

# Inter-subject Correlation and Naturalistic Stimuli

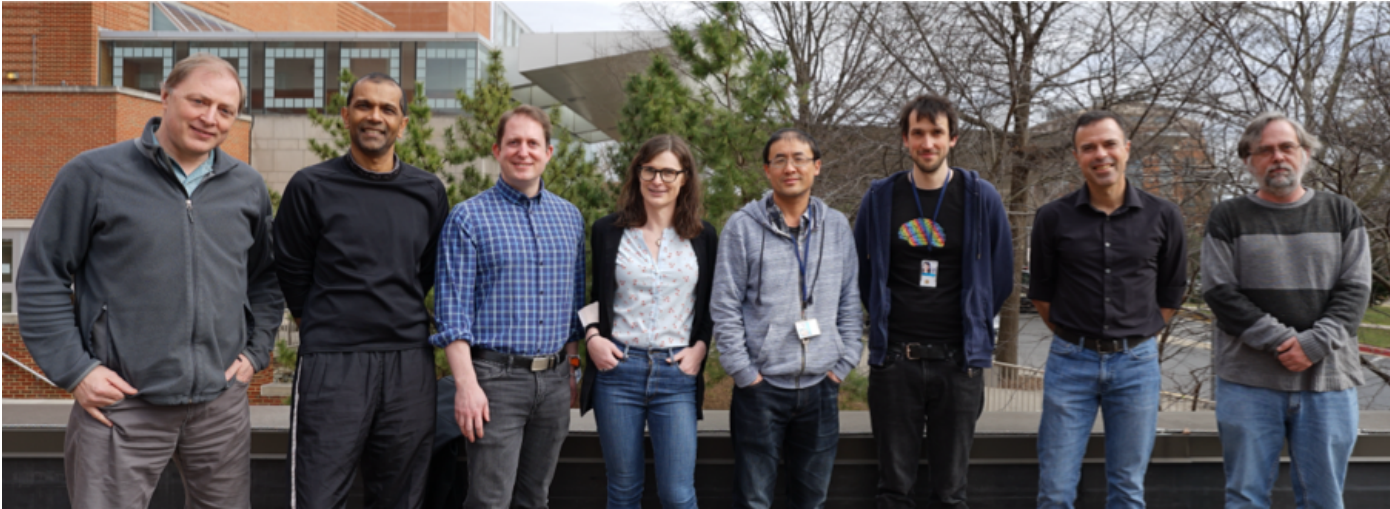
NIMH FMRI Summer Course



Peter J. Molfese, Ph.D. 2024.08.01



