

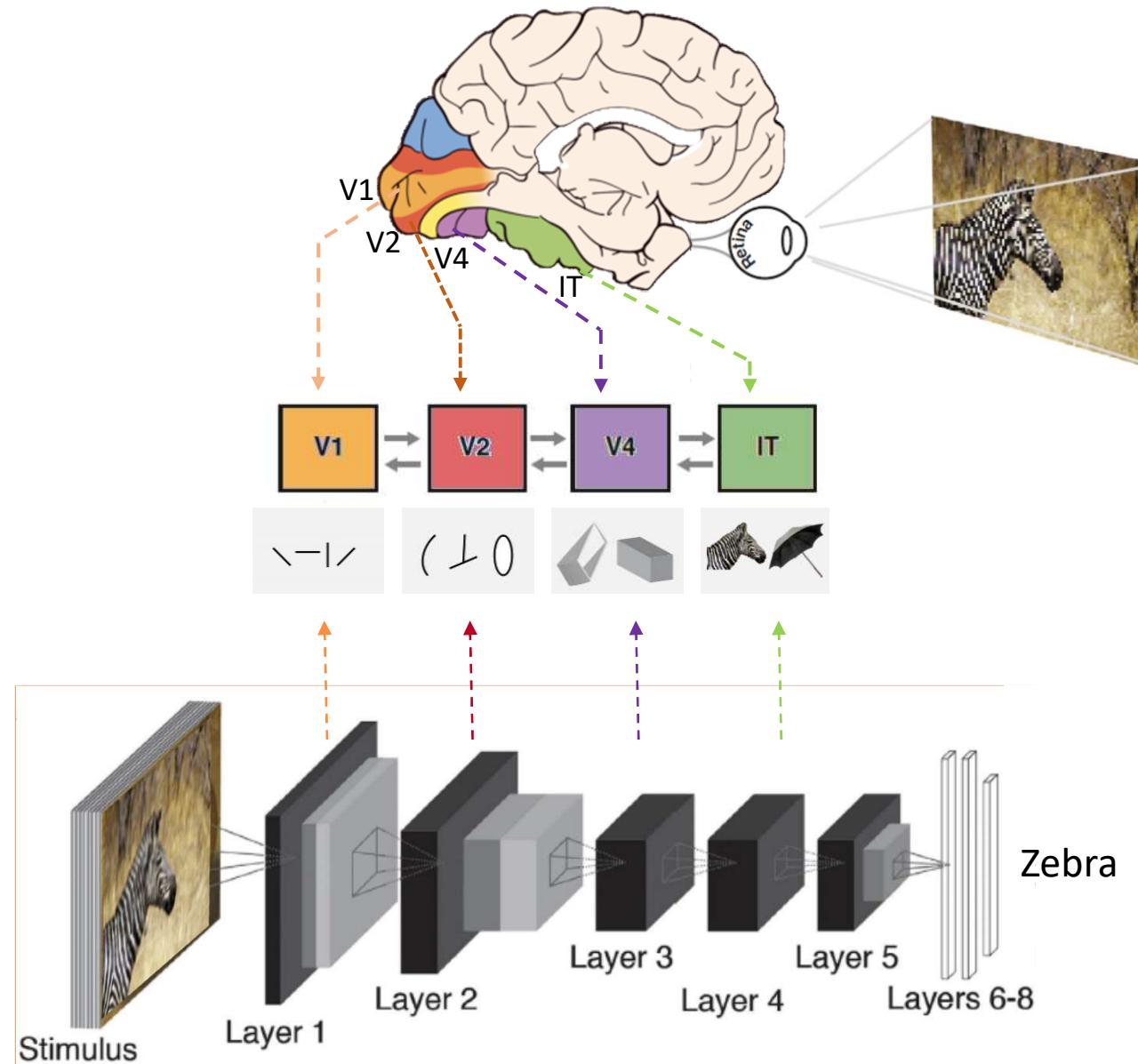


# Introduction to Brain Imaging: fMRI and MEG/EEG

## The Algonauts Workshop

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Computer Science and Artificial Intelligence Lab.  
MIT, Cambridge, USA  
July 2019

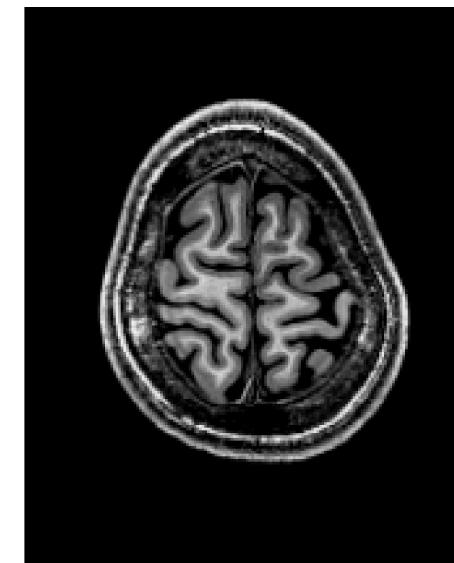
# Convnets: Brain Inspired Architectures



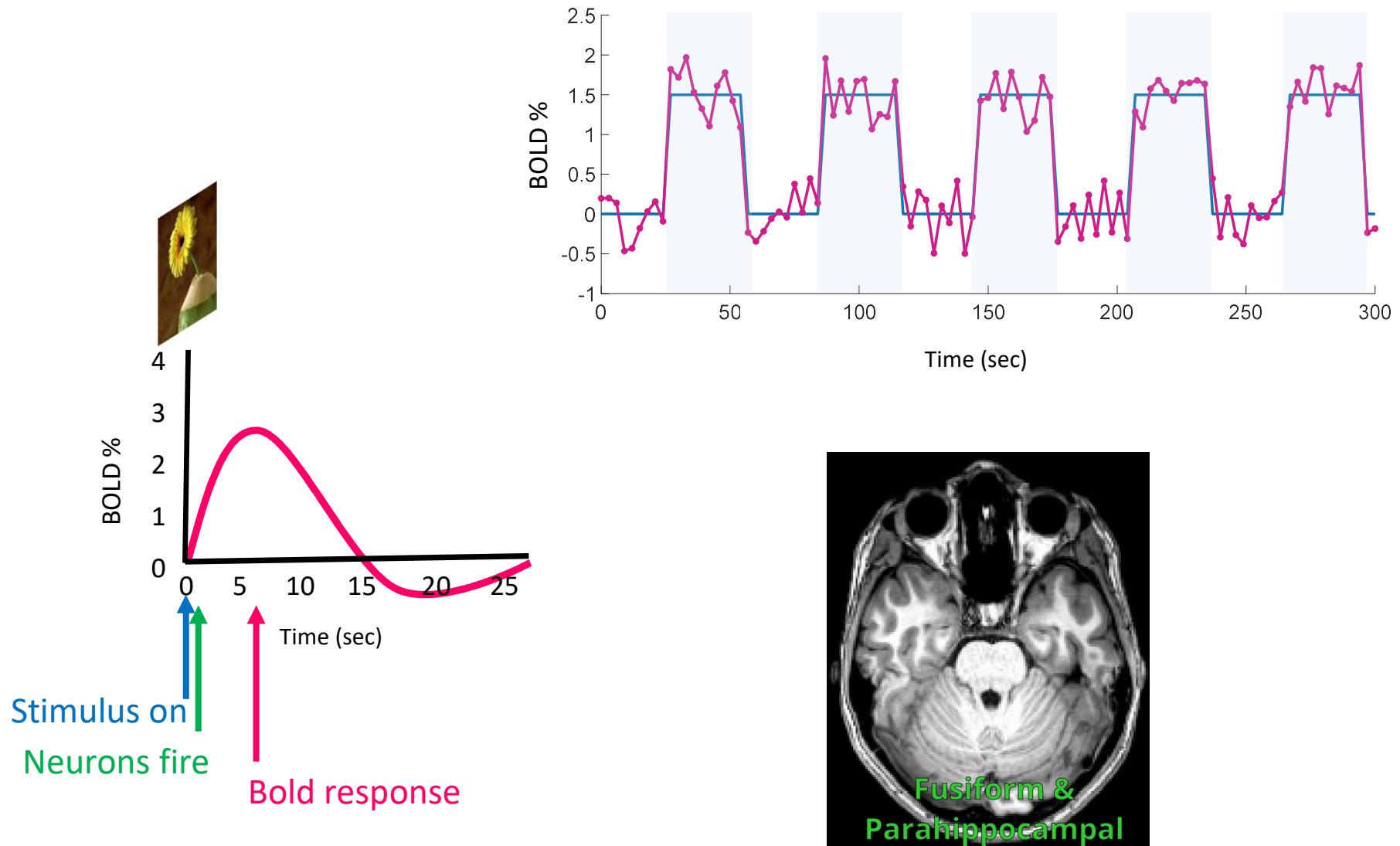
(Khaligh-Razavi et al. 2014, Yamins et al. 2014, Guclu et al. 2015, Cichy et al. 2016 )

