



**Western**  
The Brain and  
Mind Institute



**Massachusetts  
Institute of  
Technology**



# Introduction to Brain Imaging: fMRI and MEG/EEG

## The Algonauts Workshop

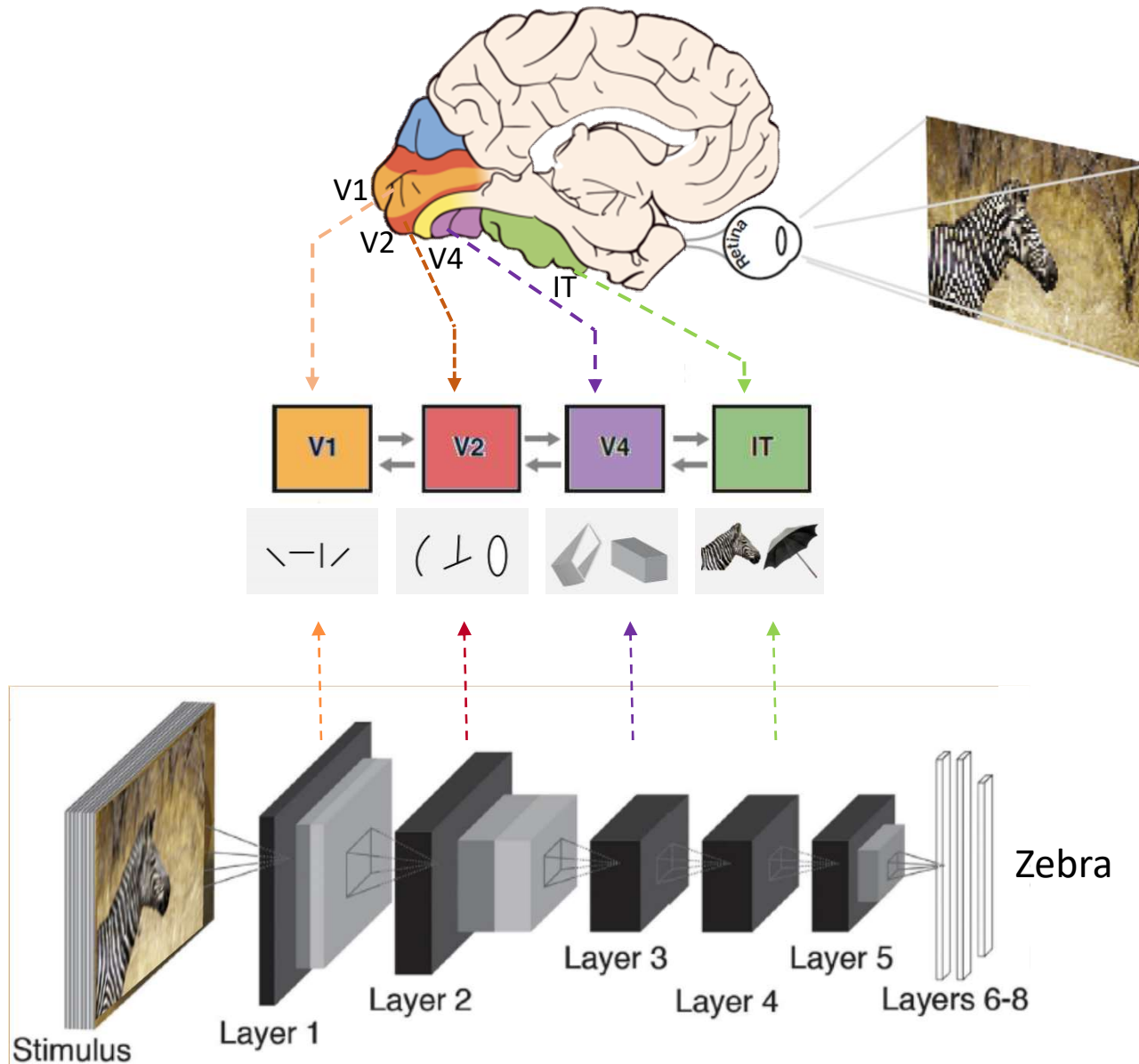
**Yalda Mohsenzadeh**

**Computer Science and Artificial Intelligence Lab.**

**MIT, Cambridge, USA**

**July 2019**

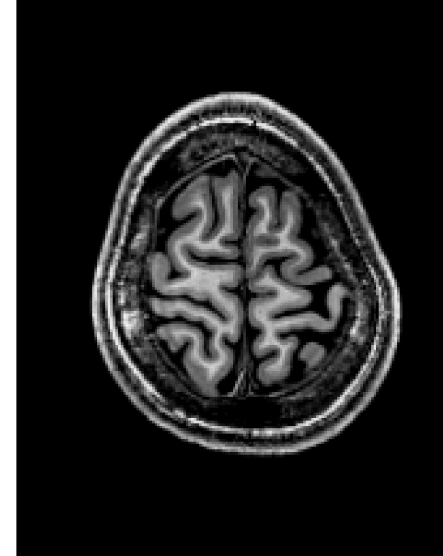
# Convnets: Brain Inspired Architectures



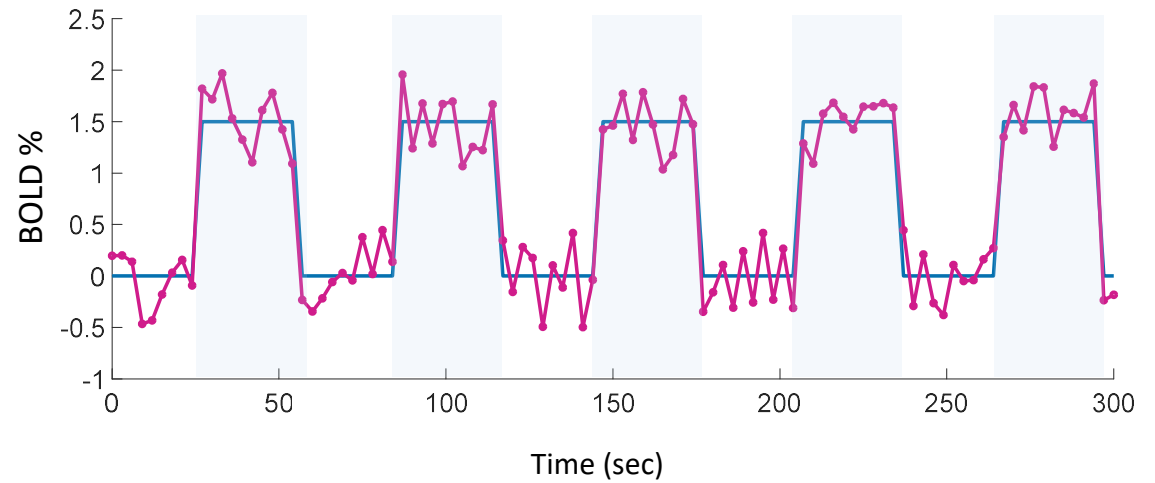
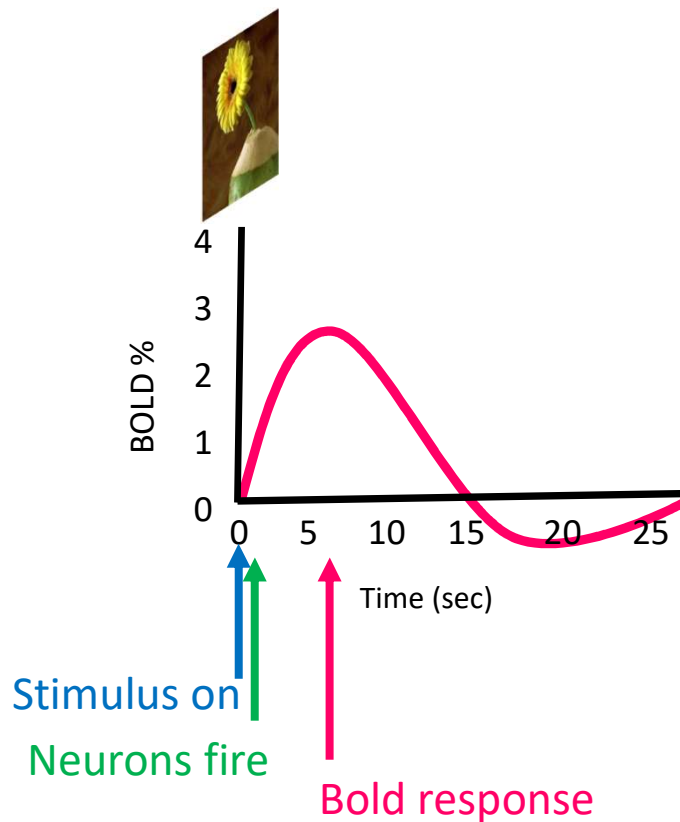
(Khaligh-Razavi et al. 2014, Yamins et al. 2014, Guclu et al. 2015, Cichy et al. 2016 )

What is fMRI?

# Magnetic Resonance Imaging (MRI)



# Functional Magnetic Resonance Imaging (fMRI)

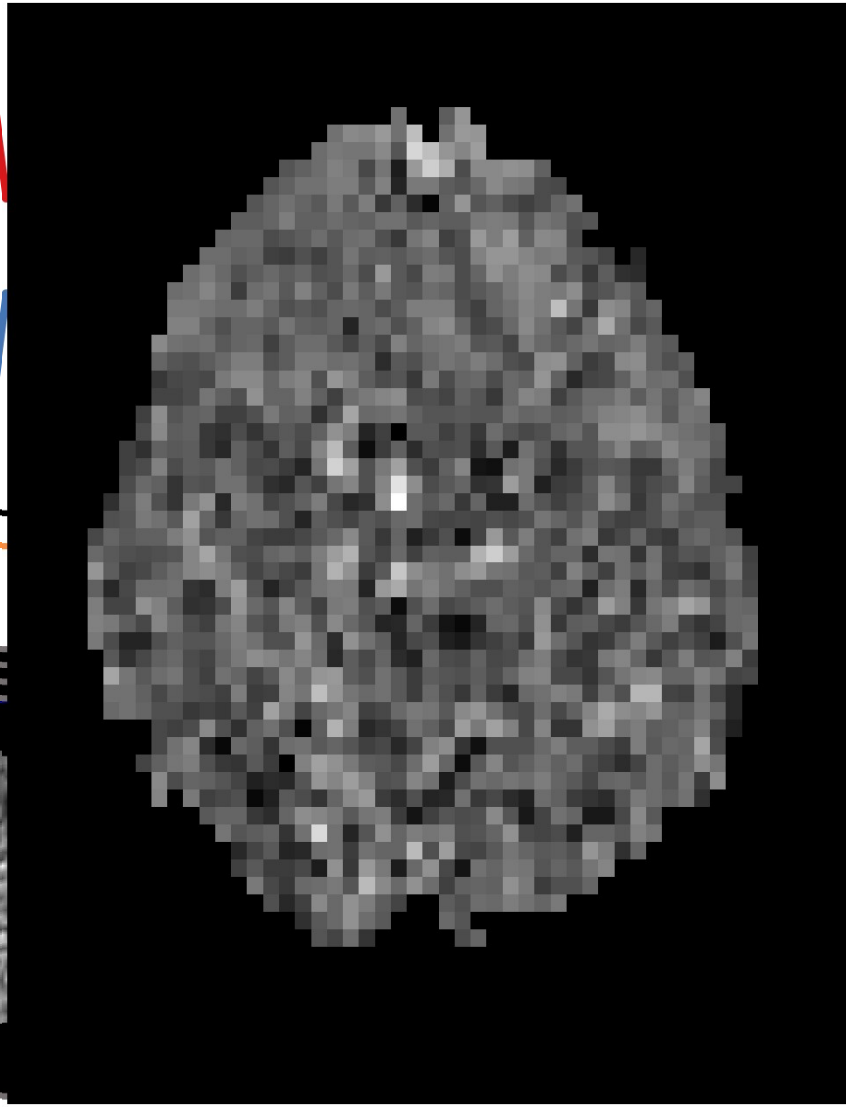
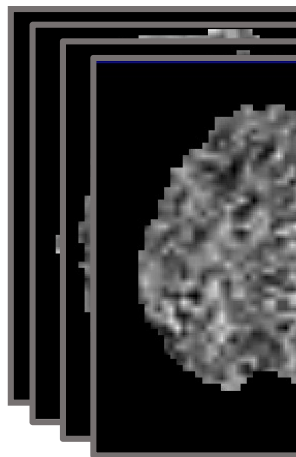