# FMRI Core Facility



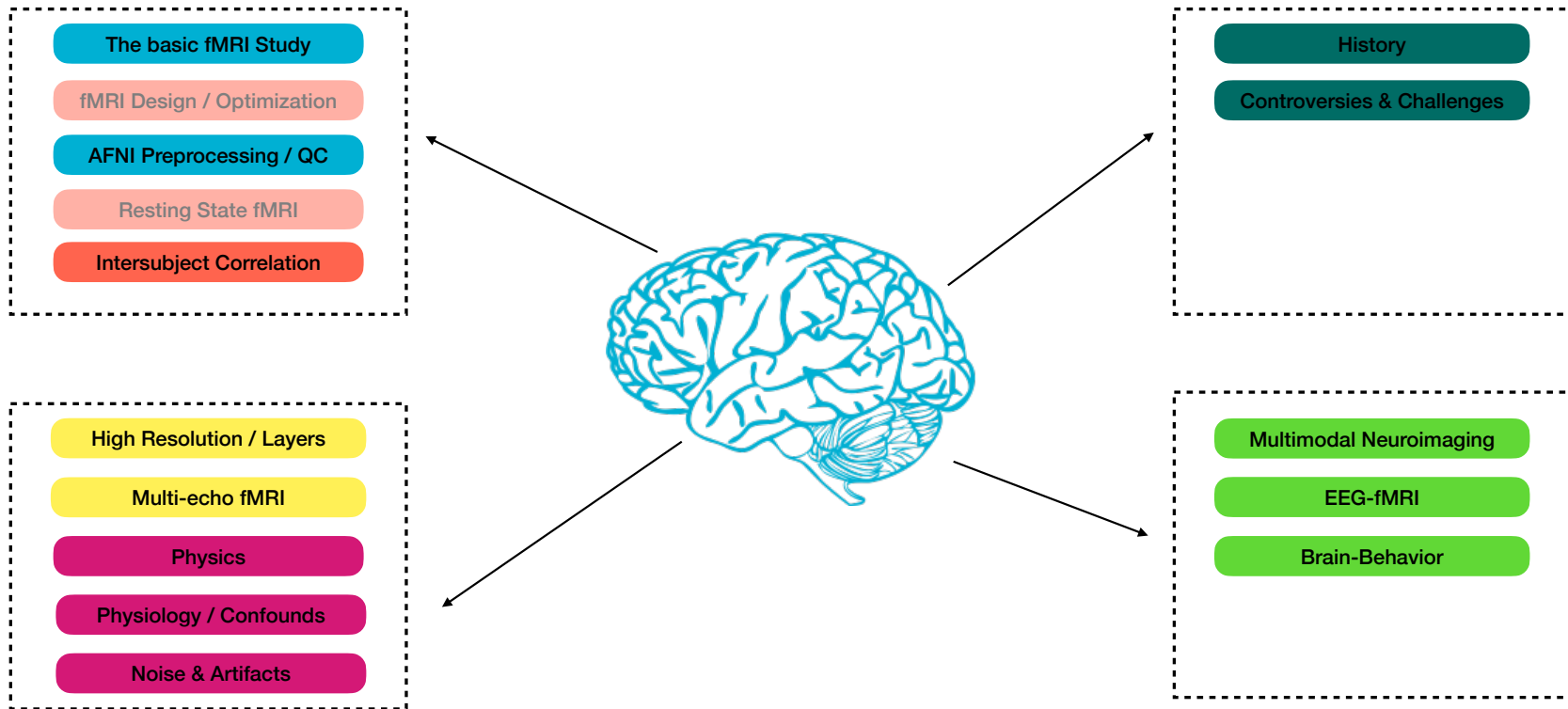


[cmn.nimh.nih.gov/cmnrworkshop2021](https://cmn.nimh.nih.gov/cmnrworkshop2021)



