

Is multi-modal integration useful?

Peter J. Molfese, Ph.D.
Section on Functional Imaging Methods, NIMH
Center for Multimodal Neuroimaging, NIMH

NIH Summer Neuroimaging Course
August 8, 2019



cmn.nimh.nih.gov



Yes.



Overview

- What is Multimodal Neuroimaging?
 - Definition
 - Motivation
- Doing this well is hard
- Doing this well is important

Multimodal Neuroimaging

- Any neuroimaging that uses multiple (complimentary) methods

- fMRI + EEG*



- MEG + EEG*

- fMRI + MRI



- fMRI + DTI

- fMRI + MEG

- tDCS/tACS/TMS + EEG*

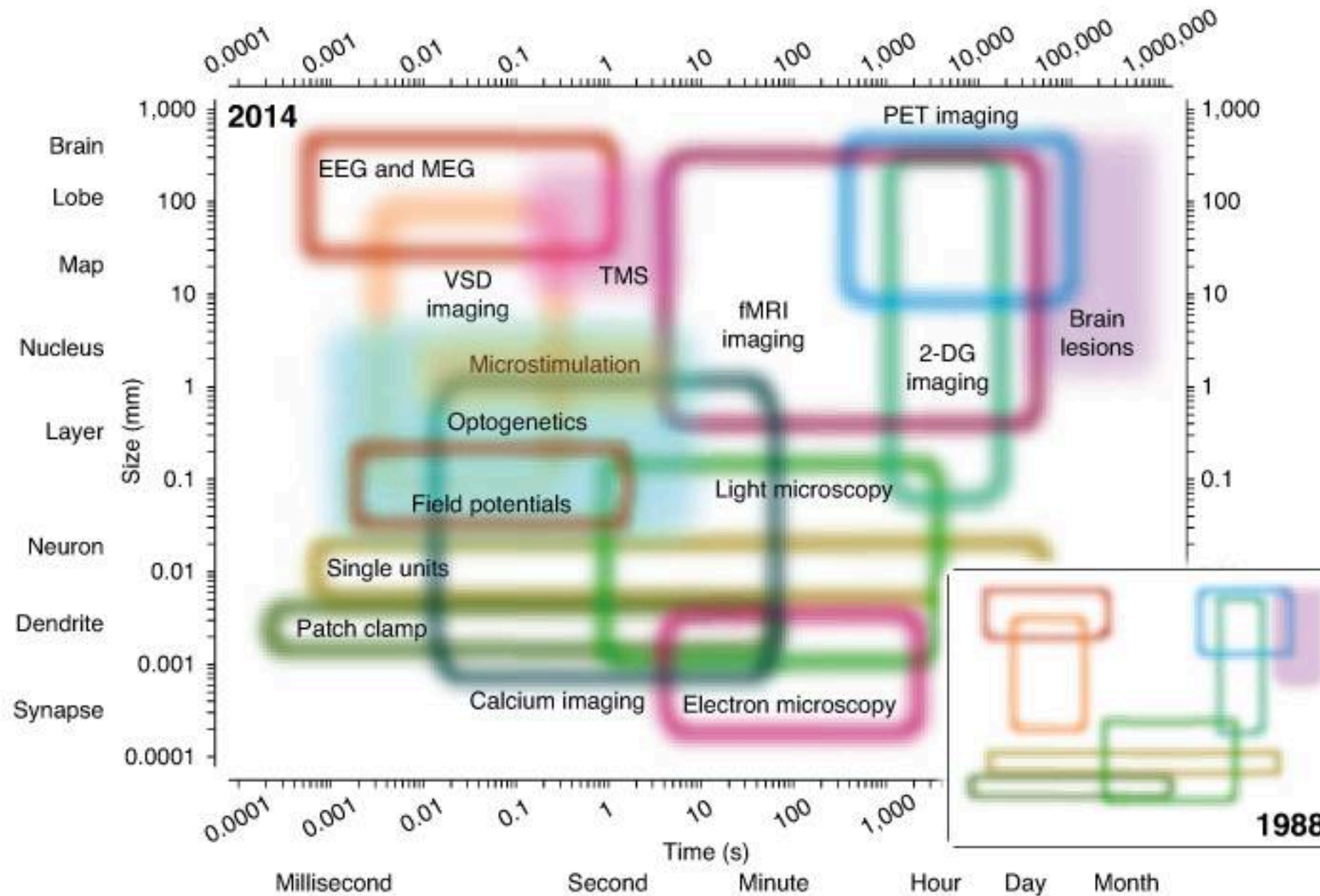
- TMS + fMRI*

- Etc...

Doesn't have to be Simultaneous

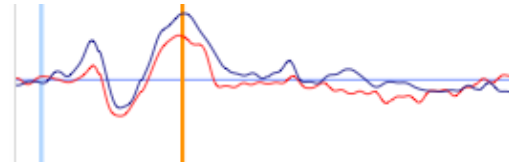
	EEG	MEG	sMRI	fMRI	DTI	MRS	PET	TMS/tDCS/ tACS
EEG	Black							
MEG	Pink	Black						
sMRI	Green	Green	Black					
fMRI	Blue	Green	Green	Black				
DTI	Pink	Green	Green	Green	Black			
MRS	Pink	Green	Green	Green	Green	Black		
PET	Green	Green	Green	Green	Green	Green	Black	
TMS/tDCS/ tACS	Pink	Pink	Green	Green	Green	Pink		Black

Temporal-Spatial Tradeoffs

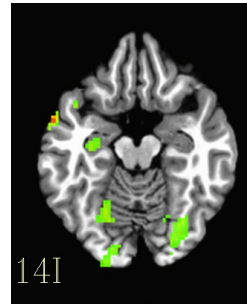


Information Tradeoffs

- “When in the brain”



- “Where in the brain”



- “What happens to a process when X area is disrupted?”