# What is fMRI?

# Magnetic Resonance Imaging (MRI)

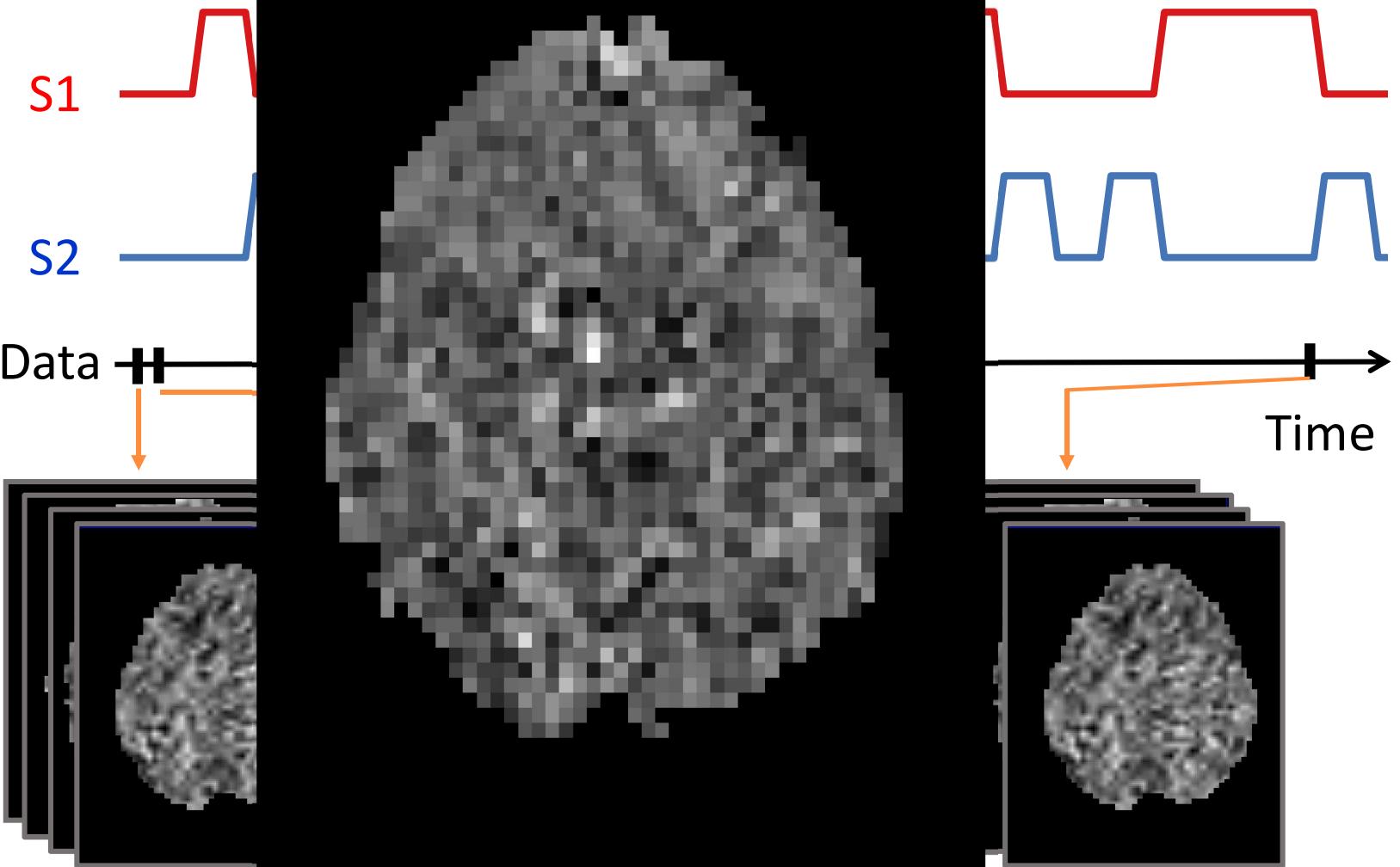


# Functional Magnetic Resonance Imaging (fMRI)

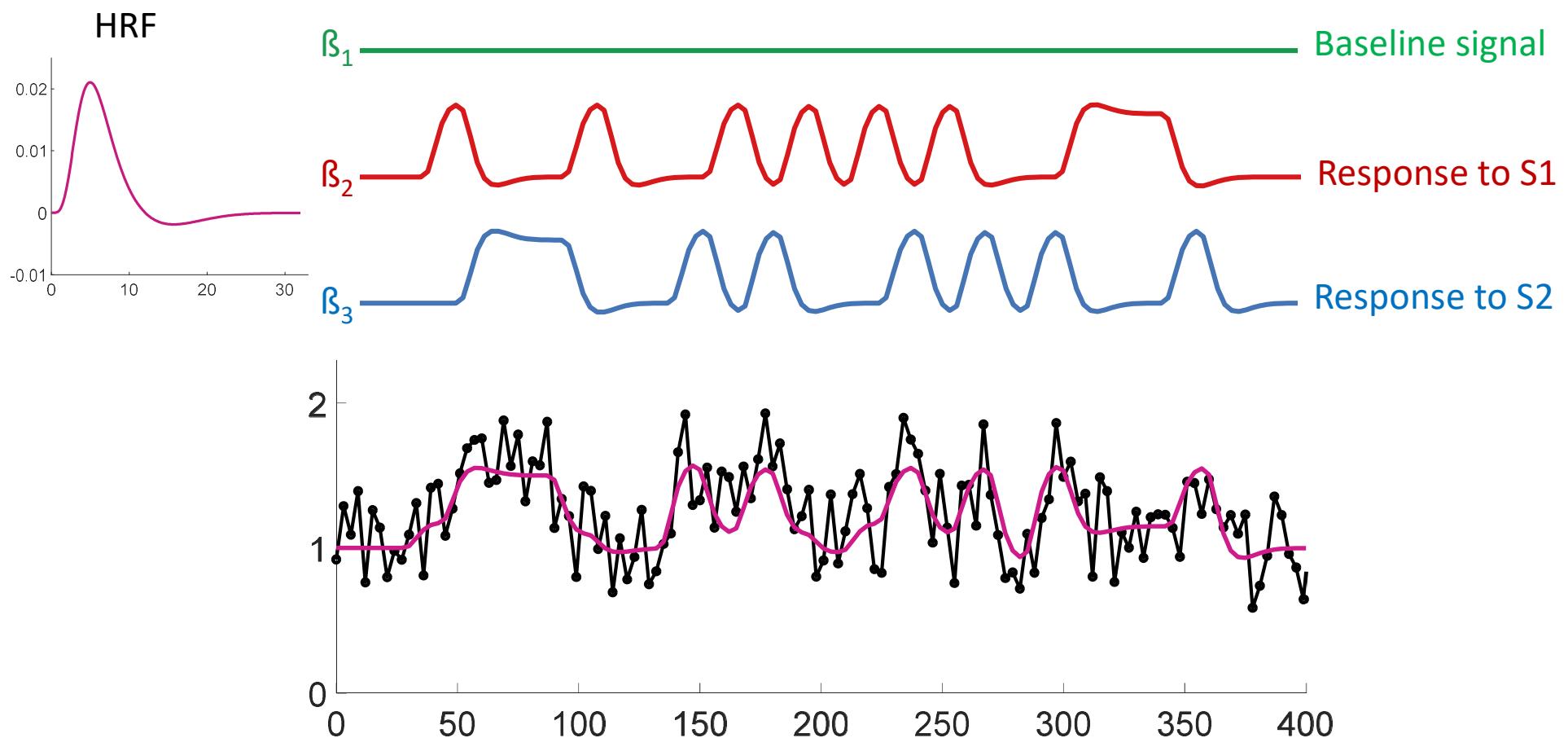


# Data Structure

Experiment

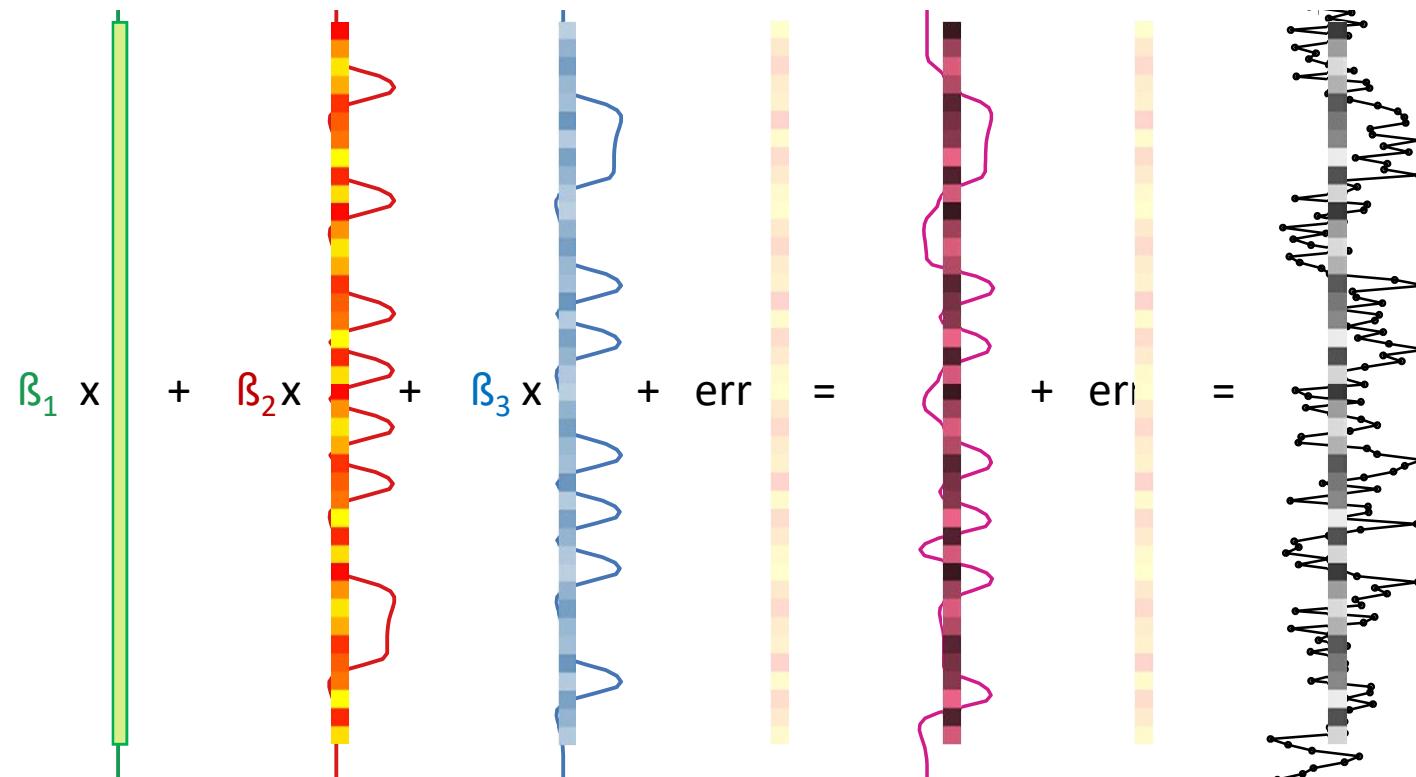


# General Linear Model: Constructing BOLD signals

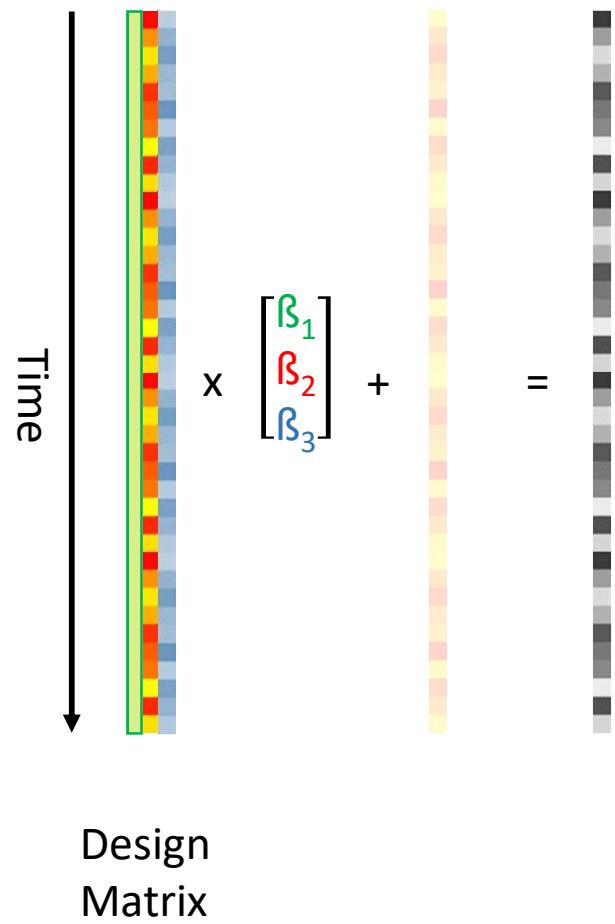


$$\text{error}(t) = \text{signal}(t) - \text{prediction}(t)$$

# General Linear Model: Constructing BOLD signals



# General Linear Model: Constructing BOLD signals



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

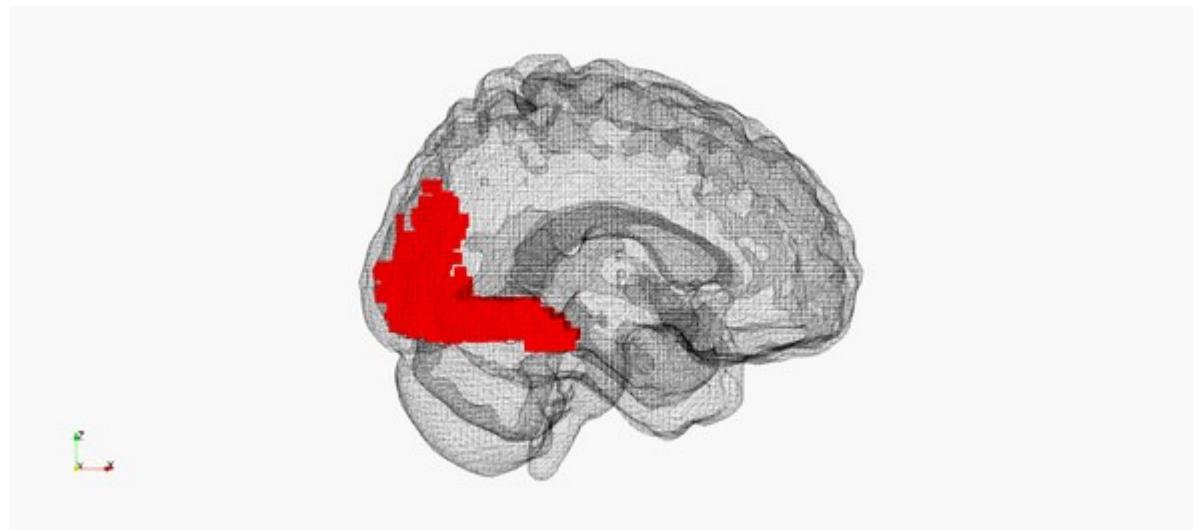
Task related variations      Noise variations

