FUNCTIONAL MAGNETIC RESONANCE IMAGING

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EPFL and CIBM

CIBM translational MR neuroimaging & spectroscopy, 25.04.2023


C I B M . C H

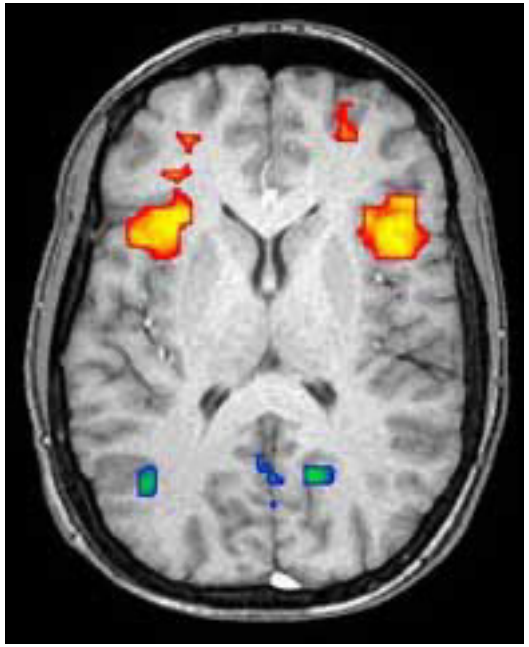
FUNCTIONAL MAGNETIC RESONANCE IMAGING

What it is about

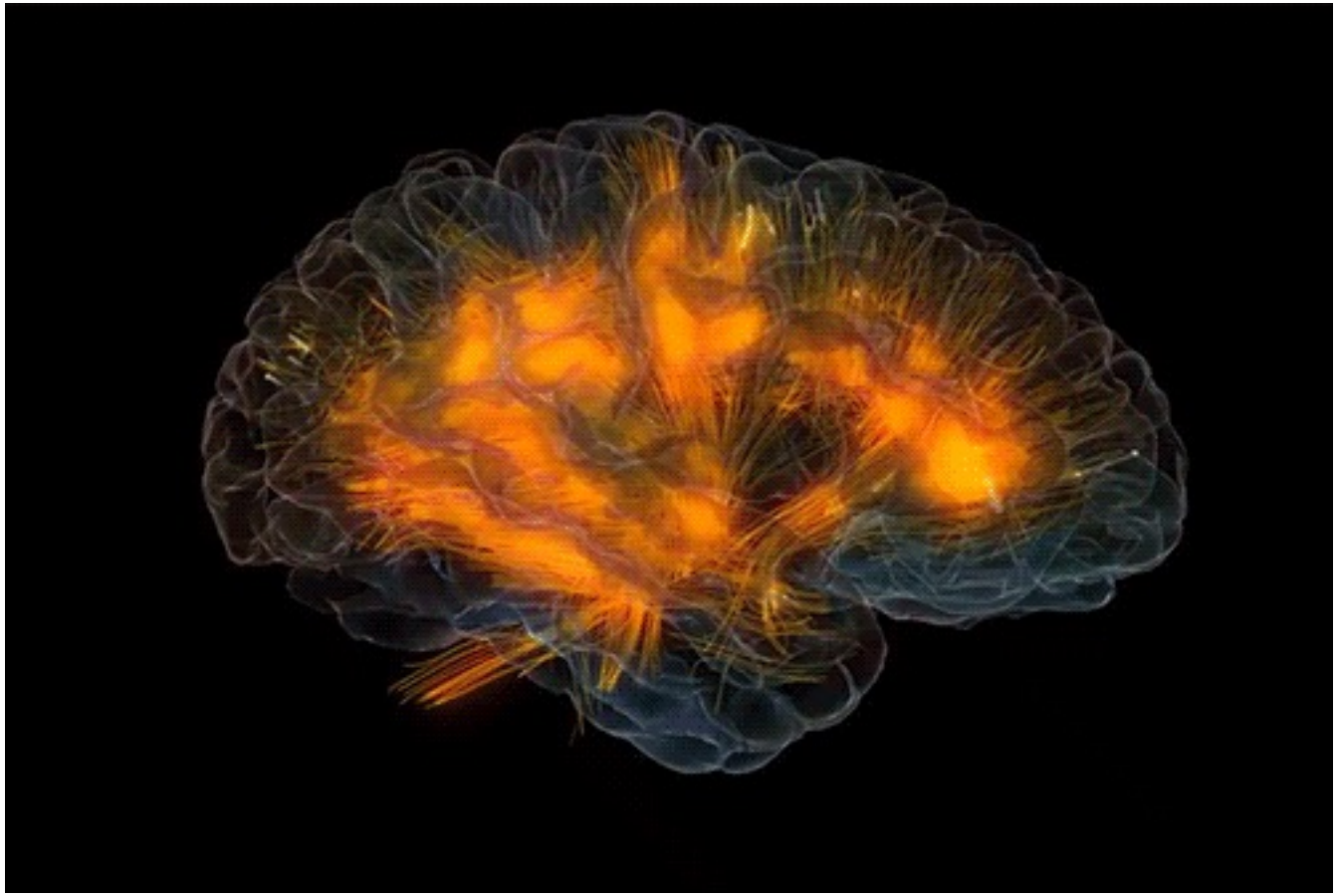
Keywords:
- Functional imaging, fMRI, BOLD, task and resting-state, block design, connectome

Readings:
- Functional Magnetic Resonance Imaging (Huettel, Song, McCarthy)
- Fundamentals of Brain Network Analysis (Fornito, Zalesky, Bullmore)

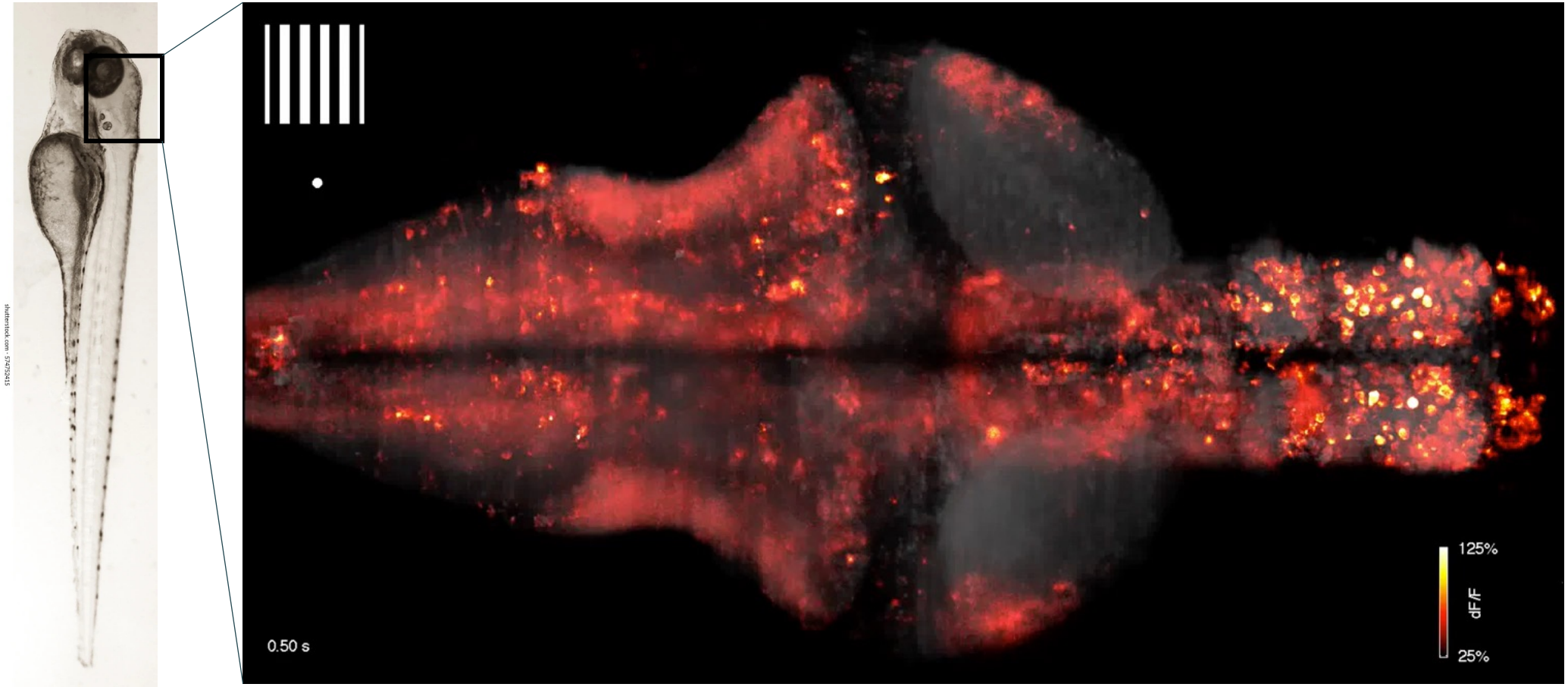
Complementary PHD courses :
- Advanced topics in network neuroscience (Dr. Enrico Amico)



FUNCTIONAL IMAGING OF BRAIN ACTIVITY



FUNCTIONAL IMAGING OF BRAIN ACTIVITY



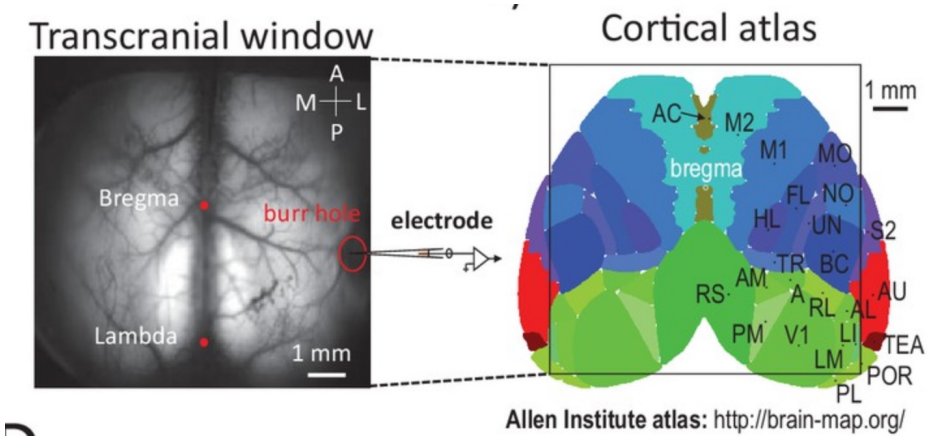
Credit: Misha Ahrens & Philipp Keller/Howard Hughes Medical Institute

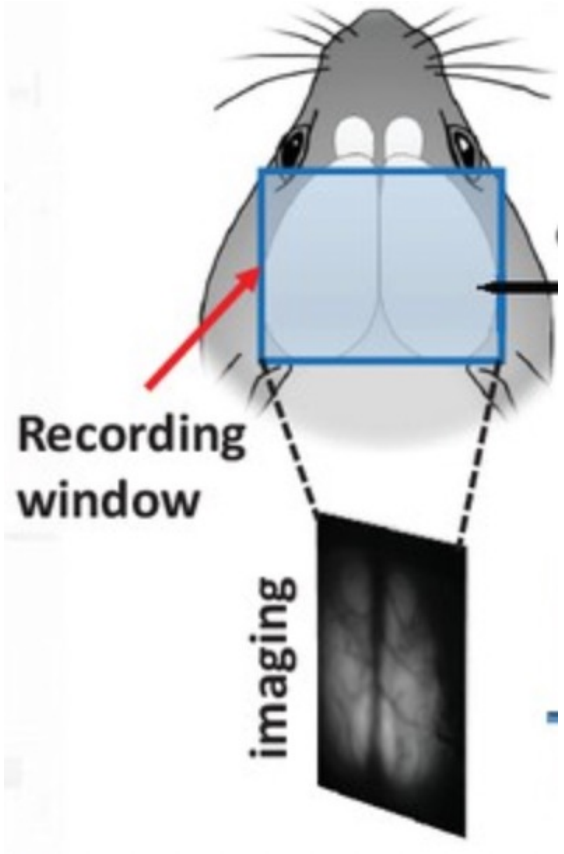
FUNCTIONAL IMAGING OF BRAIN ACTIVITY

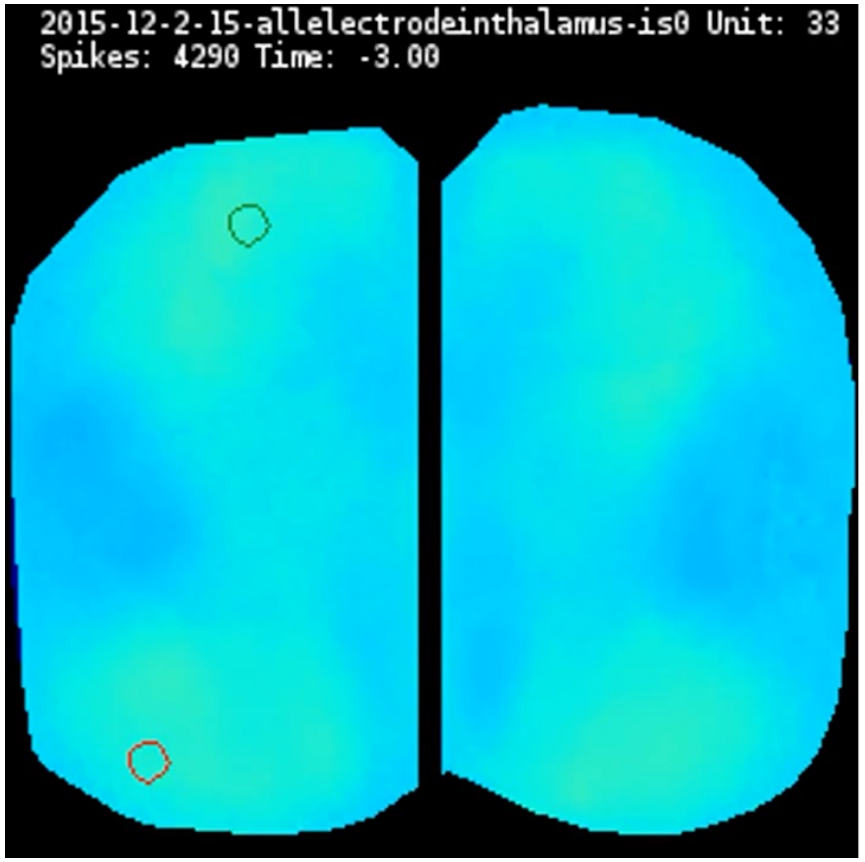
Mapping cortical mesoscopic networks of single spiking cortical or sub-cortical neurons

Dongsheng Xiao, Matthieu P Vanni, Catalin C Mitelut, Allen W Chan, Jeffrey M LeDue, Yicheng Xie, Andrew CN Chen, Nicholas V Swindale, Timothy H Murphy

Kinsmen Laboratory of Neurological Research, Canada; Beijing Institute for Brain Disorders, Capital Medical University, China; Djavad Mowafaghian Centre for Brain Health, University of British Columbia, Canada; University of British Columbia, Canada