- Is there a fallback network?

- “What happens to a process when disrupted at Y time?”

- How does the brain compensate?



Information Tradeoffs

	Pro	Con
EEG	High Temporal Resolution Comparable Across Lifespan Inexpensive	Low (Source) Spatial Resolution Source Analysis Difficult
MEG	High Temporal Resolution Less Difficult Source Analysis	Expensive Difficult to use with Children Limited Signal from Deep Tissue
fMRI	Excellent Spatial Resolution	Expensive Difficult to use with Children Low Temporal Resolution (HRF)

Doing Multimodal is Hard

Design



- Knowledge of the domain or topic
- Knowledge of component parts (e.g. MRI + EEG)
- Technical Knowledge to carry out some portion of the experiment

Data Analysis



Interpretation



More Design Questions

- Do you have the equipment?
- Do you have the expertise to operate the equipment?
- Is it worthwhile?
 - More data isn't always better.
- Can you do this well?

Doing Multimodal is Hard

Design



- Knowledge of the domain or topic
- Knowledge of component parts (e.g. MRI + EEG)
- Technical Knowledge to carry out some portion of the experiment

Data Analysis



Interpretation



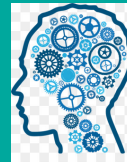
Doing Multimodal is Hard

Design



- Knowledge of the domain or topic
- Knowledge of component parts (e.g. MRI + EEG)
- Technical Knowledge to carry out some portion of the experiment
- What's the value added?
- Does it have to be simultaneous?

Data Analysis



Interpretation



Simultaneous Really?

- Quite a bit of information can be gathered from separate sessions of EEG and MRI
- The real benefits are:
 - Same environment in both cases (inside an MRI)
 - Looking at individual trial modulation of either ERP/
BOLD
 - Looking at coherence and resting state relationship at
the same time

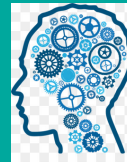
Doing Multimodal is Hard

Design



- Knowledge of the domain or topic
- Knowledge of component parts (e.g. MRI + EEG)
- Technical Knowledge to carry out some portion of the experiment
- Important choice points: Simultaneous vs. Separate
- What's the value added?

Data Analysis



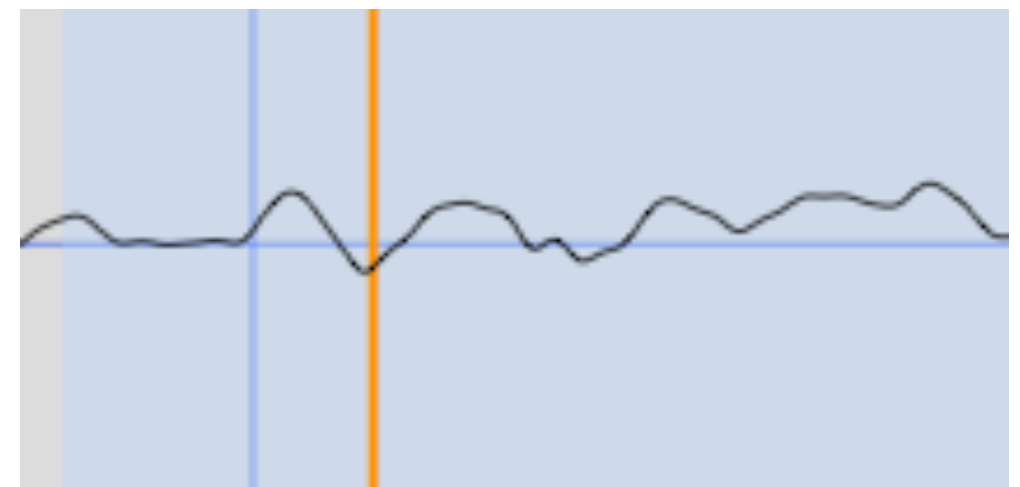
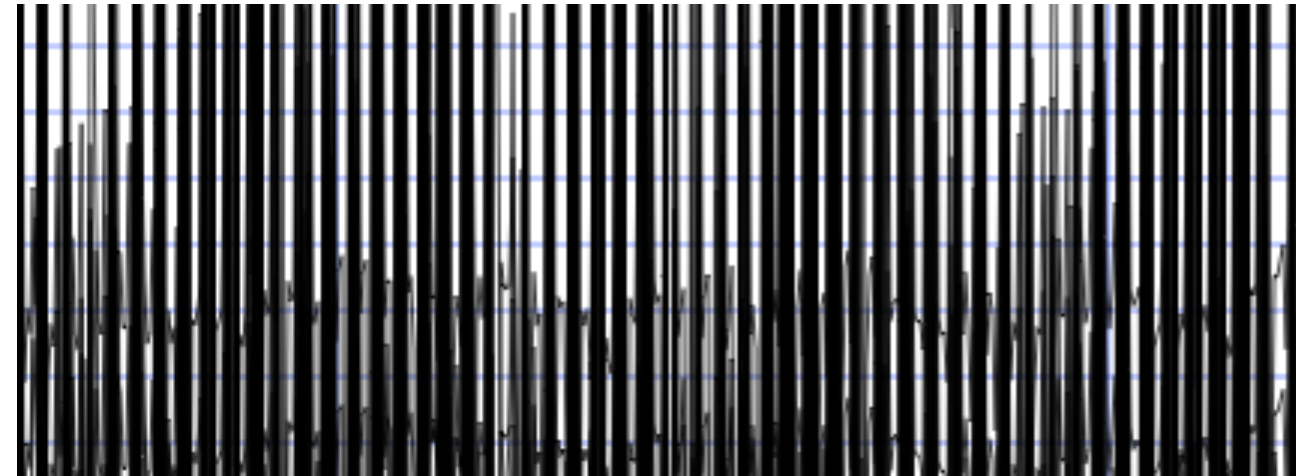
- Are there artifacts from multimodal imaging?
 - Can you fix them?