# Data Structure

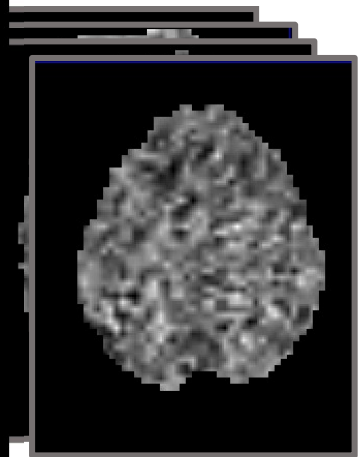
Experiment



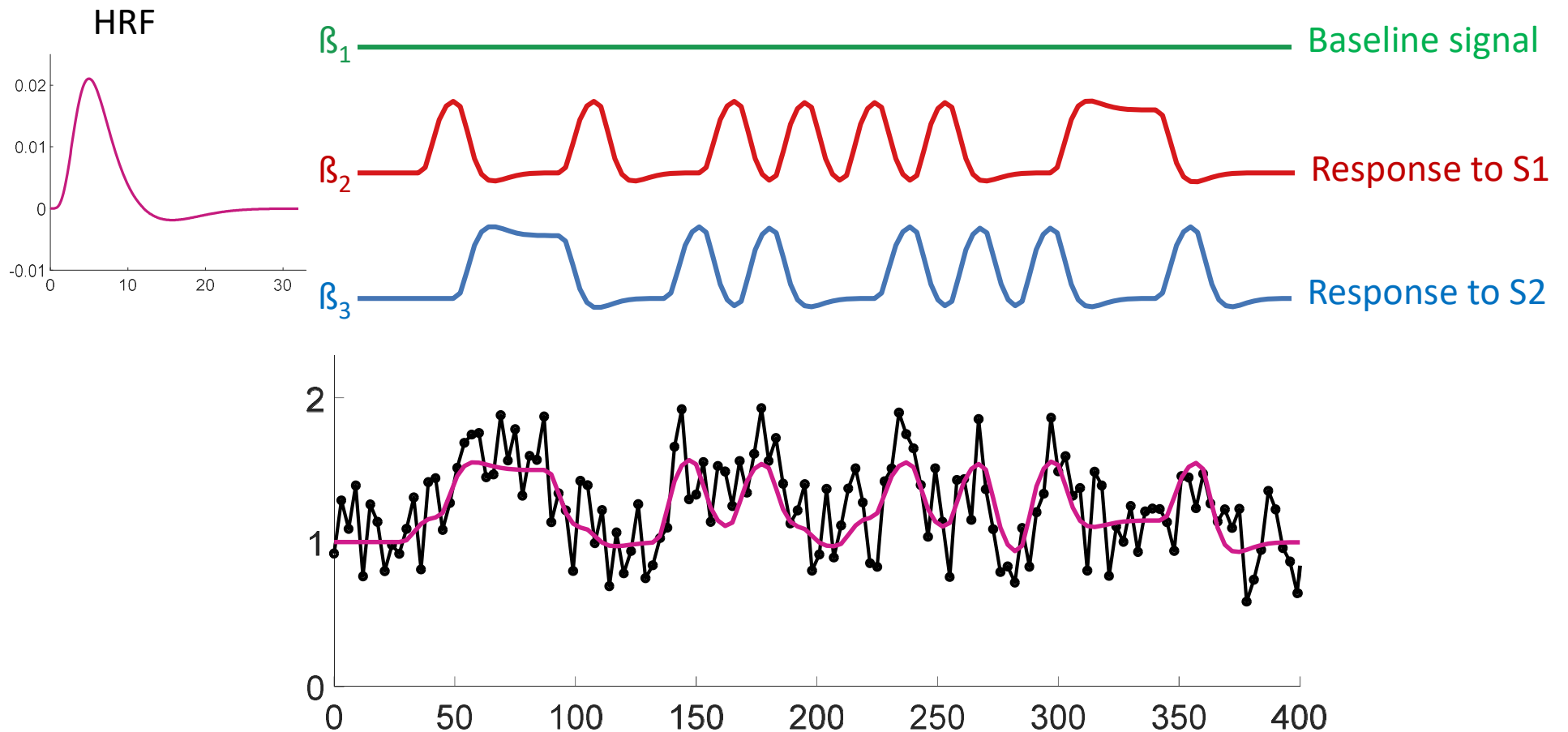
Data



Time

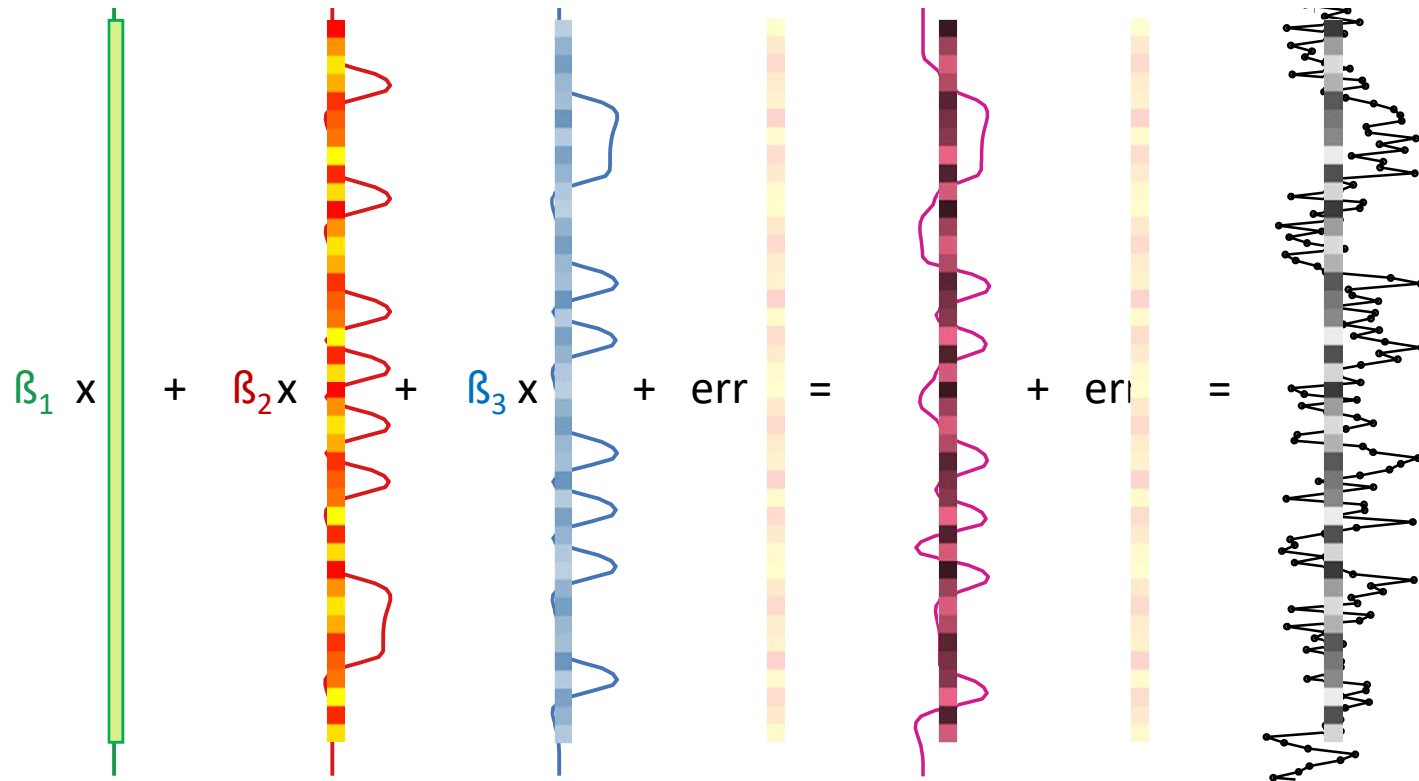


# General Linear Model: Constructing BOLD signals



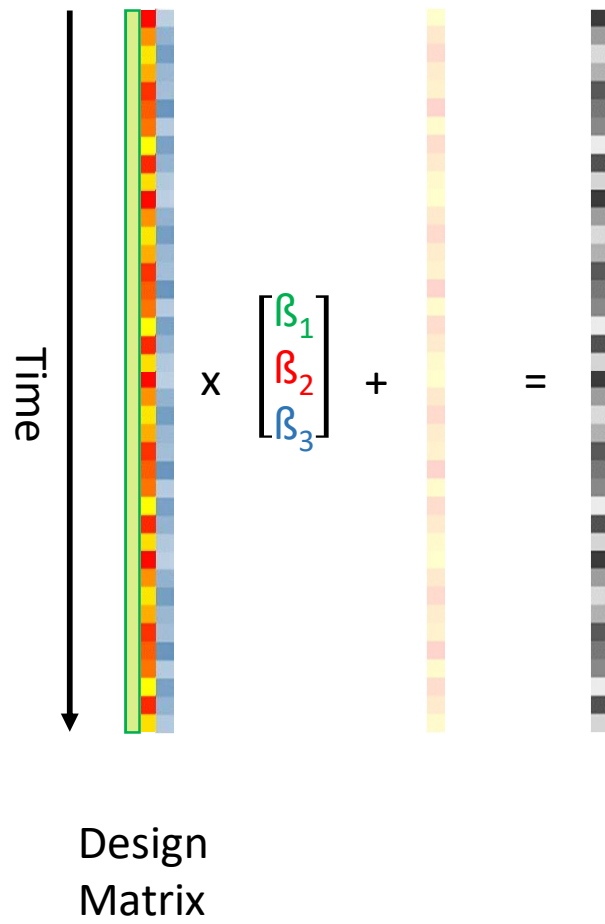
$$\text{error}(t) = \text{signal}(t) - \text{prediction}(t)$$

# General Linear Model: Constructing BOLD signals





# General Linear Model: Constructing BOLD signals



$$\text{Bold signal } Y = X \times B + e$$

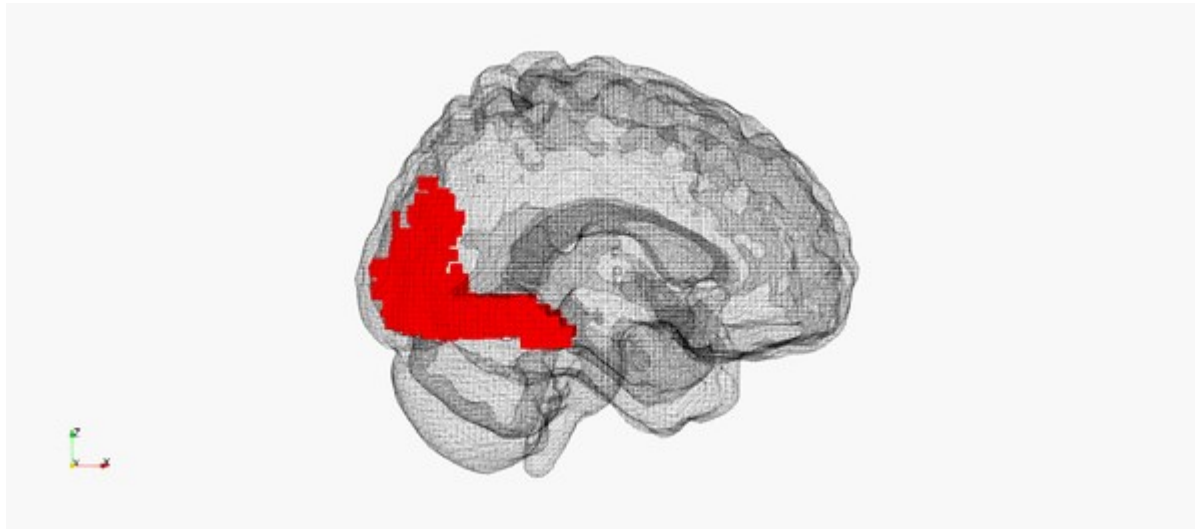
Task related variations      Noise variations