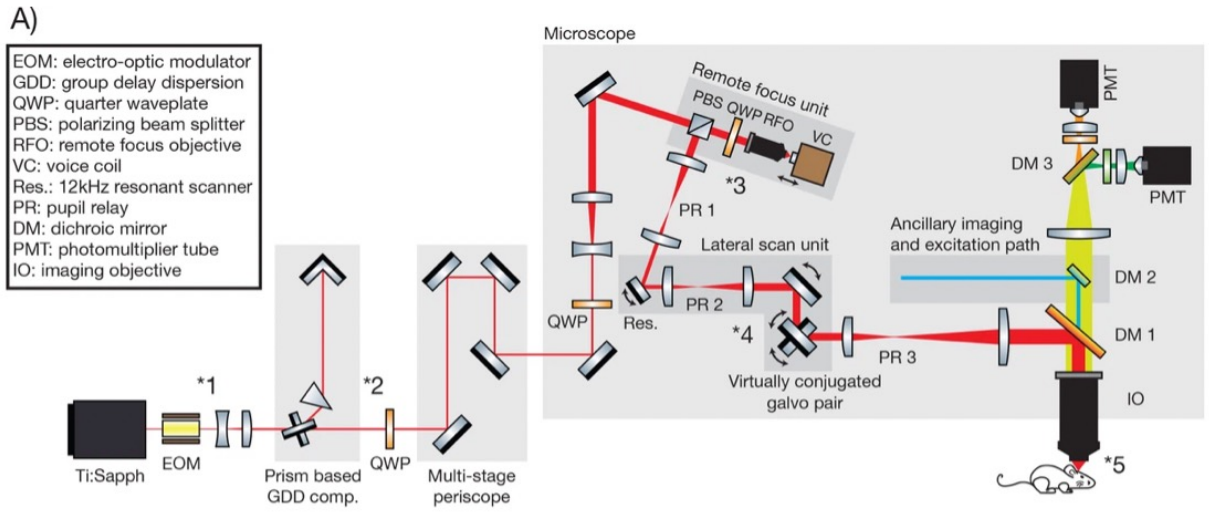


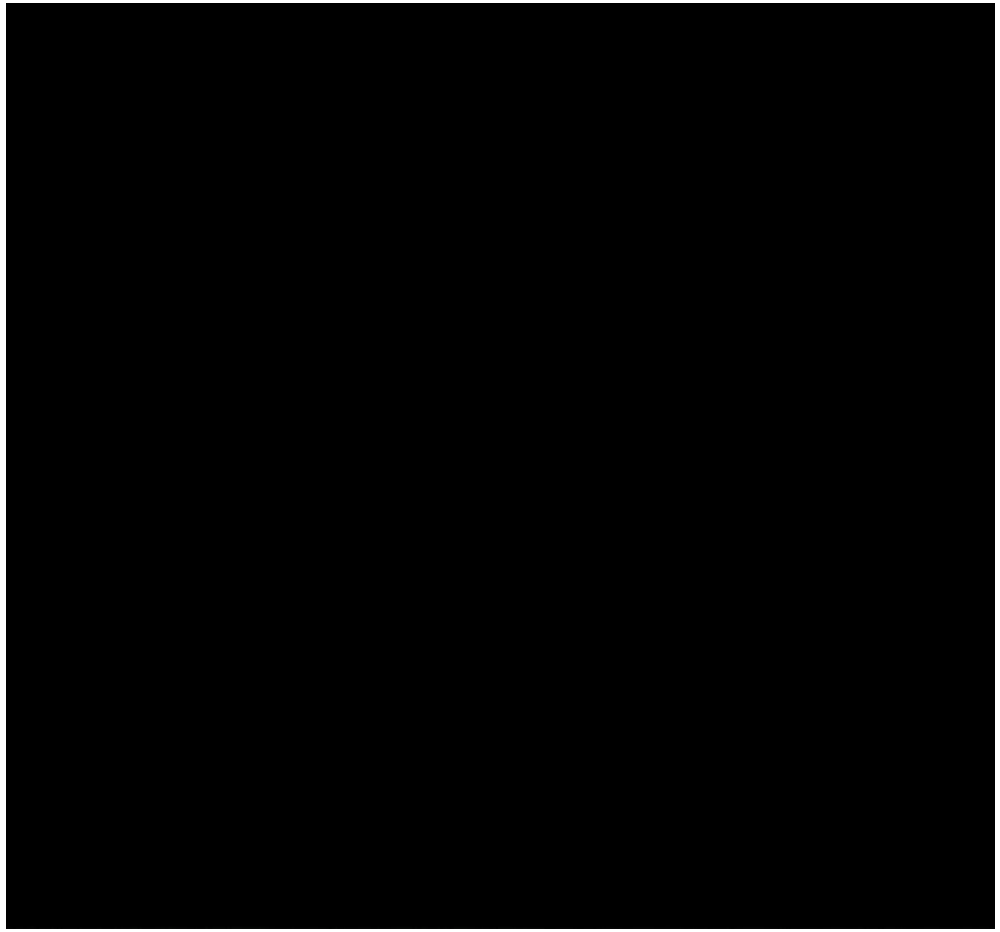


FUNCTIONAL IMAGING OF BRAIN ACTIVITY

A large field of view two-photon mesoscope with subcellular resolution for in vivo imaging

Nicholas James Sofroniew, Daniel Flickinger, Jonathan King, Karel Svoboda





CAN WE IMAGE BRAIN ACTIVITY WITH MRI?

easure fast events?

nts may be possible

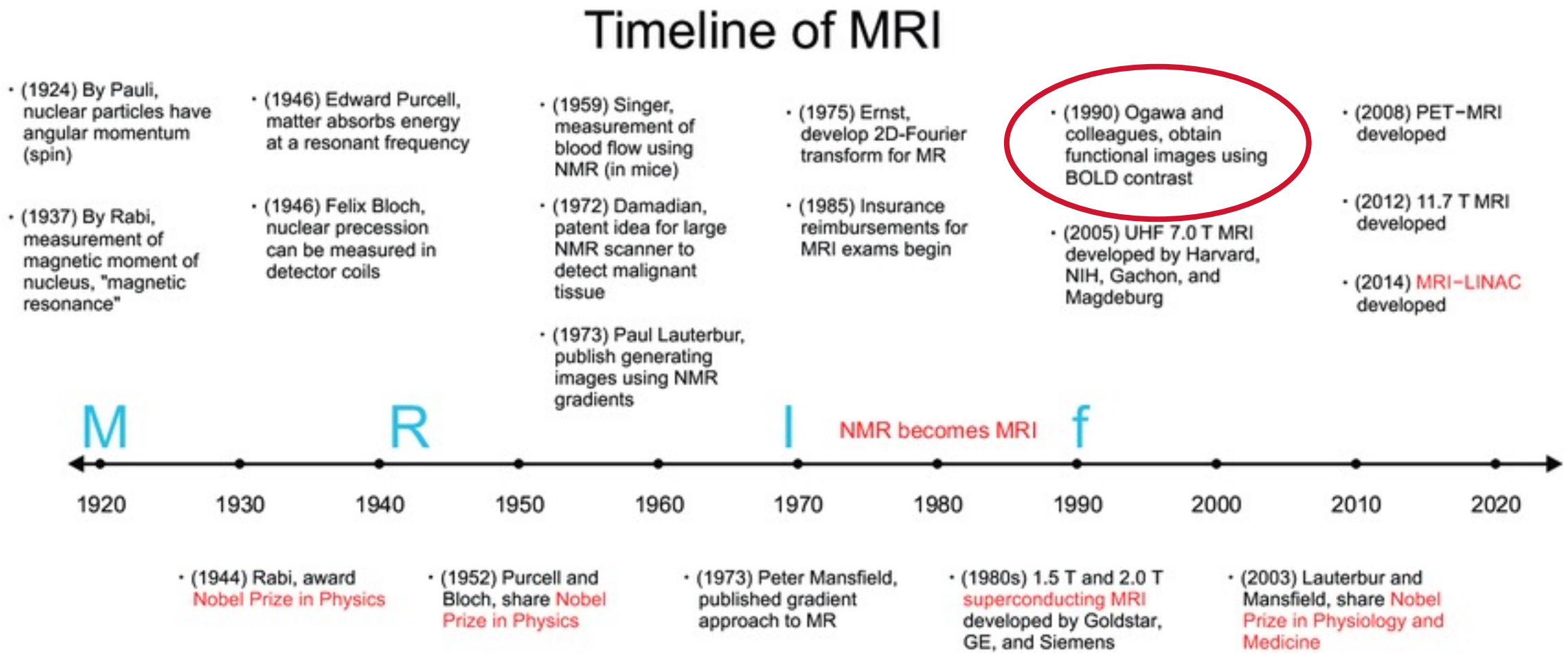
single cells events?

nts may be possible

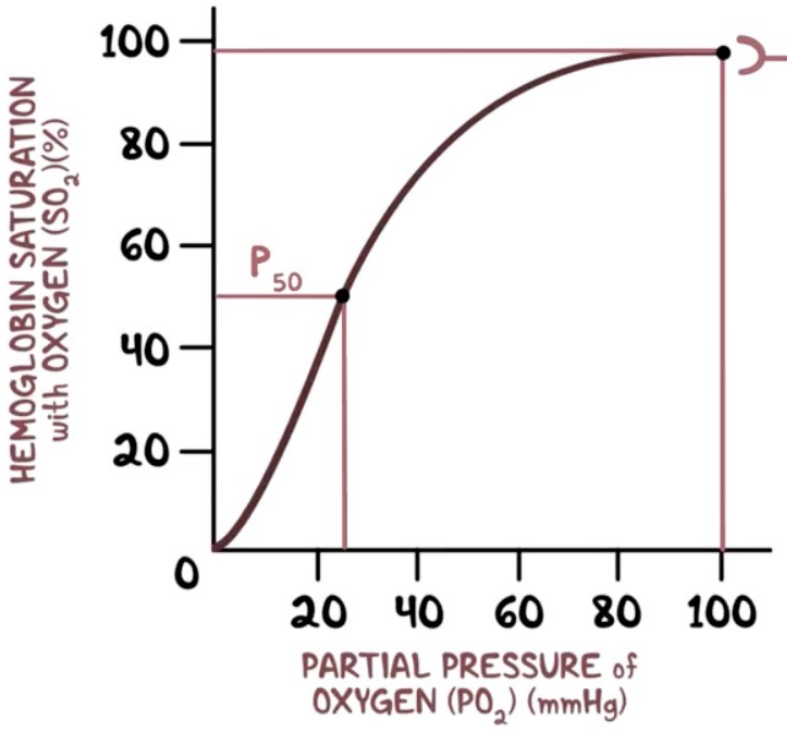
re neuronal activity?

activity nonetheless

1990: THE ADVENT OF FUNCTIONAL MRI



CONTRAST SOURCE OF FMRI



POSITIVE COOPERATIVITY

SIGMOIDAL SHAPE:
↑ O_2 AFFINITY with
↑ BOUND O_2 MOLECULES

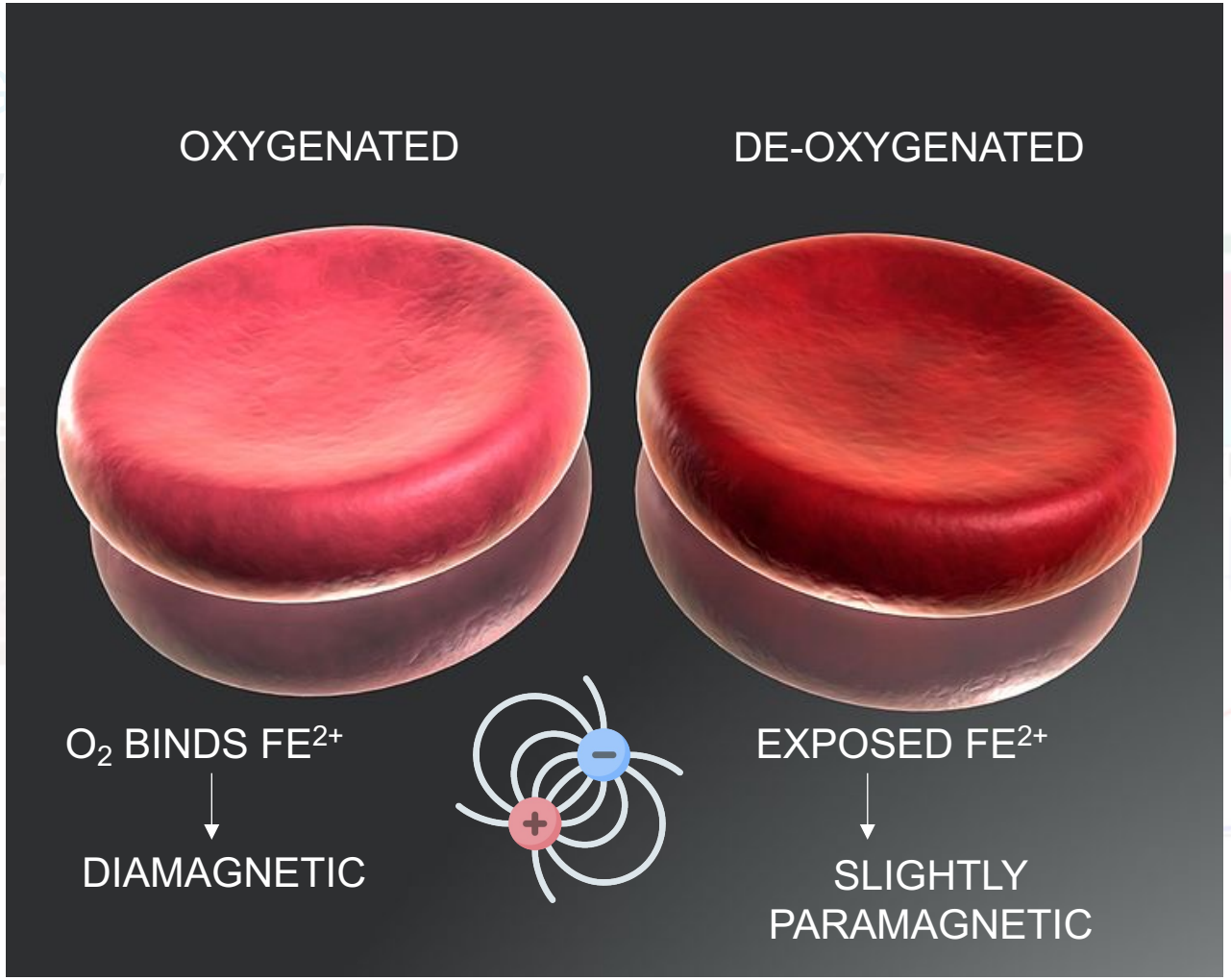
ARTERIAL BLOOD: PO_2= 100 mmHg

HEMOGLOBIN: FULLY SATURATED with O_2

VENOUS CAPILLARIES: PO_2= 40 mmHg

HEMOGLOBIN: 75% SATURATED with O_2

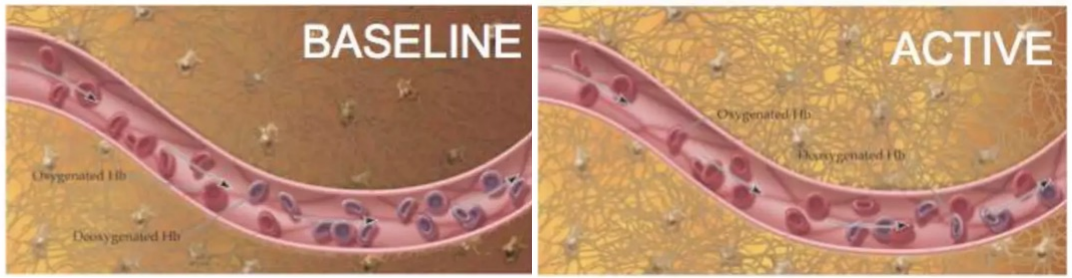
CONTRAST SOURCE OF FMRI

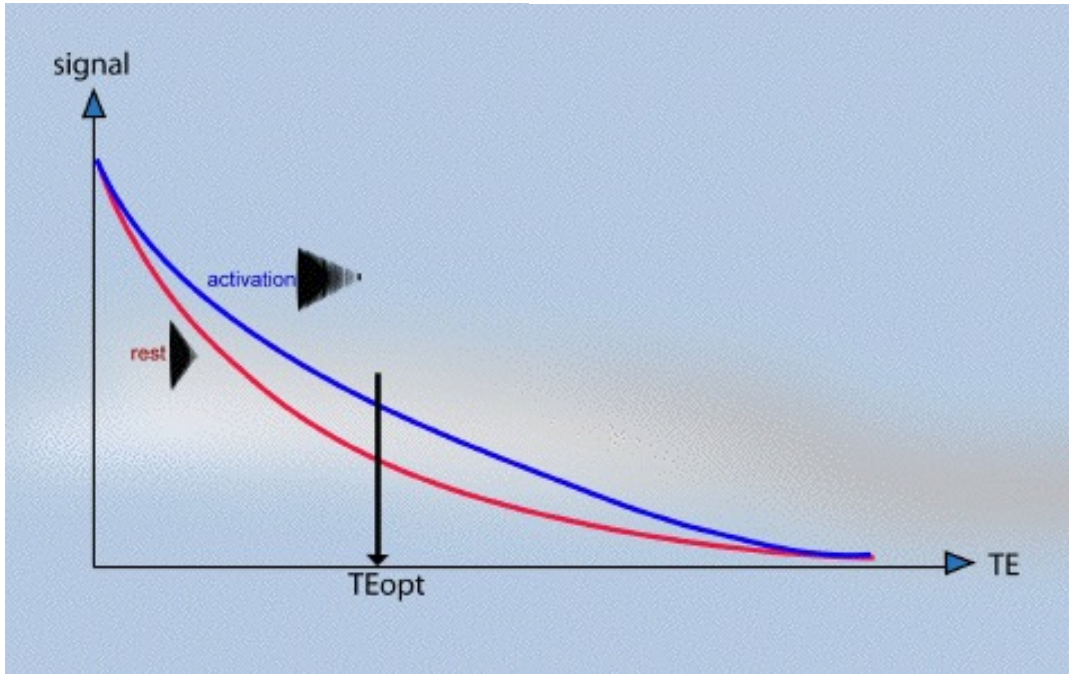


CONTRAST SOURCE OF FMRI

THE BOLD SIGNAL

- neurons consume oxygen and nutrients
- increased neural activity requires increased supply of oxygen
- oxygen is bound to hemoglobin (oxyhemoglobin vs. de-oxyhemoglobin)
- to supply neurons with oxygen and glucose, blood flow is increased locally
- the local increase in blood flow leads to a displacement of de-oxyhemoglobin
- MR signal is higher for oxygenated compared to de-oxygenated blood