Interpretation



Artifacts

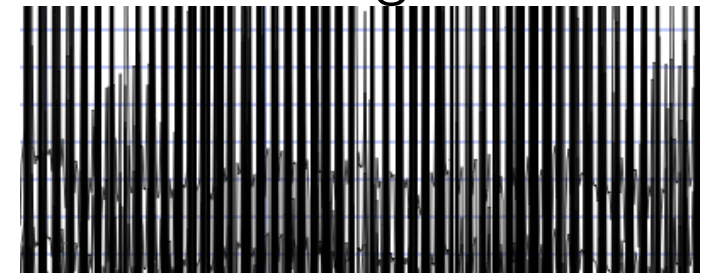
- MR Artifacts
 - Caused by the gradients
- Ballistocardiogram (BCG)
 - Caused by movement of the electrode within the magnetic field



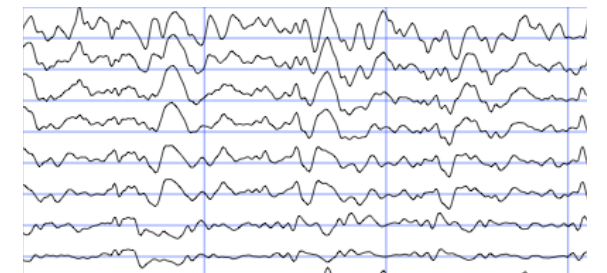
Artifact Removal

- Gradient Artifacts
 - Fairly straightforward to remove
 - Template subtraction
- BCG Artifacts
 - More prominent on the facial electrodes
 - Follows the heartbeat by ~ 250 ms
 - PCA to model the artifact, remove, reconstruct

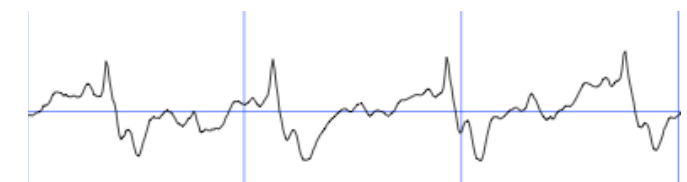
Raw Signal



Artifact Removed



BCG Removal



Doing Multimodal is Hard

Design



- Knowledge of the domain or topic
- Knowledge of component parts (e.g. MRI + EEG)
- Technical Knowledge to carry out some portion of the experiment
- Important choice points: Simultaneous vs. Separate
- What's the value added?

Data Analysis



- Are there artifacts from multimodal imaging?
 - Can you fix them?

Interpretation



Doing Multimodal is Hard

Design



- Knowledge of the domain or topic
- Knowledge of component parts (e.g. MRI + EEG)
- Technical Knowledge to carry out some portion of the experiment
- Important choice points: Simultaneous vs. Separate
- What's the value added?

Data Analysis

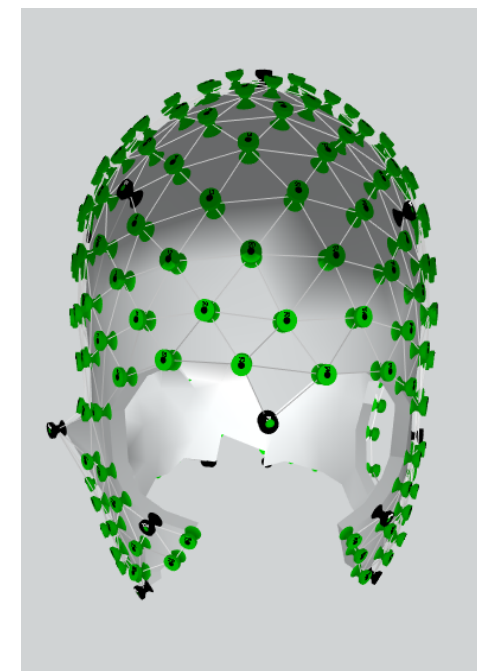


- Are there artifacts from multimodal imaging?
 - Can you fix them?
- If applicable, how will you combine the data?
 - Co-register data across modalities
 - Head Models / Single Subject vs. Group
 - EEG Sources