Find B such that Min  $\sum e_i^2$

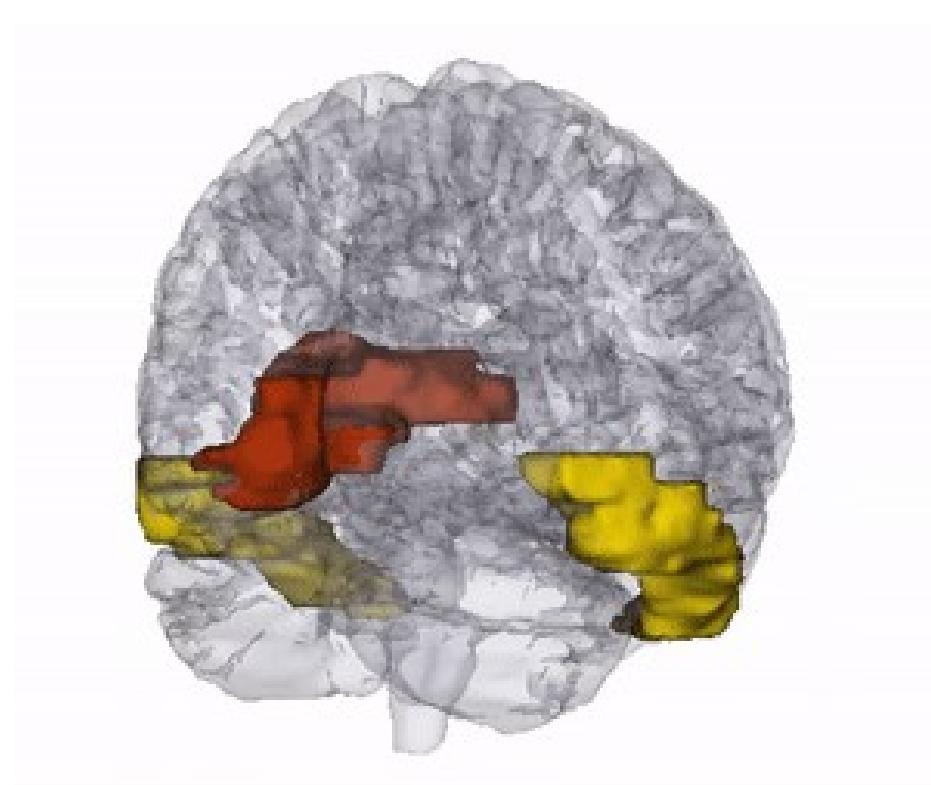
$$B = (X^T X)^{-1} X^T Y$$

# Visual Recognition in the Brain

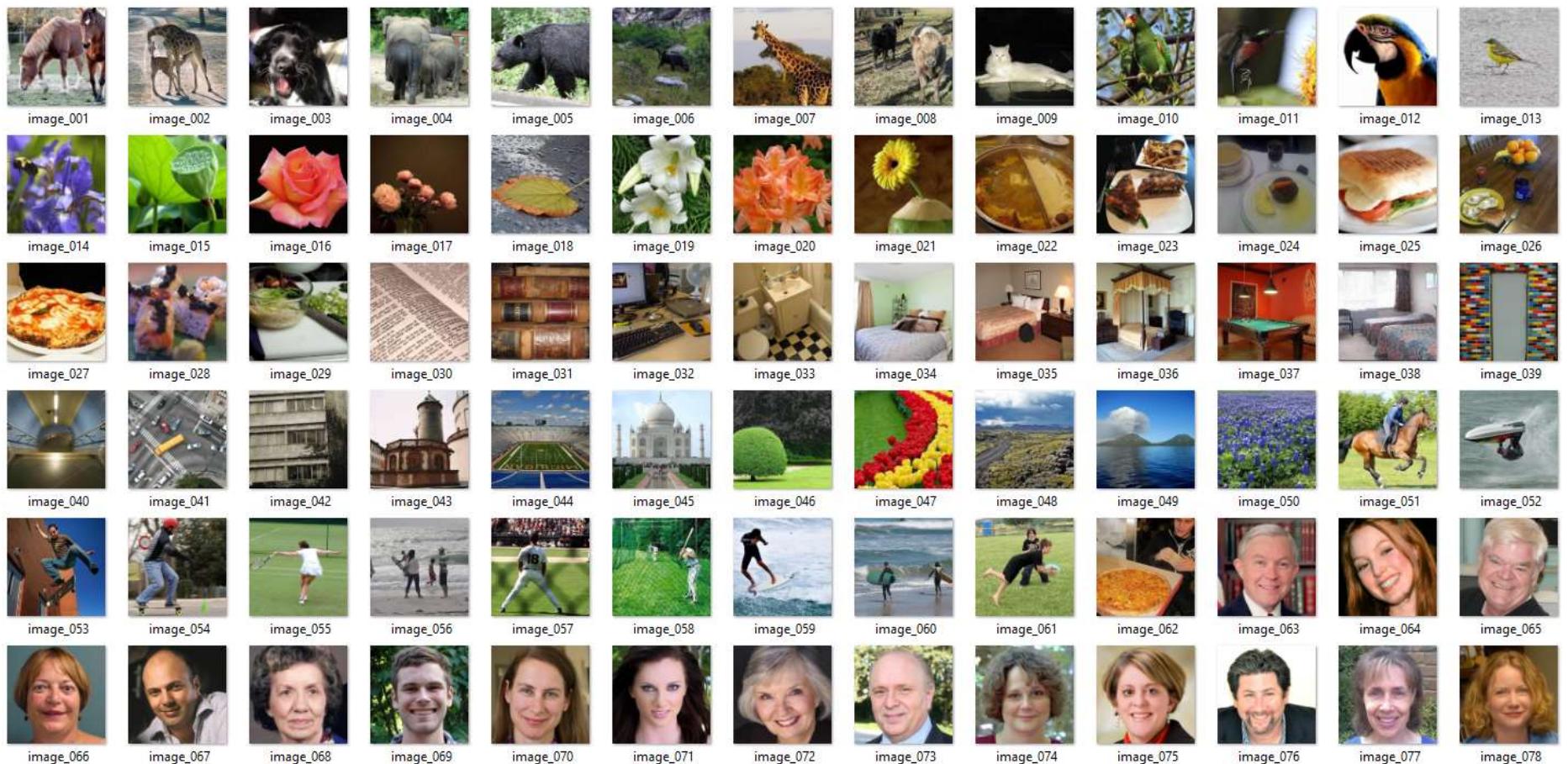
- What brain regions are engaged in visual processing?
- What kind of representations are held in these regions?
- What algorithms are being carried out by these regions?