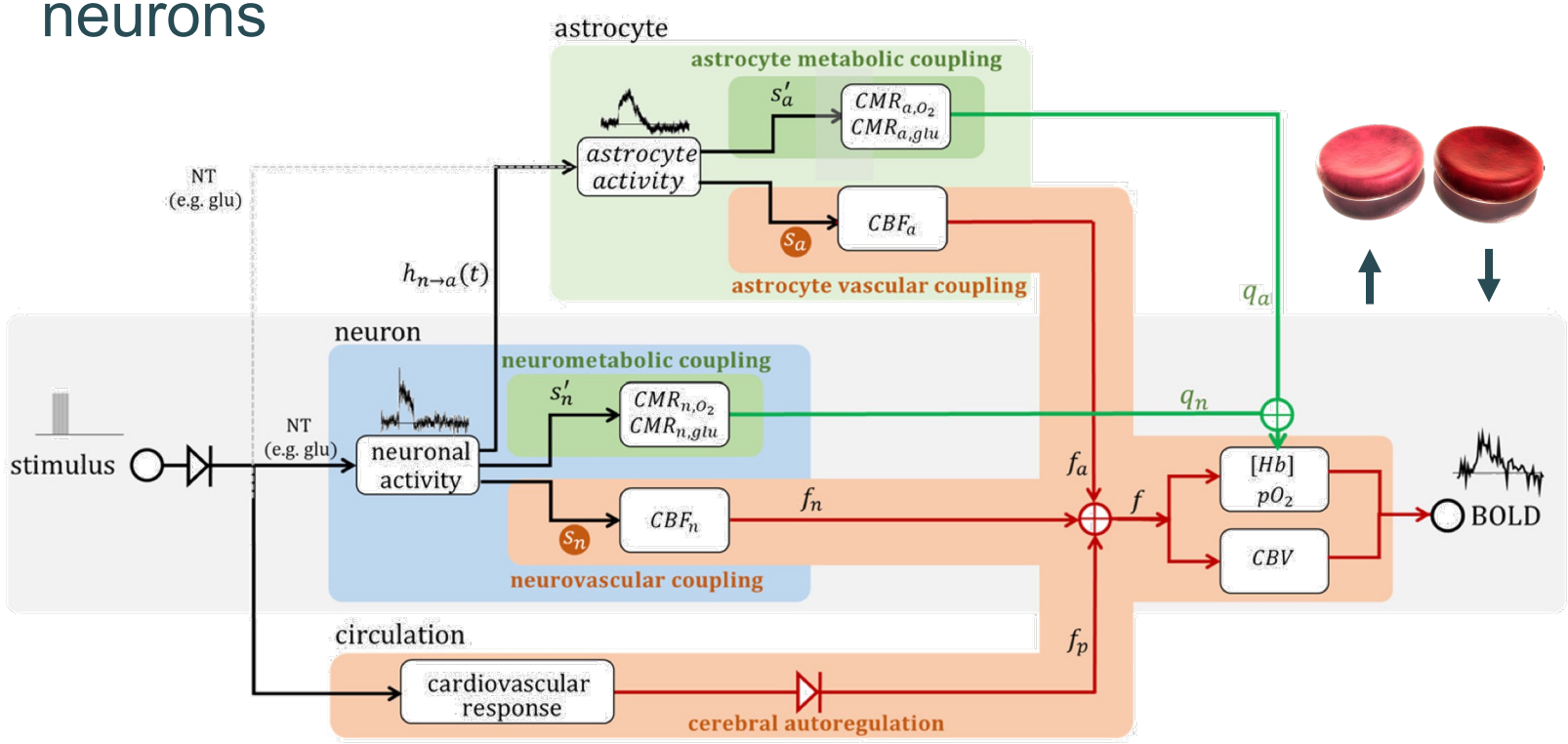




THE HEMODYNAMIC RESPONSE

not only

Made by neurons



Ioanas et al., *Neurophotonics* 2022

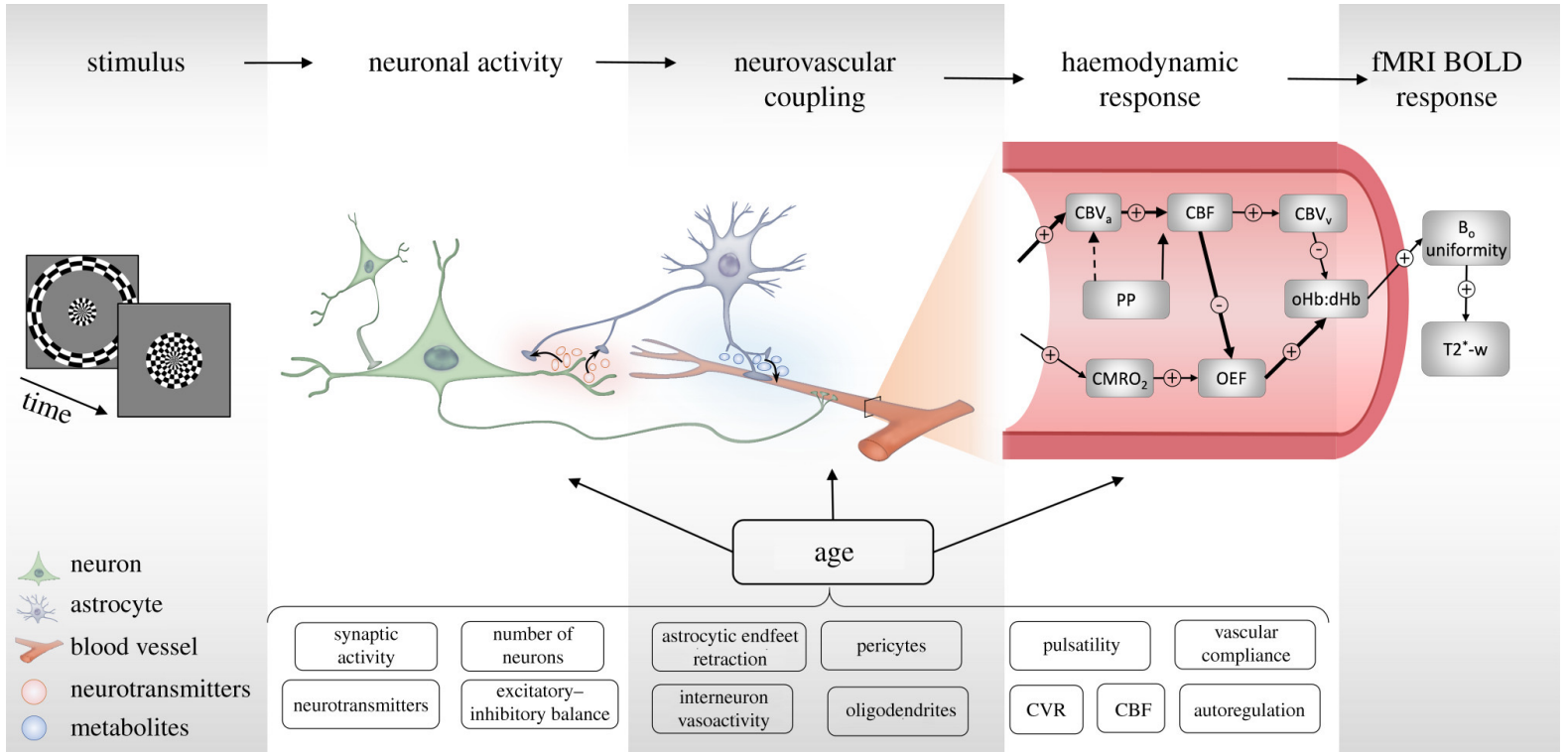
CAREFUL ON THE INTERPRETATION OF FMRI

Review articles

Separating vascular and neuronal effects of age on fMRI BOLD signals

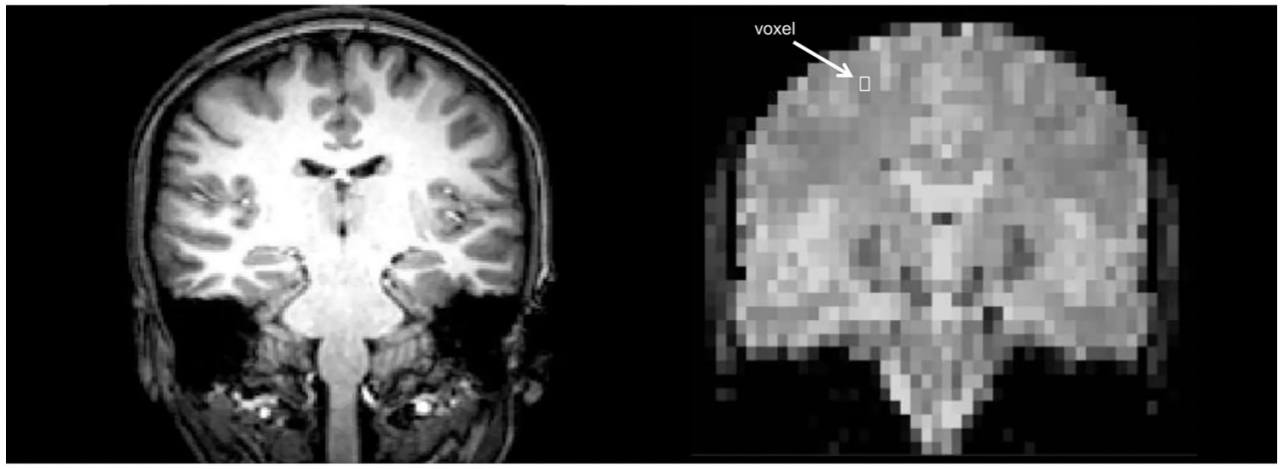
Kamen A. Tsvetanov ✉, Richard N. A. Henson and James B. Rowe

Published: 16 November 2020 | https://doi.org/10.1098/rstb.2019.0631

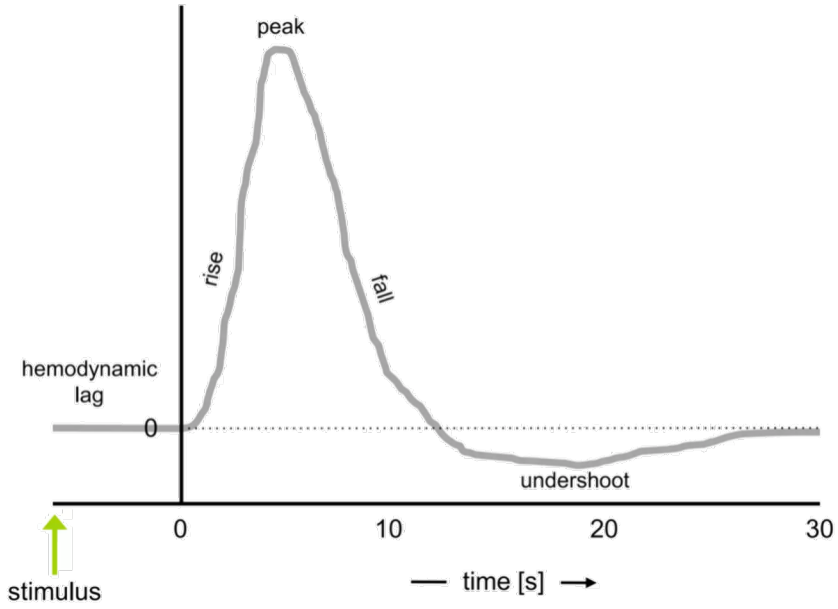


THE HEMODYNAMIC RESPONSE

The neurovascular unit works as a low-pass filter!

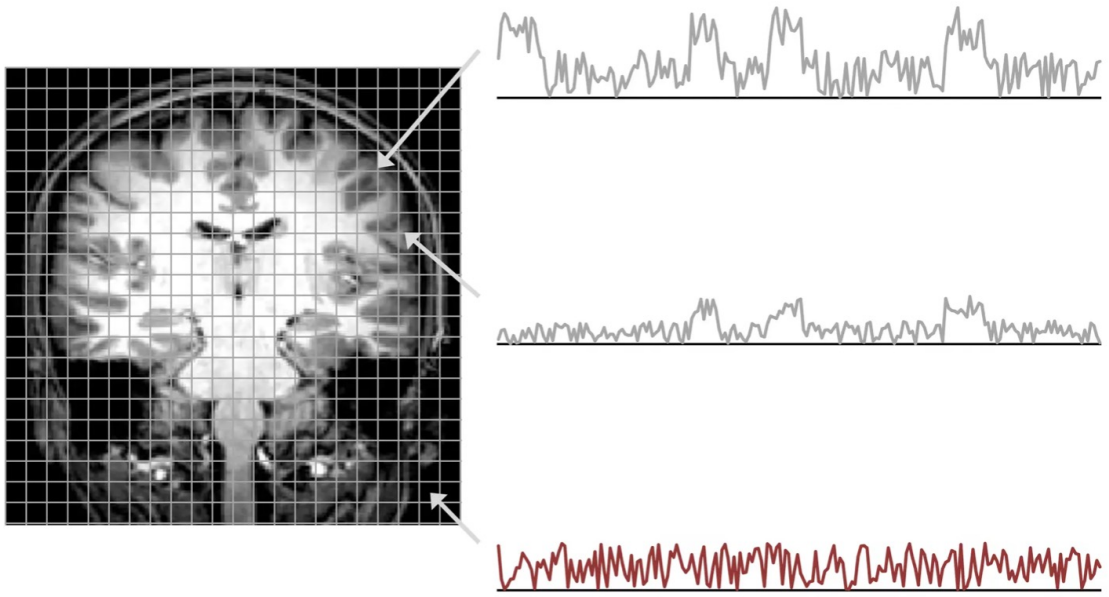


MRI functional MRI

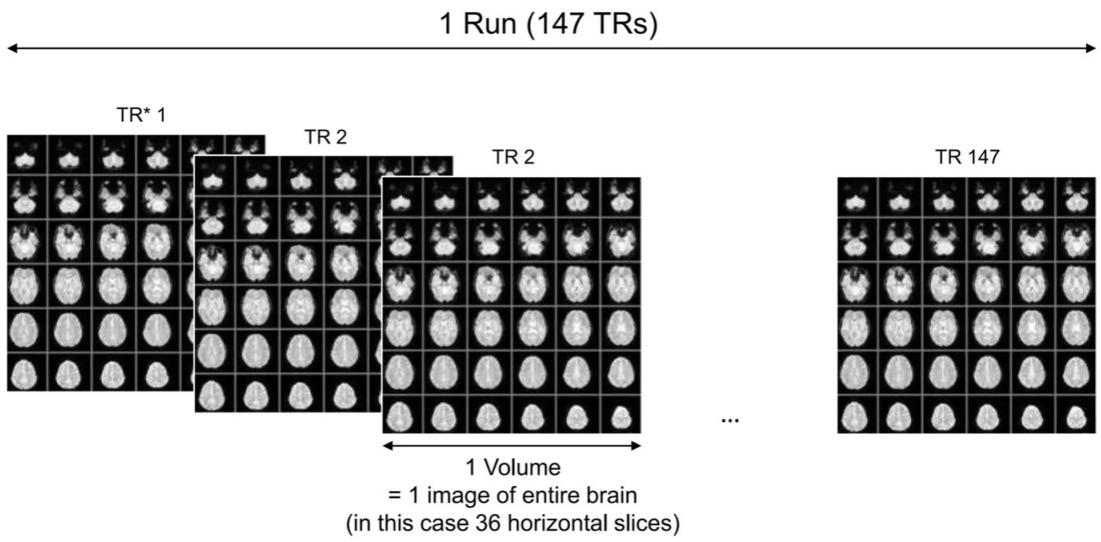


VOXEL RESOLUTION

A [BOLD] response is measured for every voxel



4-D datasets



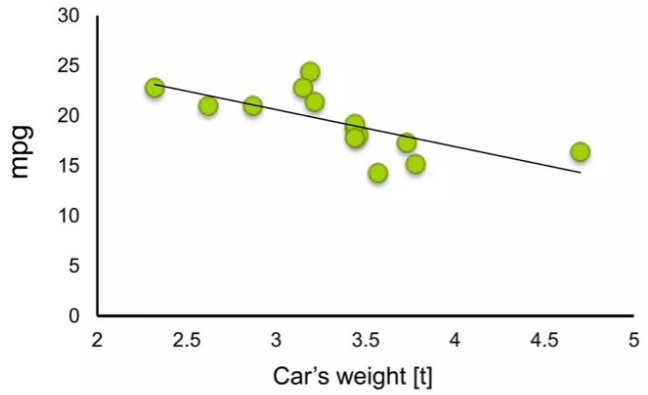
*TR = Time of Repetition = time it takes to acquire one volume