Interpretation

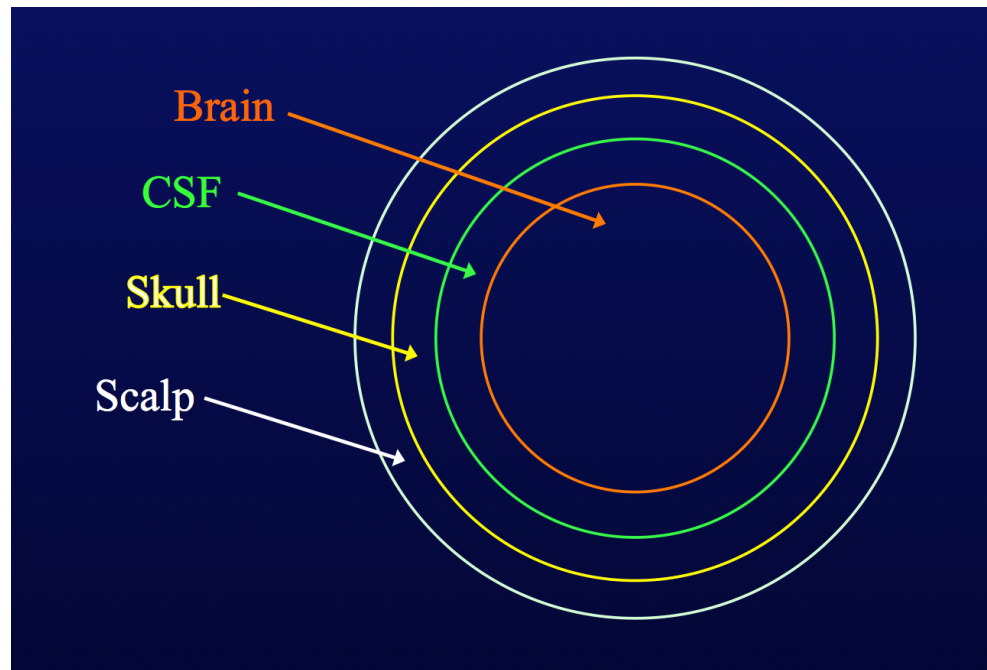


Electrode Coordinates



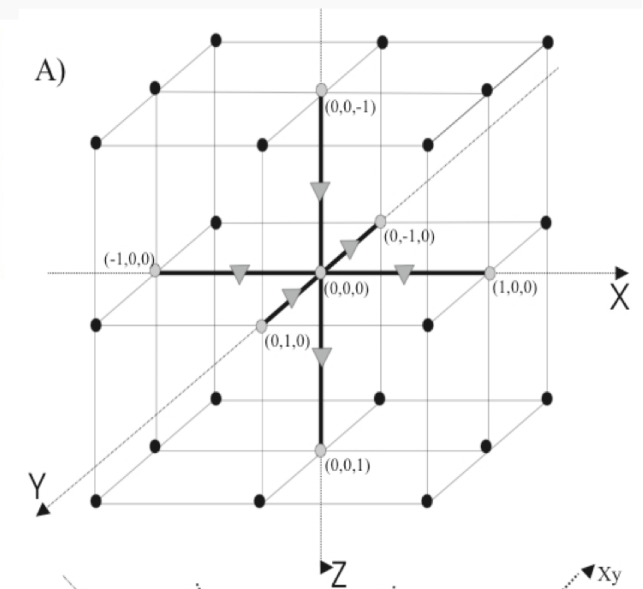
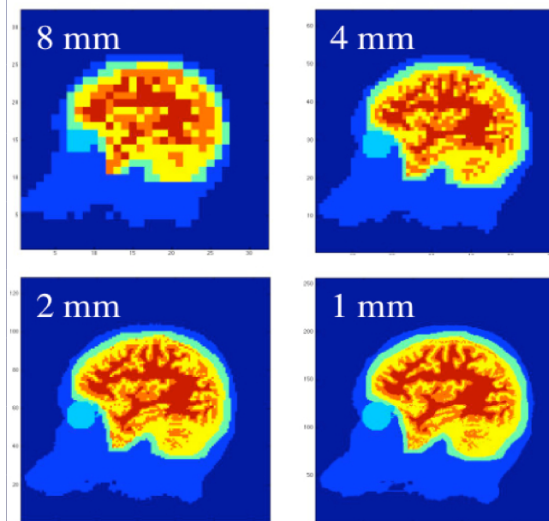
Head Models