Find B such that  $\text{Min } \sum e_i^2$

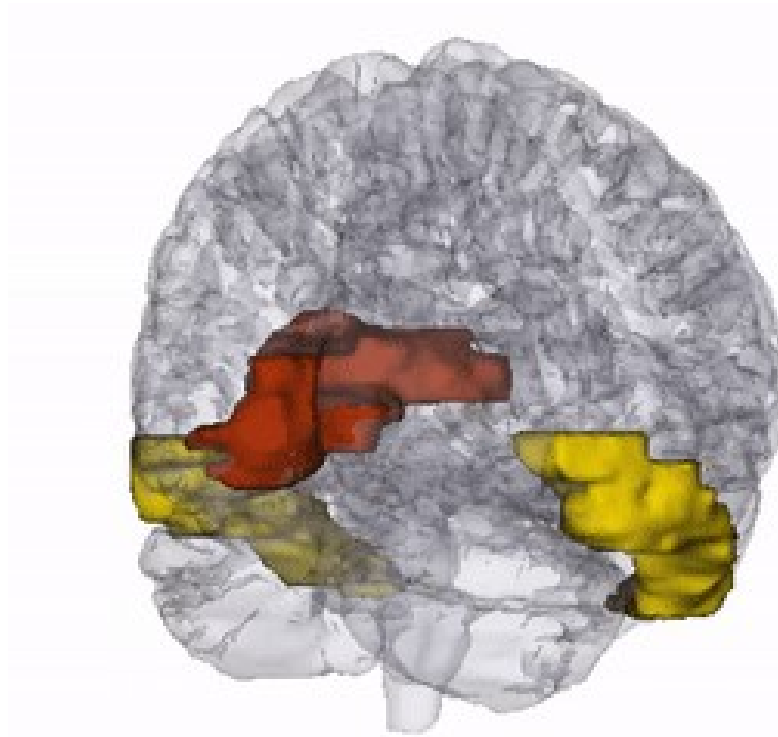
$$B = (X^T X)^{-1} X^T Y$$

# Visual Recognition in the Brain

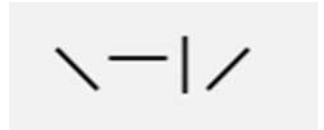
- What brain regions are engaged in visual processing?
- What kind of representations are held in these regions?
- What algorithms are being carried out by these regions?



