Introduction to Brain Imaging: fMRI and MEG/EEG
The Algonauts Workshop

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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)

Time (sec)
0      5      10     15       20      25

BOLD %
4
3
2
1
0

Stimulus on
Neurons fire

Bold response

Fusiform &
Parahippocampal
Data Structure

Experiment

S1

S2

Data

Time
General Linear Model: Constructing BOLD signals

HRF

\[ \beta_1 \] Baseline signal

\[ \beta_2 \] Response to S1

\[ \beta_3 \] Response to S2

\[ \text{error}(t) = \text{signal}(t) - \text{prediction}(t) \]
General Linear Model: Constructing BOLD signals

\[ \beta_1 x + \beta_2 x + \beta_3 x + \text{err} = \text{Y} + \text{err} = \]
General Linear Model: Constructing BOLD signals

\[
\begin{align*}
\text{Bold signal} \ Y &= X \times B + e\\
\text{Task related variations} &\quad \text{Noise variations}\\
\text{Find } B \text{ such that Min } \sum e_i^2 \\
B &= (X^T X)^{-1} X^T Y
\end{align*}
\]
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
Representational Similarity Analysis

Stimulus (e.g. images, sounds, other experimental conditions)

Representational pattern (e.g. voxels, neurons, model units)

Brain representation (e.g. fMRI pattern dissimilarities)

Compute dissimilarity (e.g. 1 - correlation)

Representational dissimilarity matrix (RDM)

fMRI Track RDMs

EVC

IT

Dissimilarity

face
Bodies
object
scene
What is MEG?
Magnetoencephalography (MEG) / Electroencephalography (EEG)

306 Channel SQUID sensor array

EEG
N=15

700 to 1000 m sec

500 m sec

700 to 1000 m sec

500 m sec

700 to 1000 m sec

PRESS BUTTON

700 to 1000 m sec

500 m sec
Stimulus on
MEG Neural Data Decoding

MEG pattern vector at time $t$

Pairwise classification

Representational dissimilarity matrix at time $t$

-300 ms  $t$  900 ms

(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

Train a SVM classifier using N-1 raw vectors at \( t_x \)

\( N \)th raw pattern vector at time \( t_y \)

Time-Time decoding matrix

MEG pattern vector at time \( t \)

\(-100 \text{ ms} \quad 700 \text{ ms}\)

(Carlson et al. 2013; Cichy et al. 2014; Isik et al. 2014; Clarke et al. 2014; Kaneshiro et al. 2015; King et al. 2016)
Possible Neural Architectures

(King et al., 2016)
A Neural Architecture with Recurrent Interactions

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

Decoding Distance

Pearson Distance

Euclidean Distance
Reliability of Distance Measures

![Graph showing reliability over time for Decoding, Euclidean, and Pearson distance measures. The graph displays a peak at around 200 ms, with the Decoding measure reaching the highest reliability. The Euclidean and Pearson measures follow closely, with the Euclidean measure slightly higher than the Pearson measure.]
MEG/ROI fMRI fusion

Early Visual Cortex (EVC)

Inferior Temporal (IT)

MEG-fMRI representational similarity in EVC

MEG-fMRI representational similarity in IT

Calculate Spearman’s rho

ROI-based fMRI-MEG fusion

Early Visual Cortex (EVC)

Inferior Temporal (IT)

Spearman’s rho

Time (ms)

Early

Late

EVC

IT
MEG Track RDMs

Early

Late

Dissimilarity

face
Bodies
object
scene
Summary
Brain Imaging Methods
Brain Imaging Methods

fMRI

MRI

Fusiform & Parahippocampal
Brain Imaging Methods

MRI

fMRI

EEG

MEG

BOLD %

Time (sec)
Representational Similarity Analysis

Brain representation
(e.g. fMRI pattern dissimilarities)

Behavior
(e.g. dissimilarity judgments)

Stimulus description
(e.g. pixel-based dissimilarity)

Computational model representation
(e.g. face-detector model)

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Mohsenzadeh Lab

COGNITIVE NEUROSCIENCE & ARTIFICIAL INTELLIGENCE LAB

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