Shell Models



Finite Difference/Element Models

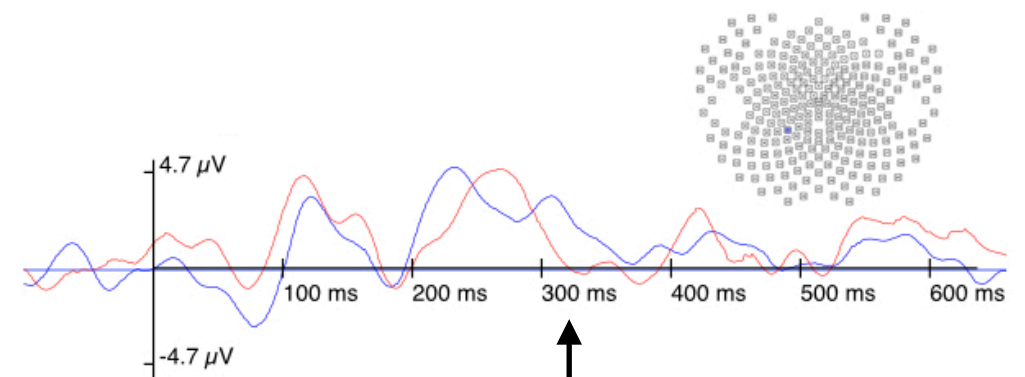
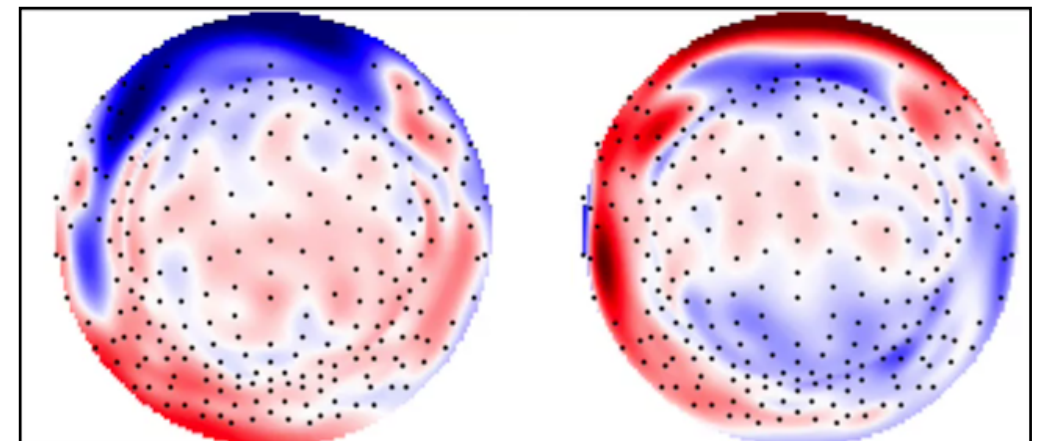
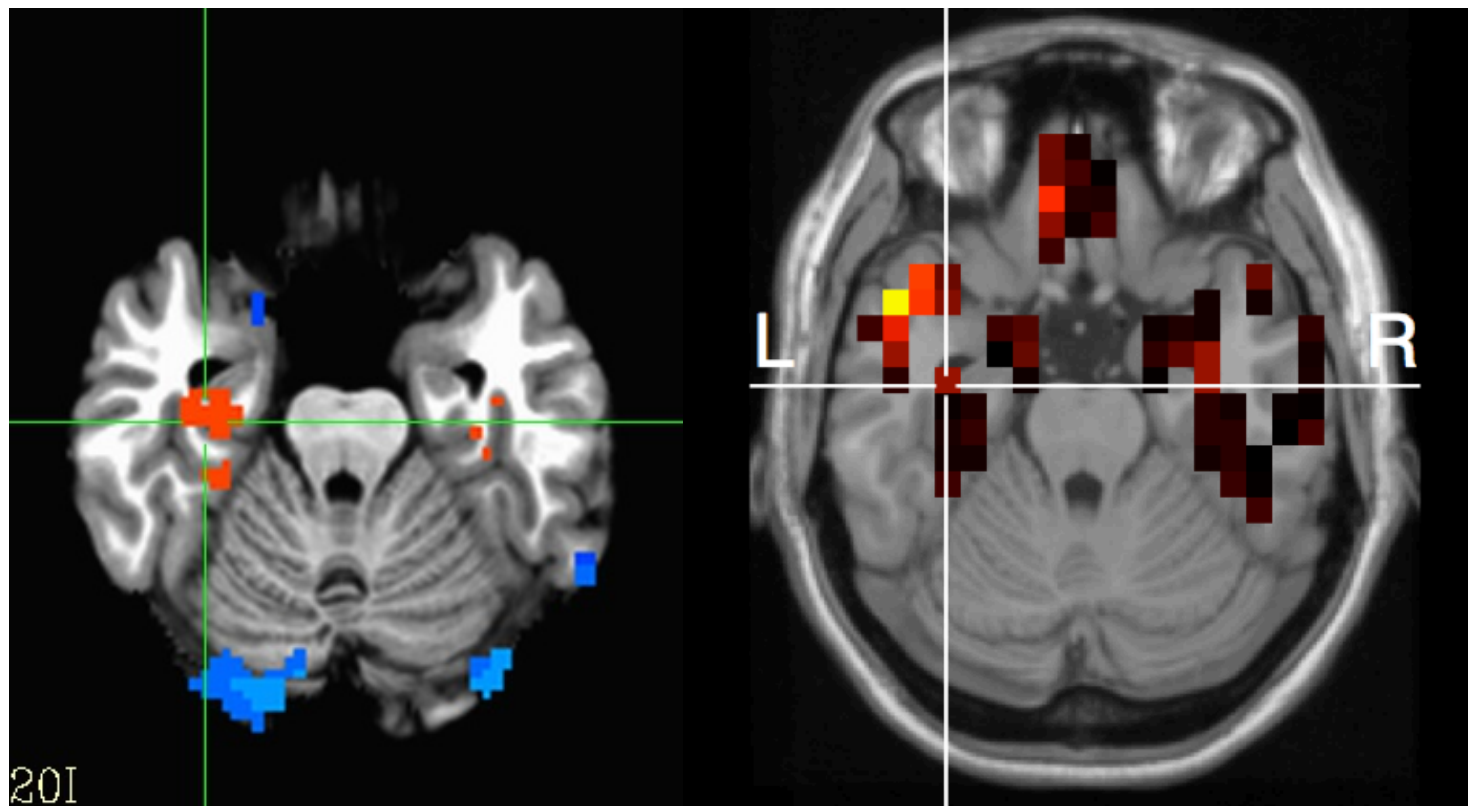
Finite Difference Models: Role of Resolution: from
32768 to 16777216 voxels



Difficulty Combining Very Different Measures

fMRI

EEG



Parahippocampal Activation to P300

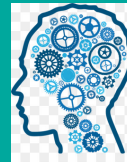
Doing Multimodal is Hard

Design



- Knowledge of the domain or topic
- Knowledge of component parts (e.g. MRI + EEG)
- Technical Knowledge to carry out some portion of the experiment
- Important choice points: Simultaneous vs. Separate
- What's the value added?