# Visual Recognition in the Brain



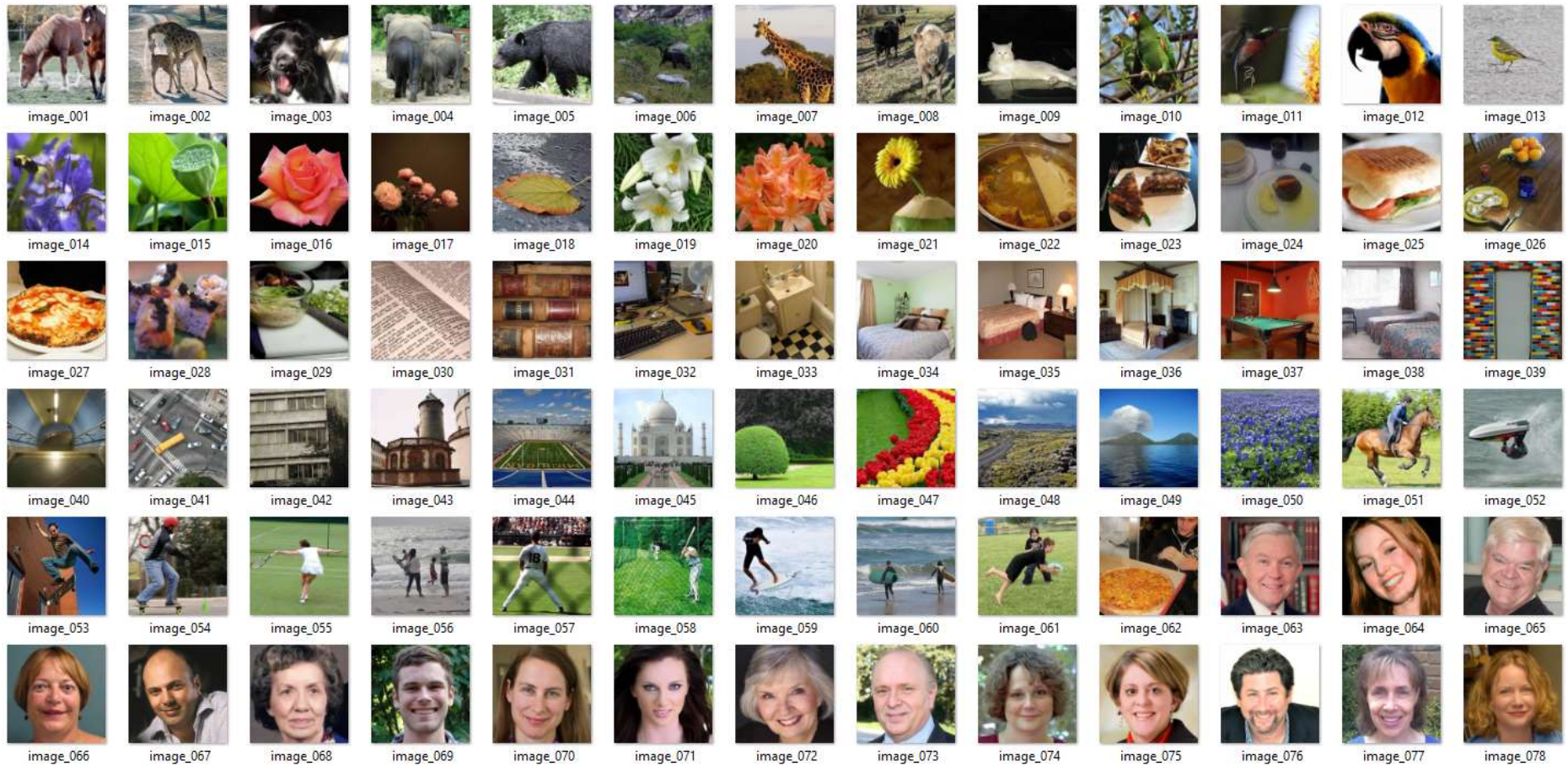
■ EVC



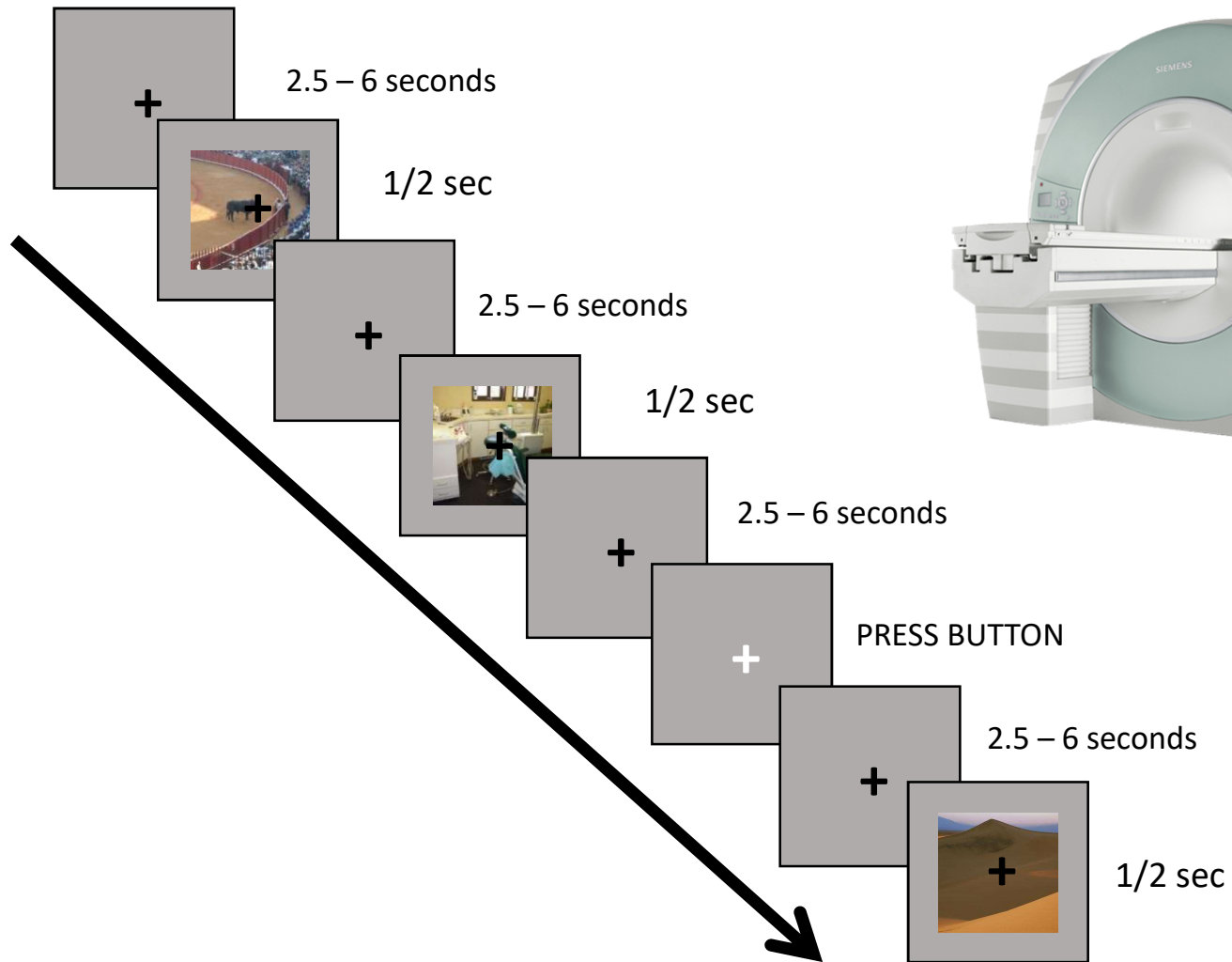
■ IT



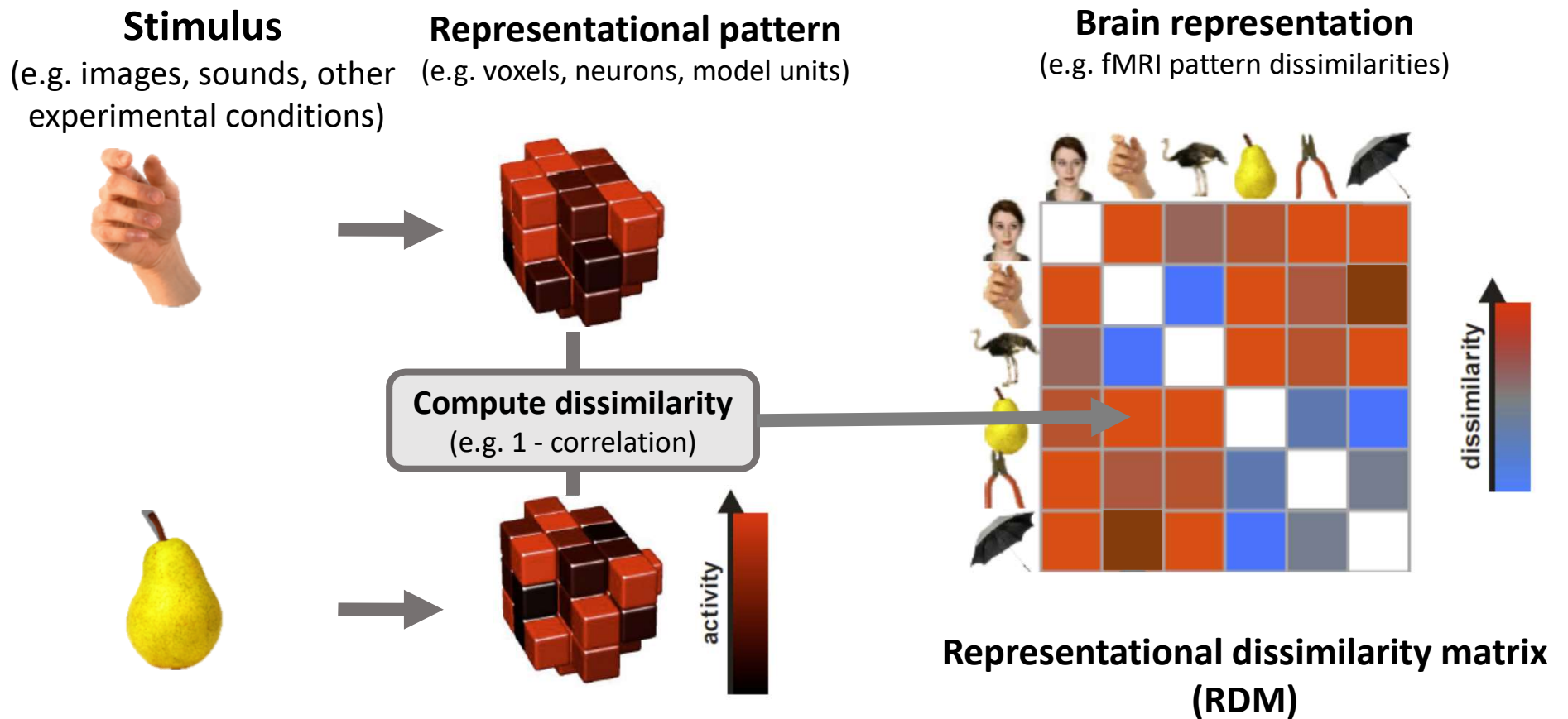
# Stimulus set



N=15

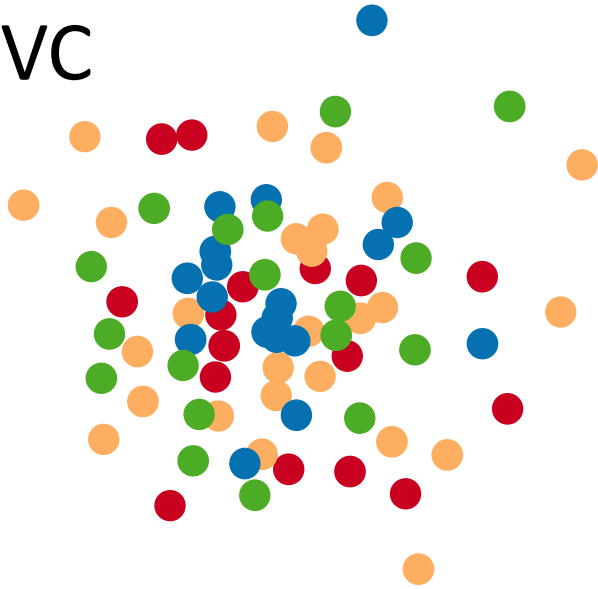


# Representational Similarity Analysis



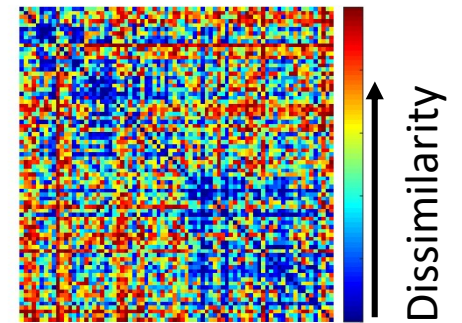
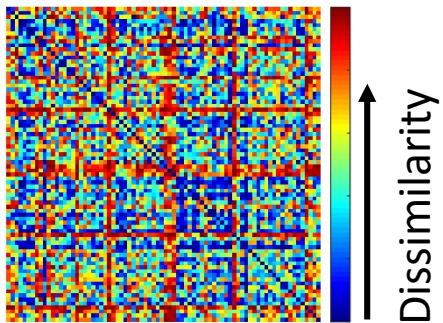
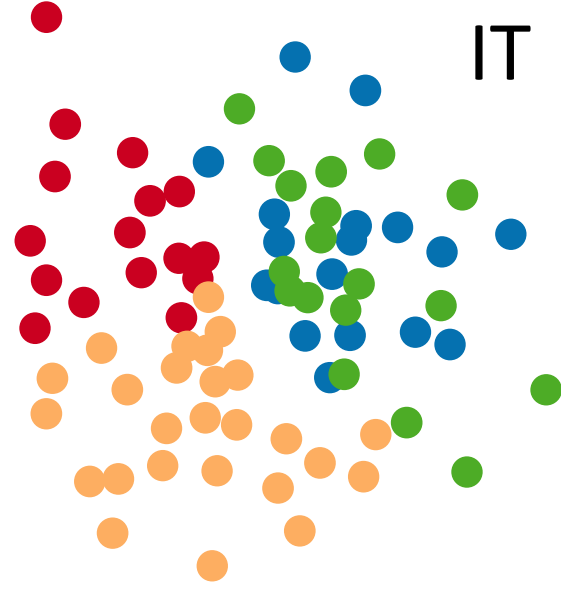
# fMRI Track RDMs

EVC



- face
- Bodies
- object
- scene

IT



What is MEG?



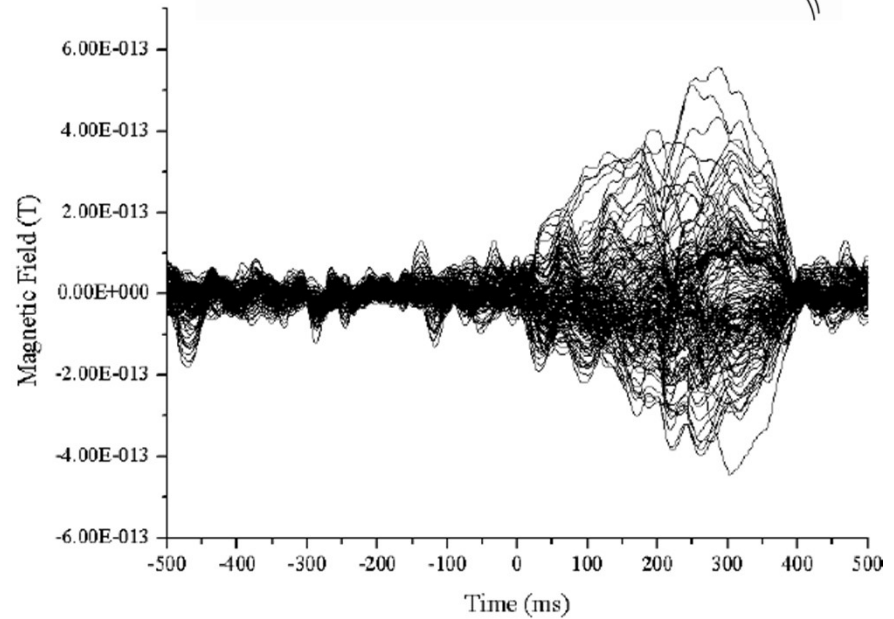
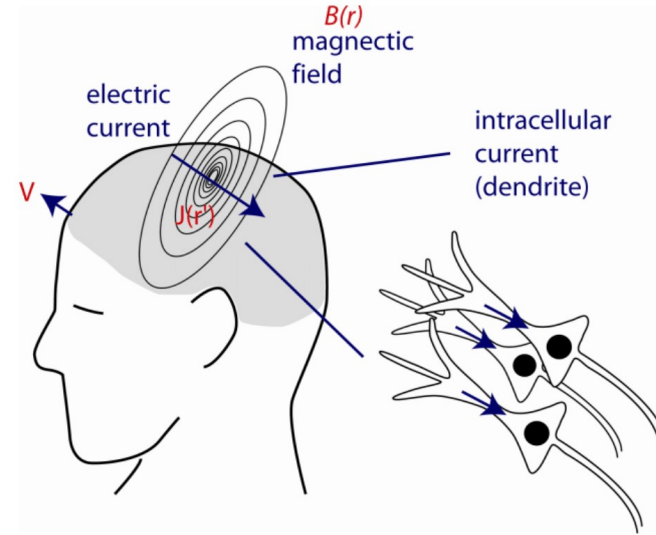
# Magnetoencephalography (MEG) / Electroencephalography (EEG)