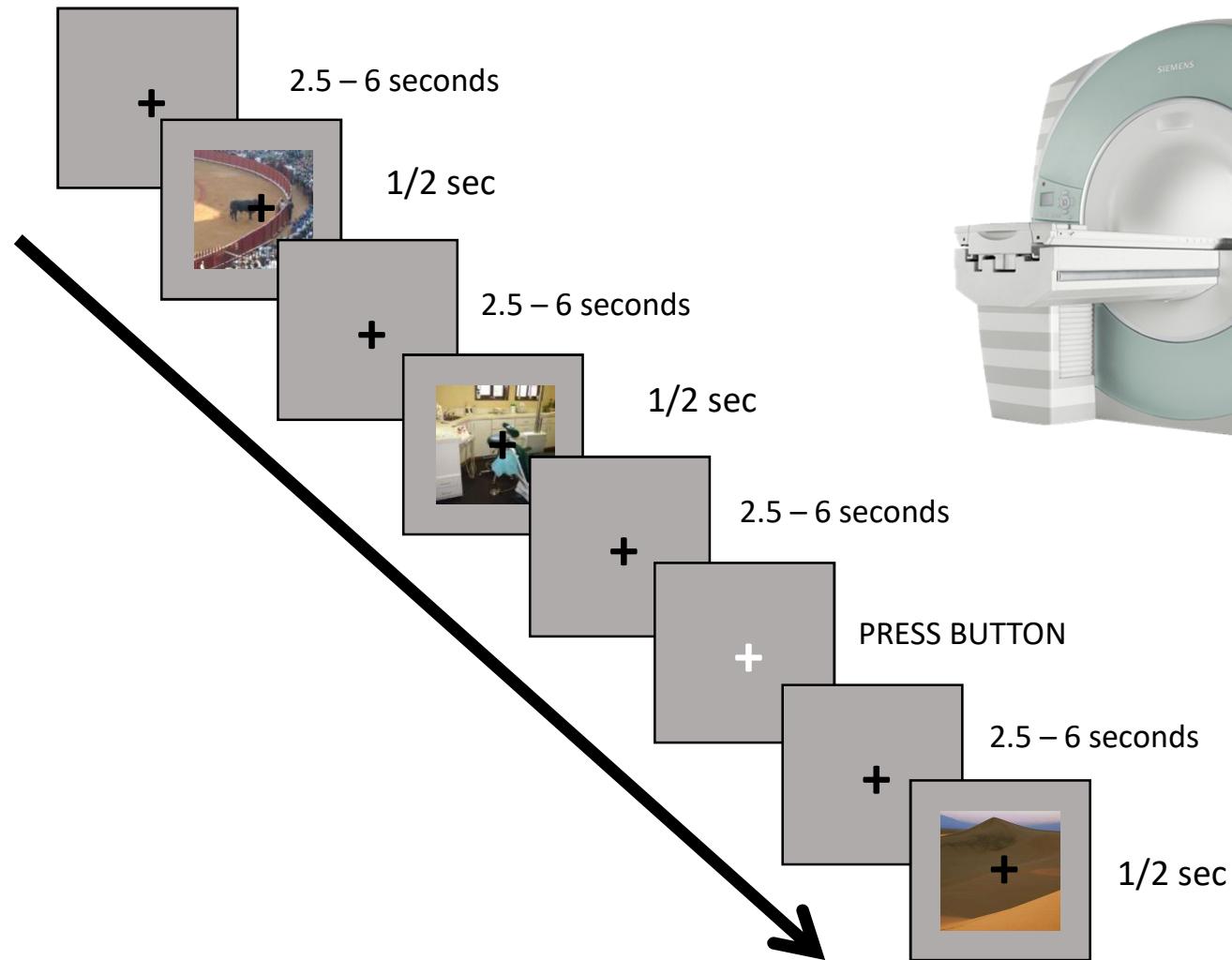
# Visual Recognition in the Brain



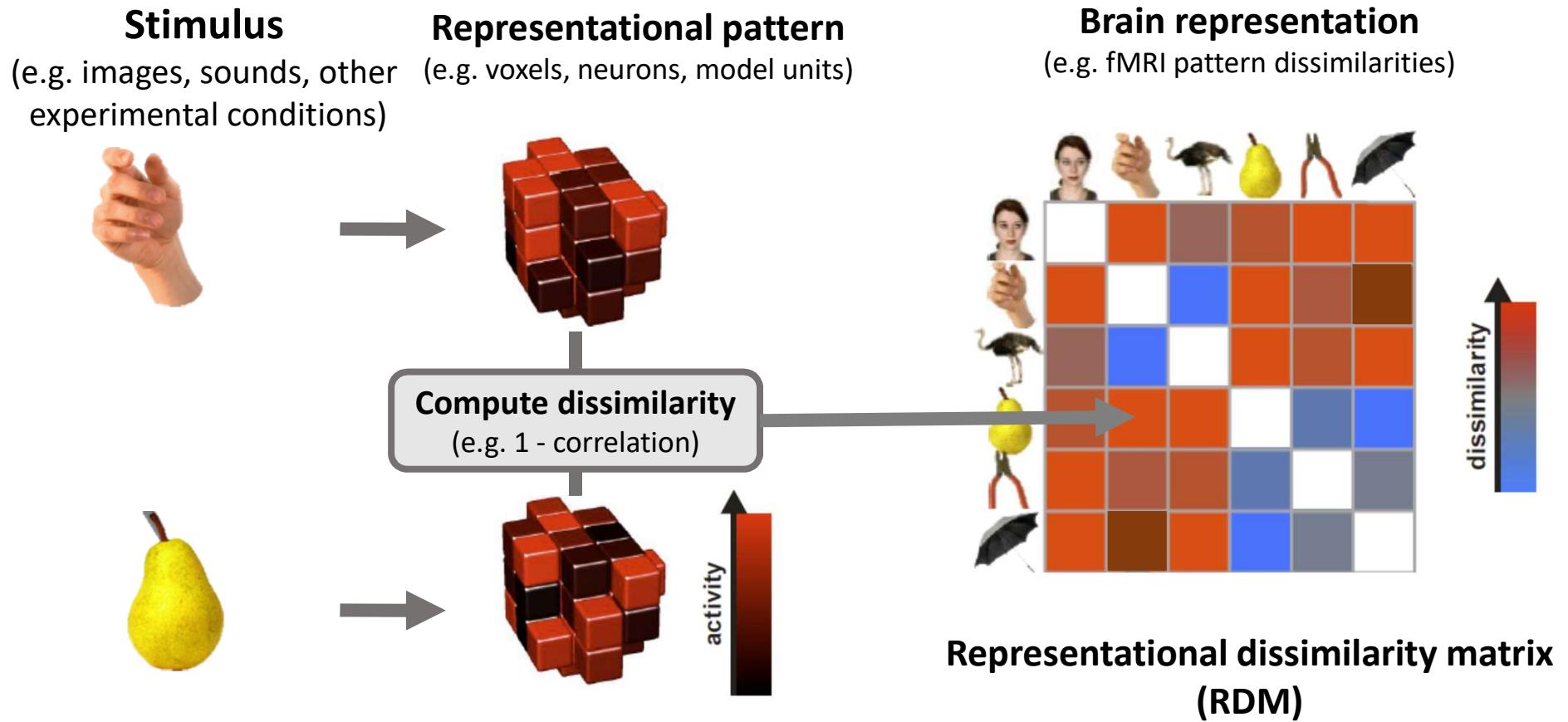
# Stimulus set



N=15

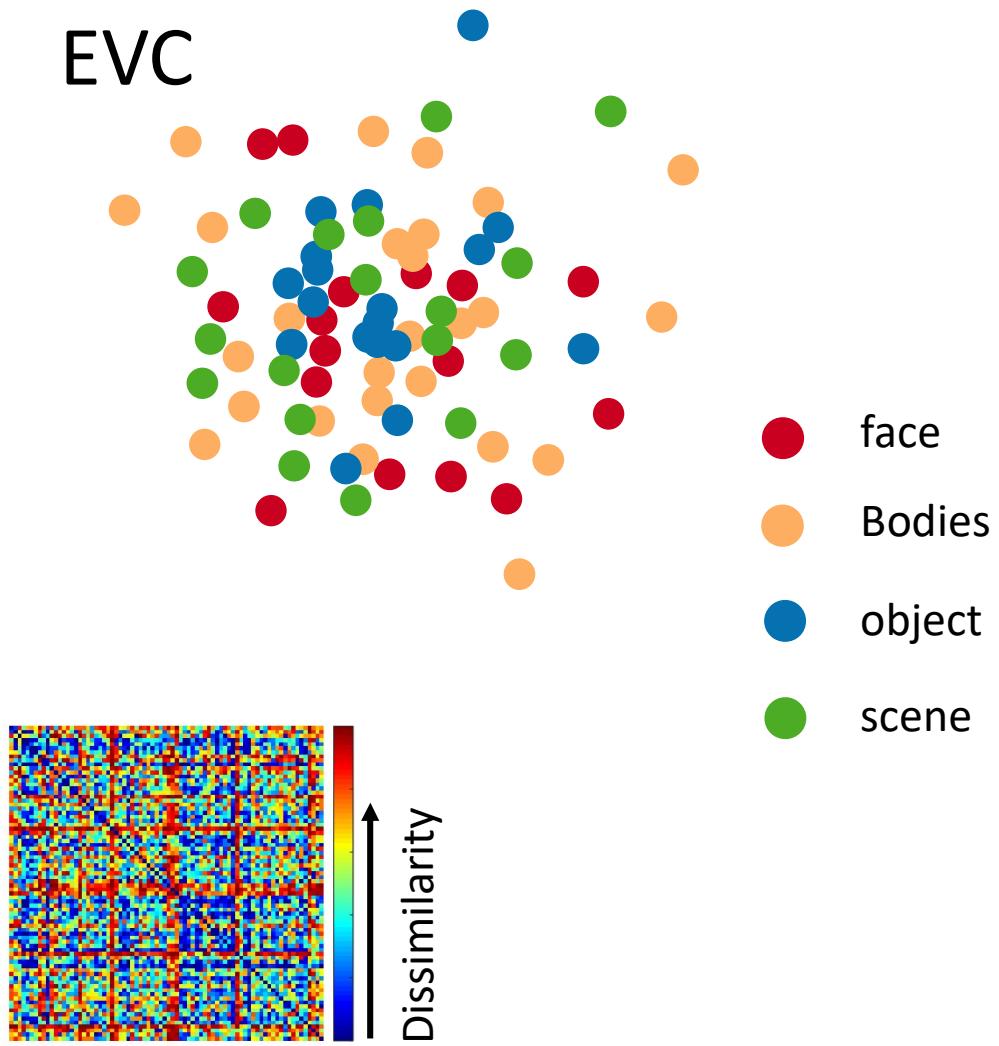


# Representational Similarity Analysis

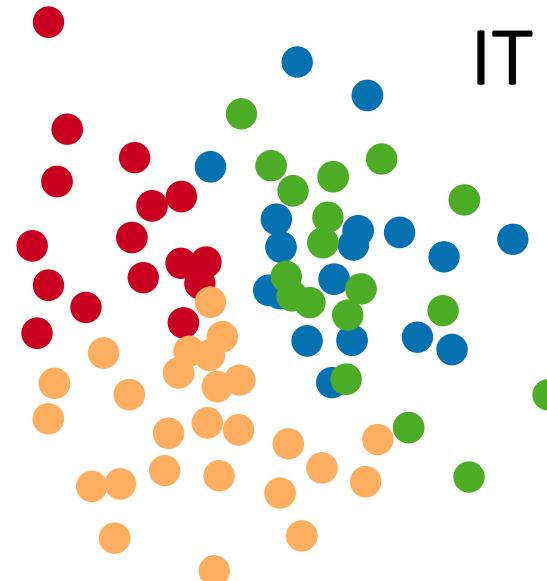


# fMRI Track RDMs

EVC



IT



Dissimilarity

# What is MEG?

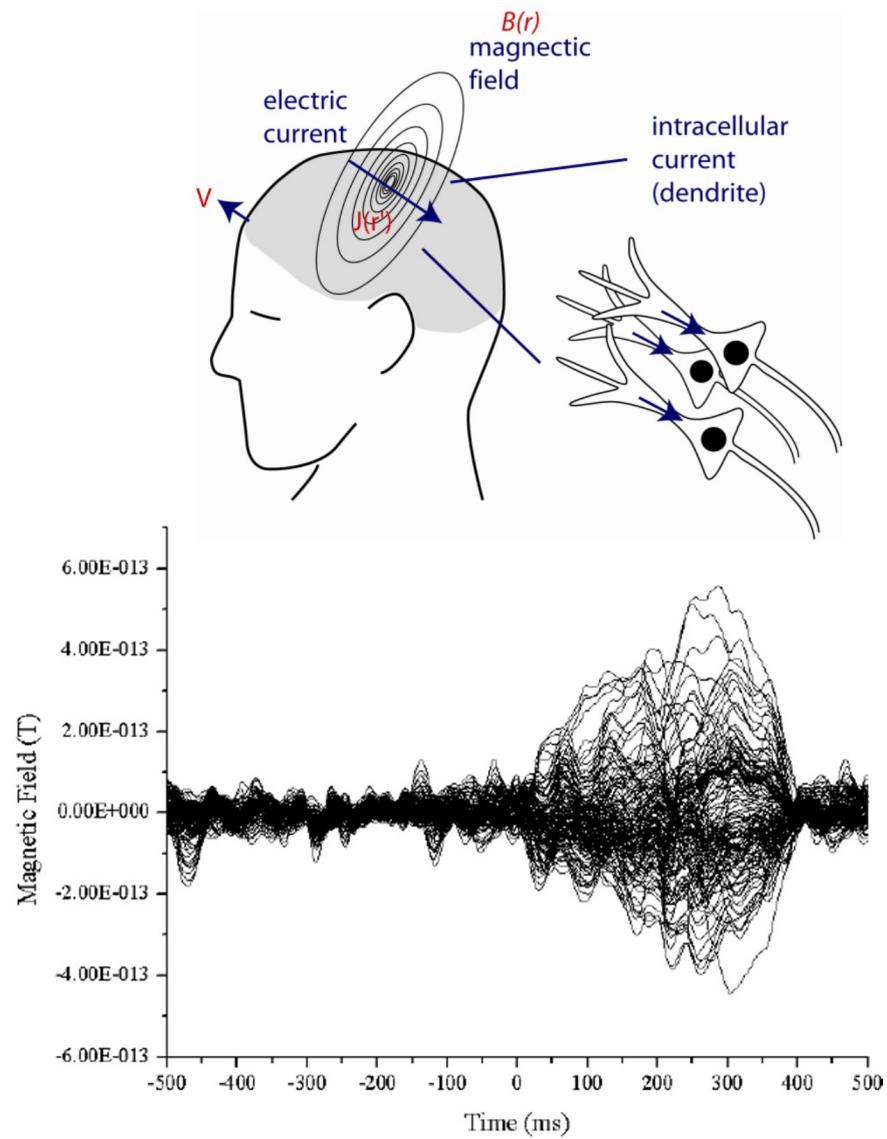
# Magnetoencephalography (MEG) / Electroencephalography (EEG)