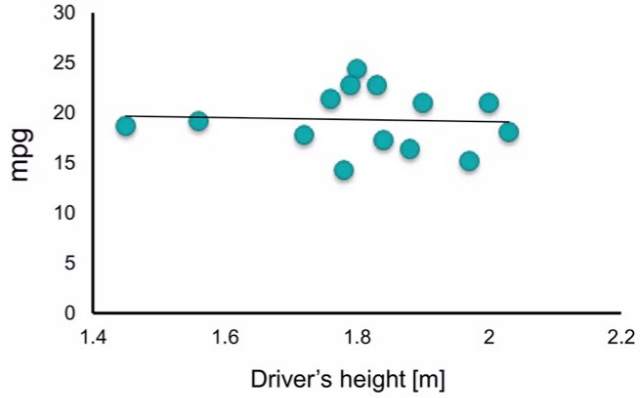
Regression in fMRI

Core idea: observed data can be explained by a combination of weighted regressors

Example: explain fuel consumption of a car (miles per gallon), based on the car's weight and the driver's height

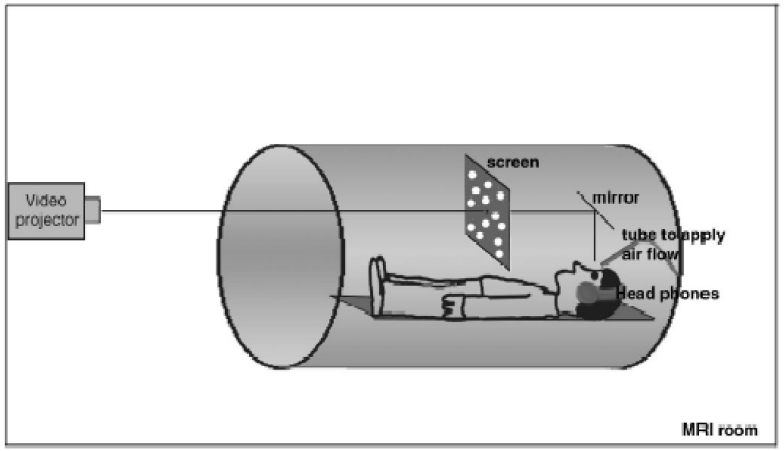
Observed data: mpg
Regressor: car's weight, driver's height
Weights: $\beta_{\text{car's weight}}$ = high
$\beta_{\text{driver's height}}$ = low

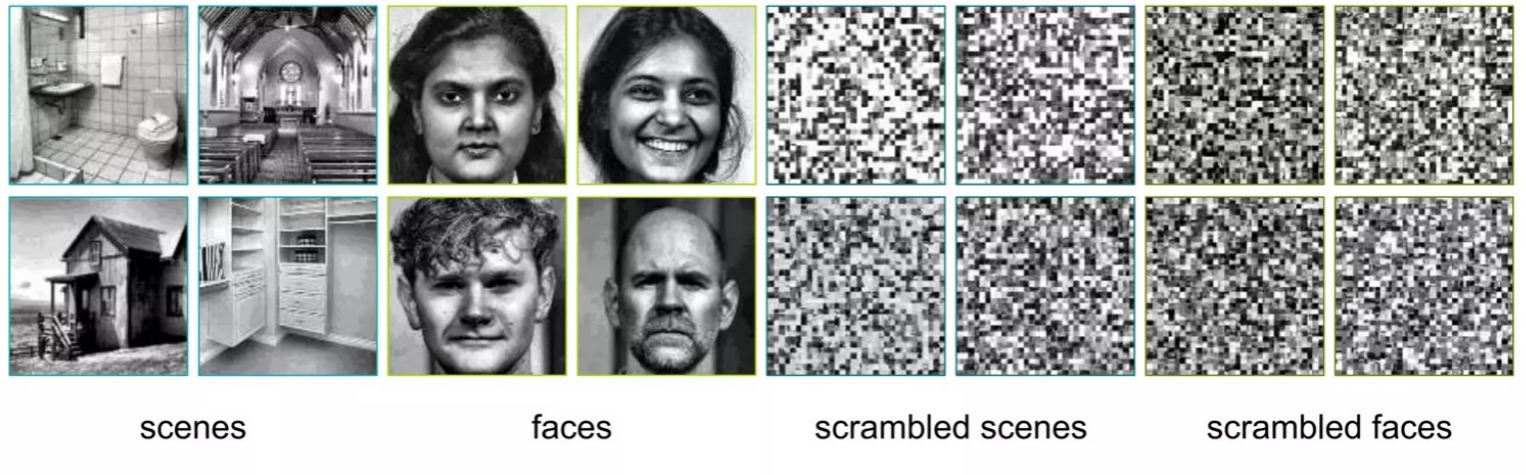




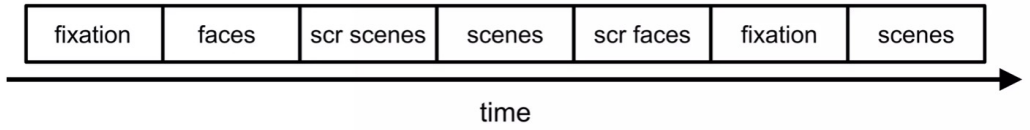
FMRI DATA ANALYSIS

Research question: which brain areas decode for scene/faces from scrambled images?



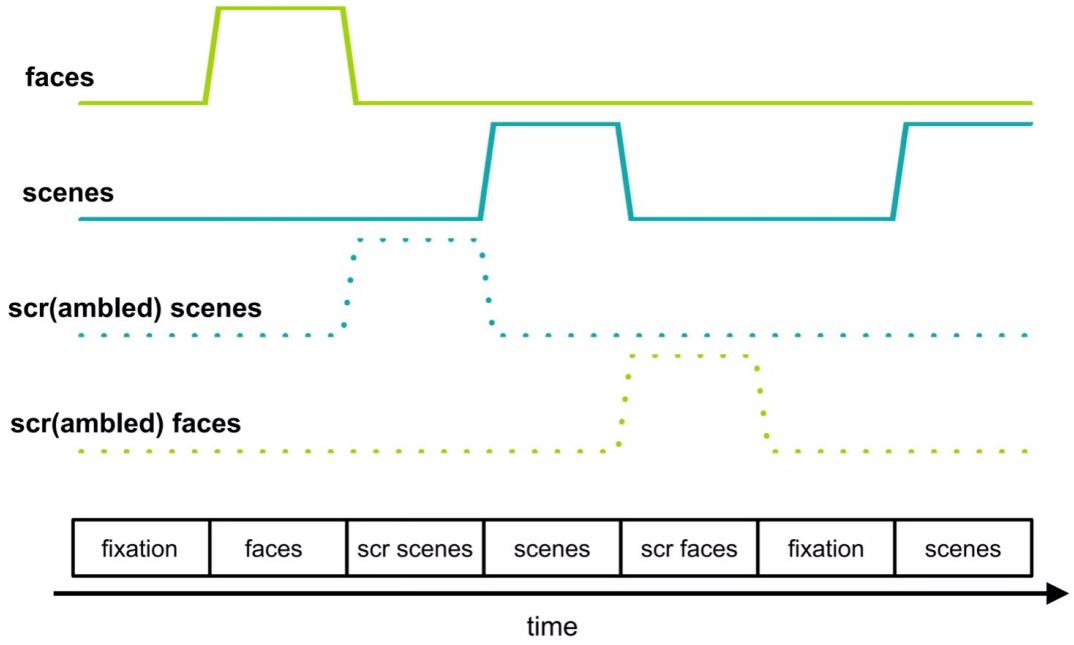


Stimuli are presented in a blocked design:



FMRI DATA ANALYSIS

Regressors: timing of conditions combined with assumptions about the shape of the BOLD response



FMRI DATA ANALYSIS

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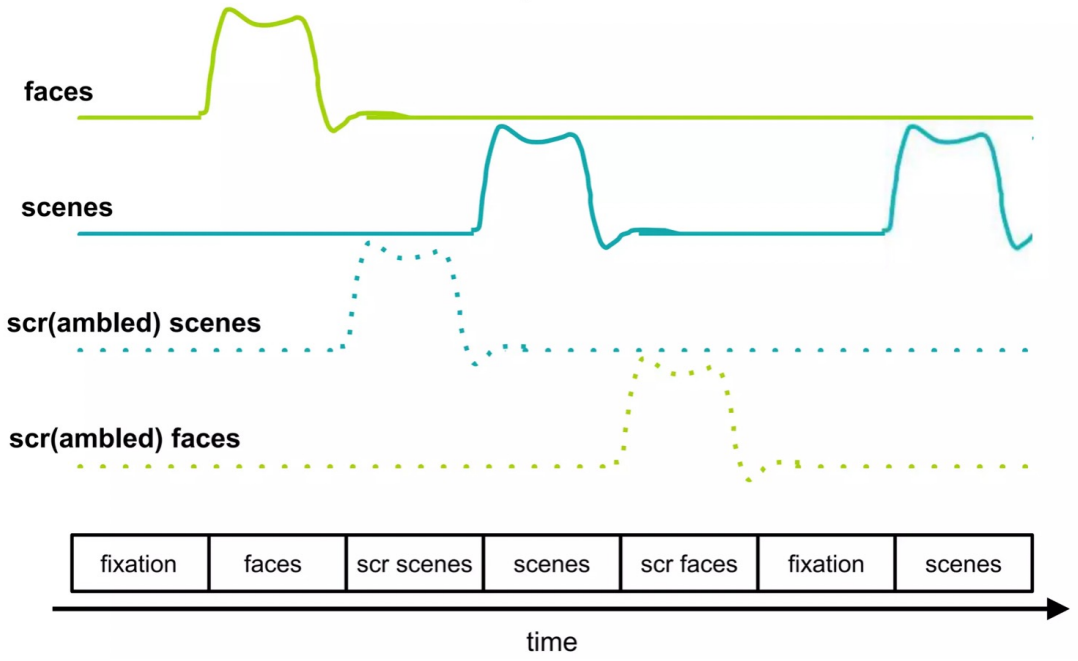

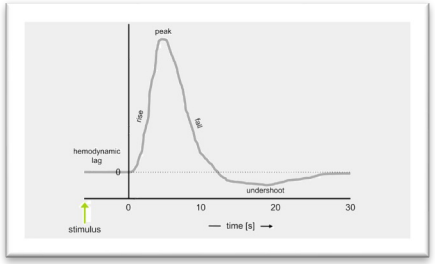

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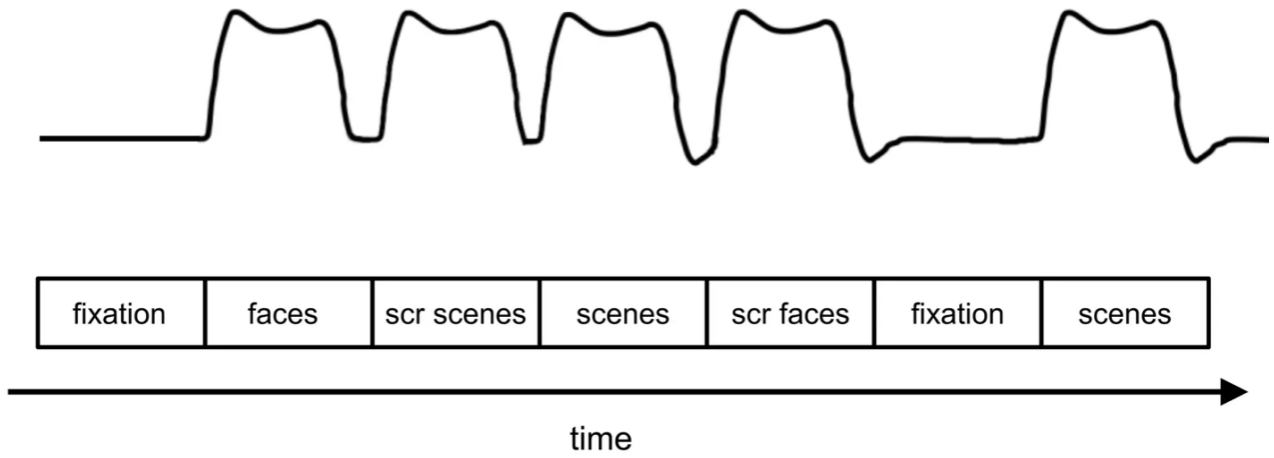
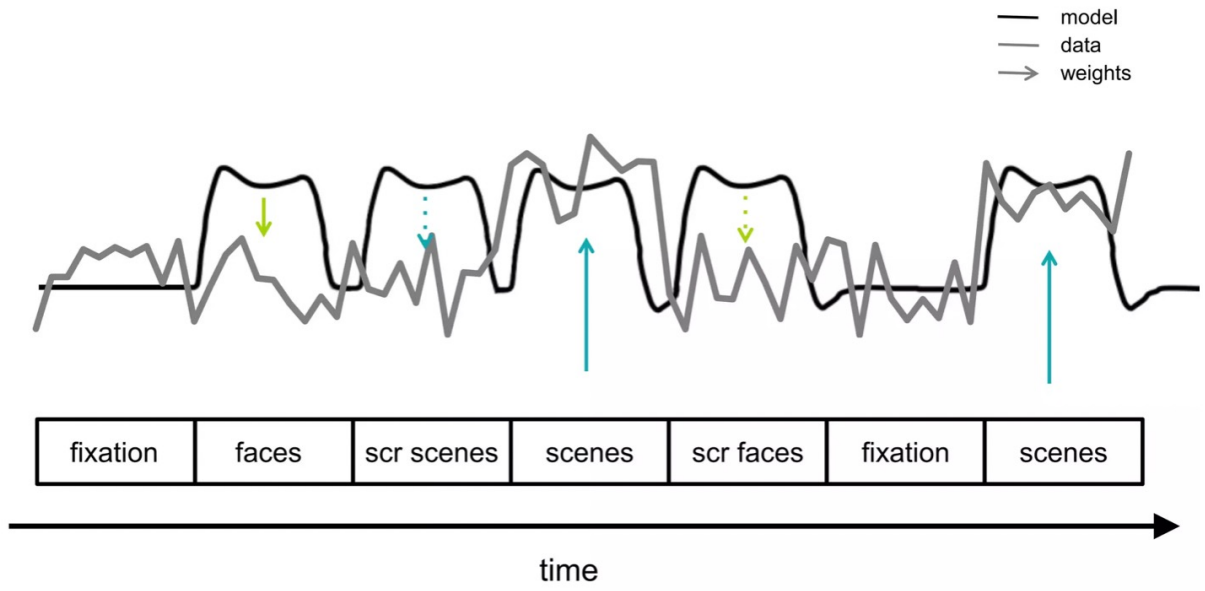


FMRI DATA ANALYSIS

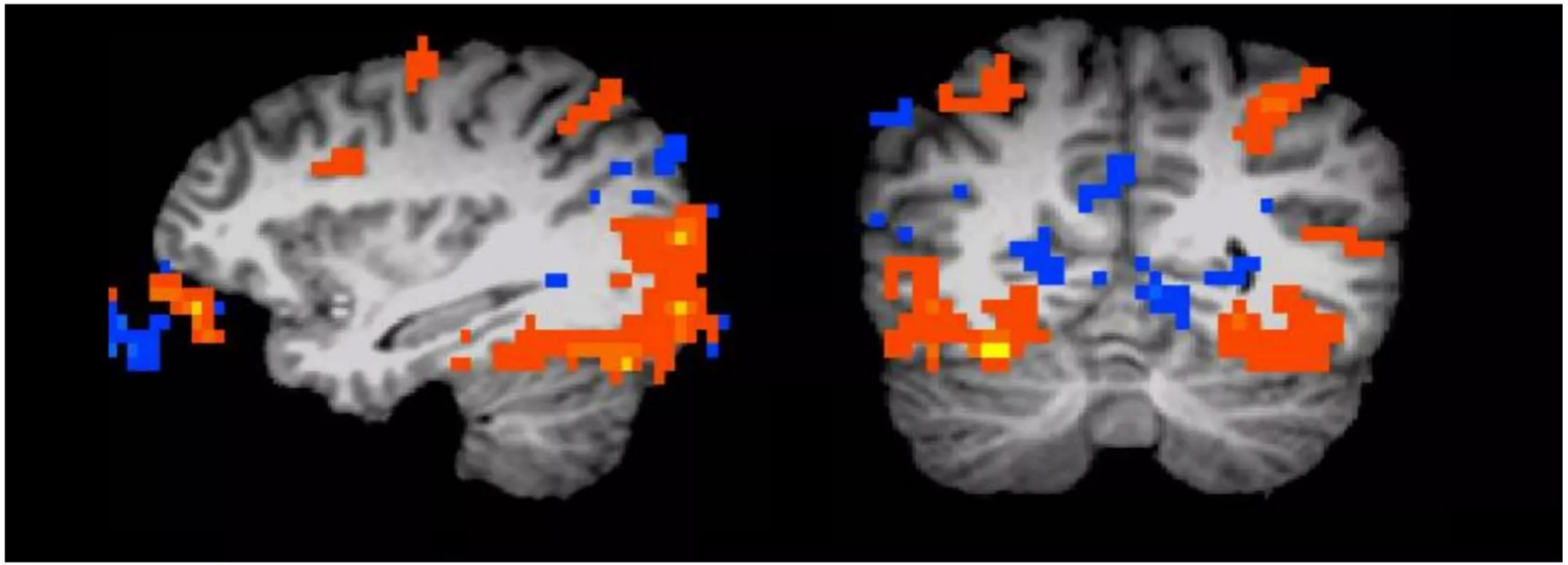
Regressors: timing of conditions combined with assumptions about the shape of the BOLD response



Regressors that account for a lot of variance in the signal receive high beta values (weights)!