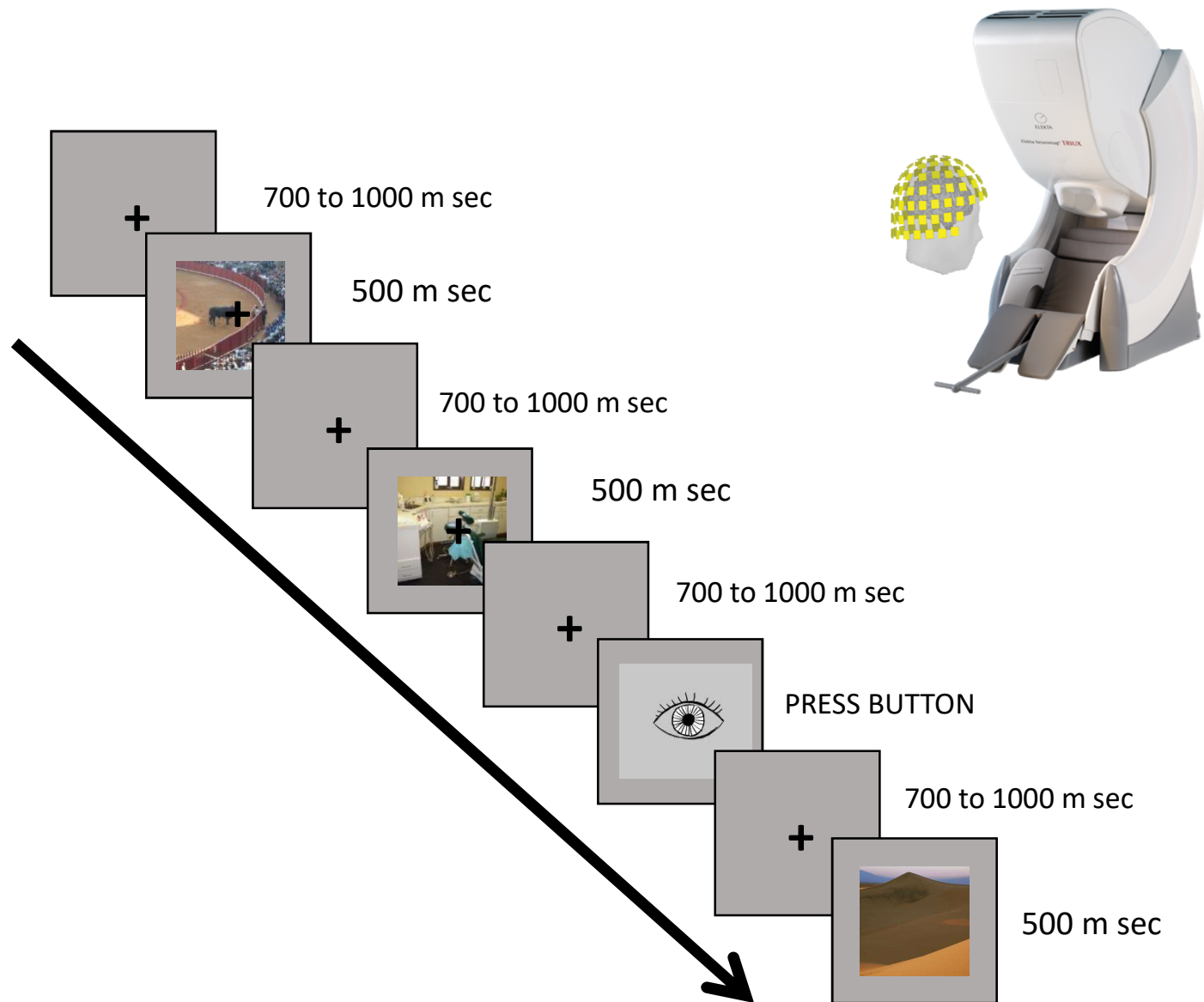
306 Channel  
SQUID sensor array

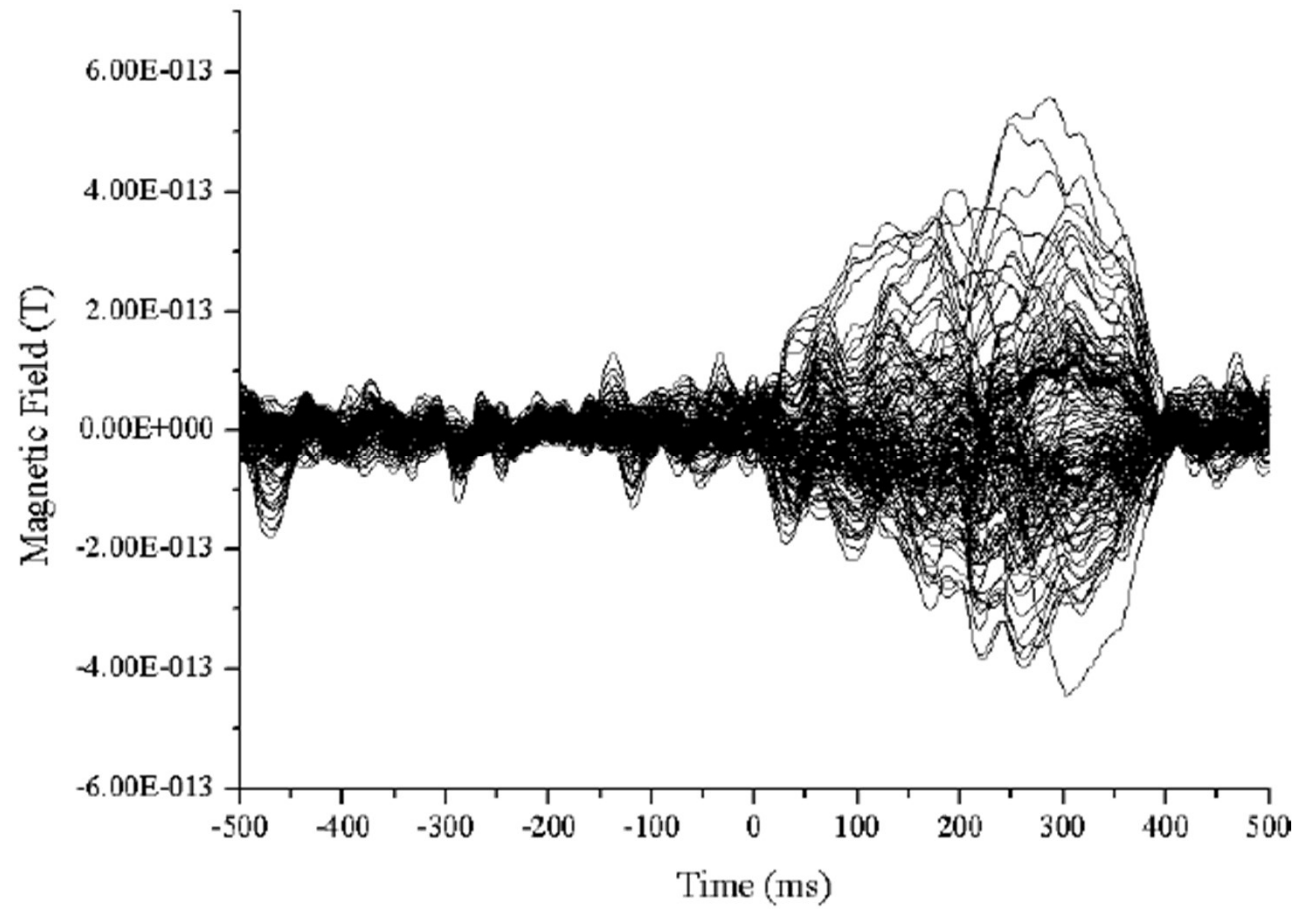


EEG



N=15





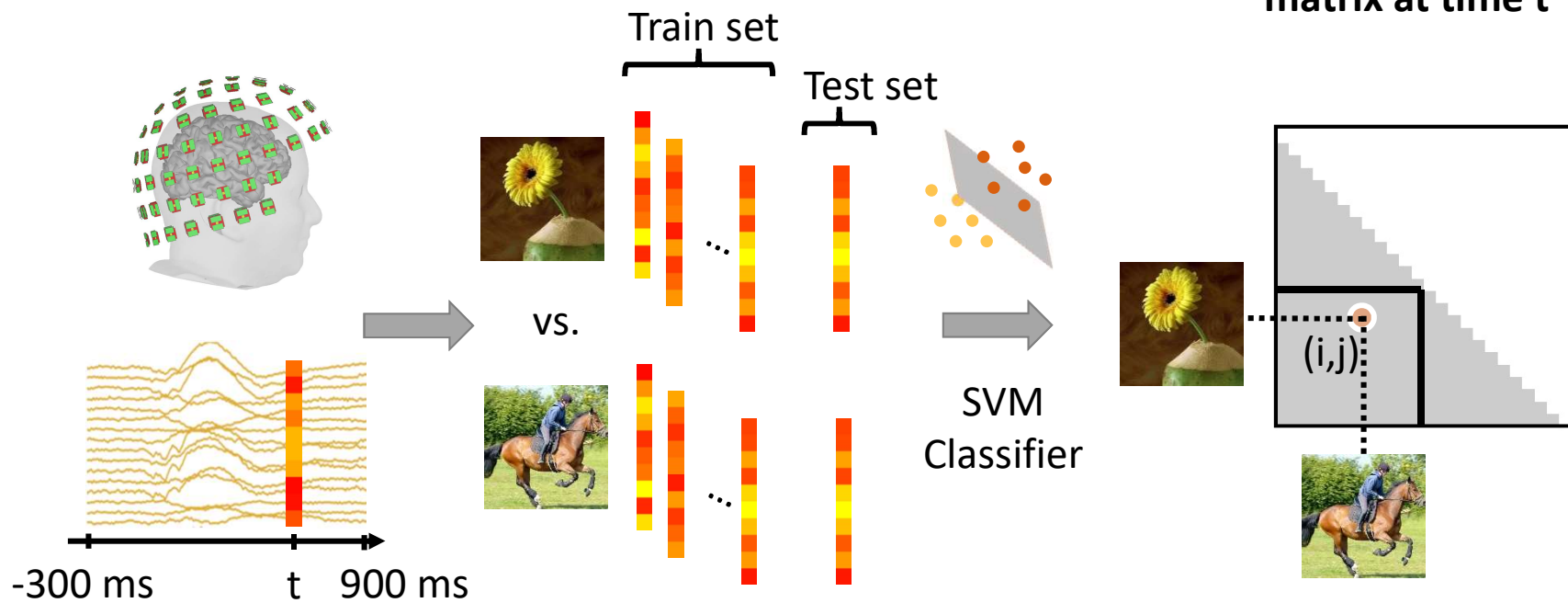
↑  
**Stimulus on**

# MEG Neural Data Decoding

MEG pattern vector at time  $t$

Pairwise classification

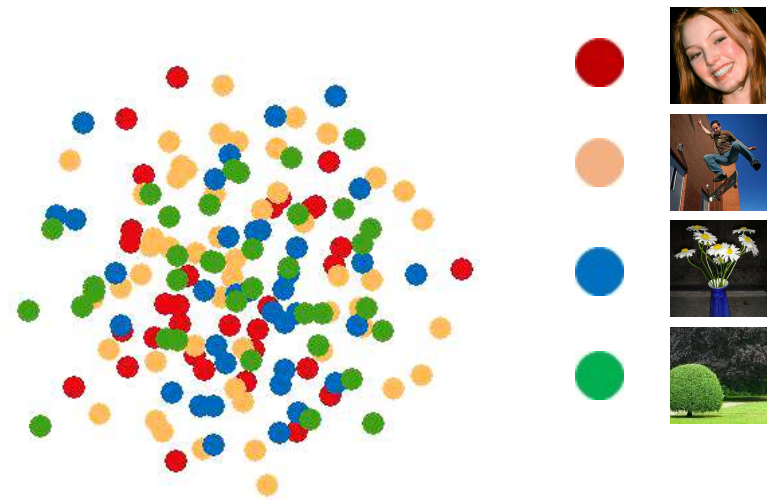
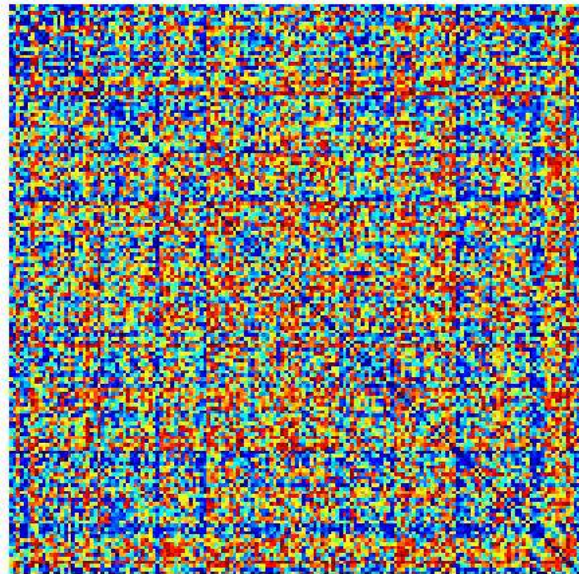
Representational  
dissimilarity  
matrix at time  $t$



(Carlson et al. 2013; Cichy et al. 2014; Isik et al. 2014; Clarke et al. 2014; Kaneshiro et al. 2015)