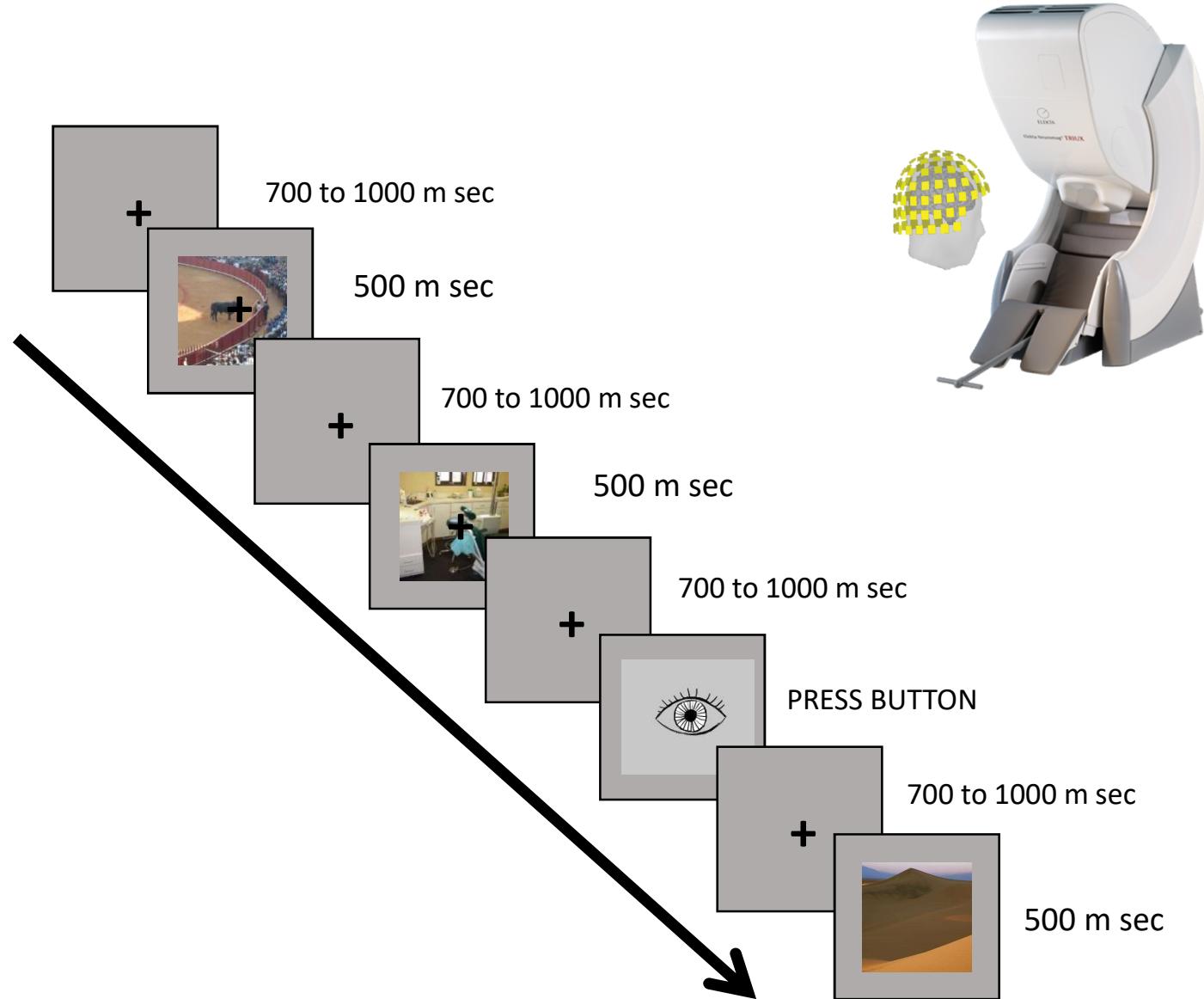
306 Channel  
SQUID sensor array

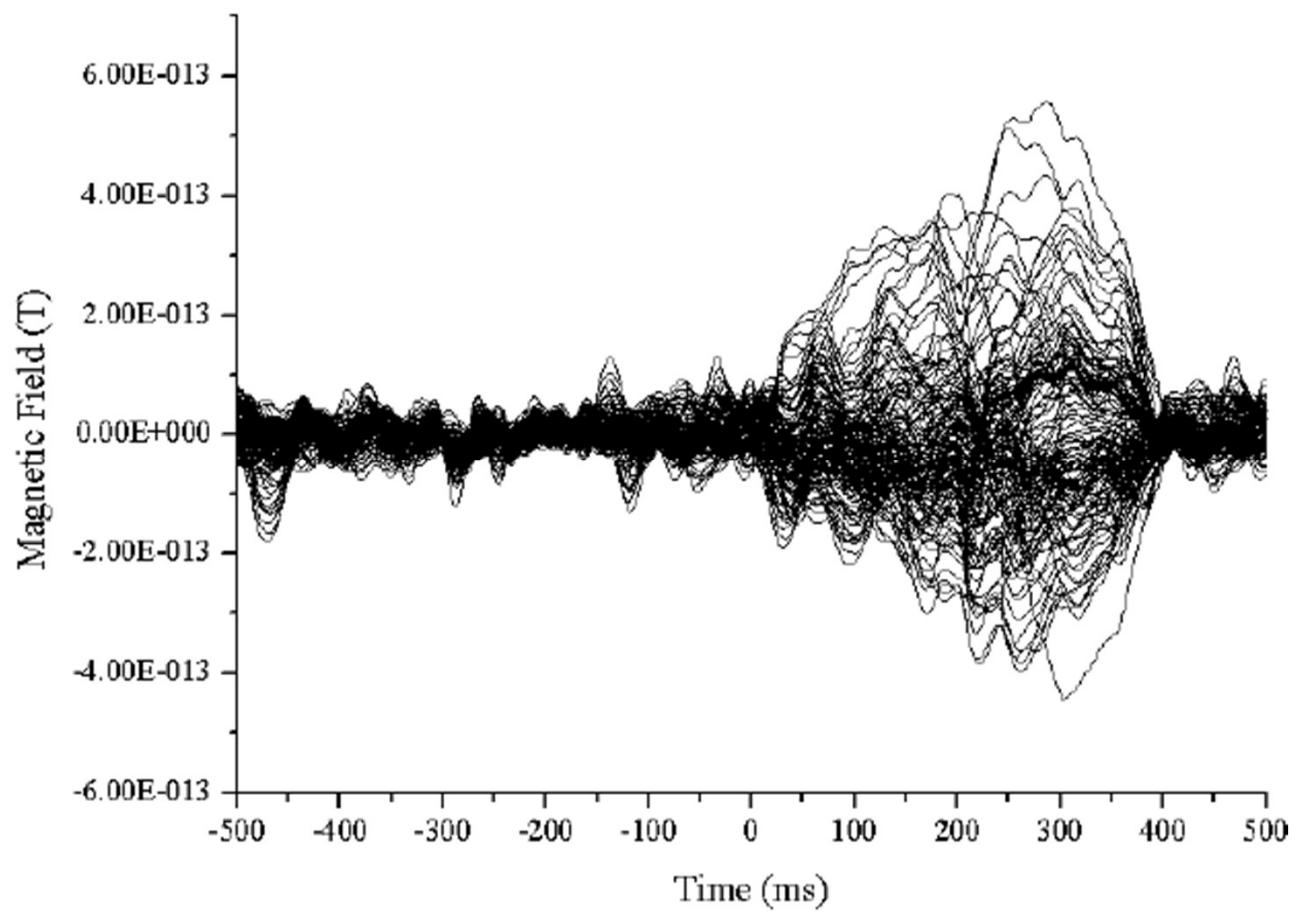


EEG



N=15

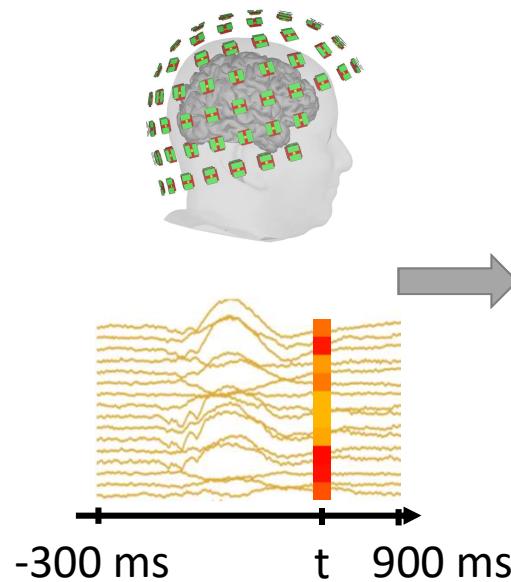




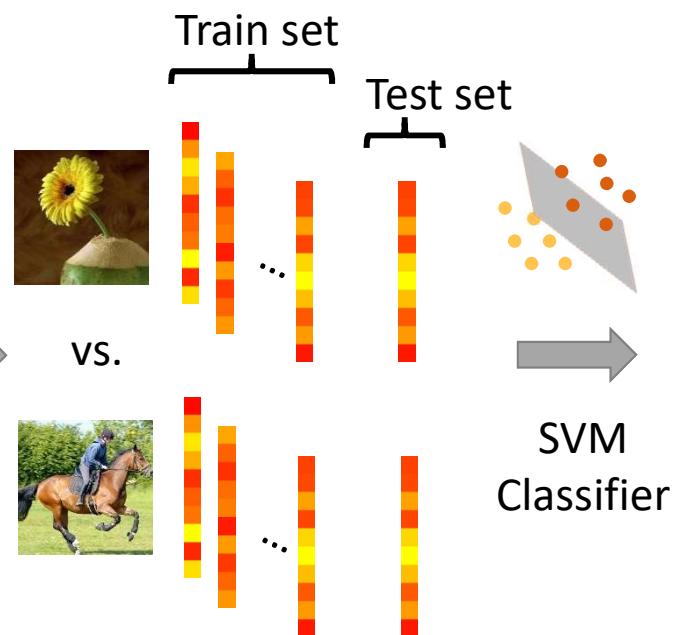
↑  
**Stimulus on**

# MEG Neural Data Decoding

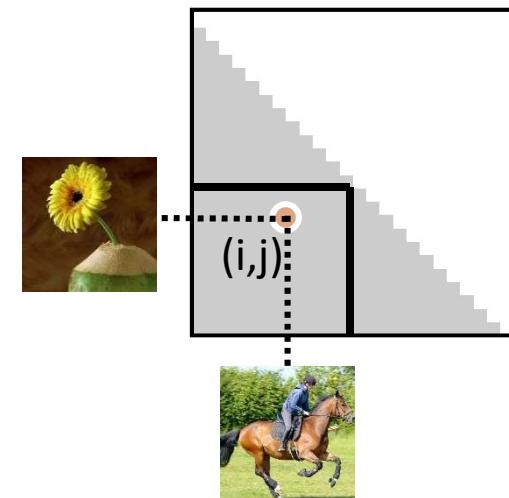
MEG pattern vector at time t



Pairwise classification

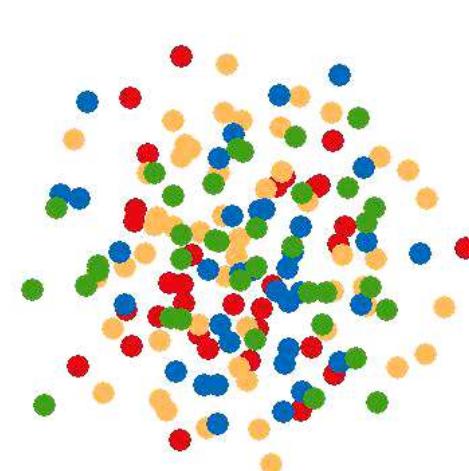
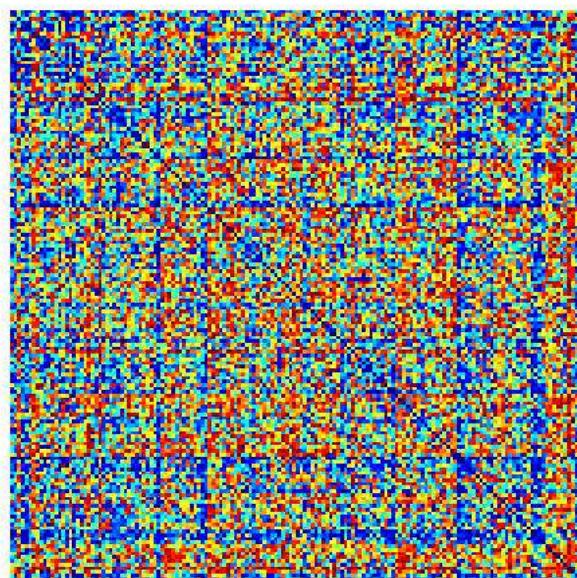