FIRST LEVEL ANALYSIS

Weights are plotted as statistical parametric maps

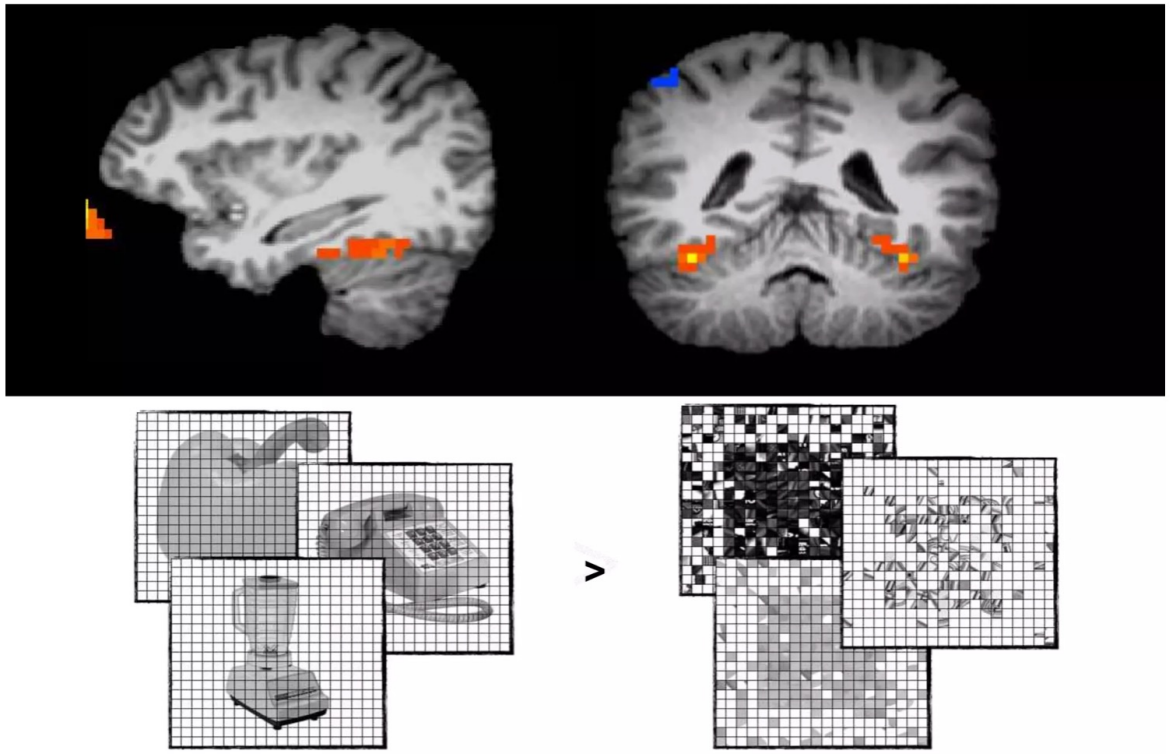


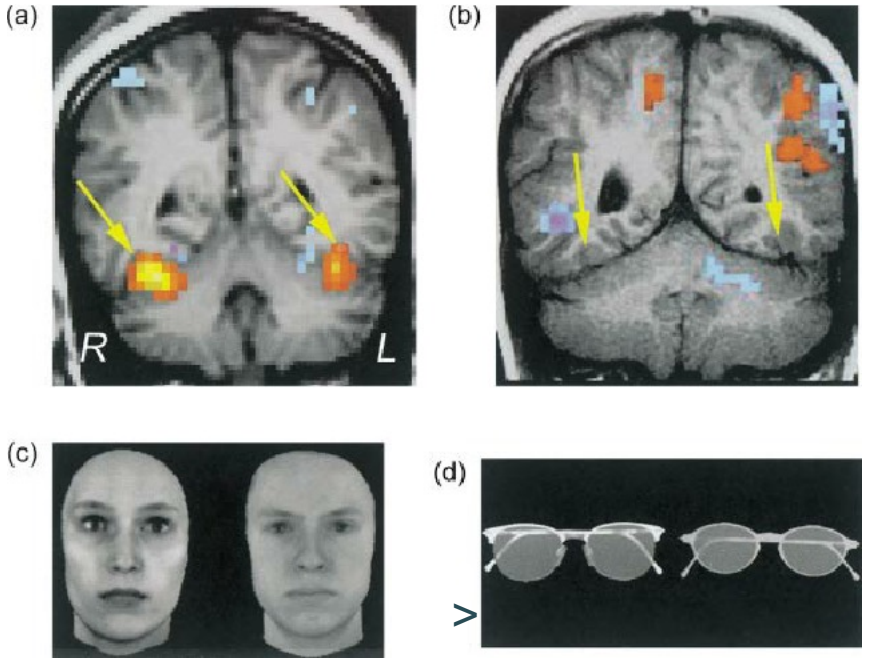
Eg. Voxels that get significantly activated during scenes

SECOND LEVEL ANALYSIS

Contrasts are used to test for differences among the levels of a factor:

Contrasts: intact vs. scrambled objects





Review > Dev Psychobiol. 2002 Apr;40(3):213-25. doi: 10.1002/dev.10028.

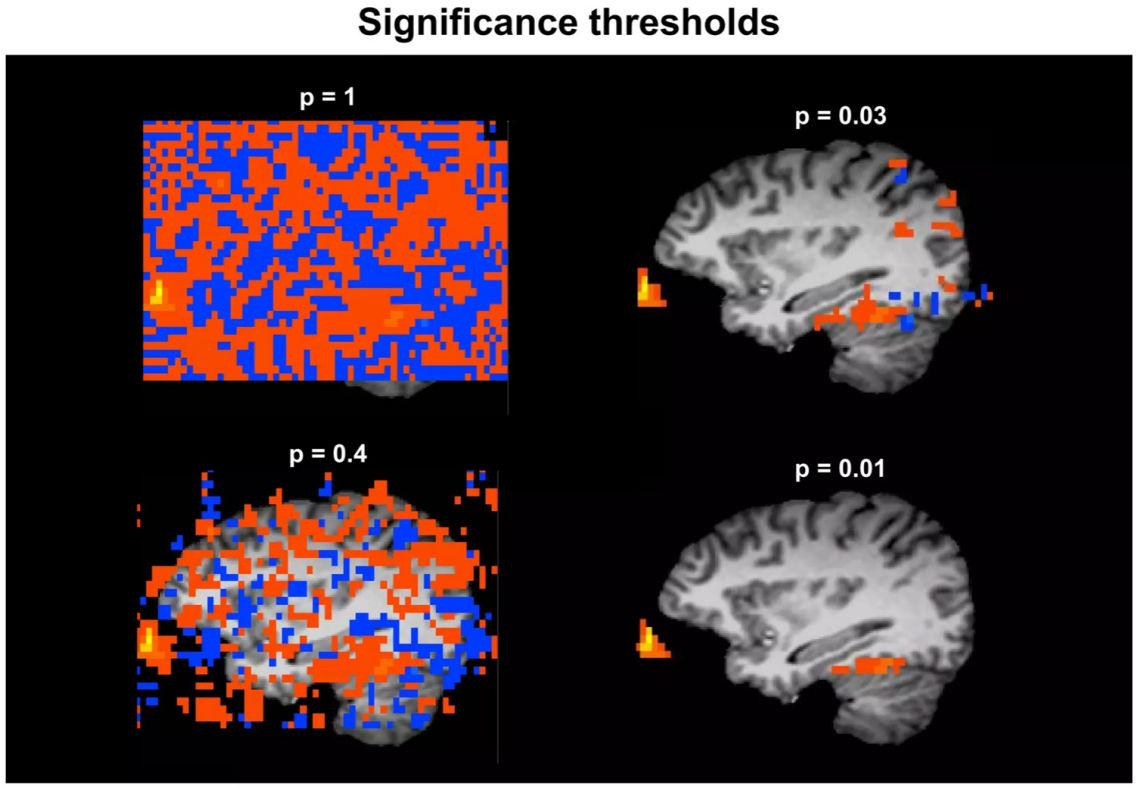
Social interest and the development of cortical face specialization: what autism teaches us about face processing

David J Grelotti [1], Isabel Gauthier, Robert T Schultz

Affiliations + expand

PMID: 11891634 DOI: 10.1002/dev.10028

THE DEAD SALMON

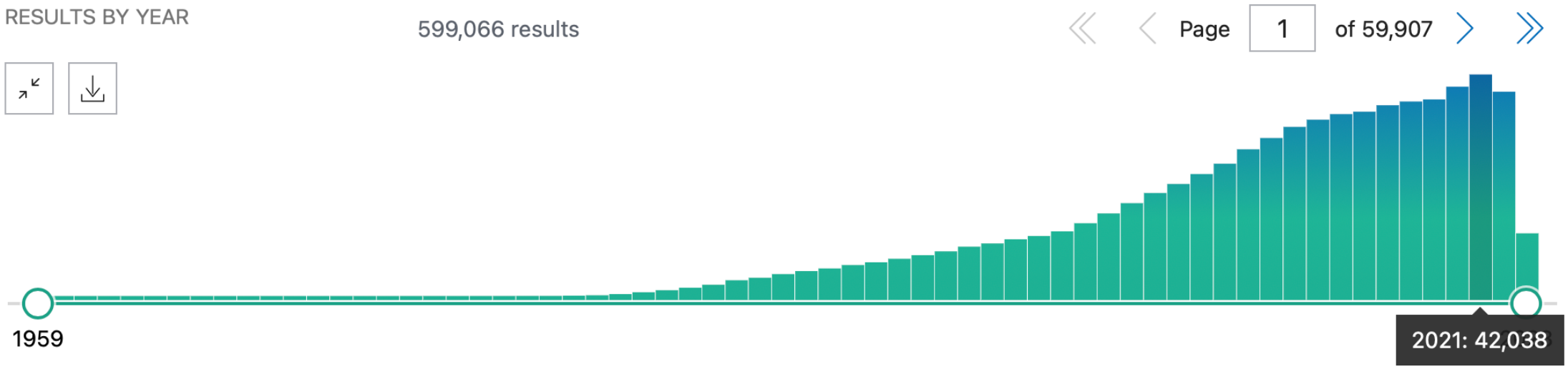


IgNobel Prize in Neuroscience: The dead salmon study

Bennett et al. "Neural Correlates of Interspecies Perspective Taking in the Post-Mortem Atlantic Salmon: An Argument For Proper Multiple Comparisons Correction" Journal of Serendipitous and Unexpected Results, 2010.

FMRI: STRENGTH IN NUMBERS

Number of articles with “fMRI” in their abstract



Source: pubmed.com

FMRI: STRENGTH IN NUMBERS

fMRI is still controversial today

nature

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Article | Open Access | Published: 16 March 2022

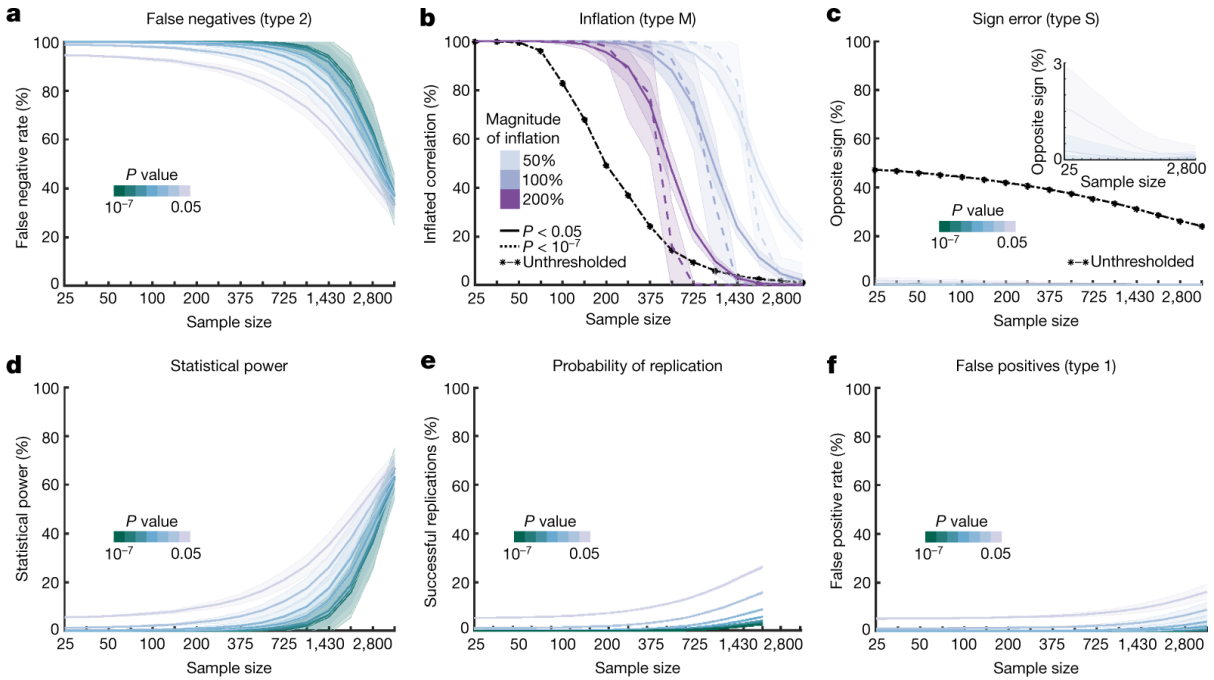
Reproducible brain-wide association studies require thousands of individuals

Scott Marek ✉, Brenden Tervo-Clemmens ✉, Finnegan J. Calabro, David F. Montez, Benjamin P. Kay, Alexander S. Hatoum, Meghan Rose Donohue, William Foran, Ryland L. Miller, Timothy J. Hendrickson, Stephen M. Malone, Sridhar Kandala, Eric Feczko, Oscar Miranda-Dominguez, Alice M. Graham, Eric A. Earl, Anders J. Perrone, Michaela Cordova, Olivia Doyle, Lucille A. Moore, Gregory M. Conan, Johnny Uriarte, Kathy Snider, Benjamin J. Lynch, James C. Wilgenbusch, Thomas Pengo, Angela Tam, Jianzhong Chen, Dillan J. Newbold, Annie Zheng, Nicole A. Seider, Andrew N. Van, Athanasia Metoki, Roselyne J. Chauvin, Timothy O. Laumann, Deanna J. Greene, Steven E. Petersen, Hugh Garavan, Wesley K. Thompson, Thomas E. Nichols, B. T. Thomas Yeo, Deanna M. Barch, Beatriz Luna, Damien A. Fair ✉ & Nico U. F. Dosenbach ✉ — Show fewer authors

Nature **603**, 654–660 (2022) | Cite this article

64k Accesses | **277** Citations | **1511** Altmetric | Metrics

"A primary challenge has been replicating associations between inter-individual differences in brain structure or function and complex cognitive or mental health phenotypes (brain-wide association studies (BWAS))"