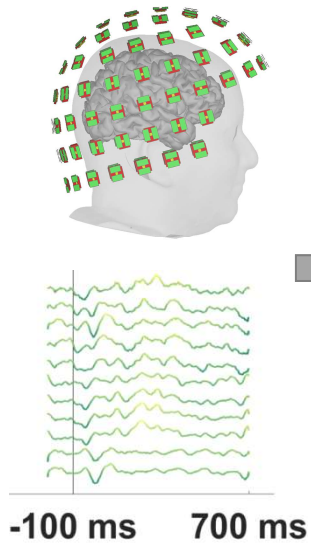
# Time-Resolved MEG RDMs

1ms

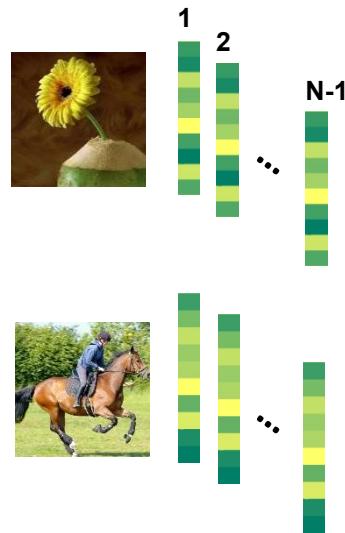


# Temporal Generalization

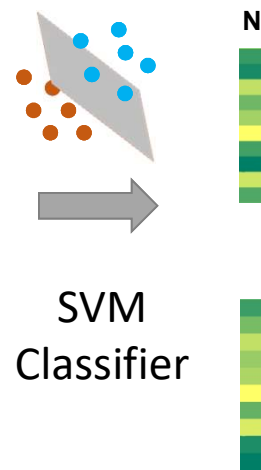
MEG pattern vector  
at time  $t$



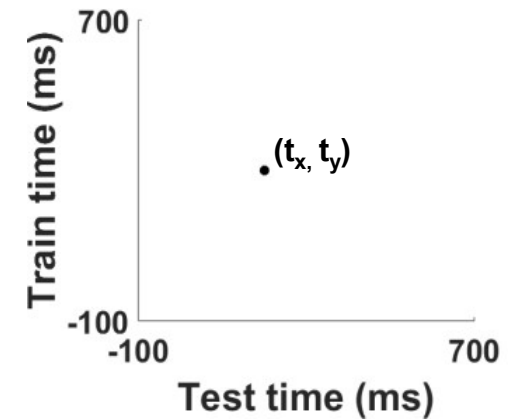
Train a SVM  
classifier using  $N-1$   
raw vectors at  $t_x$



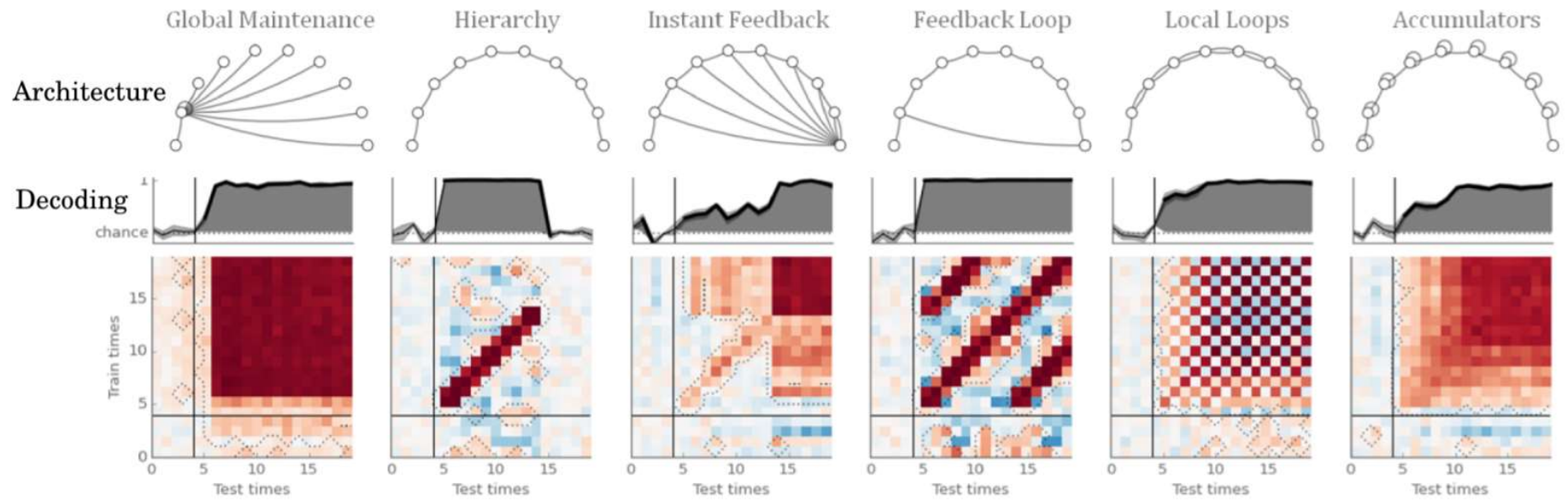
$N^{\text{th}}$  raw pattern  
vector at time  $t_y$



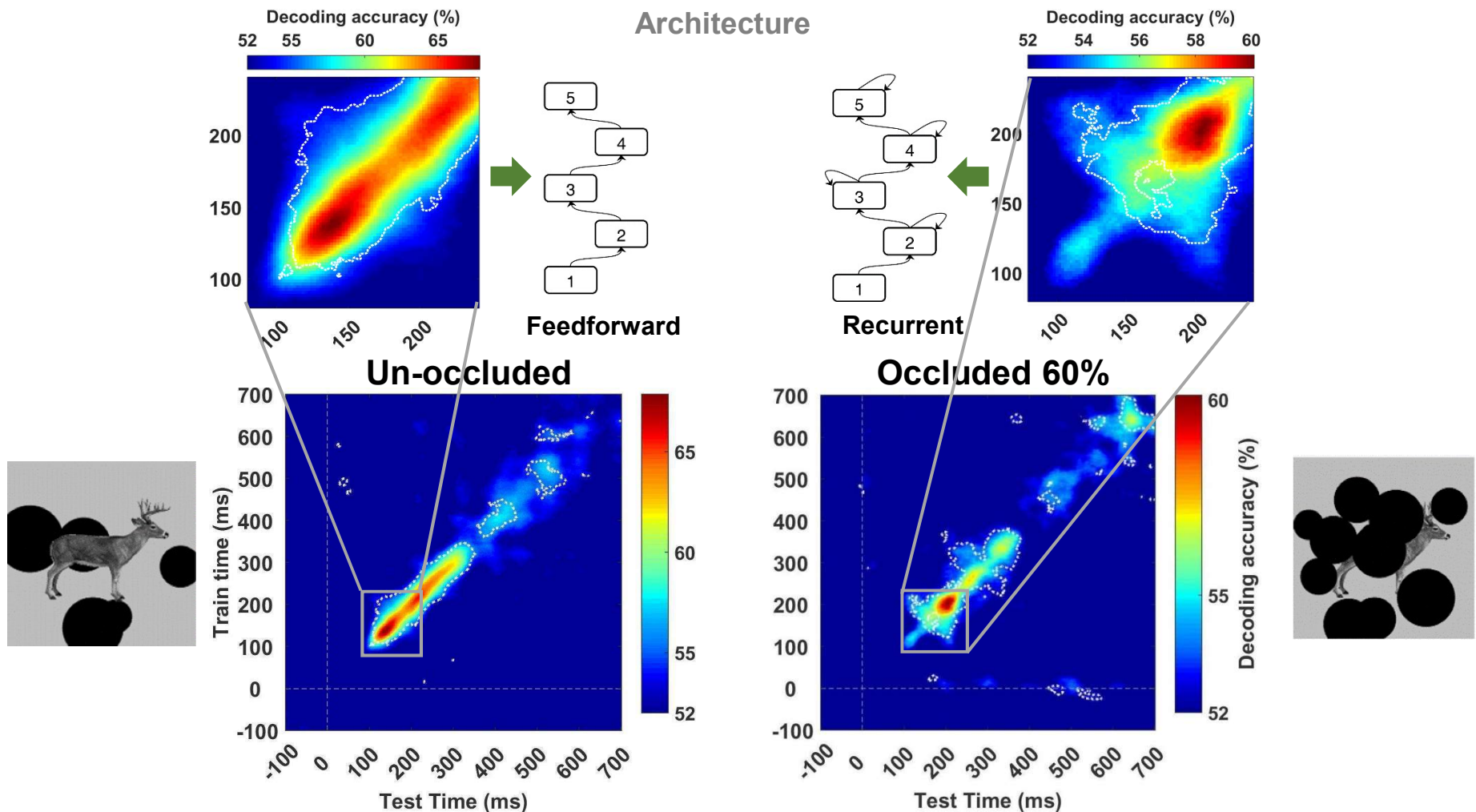
Time-Time  
decoding matrix



# Possible Neural Architectures



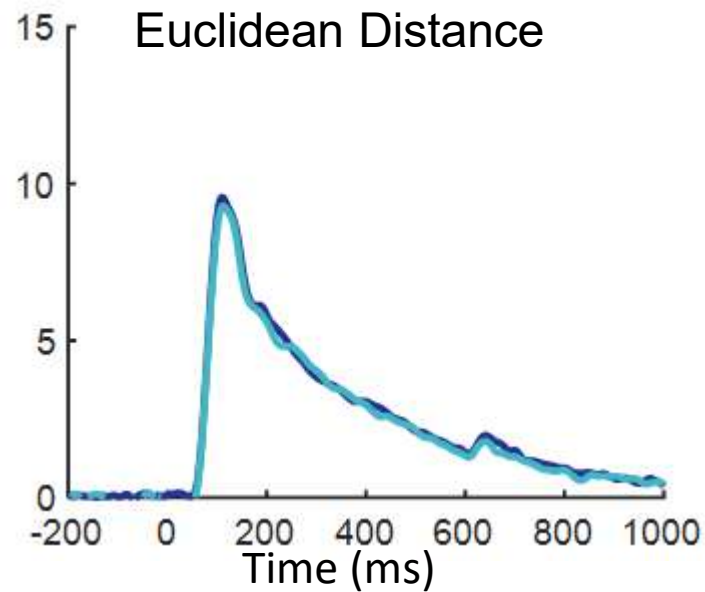
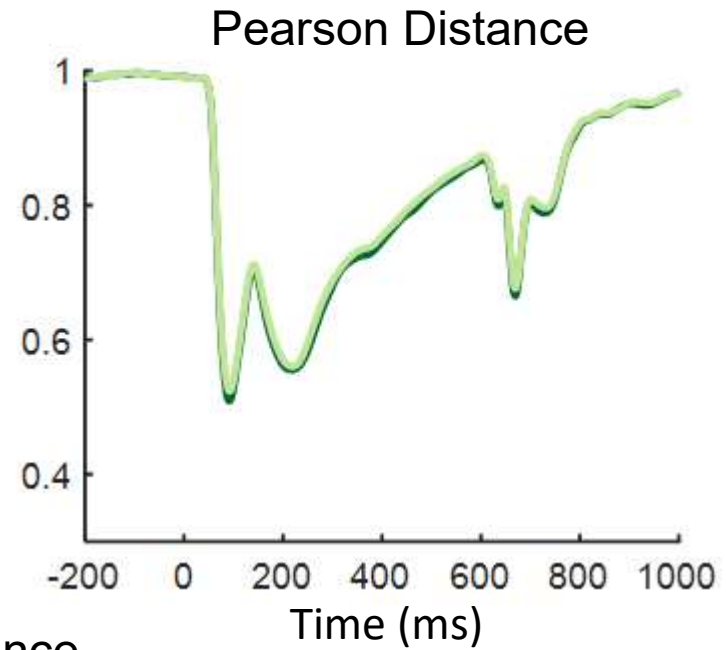
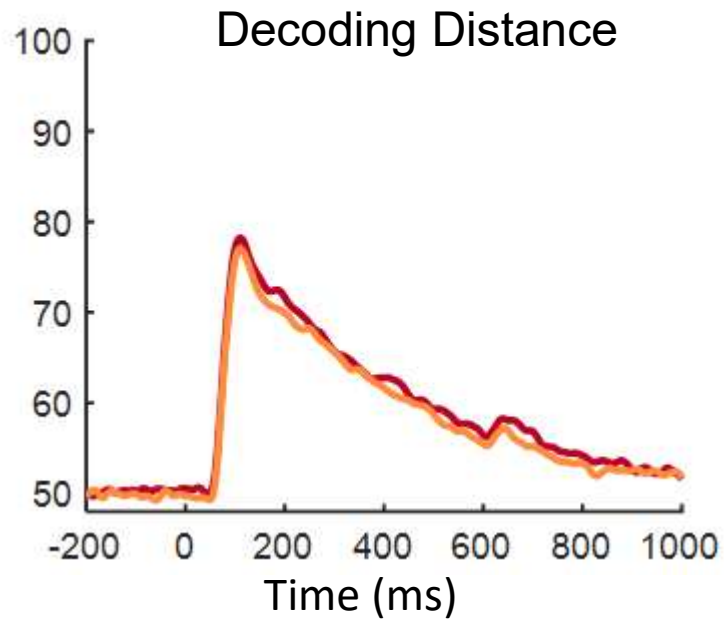
# A Neural Architecture with Recurrent Interactions