Representational  
dissimilarity  
matrix at time t



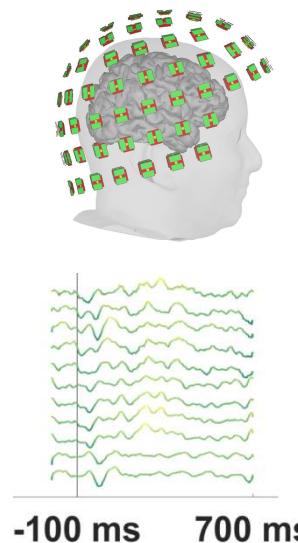
# Time-Resolved MEG RDMs

**1ms**

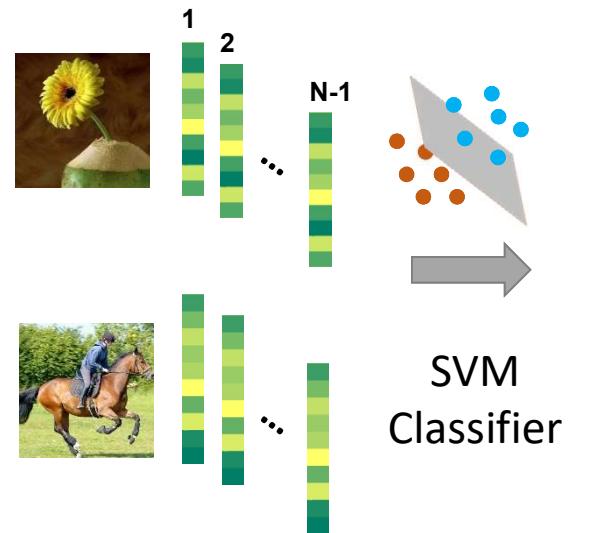


# Temporal Generalization

MEG pattern vector  
at time  $t$

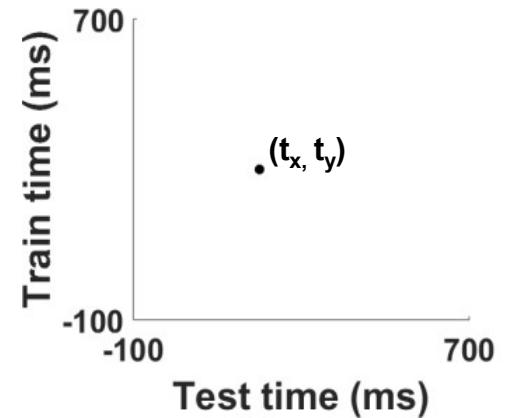


Train a SVM  
classifier using  $N-1$   
raw vectors at  $t_x$

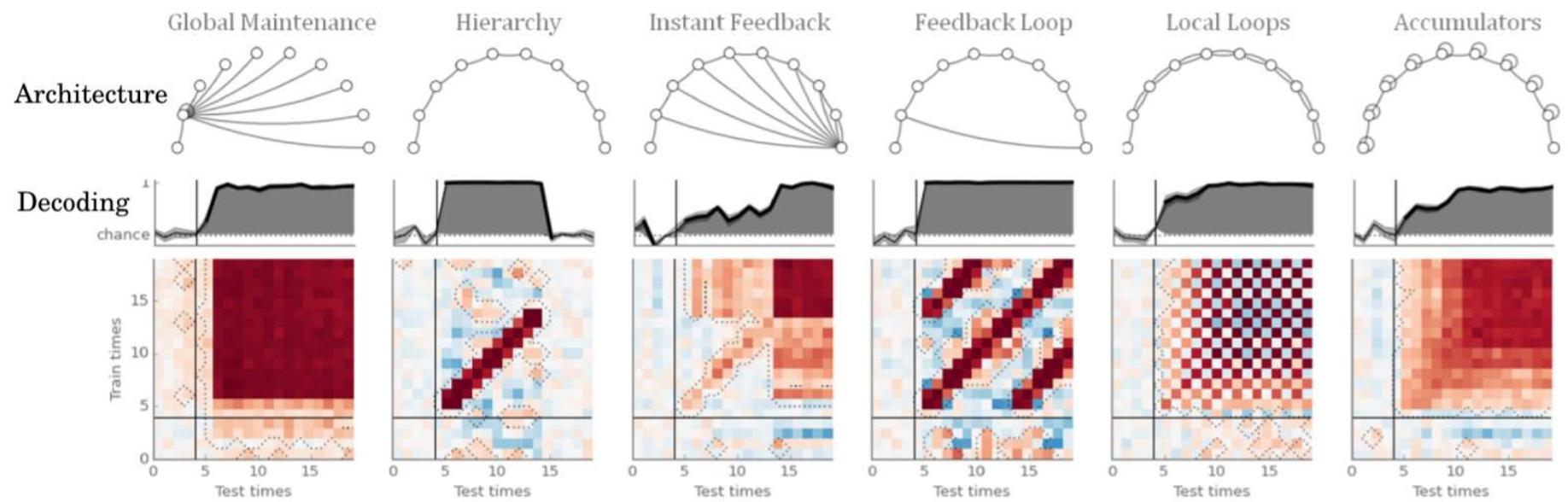


$N^{\text{th}}$  raw pattern  
vector at time  $t_y$

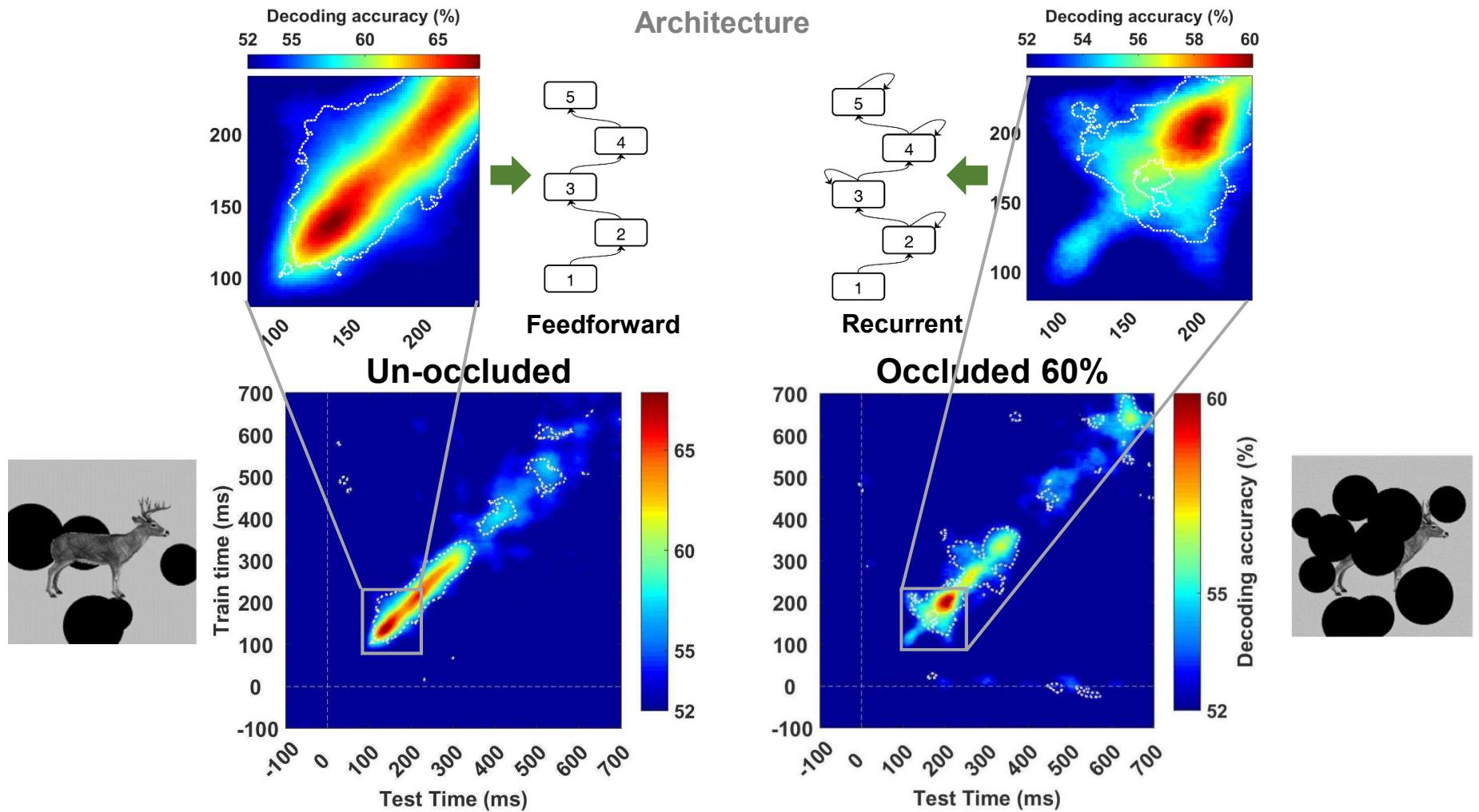
Time-Time  
decoding matrix



# Possible Neural Architectures

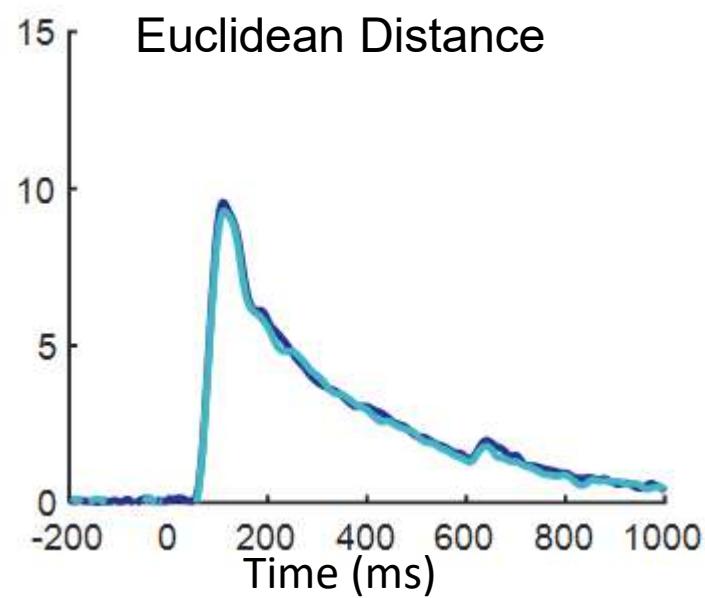
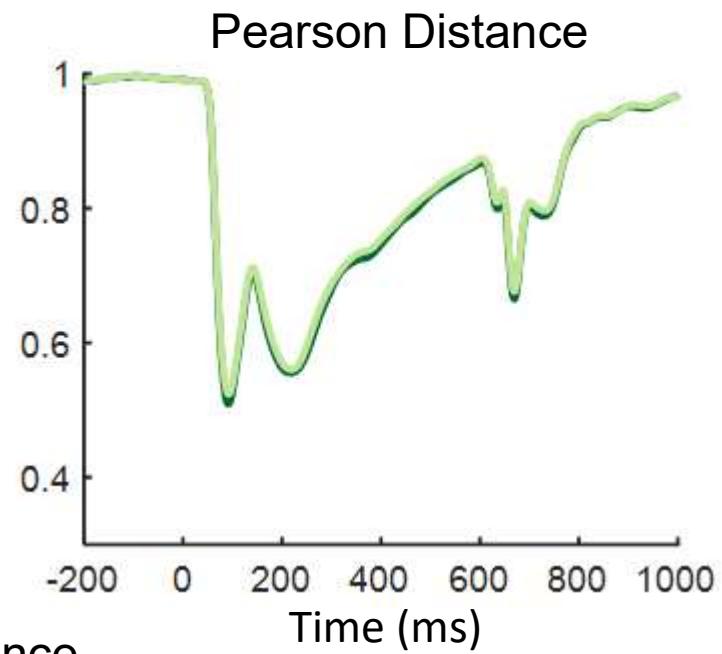
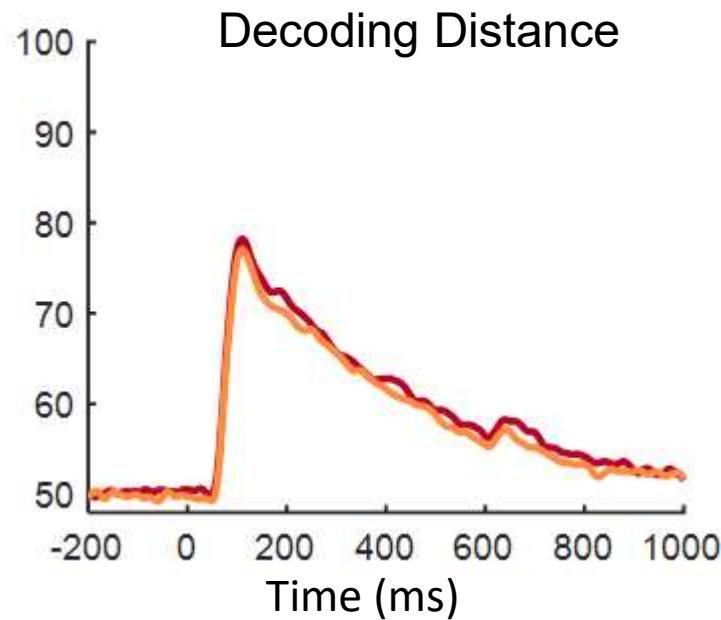