# Overview

## How does this talk fit in?

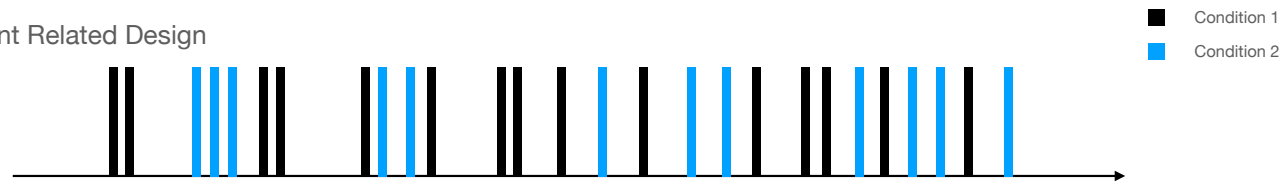


# Traditional fMRI Study Designs

Block Design



Event Related Design



AFNI Representation

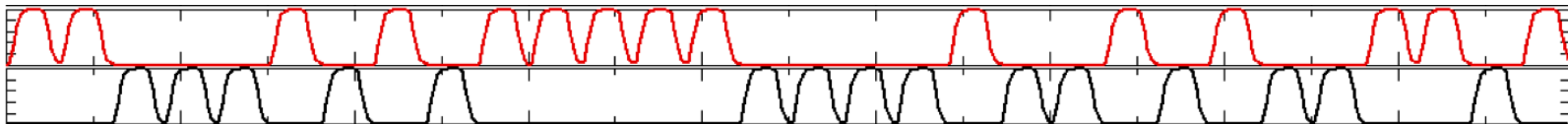


# Analysis of Block & Event Related

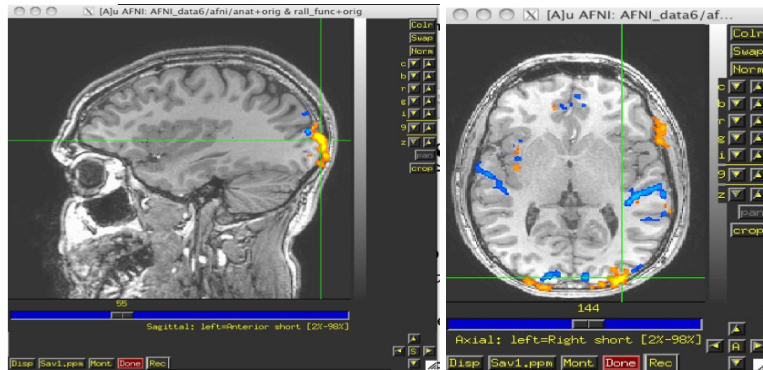
AFNI Design



Convolved With HRF



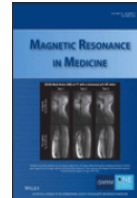
Results In AFNI Viewer





# Resting State

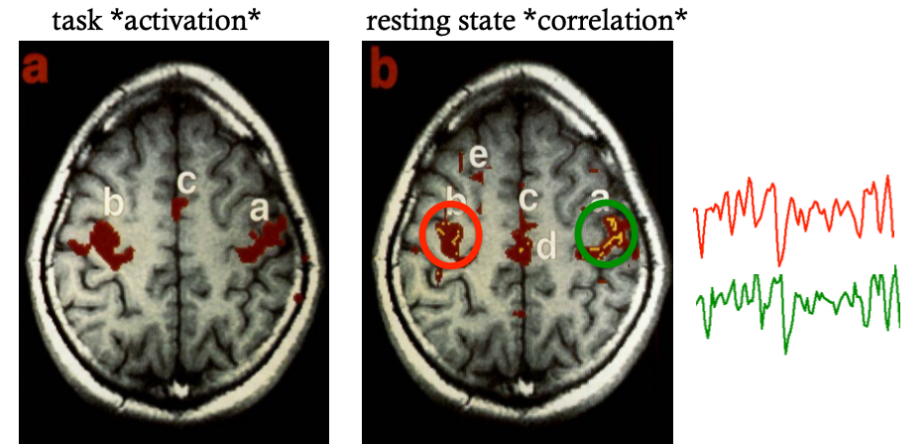
## Briefly



### Functional Connectivity in the Motor Cortex of Resting Human Brain Using Echo-Planar MRI

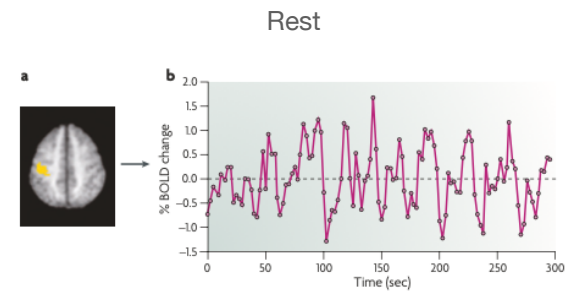
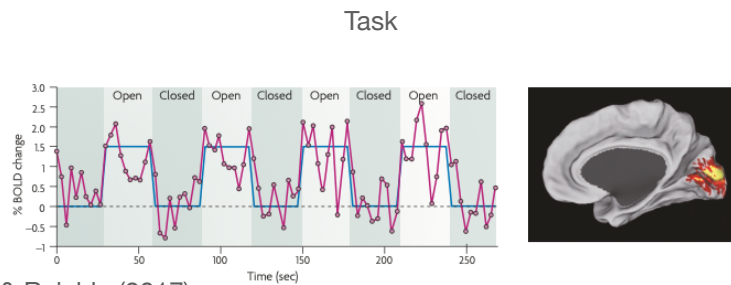
Bharat Biswal, F. Zerrin Yetkin, Victor M. Haughton, James S. Hyde

- Resting state - no task/stimuli
  - “Keep eyes open” or “Keep Eyes Closed”
- Can be analyzed in numerous ways
  - Functional Connectivity (“Correlation”)
  - Suggestion that networks interact