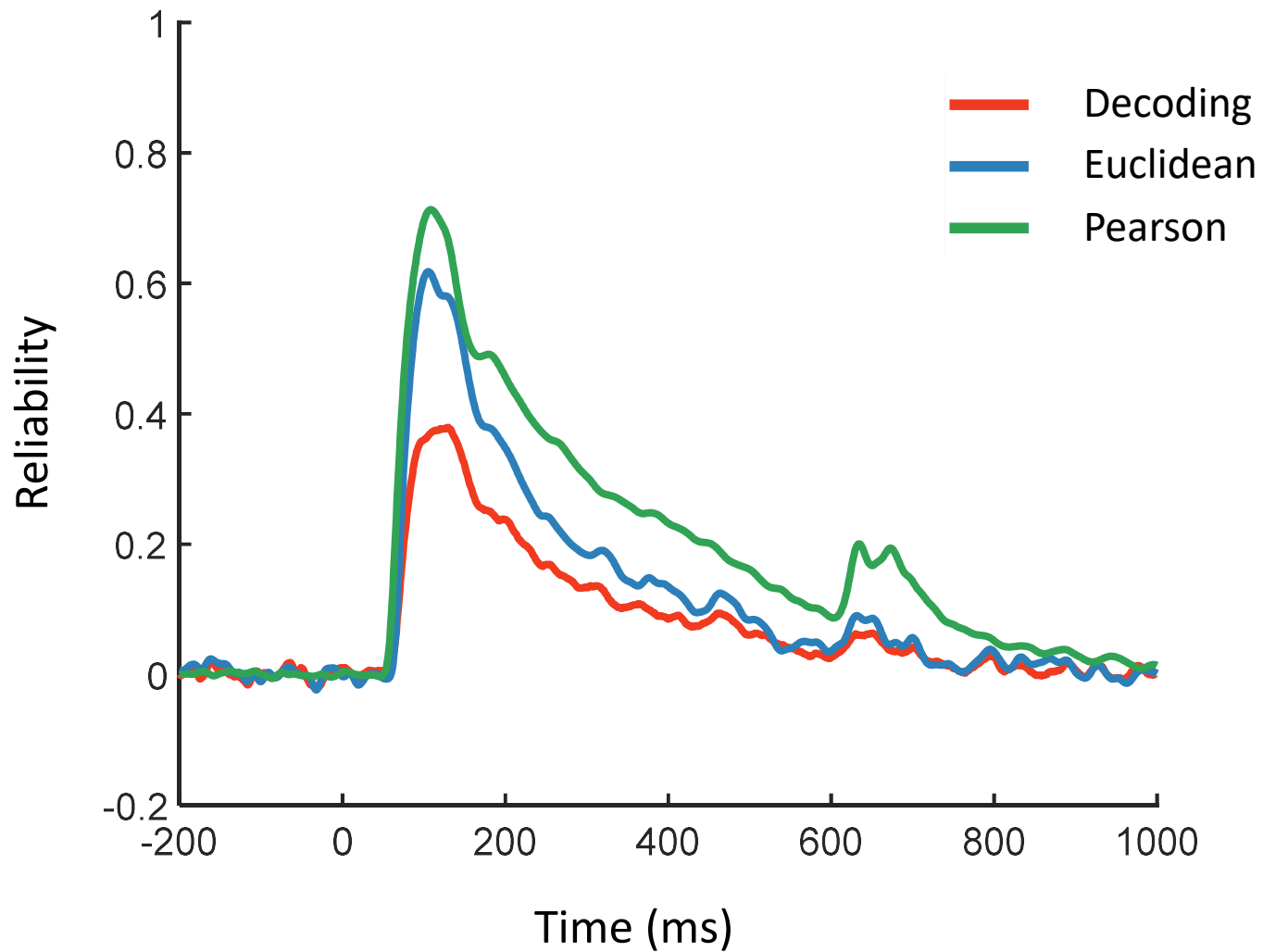
(Rajaei, Mohsenzadeh, Ebrahimpour, Khaligh-Razavi, 2019)



# Distance Measures

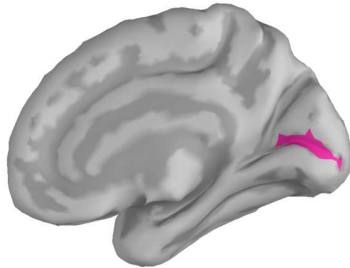


# Reliability of Distance Measures

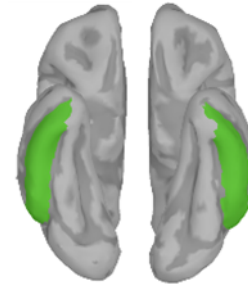


# MEG/ ROI fMRI fusion

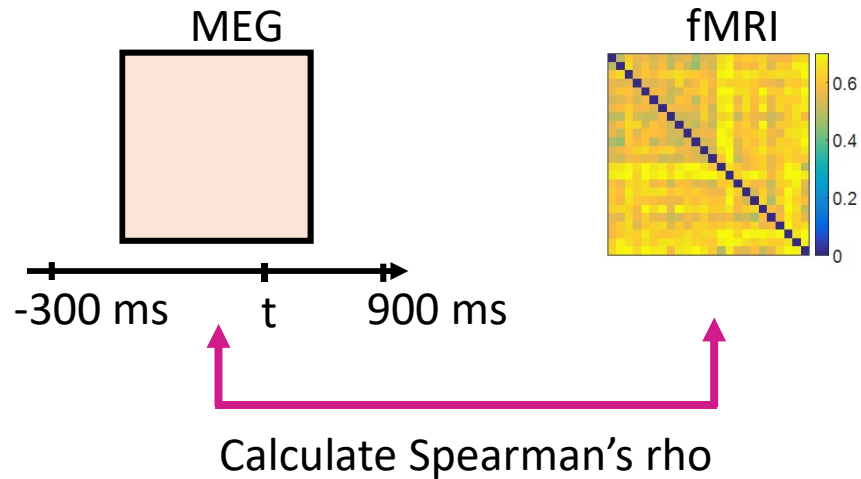
Early Visual Cortex (EVC)



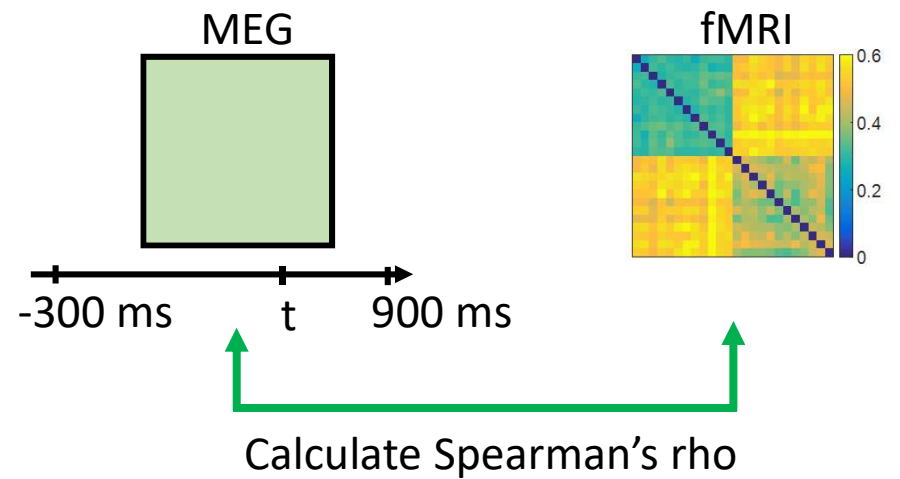
Inferior Temporal (IT)



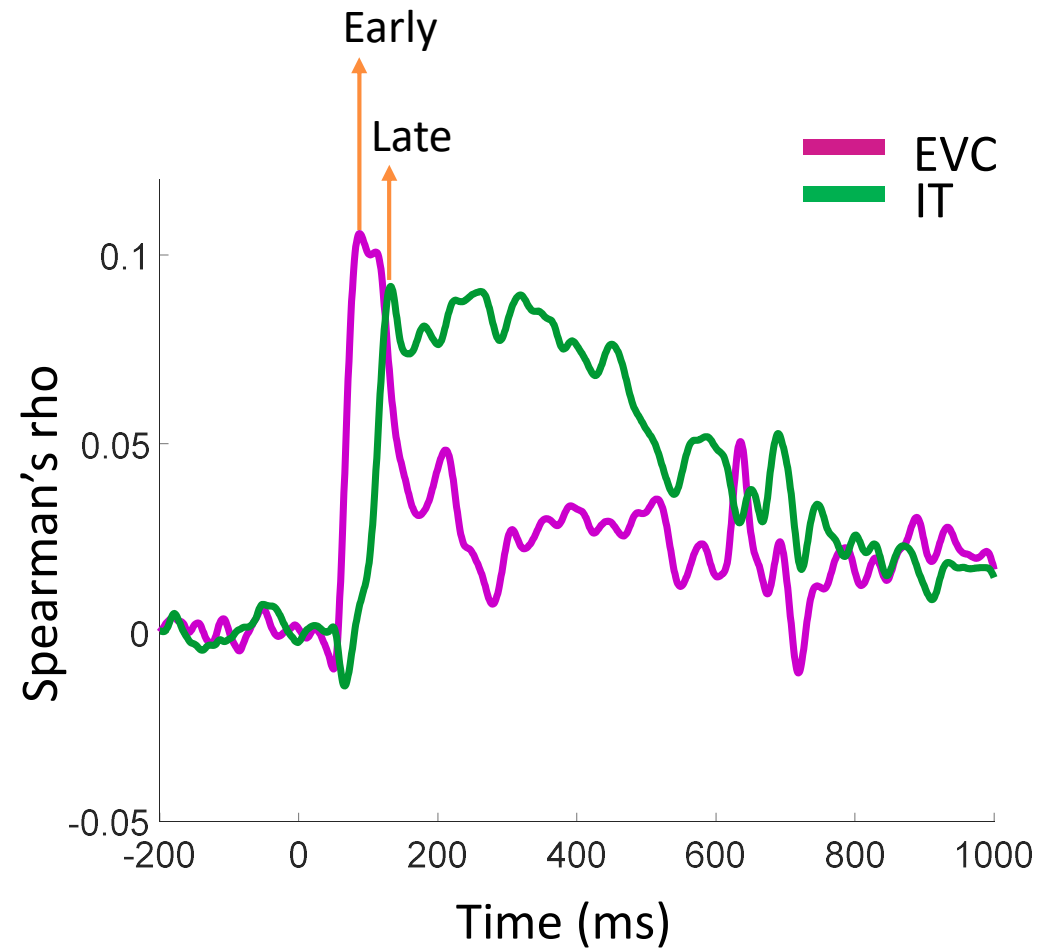
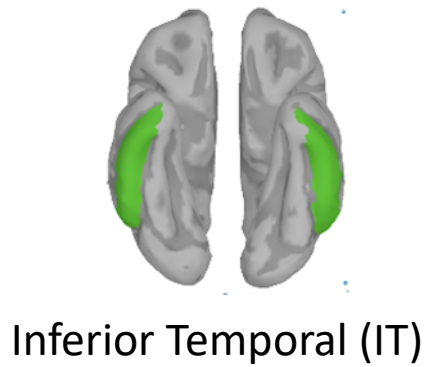
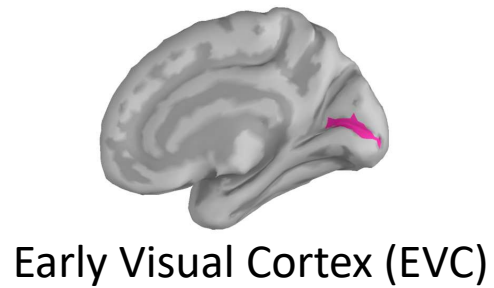
MEG-fMRI representational similarity in EVC