Data Analysis



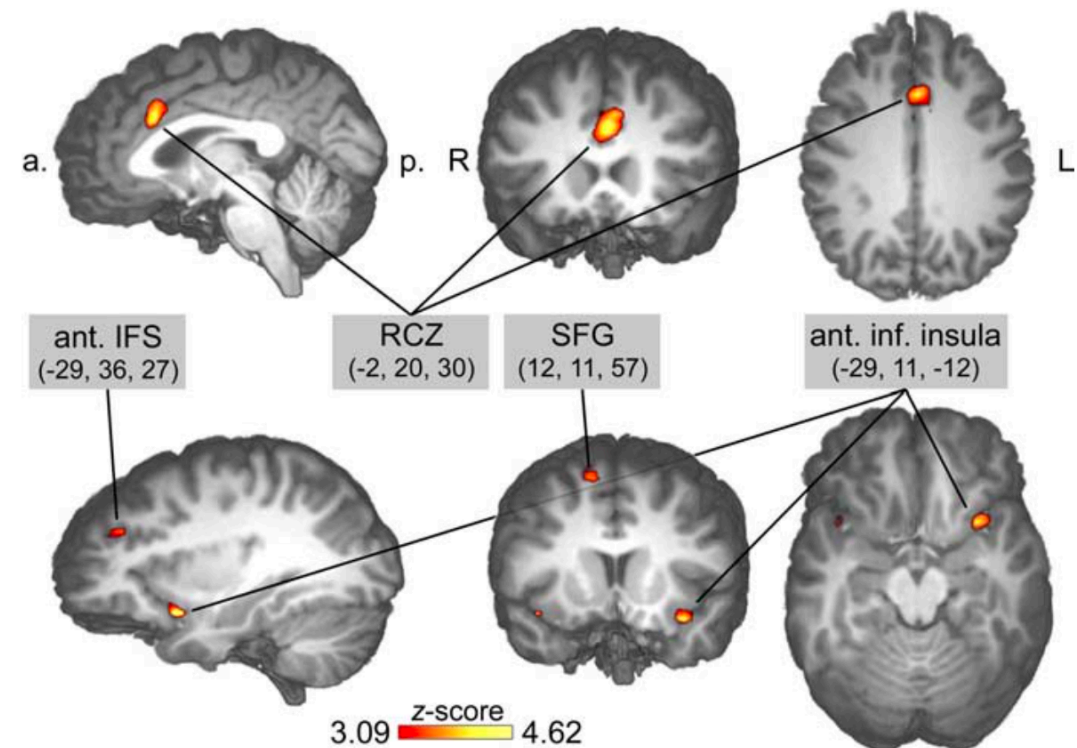
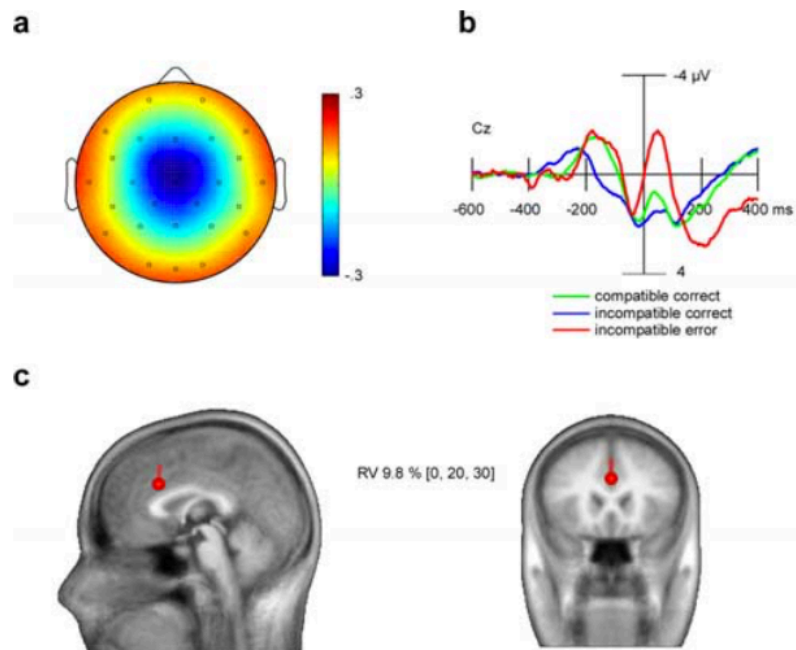
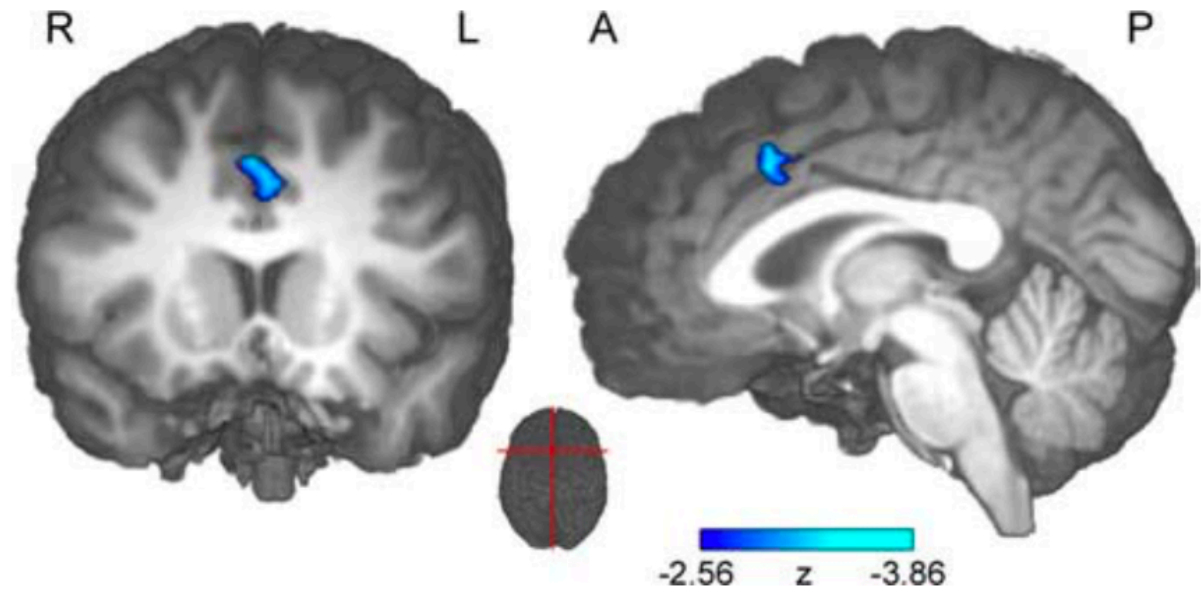
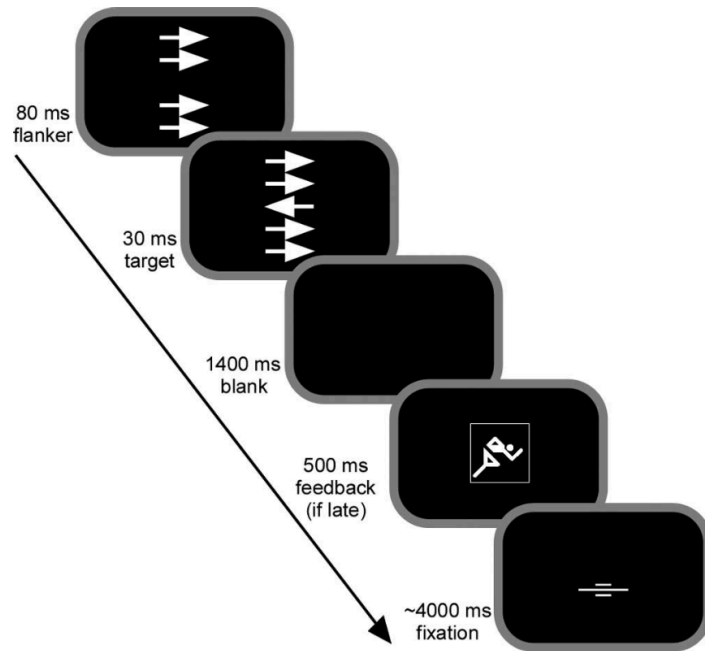
- Are there artifacts from multimodal imaging?
 - Can you fix them?
- If applicable, how will you combine the data?
 - Co-register data across modalities
 - Head Models / Single Subject vs. Group
 - EEG Sources