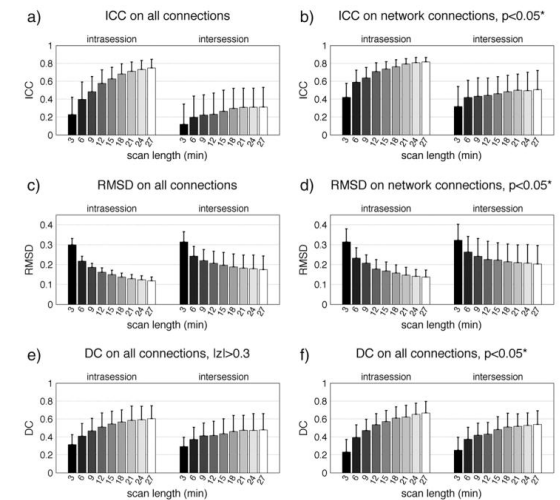


# Task vs. Resting State



Adapted from Fox & Raichle (2017)

- Range of durations: 5-20 minutes
- Extending scan duration to 12-minutes results in 20% greater intra-session ICC
- Greatly improved Functional Connectivity in scans at > 12 minutes
- Often suggestions for even longer durations (e.g. Nee; 2019)



Rasmus Birn et al. (2013)



# Resting State Networks or Intrinsic Networks

- Seed in sensorimotor cortex
- The time series of that seed used as a regressor
  - Correlated brain regions
  - In this case we see the rest of the sensorimotor network
- Similar strategy can be employed to pull out 7 major brain networks
- Networks are very reliable
  - Some variation in clinical groups

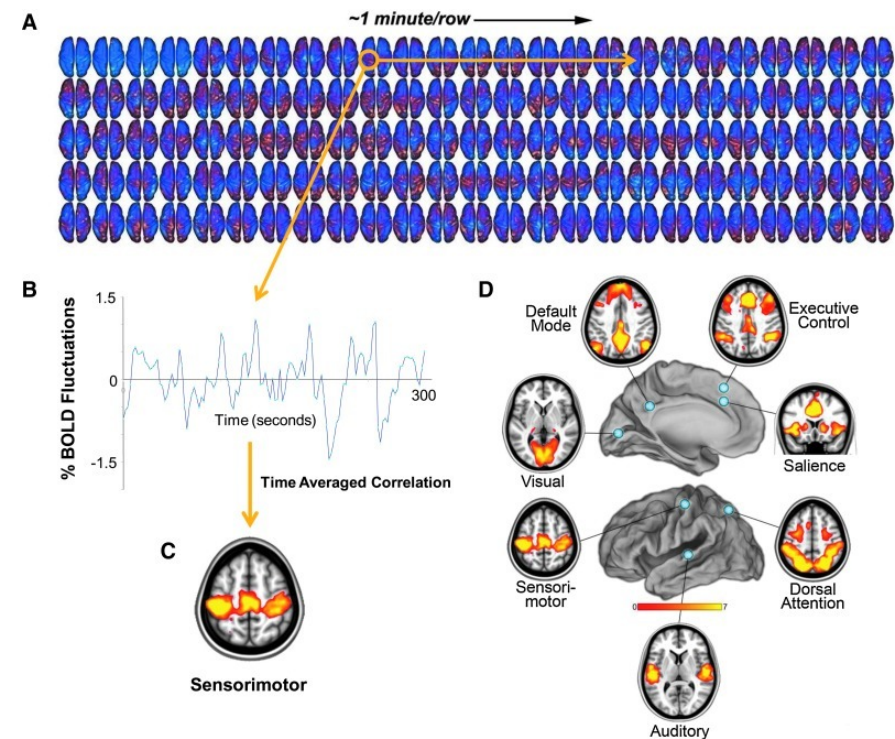


[Brain Connect.](#) 2011 Feb; 1(1): 3–12.  
doi: [10.1089/brain.2011.0019](https://doi.org/10.1089/brain.2011.0019)

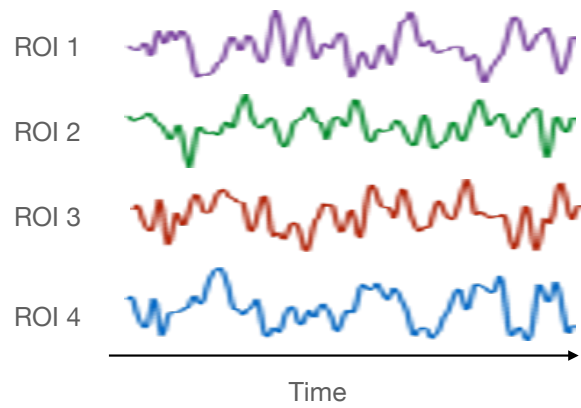
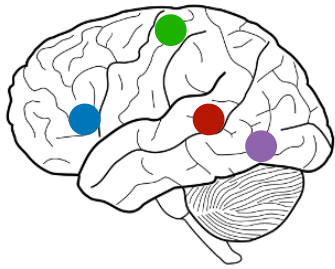
PMCID: PMC3621343  
PMID: [22432951](https://pubmed.ncbi.nlm.nih.gov/22432951/)