MEG-fMRI representational similarity in IT

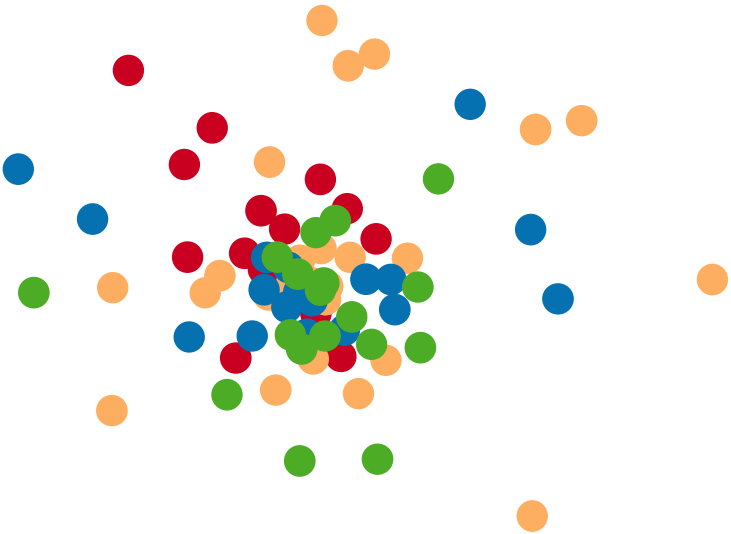


# ROI-based fMRI-MEG fusion

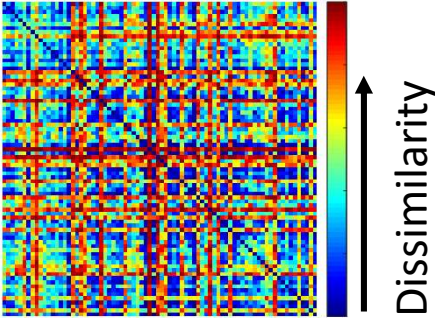
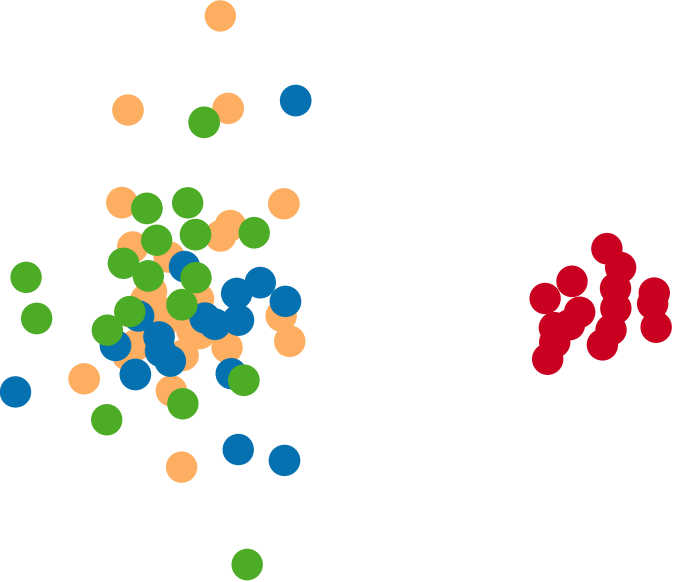


# MEG Track RDMs

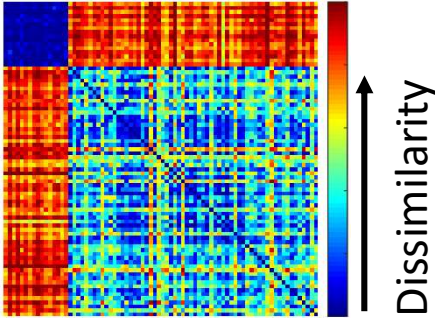
Early



Late



- face
- Bodies
- object
- scene



# Summary

# Brain Imaging Methods



MRI

# Brain Imaging Methods

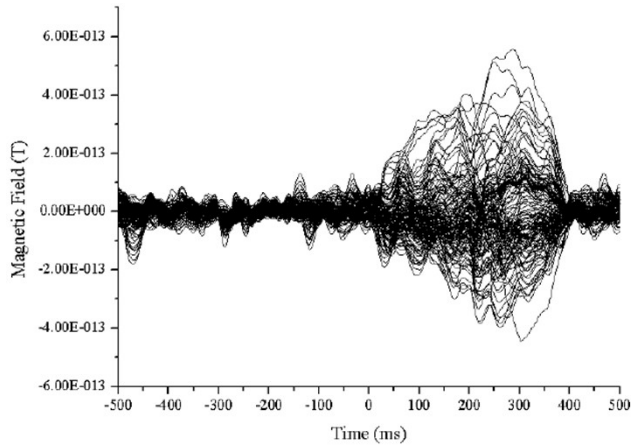
fMRI



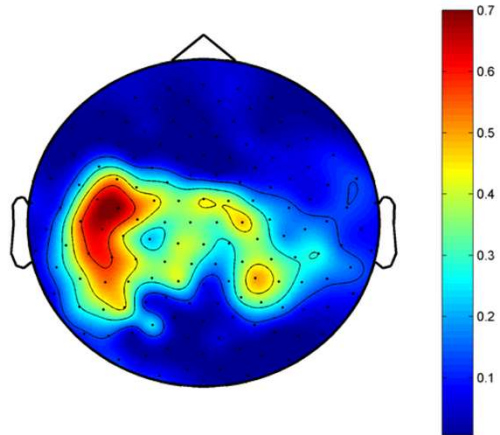
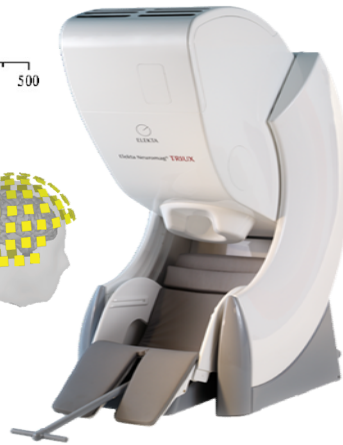
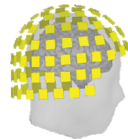
MRI



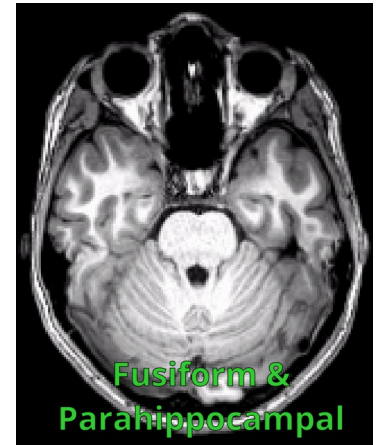
# Brain Imaging Methods



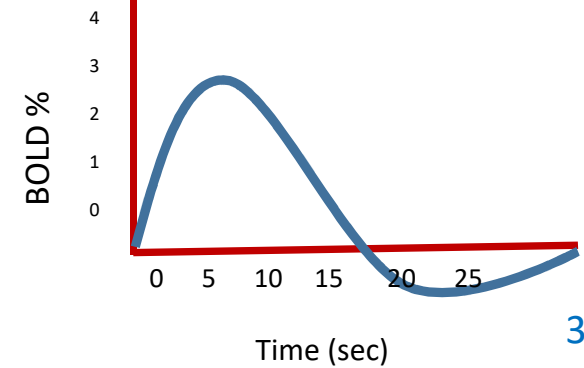
EEG  
MEG



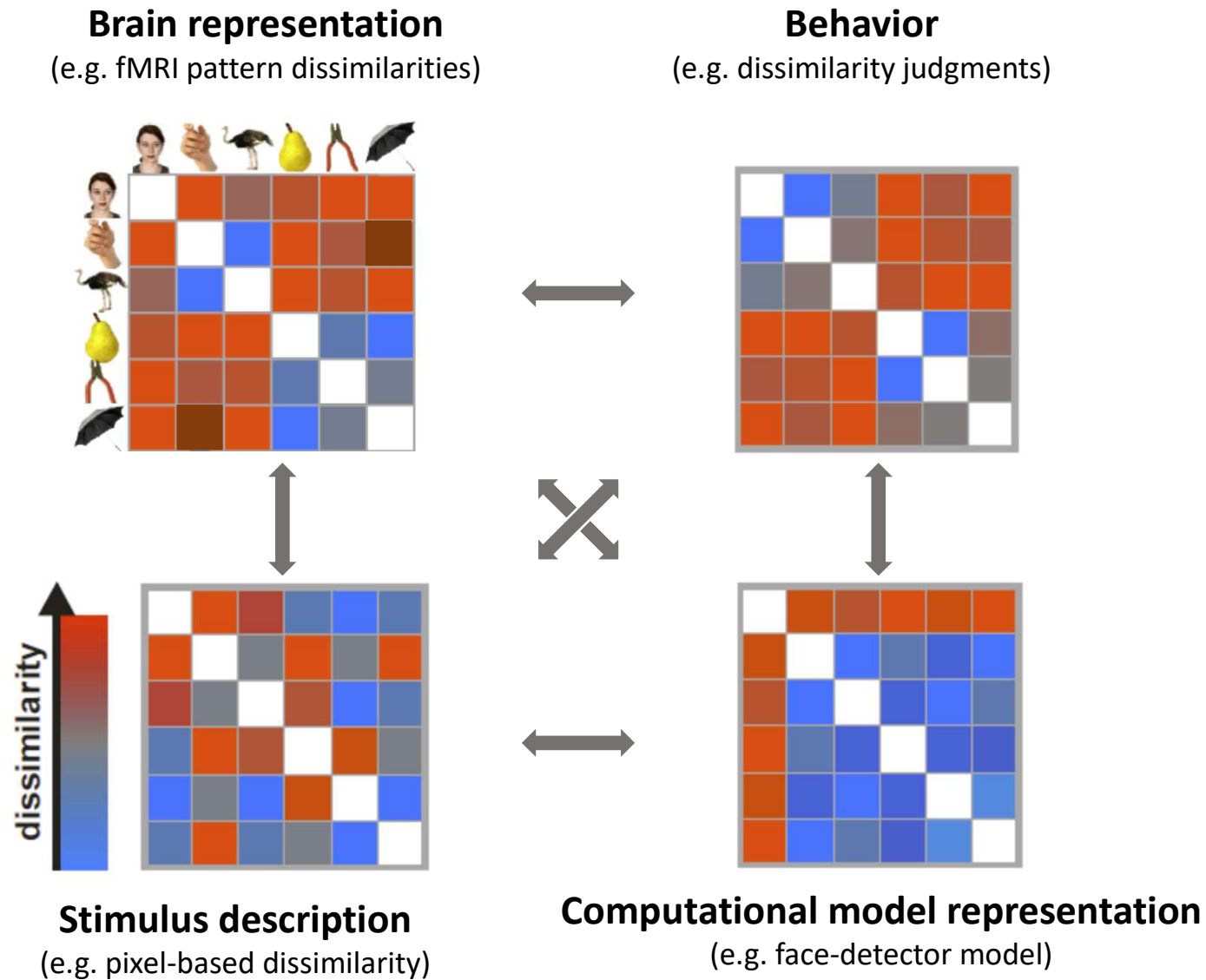
fMRI



MRI



# Representational Similarity Analysis



# Acknowledgments



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Principal Research Scientist, MIT



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MIT-IBM Watson AI Lab



Mohsenzadeh Lab

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