Interpretation



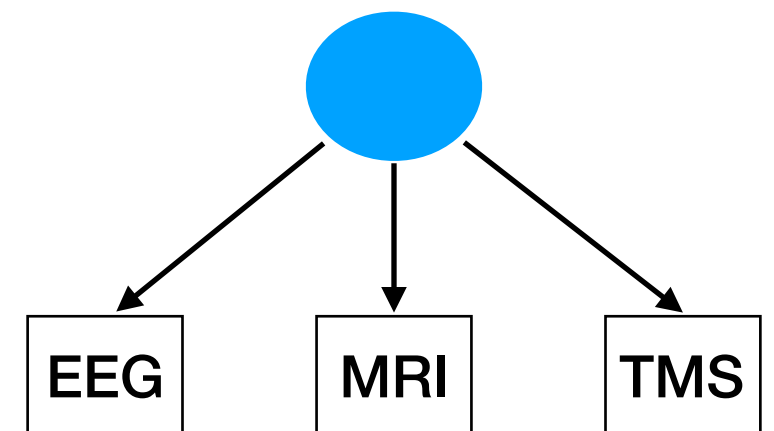
- How to interpret findings?
 - Do the analyses of your data let you make certain generalizations?
- What does it really mean?

Flanker Example



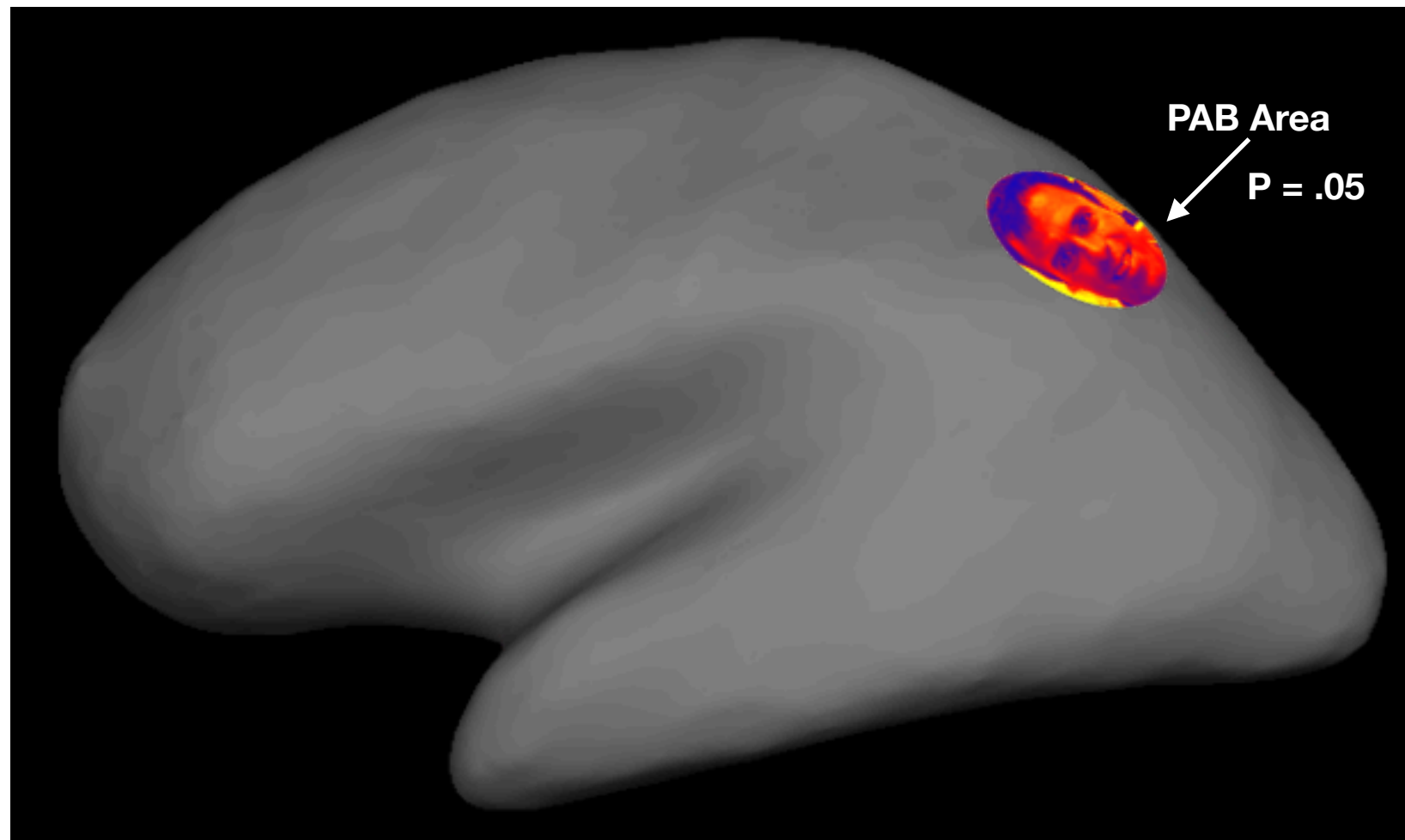
Multimodal is Important

- Provides (hopefully) complimentary and (possibly) overlapping information
- May facilitate better studies of individual differences
 - May be used as a control within subject!
 - Allow for creation of multi-measure latent variable models
- Improve reliability/replication



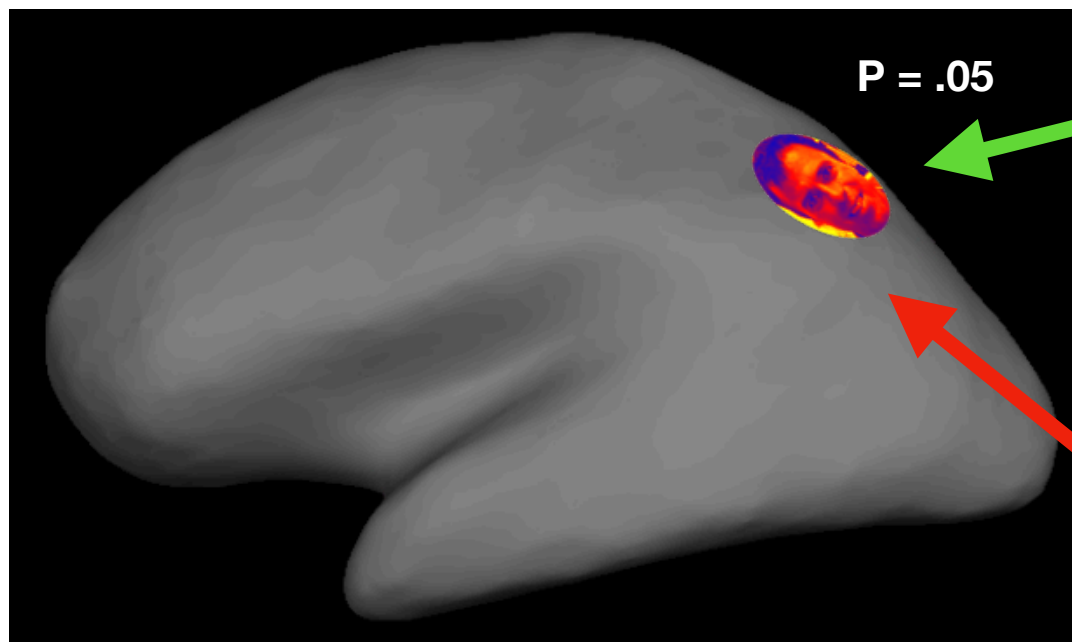
Multimodal Example