The Restless Brain

[Marcus E. Raichle](#)<sup>1</sup>



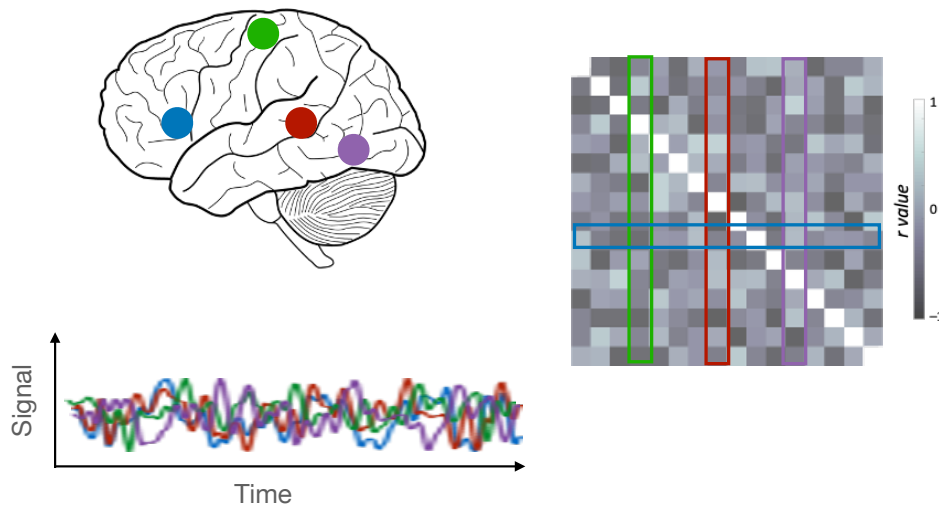
# Functional Connectivity



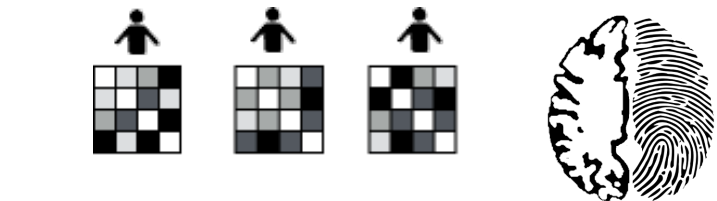


# Functional Connectivity

## Single Subject to Group



- Temporal correlation or synchronization of activity between spatially distinct brain regions
- Can be studied at rest
- Or during task (PPI)



Figures Courtesy Emily Finn



NIH Public Access

Author Manuscript

*Magn Reson Imaging*. Author manuscript; available in PMC 2008 December 1.

Published in final edited form as:

*Magn Reson Imaging*. 2007 December ; 25(10): 1347–1357.

### Assessing Functional Connectivity in the Human Brain by FMRI

Baxter P. Rogers<sup>1,3</sup>, Victoria L. Morgan<sup>1,3</sup>, Allen T. Newton<sup>2,3</sup>, and John C. Gore<sup>1,2,3</sup>

<sup>1</sup>Department of Radiology and Radiological Sciences Vanderbilt University, Nashville, TN, U.S.A.

<sup>2</sup>Department of Biomedical Engineering Vanderbilt University, Nashville, TN, U.S.A.

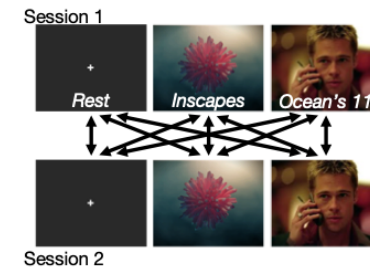
<sup>3</sup>Vanderbilt University Institute of Imaging Science Vanderbilt University, Nashville, TN, U.S.A.