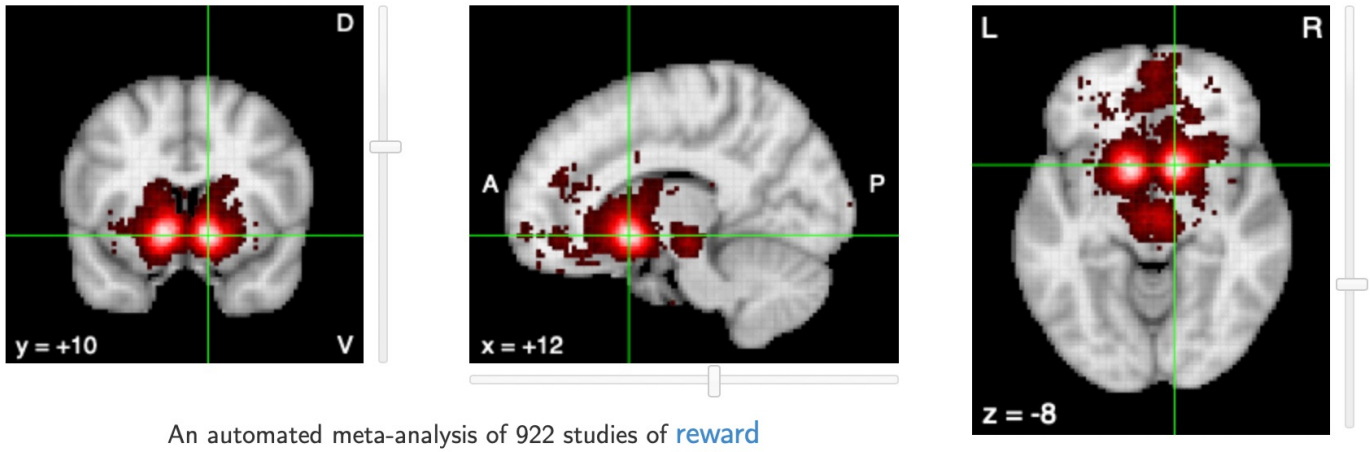


FMRI: STRENGTH IN NUMBERS

neurosynth.org

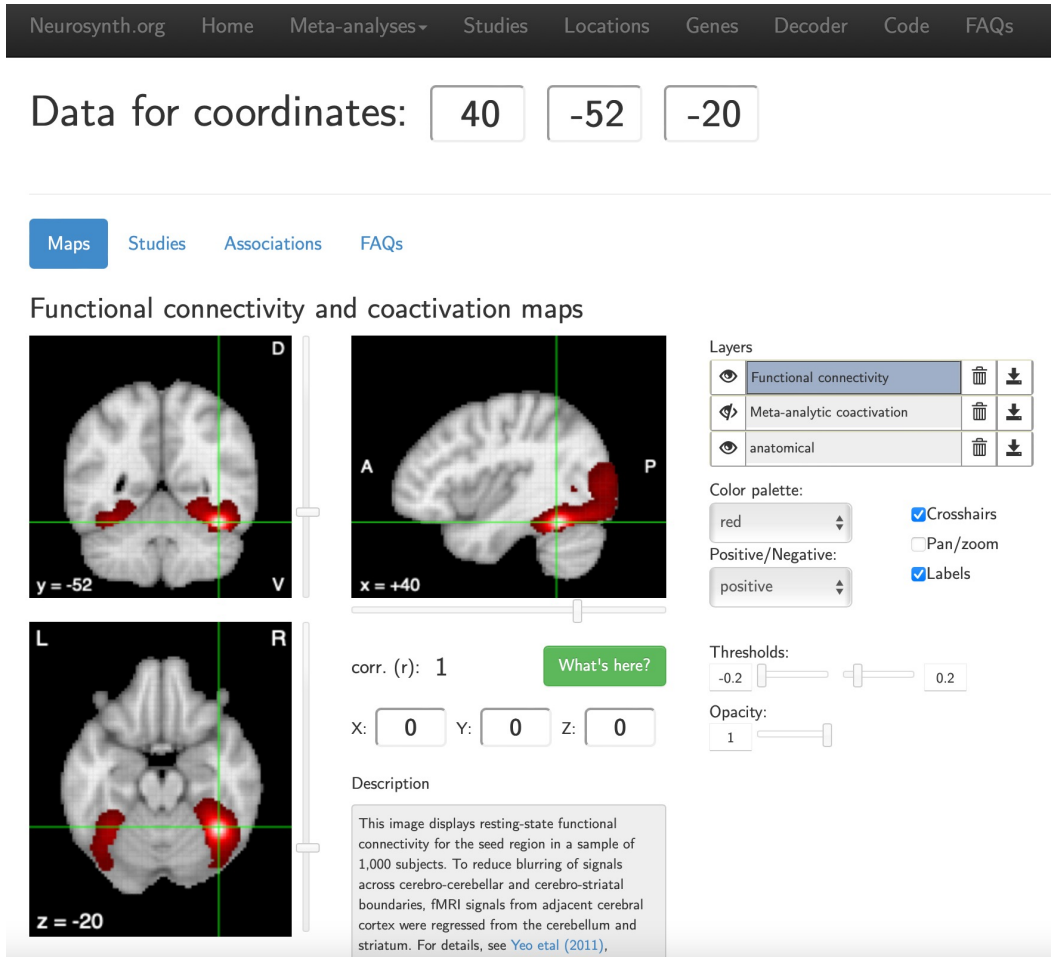
Neurosynth is a platform for large-scale, automated synthesis of functional magnetic resonance imaging (fMRI) data.

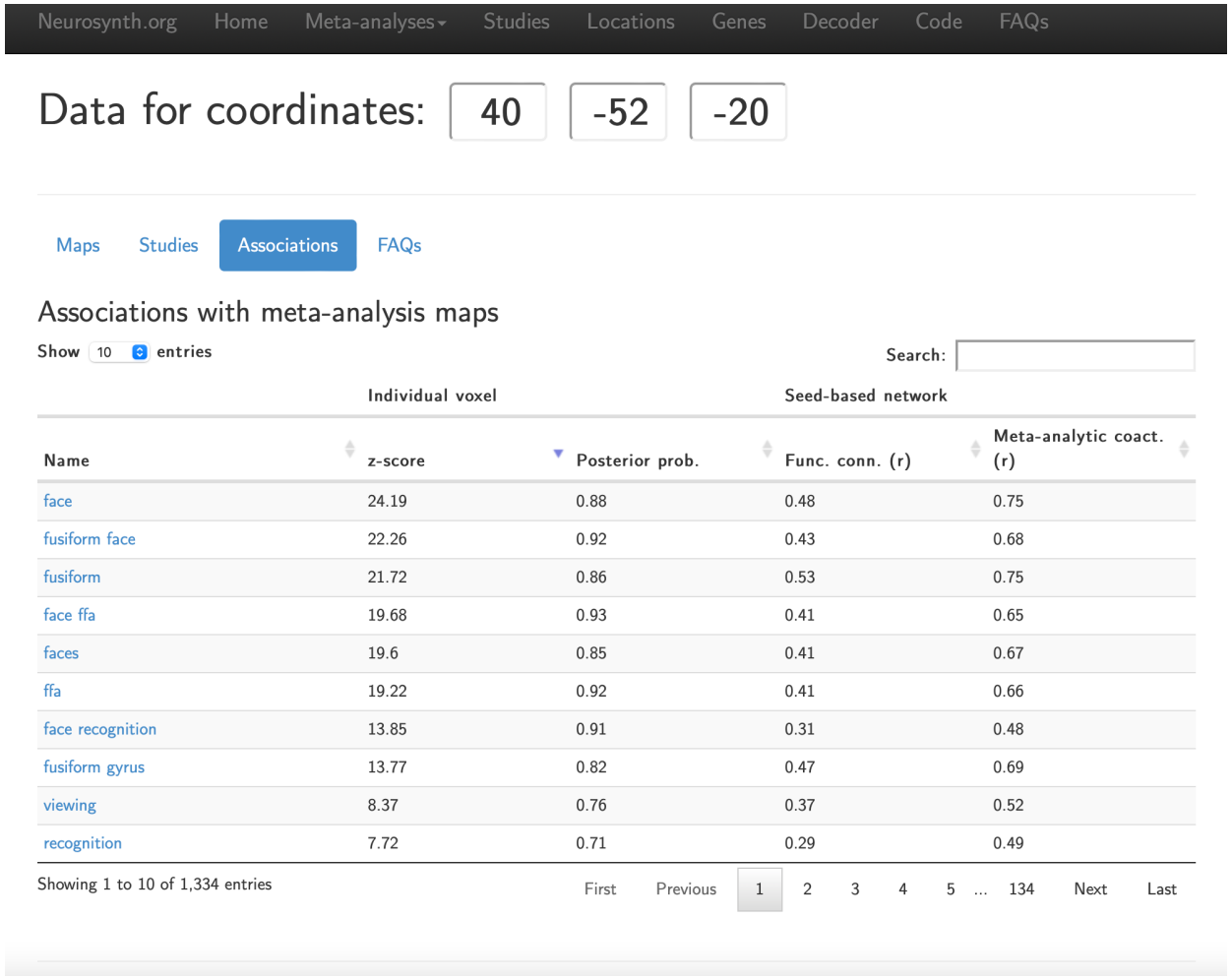
It takes thousands of published articles reporting the results of fMRI studies, chews on them for a bit, and then spits out images that look like this:



An automated meta-analysis of 922 studies of reward

FMRI: STRENGTH IN NUMBERS

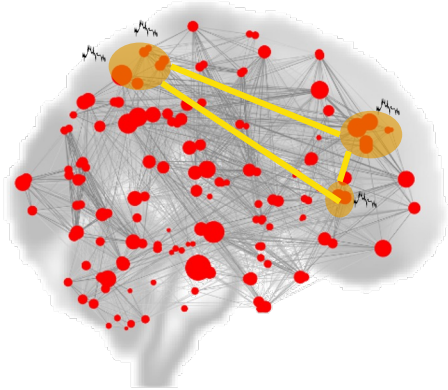


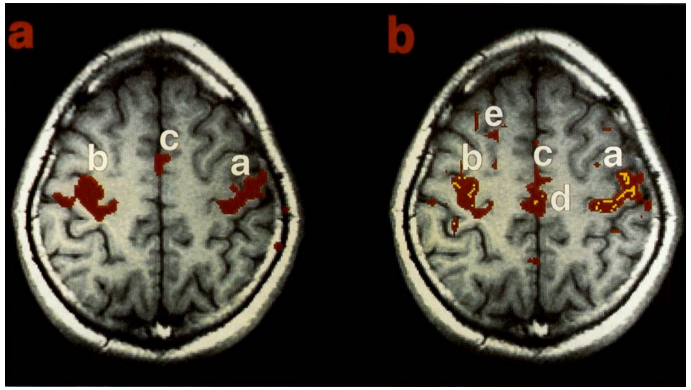


CAN WE MEASURE MEANINGFUL BRAIN ACTIVITY IN THE ABSENCE OF A TASK?

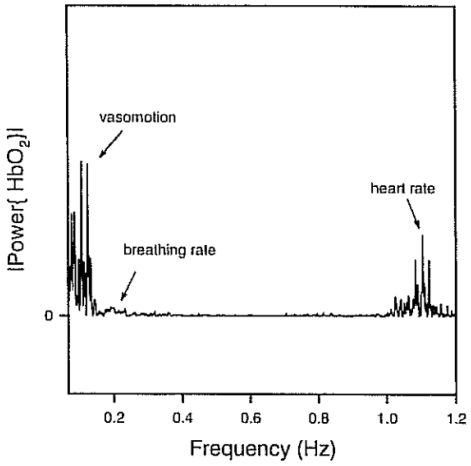
→ RESTING-STATE fMRI

- the brain is always active, even in the absence of explicit input or output
  - task-related changes in neuronal metabolism are only about 5% of brain's total energy consumption
- what is the "noise" in standard activation studies?
  - peaks in frequency oscillations from 0.01 – 0.10 Hz
  - distinct from faster frequencies of respiratory and cardiac responses

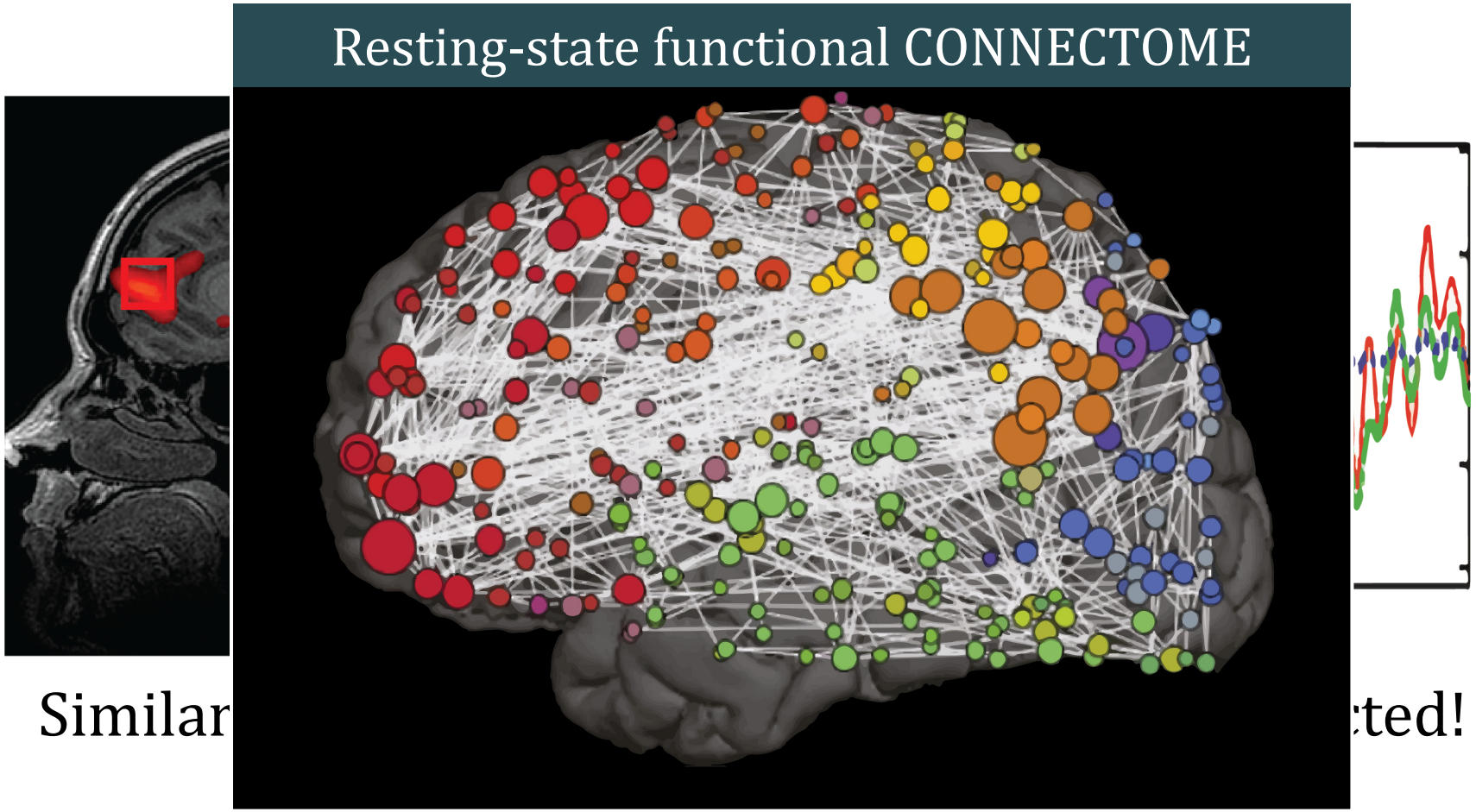




Biswal et al., 1995

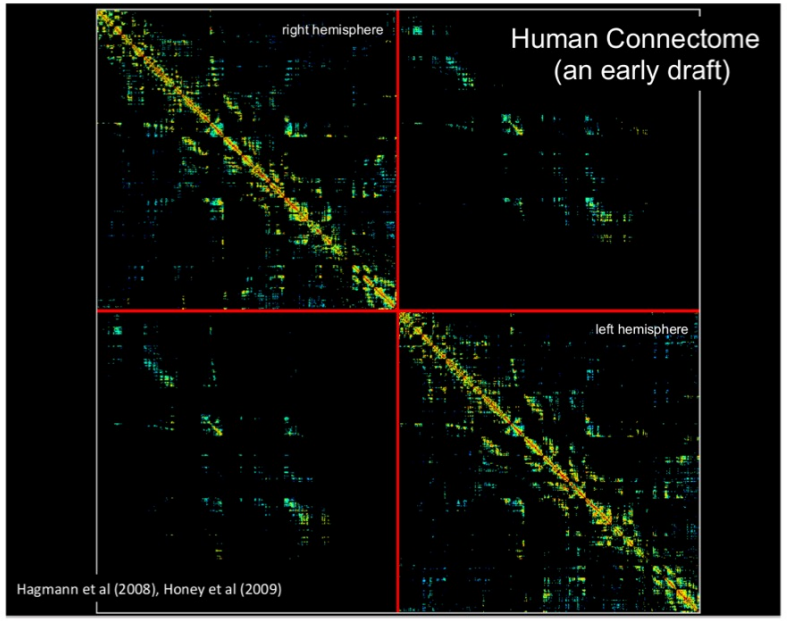


CAN WE MEASURE MEANINGFUL BRAIN ACTIVITY IN THE ABSENCE OF A TASK?