fMRI Study:

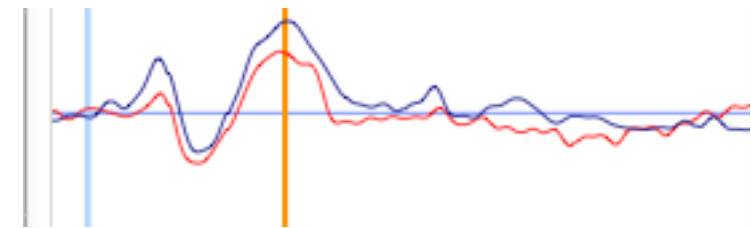


Multimodal Example

fMRI Study:

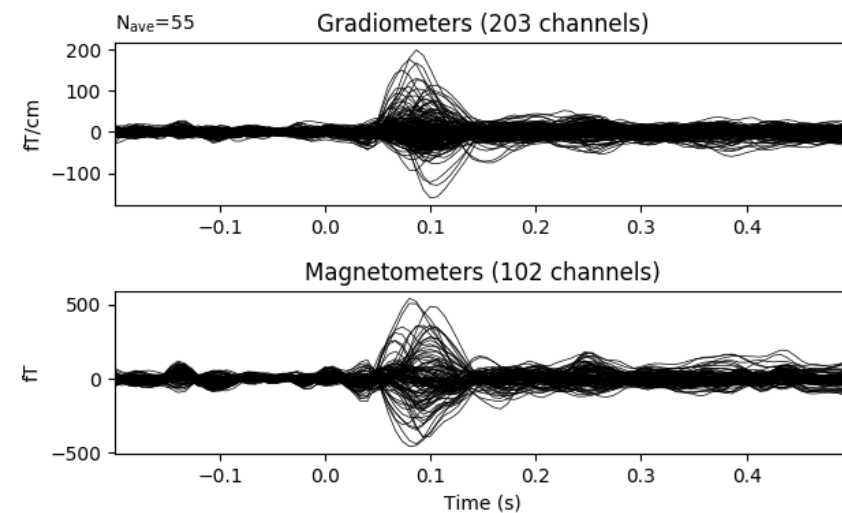


EEG



$P = .05$

MEG



$P = .05$

What's the probability of finding overlapping significance?

Hint: They're not fully dependent, or independent measures

Open Questions

- Design: What Questions best lend themselves to multi-modal imaging?
- Analysis: How should analyses be standardized to best make use of multimodal imaging?
- Interpretation: What will be the scientific/statistical level of rigor to support multimodal imaging conclusions

Questions?

Peter.Molfese@nih.gov