# Comparing Rest to Driven Stimuli

## Can increase subject identification via FC

- Rest
  - Fixation
- Inscapes
  - “Fancy screensaver”
- Oceans 11
- Inscapes better at driving FC matrices for subject identification (i.e. “fingerprinting”)



Vanderwal et al., NeuroImage (2017)

# Recap

## Designs, Resting State, FC

- Traditional designs great for tasks
  - “What does the brain do during...”?
  - How does Group A differ from Group B in X process?
- Resting State can also be a useful tool
  - Identify networks in subjects/groups
- Functional Connectivity
  - Inspects the interaction / correlation between multiple “nodes”
  - “Fingerprinting”

### nature neuroscience

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Article | Published: 12 October 2015

### Functional connectome fingerprinting: identifying individuals using patterns of brain connectivity

[Emily S Finn](#) , [Xilin Shen](#), [Dustin Scheinost](#), [Monica D Rosenberg](#), [Jessica Huang](#), [Marvin M Chun](#), [Xenophon Papademetris](#) & [R Todd Constable](#)

[Nature Neuroscience](#) **18**, 1664–1671 (2015) | [Cite this article](#)

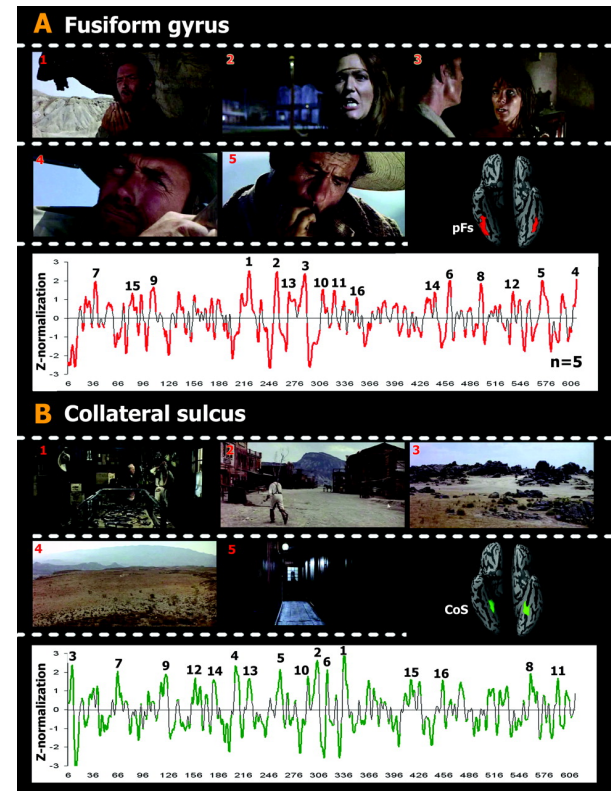
**64k** Accesses | **1570** Citations | **962** Altmetric | [Metrics](#)

**And if movies can do that...**

# Movies are great stimuli

## Hollywood excels at eliciting reactions

- Watched 30 minutes of a movie
  - “The good, the bad, and the ugly”
- Two ROIs
  - Fusiform Face Area (FFA)
  - Collateral Sulcus - buildings
- Inter-subject Correlation of time courses in each ROI
  - Highly consistent across subjects