# A Neural Architecture with Recurrent Interactions

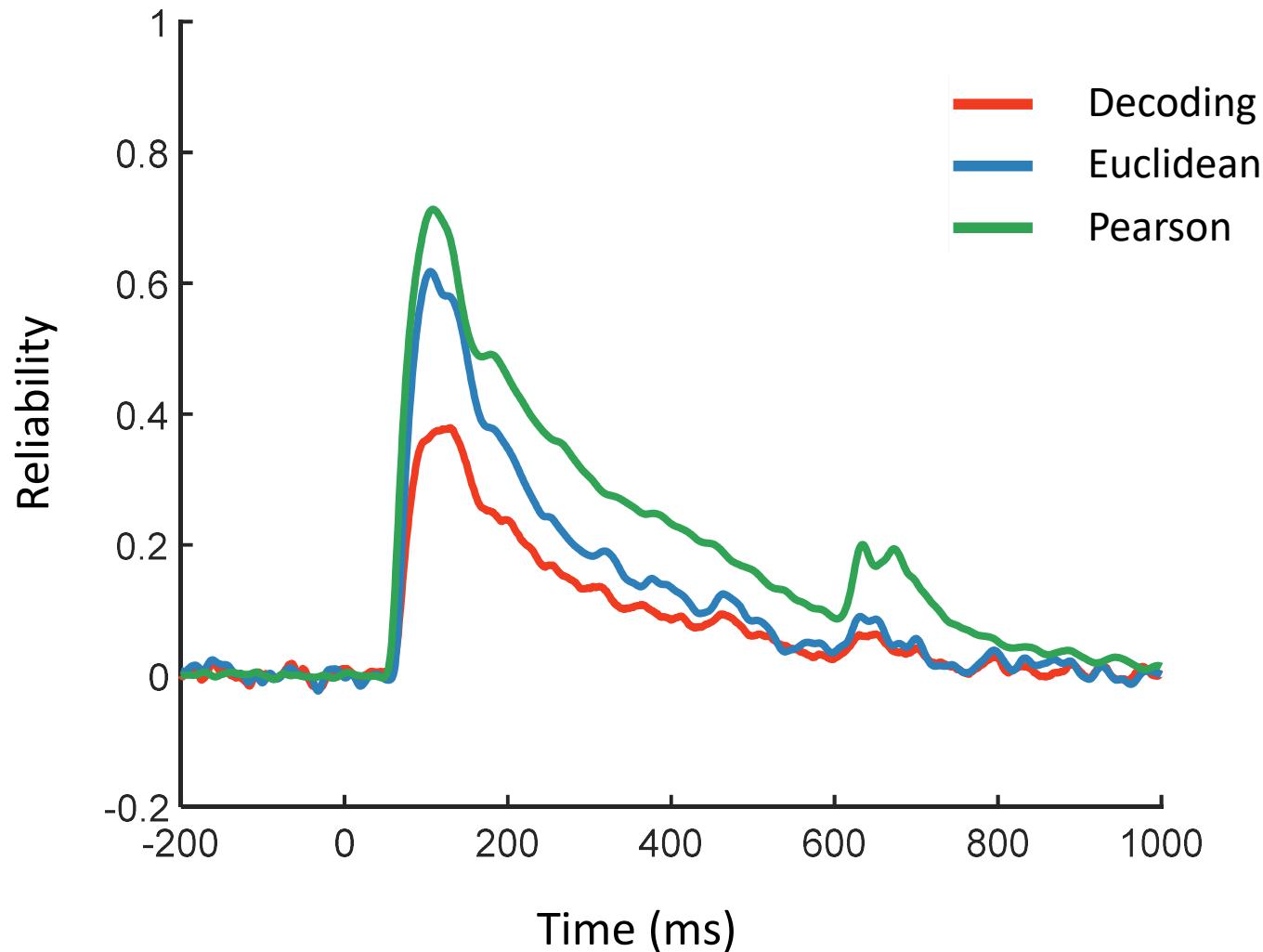


(Rajaei, Mohsenzadeh, Ebrahimpour, Khaligh-Razavi, 2019)

# Distance Measures

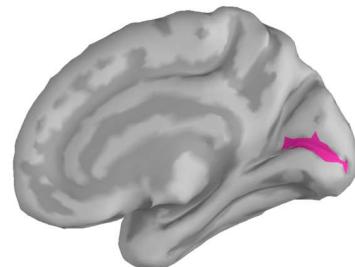


# Reliability of Distance Measures

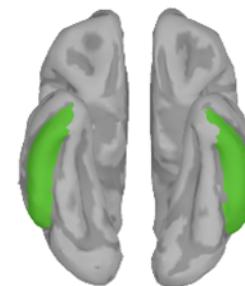


# MEG/ ROI fMRI fusion

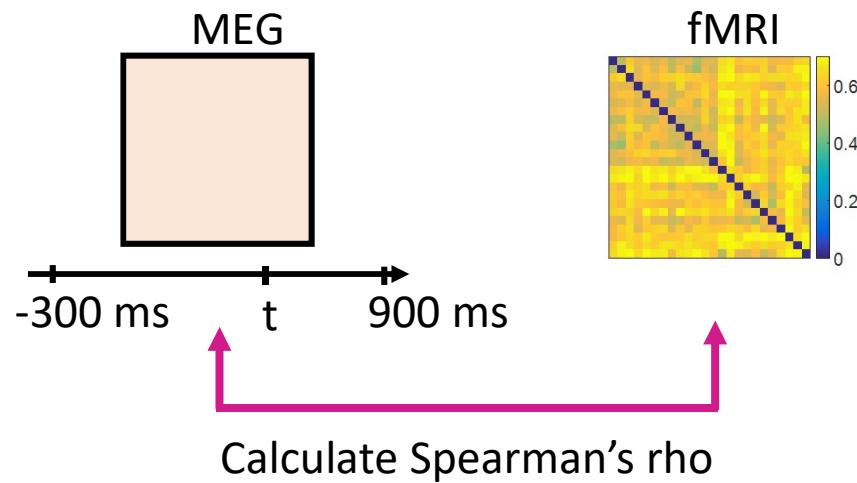
Early Visual Cortex (EVC)



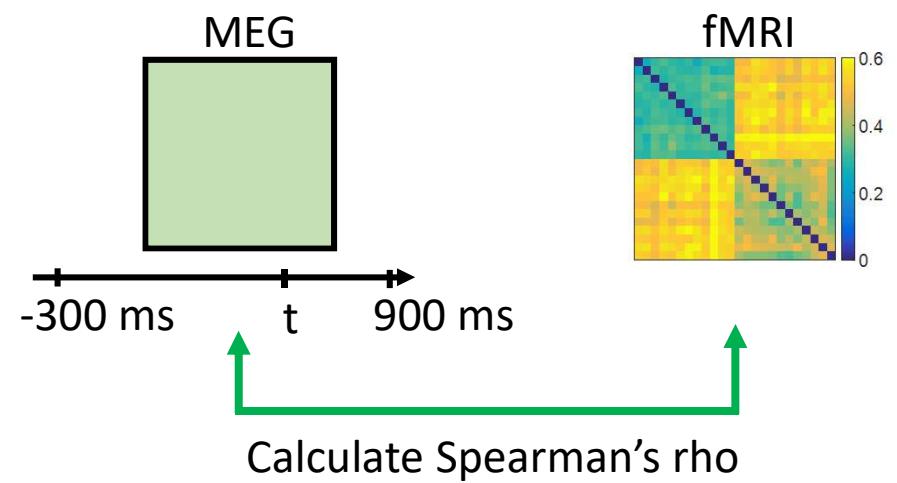
Inferior Temporal (IT)



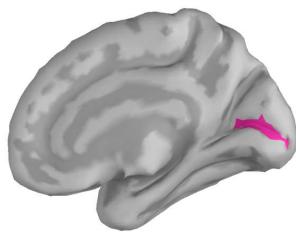
MEG-fMRI representational similarity in EVC



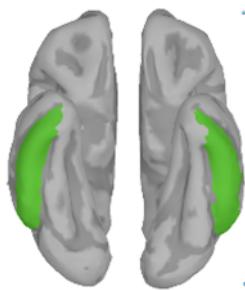
MEG-fMRI representational similarity in IT



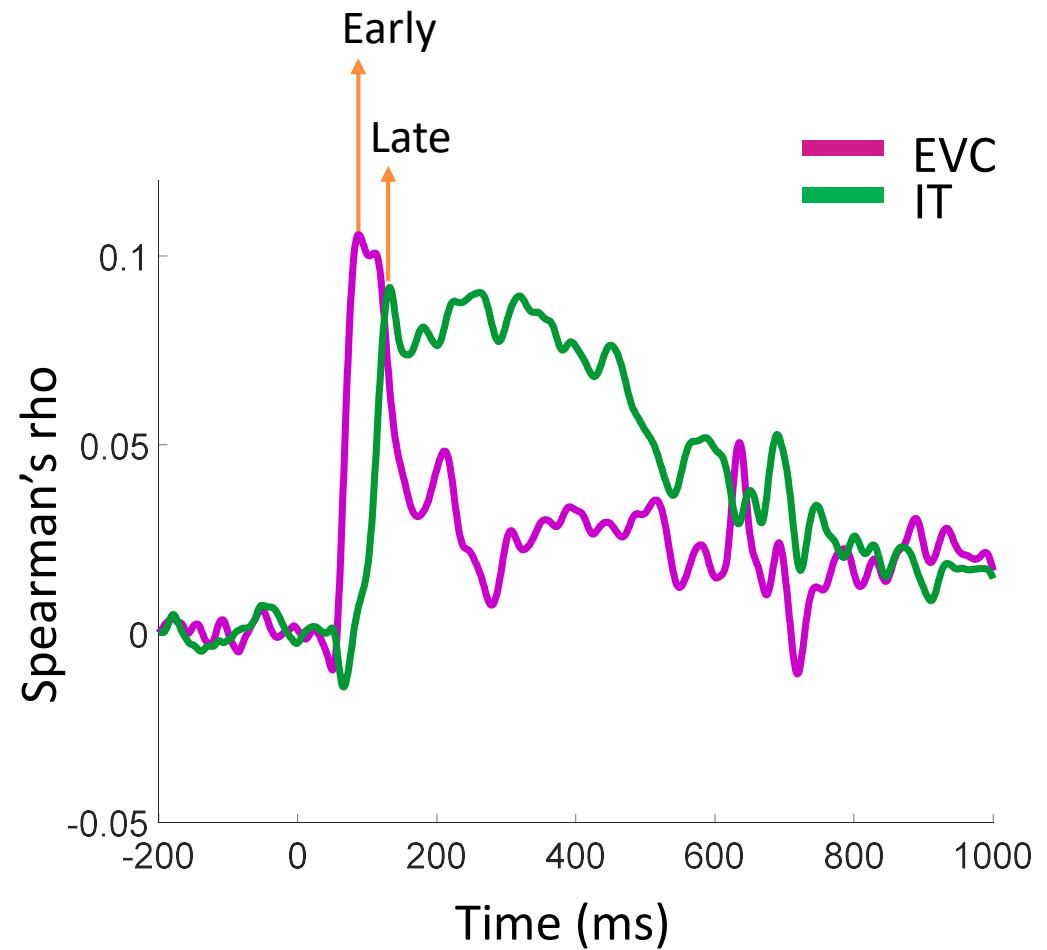
# ROI-based fMRI-MEG fusion



Early Visual Cortex (EVC)