THE CONNECTOME

In 2005, Dr. Olaf Sporns at Indiana University and Dr. Patric Hagmann at Lausanne University Hospital independently and simultaneously suggested the term **"connectome"** to refer to a map of the neural connections within the brain. This term was directly inspired by the ongoing effort to sequence the human genetic code—to build a genome. **"Connectomics"** (Hagmann, 2005) has been defined as the science concerned with assembling and analyzing connectome data sets.



“a comprehensive description of all the network of elements and connections forming the brain ".

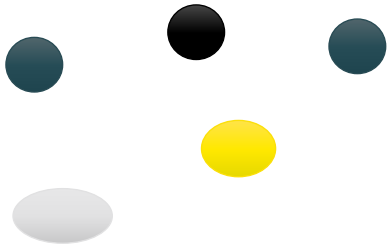
THE CONNECTOME

Connectome (Google search, 2005) = “Connect home?”

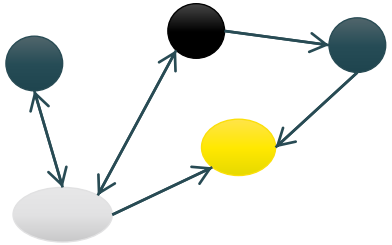
Connectome (Google search, 2020) = 1.500.000 results

THE CONNECTOME

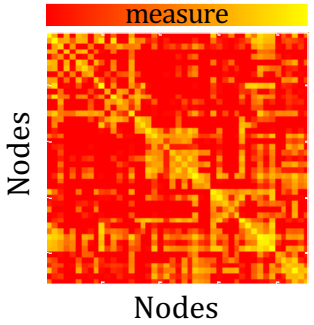
Step 1: define “nodes” (brain regions)



Step 2: define “edges” (brain connections)



Step 3: analysis of the connectivity matrix



THE CONNECTOME

- From an anatomical perspective, the connectome is the ensemble of all brain neurons of axonal origin, termination, and trajectory relative to other structures

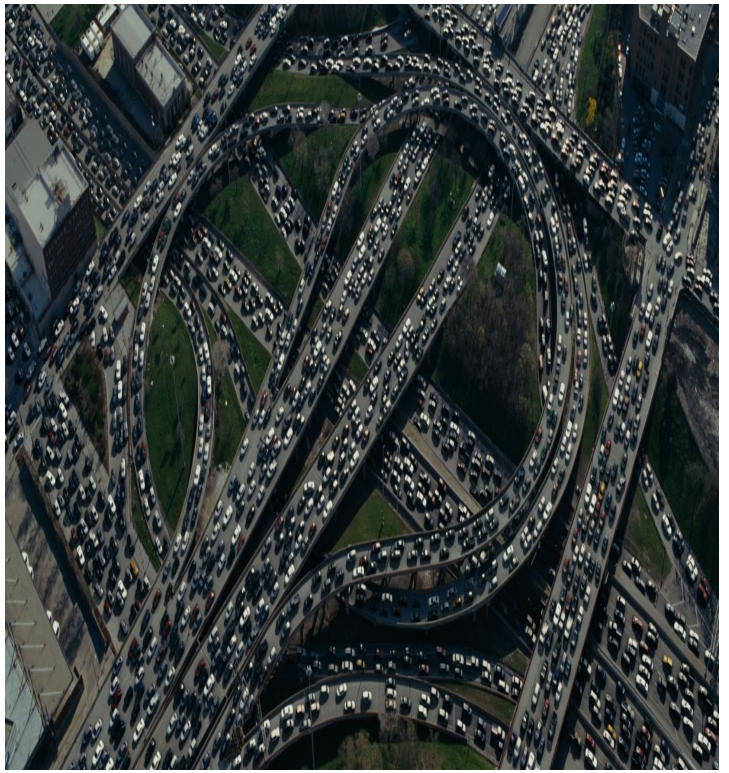
Structural/Anatomical connectome

Functional connectome

THE CONNECTOME

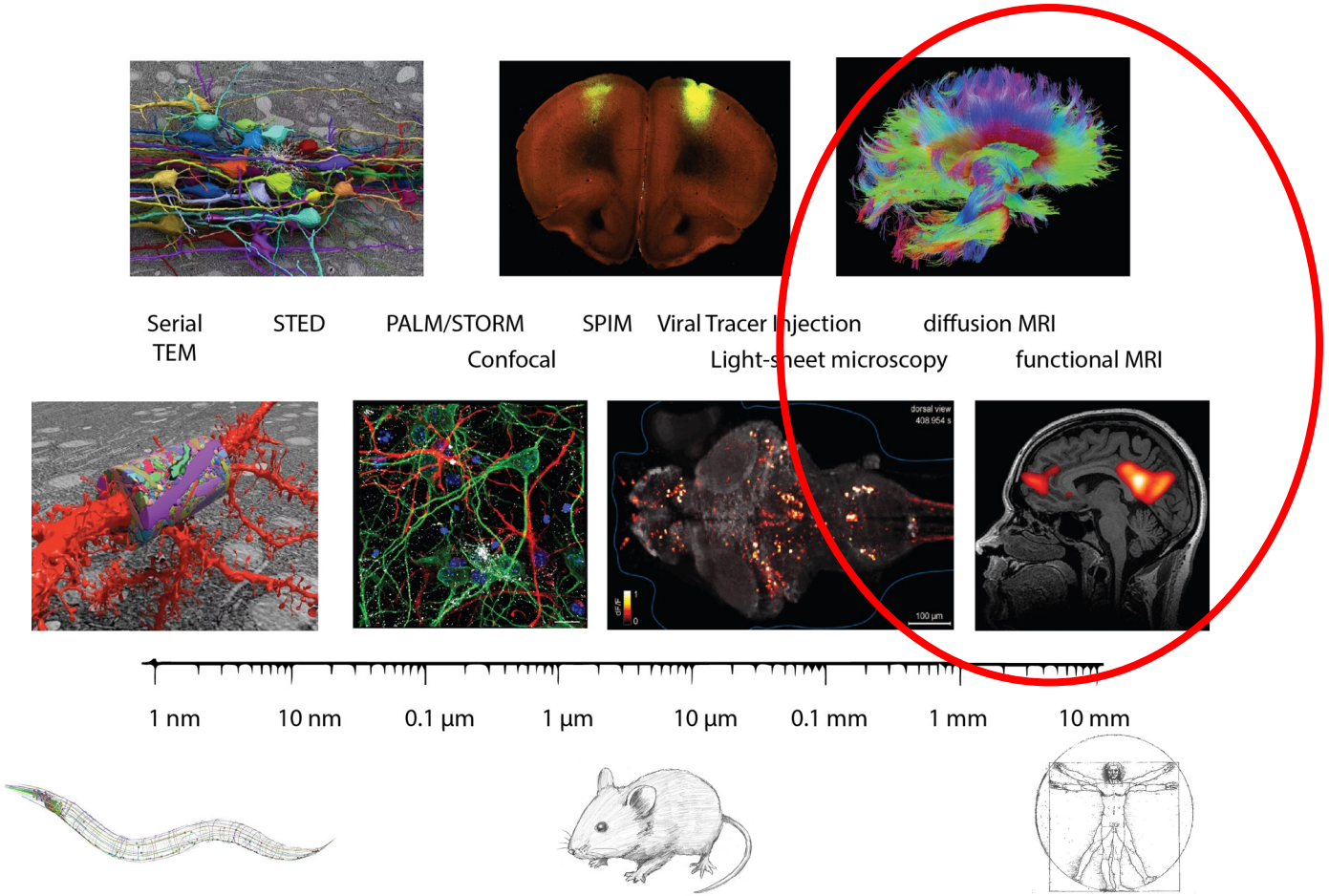
- From a functional perspective, the connectome is the description of how neurons/areas interact with each other

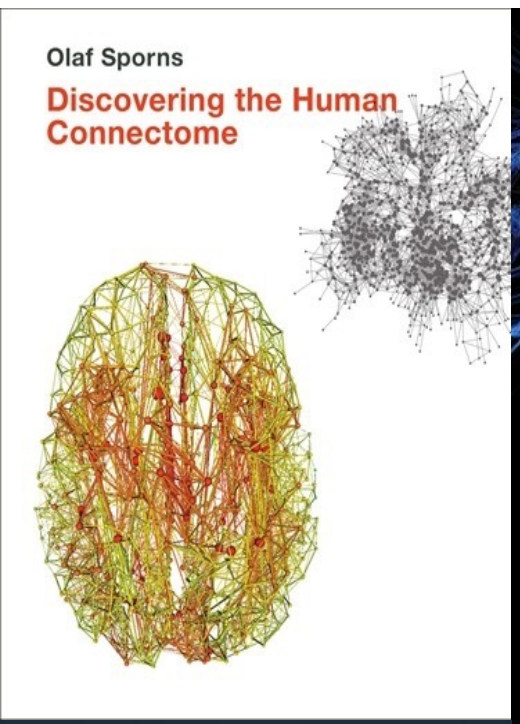
Structural/Anatomical connectome



Functional connectome

CONNECTOMICS AT DIFFERENT SCALES

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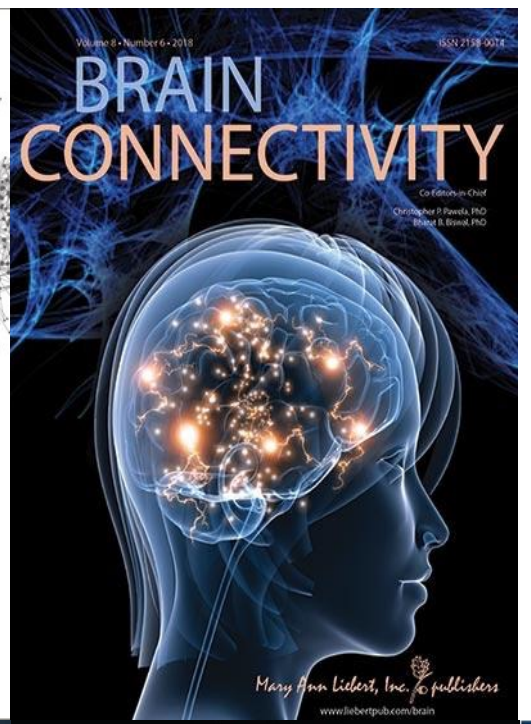
Discovering the Human Connectome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Volume 23 Number 1
January 2019
ISSN 1364-6613
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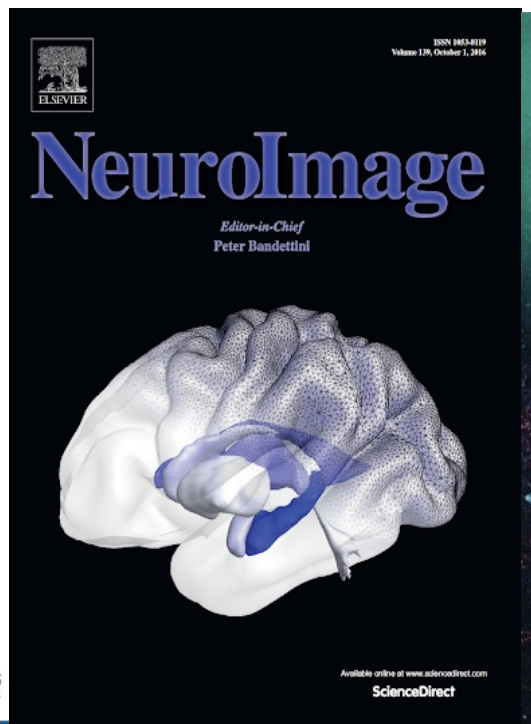
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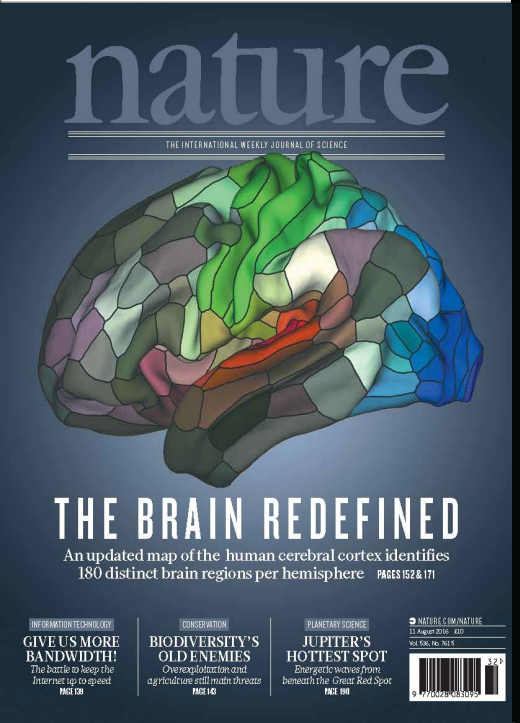
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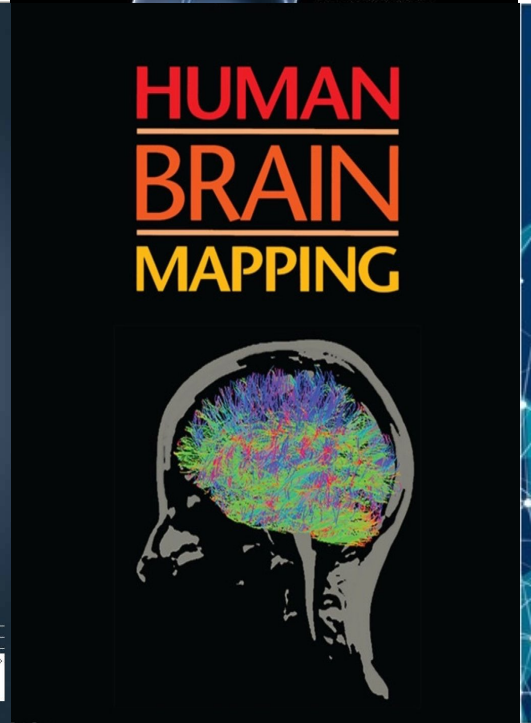
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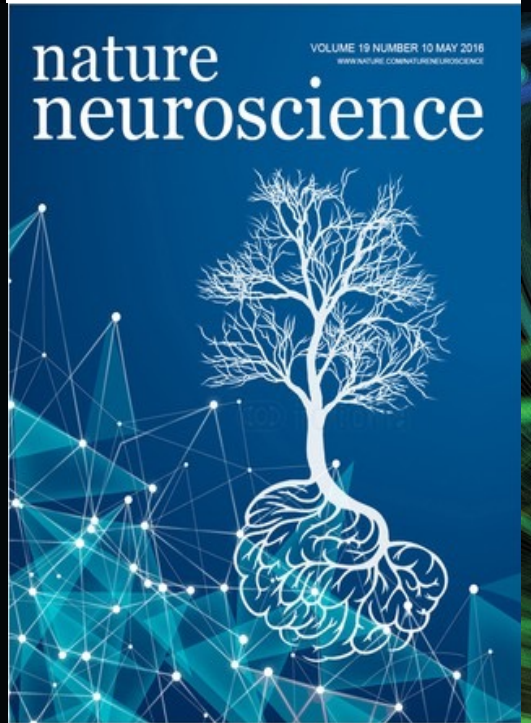
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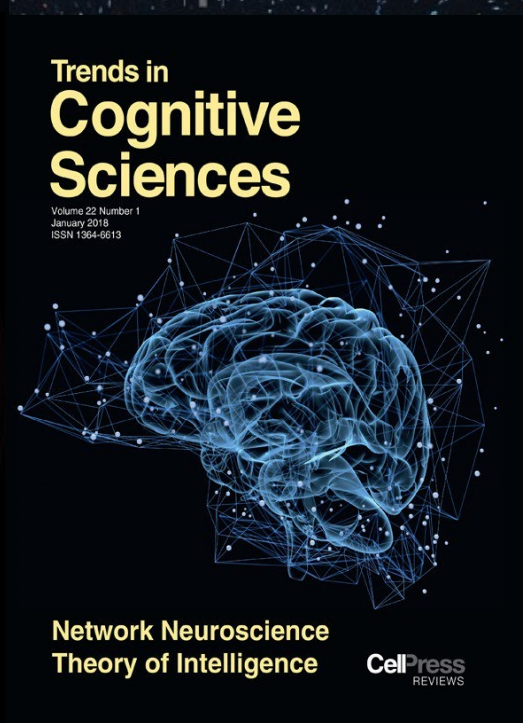
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REVIEWS