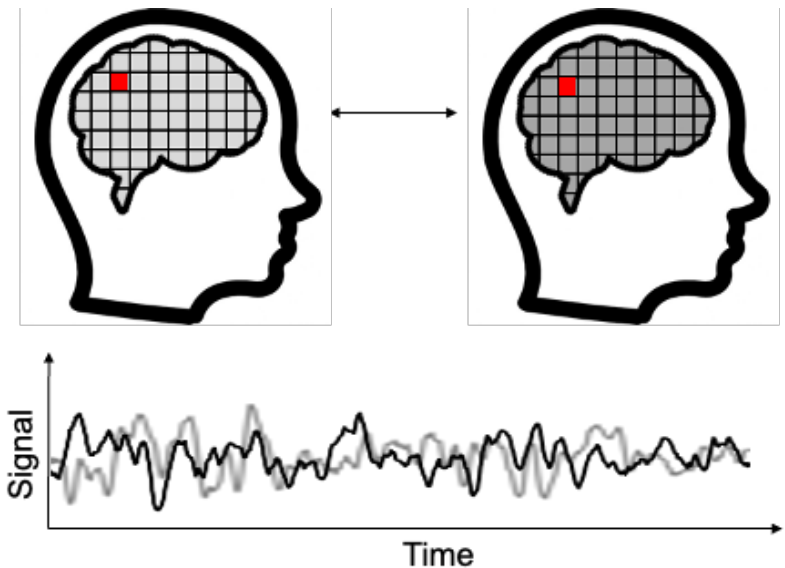
Hasson et al. (2004) @ Science



# Inter-Subject Correlation (ISC)

## Correlation of each voxel pairwise across subjects

- When two people watch the same movie in the scanner, many parts of the brain synchronize
- Correlate same voxel in participants A and B
  - $A_{ijk}$  with  $B_{ijk}$
- Easily done in AFNI
  - 3dTcorrelate / 3dISC
- Analysis focuses on similarities with other participants



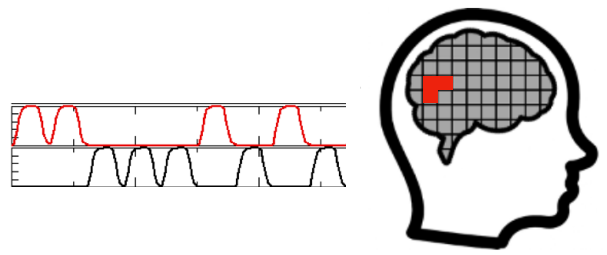
Figures courtesy of Emily Finn



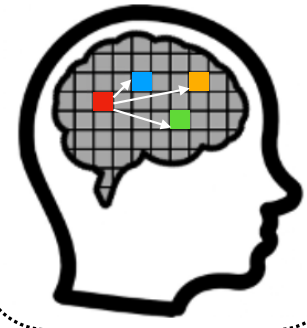


# Assumptions and Designs

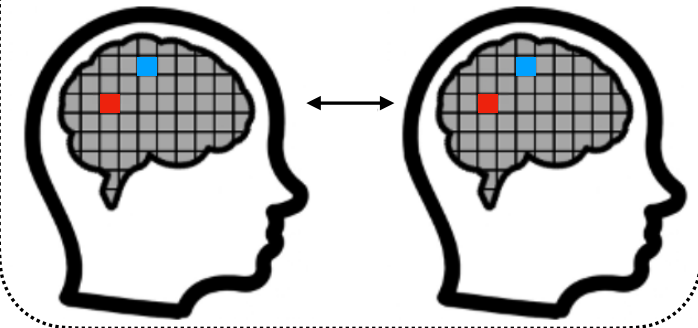
GLM Analysis



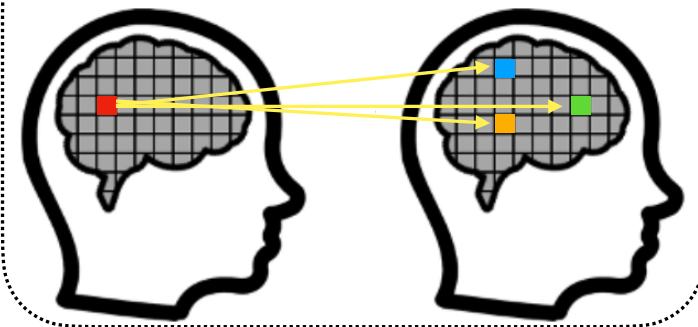
Functional Connectivity



Intersubject Correlation



Intersubject Functional Connectivity



Figures Adapted from Emily Finn

# ISC Pros and Cons

- Pro

- More driven brain responses than rest
- “Naturalistic” stimuli more approximate real life
- Growing track record of use in categorizing individuals based on states and traits

- Cons

- Pairwise measurement
- Tricky to go back and “freeze” a particular moment



Neuropsychologia  
Volume 143, June 2020, 107489



What do across-subject analyses really tell us about neural coding?

Fernando M. Ramírez , Cambria Revsine, Elisha P. Merriam

Laboratory of Brain and Cognition, National Institute of Mental Health, NIH, Building 10, Rm 4C118, Bethesda, MD, 20892-1366, USA

Received 10 December 2019, Revised 27 April 2020, Accepted 4 May 2020, Available online 11 May 2020, Version of Record 20 May 2020.

