left ITG, left fusiform, and IPL).
- LSW sources showed significant difference in left MTG (area 83, p= 0.035), and left ORG (area 41,45,49: p= 0.035), as well as a few marginally differences in left IPL and left ITL (ps=0.058-0.059).



Left MTG



Left ORG

Discussion

- Sources of LSW showed significant differences between memory conditions in multiple areas that have been identified using fMRI, presenting remarkable overlaps in the neurophysiological signals between the two modalities. P2 sources showed similar trends of overlapping, but was not significant.
- LSW source differences in MTG potentially links the functionality of LSW to semantic information processing during memory encoding.
- Next step: apply subject-space fMRI ROI masks to individual EEG source results to better pinpoint the overlaps.

Take-Home Message

Memory-related components identified in EEG exhibit similar source differences compared to fMRI ROIs. Source differences in MTG directs attention to the functionality of LSW during memory.

Acknowledgements

Thank you Dr. John Richards for the collaboration on source localization analysis. Thank you Dr. Gregory Hancock for the assistance on SEM analysis. Thank you to the families that participated in this research study and to members of the Neurocognitive Development Lab for assistance with data collection. Support for this research was provided by NICHD under Grant HD079518 (TR).