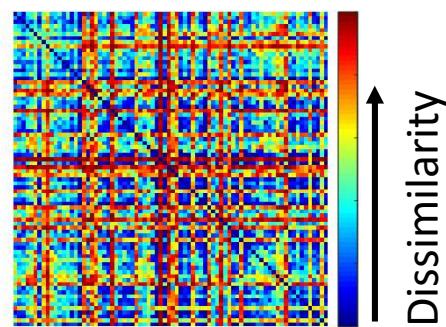
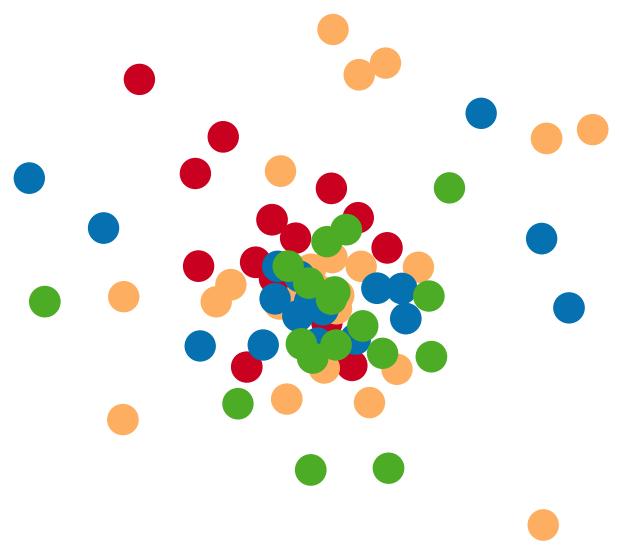


Inferior Temporal (IT)



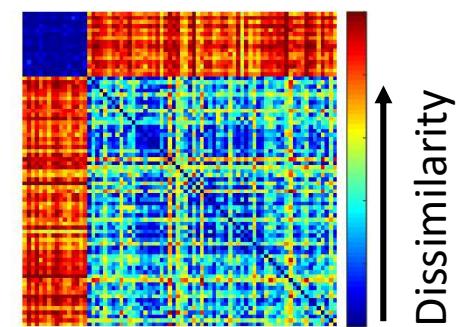
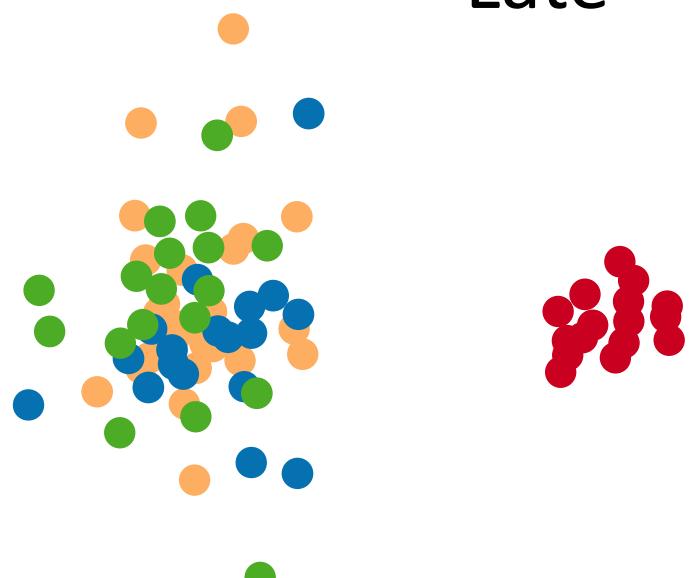
# MEG Track RDMs

Early



- face
- Bodies
- object
- scene

Late



# Summary

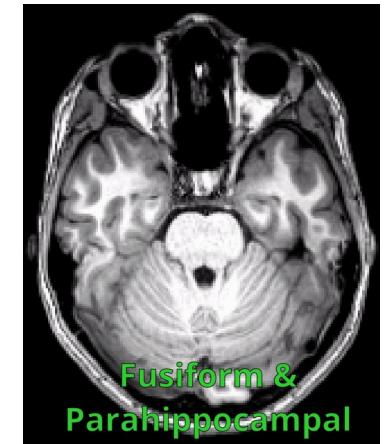
# Brain Imaging Methods



MRI

# Brain Imaging Methods

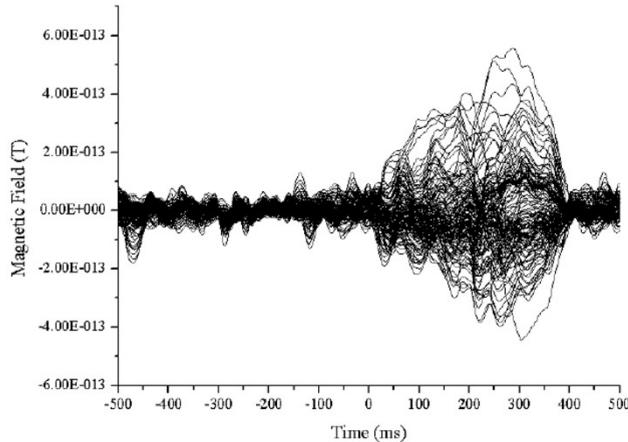
fMRI



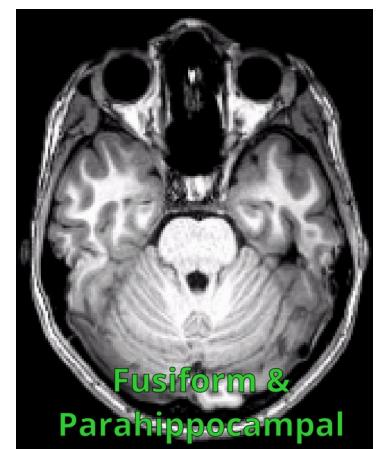
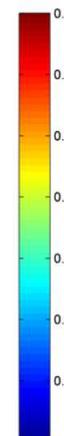
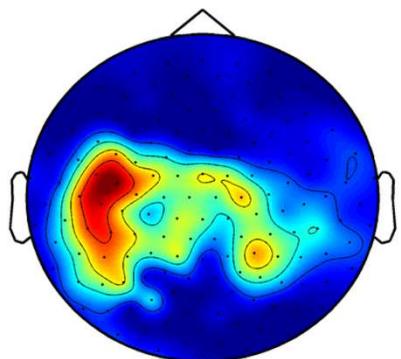
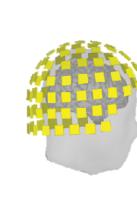
MRI



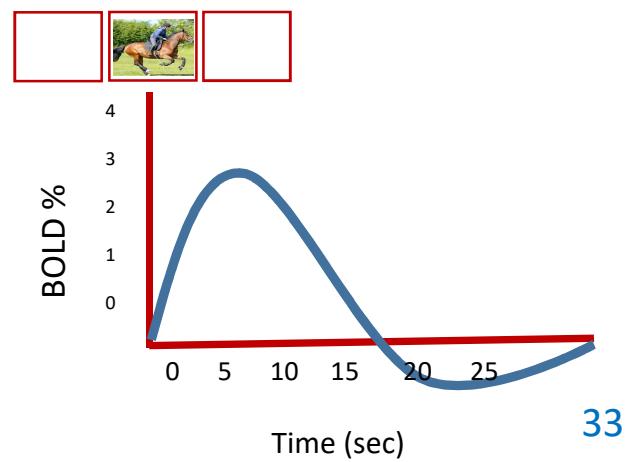
# Brain Imaging Methods



EEG  
MEG

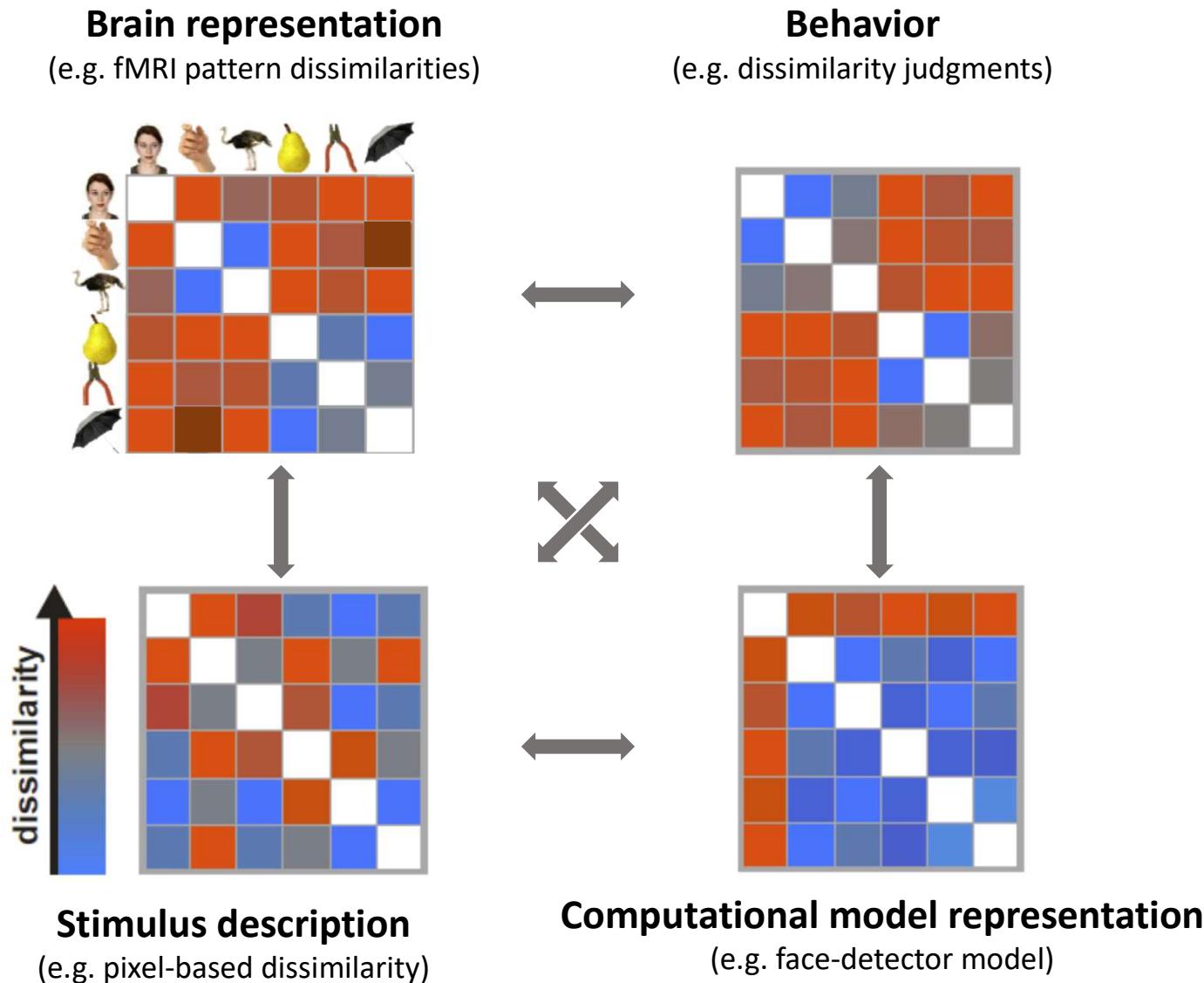


fMRI



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# Representational Similarity Analysis



# Acknowledgments



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MIT-IBM Watson AI Lab



Mohsenzadeh Lab

COGNITIVE  
NEUROSCIENCE  
&  
ARTIFICIAL INTELLIGENCE  
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