CONNECTOME: ONE APPLICATION

Resting-state fMRI

Functional connectome fingerprinting: identifying individuals using patterns of brain connectivity

Emily S Finn[1,7], Xilin Shen[2,7], Dustin Scheinost[2], Monica D Rosenberg[3], Jessica Huang[2], Marvin M Chun[1,3,4], Xenophon Papademetris[2,5] & R Todd Constable[1,2,6]

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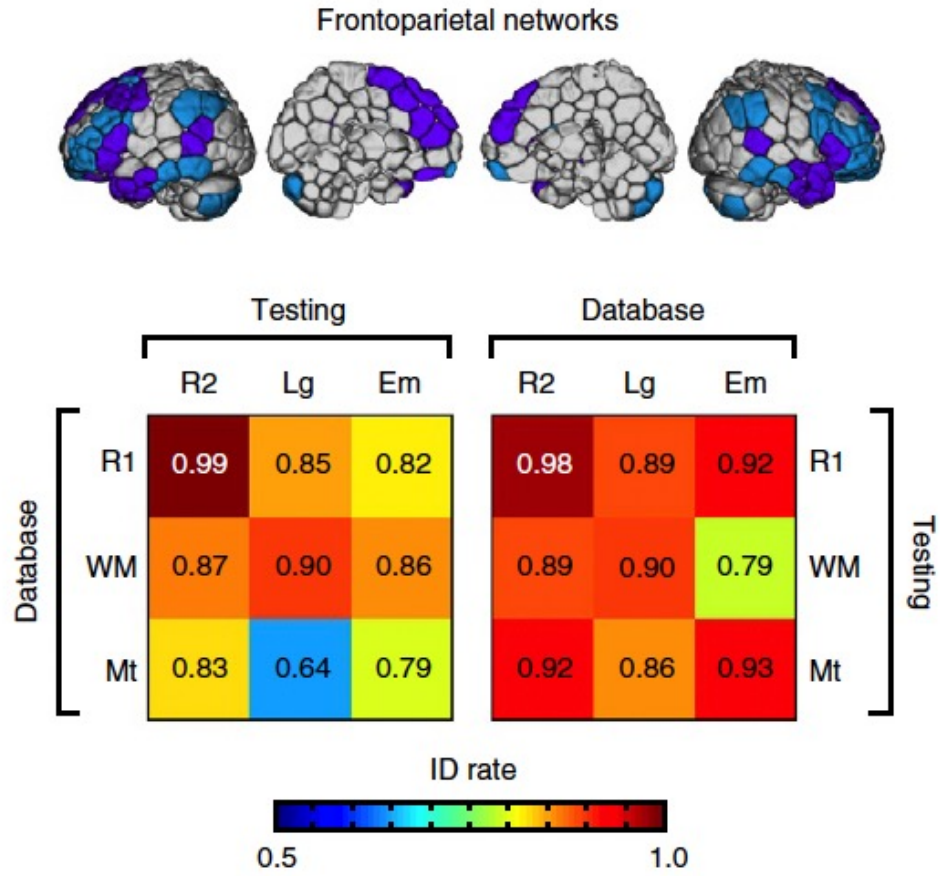

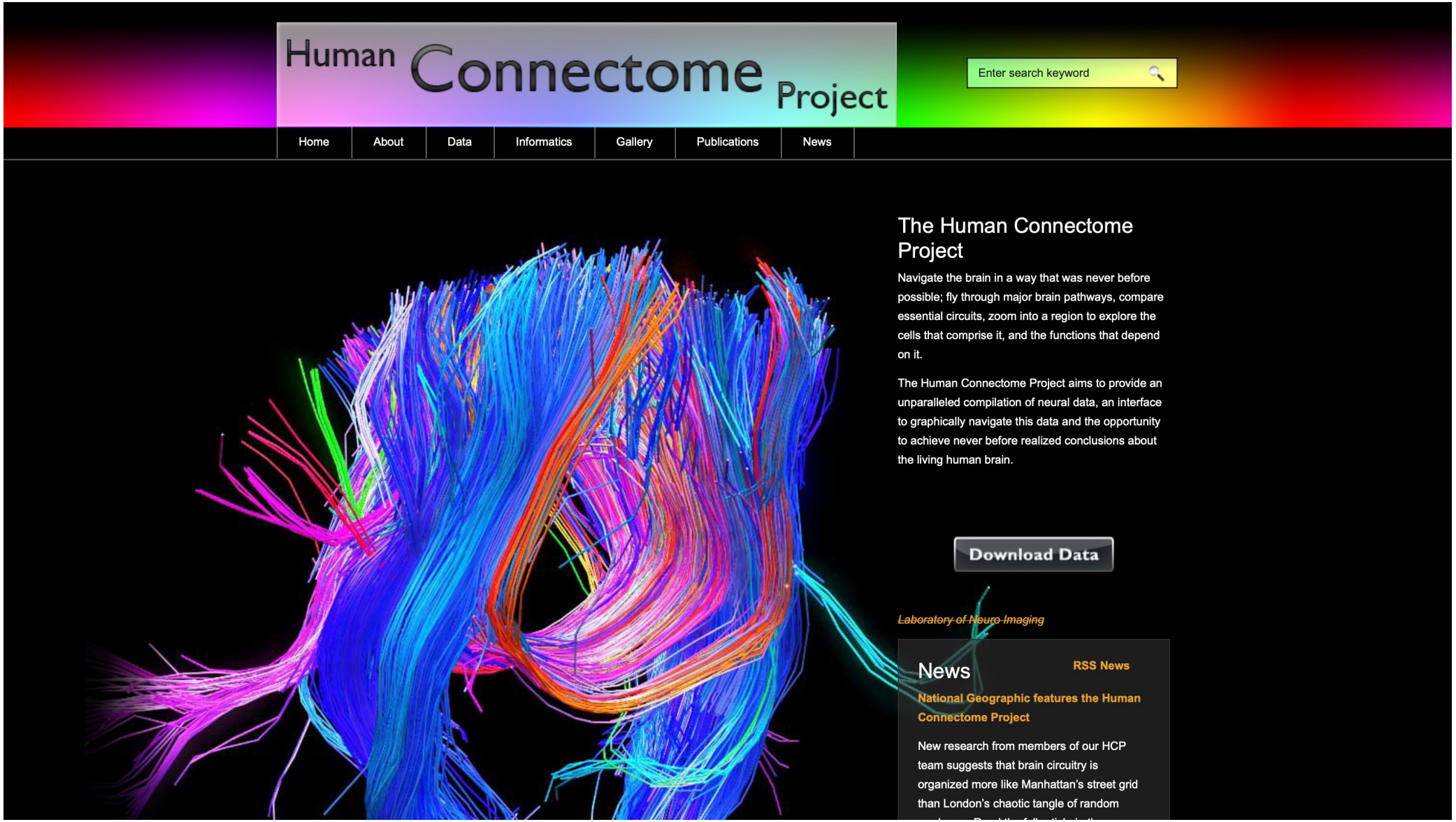
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Welcome to the Autism Brain Imaging Data Exchange!

ABIDE
Autism Brain Imaging Data Exchange

Introduction

Autism spectrum disorder (ASD) is characterized by qualitative impairment in social reciprocity, and by repetitive, restricted, and stereotyped behaviors/interests. Previously considered rare, ASD is now recognized to occur in more than 1% of children. Despite continuing research advances, their pace and clinical impact have not kept up with the urgency to identify ways of determining the diagnosis at earlier ages, selecting optimal treatments, and predicting outcomes. For the most part this is due to the complexity and heterogeneity of ASD. To face these challenges, large-scale samples are essential, but single laboratories cannot obtain sufficiently large datasets to reveal the brain mechanisms underlying ASD. In response, the Autism Brain Imaging Data Exchange (ABIDE) initiative has aggregated functional and structural brain imaging data collected from laboratories around the world to accelerate our understanding of the neural bases of autism. With the ultimate goal of facilitating discovery science and comparisons across samples, the ABIDE initiative now includes two large-scale collections: ABIDE I and ABIDE II. Each collection was created through the aggregation of datasets independently collected across more than 24 international brain imaging laboratories and are being made available to investigators throughout the world, consistent with open science principles, such as those at the core of the International Neuroimaging Data-sharing Initiative. For details about these initiatives visit the collection specific pages: **ABIDE I** and **ABIDE II**.

Last Updated March 27, 2017.


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ENIGMA
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Enhancing Neuro Imaging Genetics through Meta Analysis
Disease
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What is ENIGMA?
The ENIGMA Consortium brings together researchers in imaging genomics to understand brain structure, function, and disease, based on brain imaging and genetic data. We welcome brain researchers, imagers, geneticists, methods developers, and others interested in cracking the neuro-genetic code!
The ENIGMA Consortium has several goals:
To create a network of like-minded individuals, interested in pushing forward the field of imaging genetics.
To ensure promising findings are replicated via member collaborations.
To share ideas, algorithms, data, and information on research studies and methods.
To facilitate training, including workshops and conferences on key methods and emerging directions in imaging genetics.
There are 50 active ENIGMA working groups!! Full details of each ENIGMA project can be accessed by clicking on the links provided. If you are interested in joining and contributing to a current group, or would like to propose a group you do not see listed, please contact us at enigma.usc.edu

CIBM
Center for Biomedical Imaging

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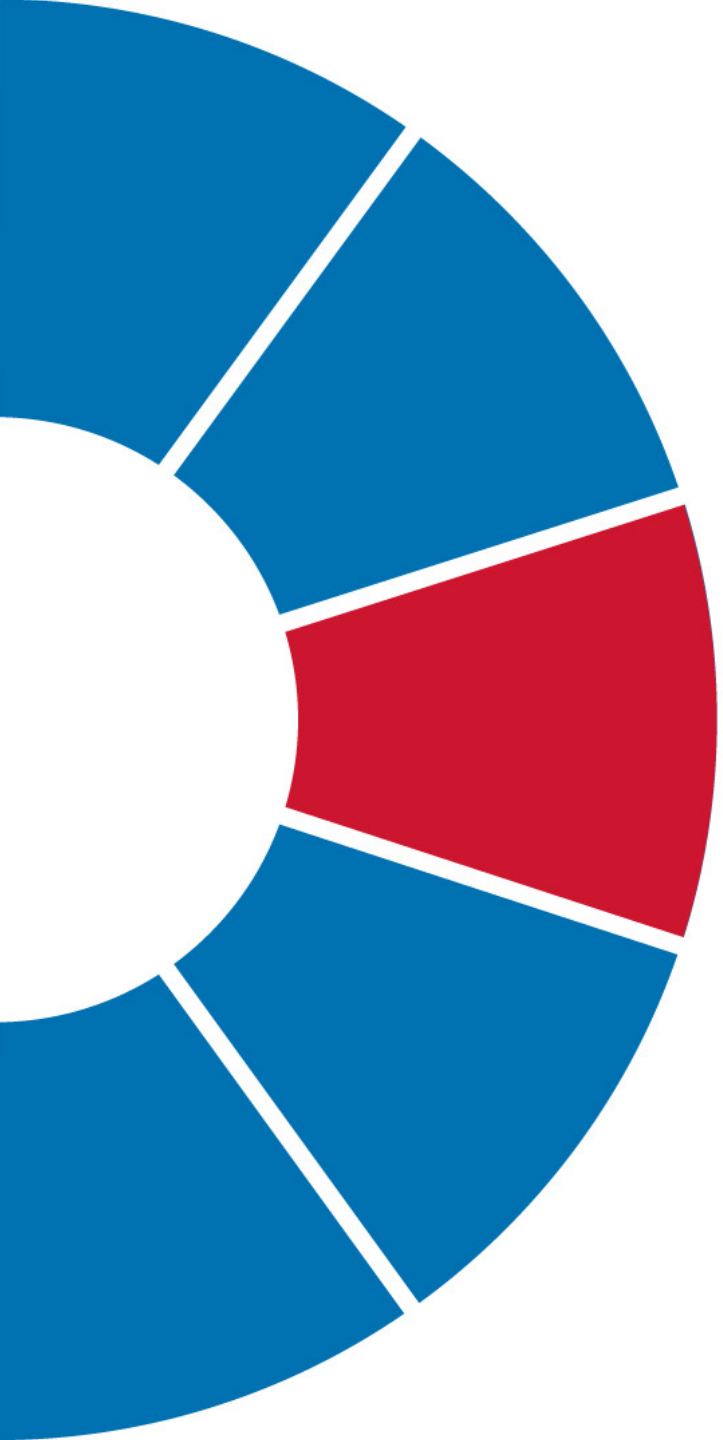
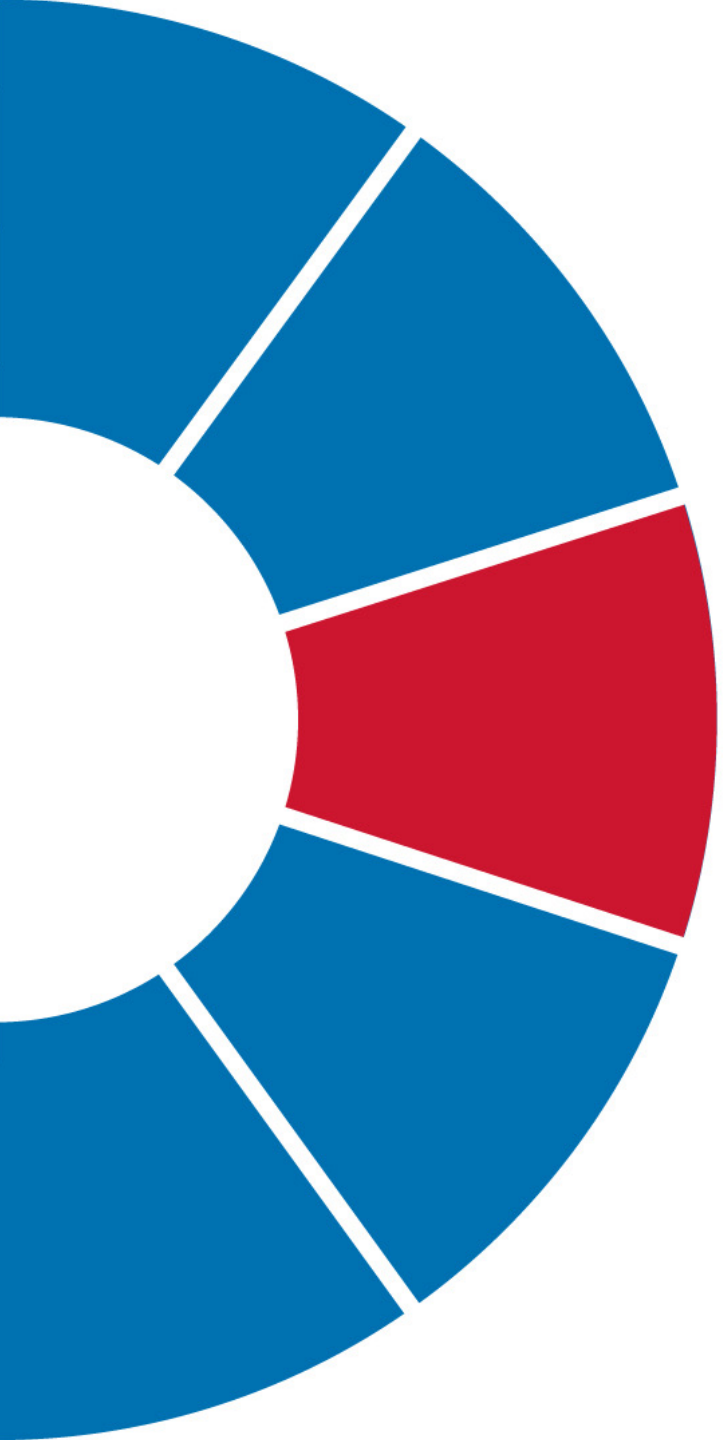


FOR ANY QUESTIONS YOU MAY HAVE,

PLEASE WRITE AT:

VALERIO.ZERBI@EPFL.CH



MR COIL WORKSHOP – TOMORROW, WEDNESDAY 26TH

Group1 (Morning) 8.15am-12am:

Francesca Barcellini
Gercek Berk
Jenifer Miehlbradt
Guibert Fabrice Jean
Brayan Alves
Huang Zhiwei

Group2 (Afternoon) 13.15-17:

Liu Chang
Jan Luxemburg
Nikolaos Molochidis
Mustafa Arslan
Mark Stephan Widmaier