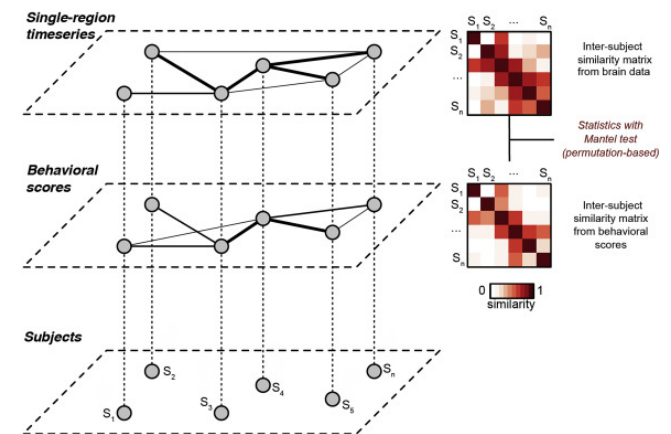
**But what if I care about  
Individual Differences?**



# Representational Similarity Analysis (RSA)

## The short version

- Similar behavior should also mean similar neural responses
- Construct similarity matrix of behavior
- Construct similarity matrix of brain response
- Correlate (mantel test) the two matrices
- How do you interpret?



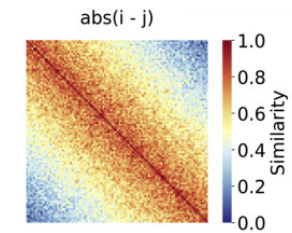
# Interpreting ISC

## Going beyond paired values

- Sort rows/cols of the ISC matrix by behavioral score
- Nearest Neighbors - subjects similar in behavior will be similar in brain relative to each other
- AnnaK - Similarity increases as an absolute (not relative) as we move up/down scale

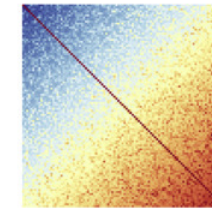


Nearest Neighbors

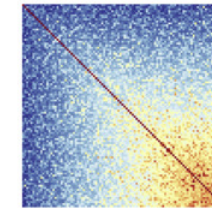


Anna Karenina (“AnnaK”)

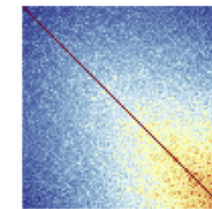
mean(i, j)



min(i, j)



abs(i - j)\*mean(i, j)



“All happy families are alike; each unhappy family is unhappy in its own way”

-Leo Tolstoy in Anna Karenina



# Inter-Subject Correlation (ISC)

## Going beyond pairs

- ISC is sensitive to State of Subject
  - Features of the stimulus
  - Explicit Manipulations of Attention & Prior Beliefs
  - Behavioral ratings of stimuli & Interpretations of the stimuli
- ISC also sensitive to Traits of Subjects
  - High Trait Paranoia
  - Wholistic vs. analytical thinking
  - Depression
  - And more...

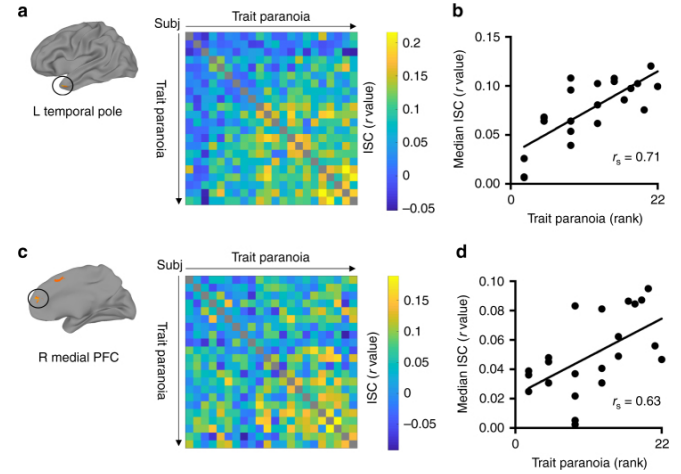
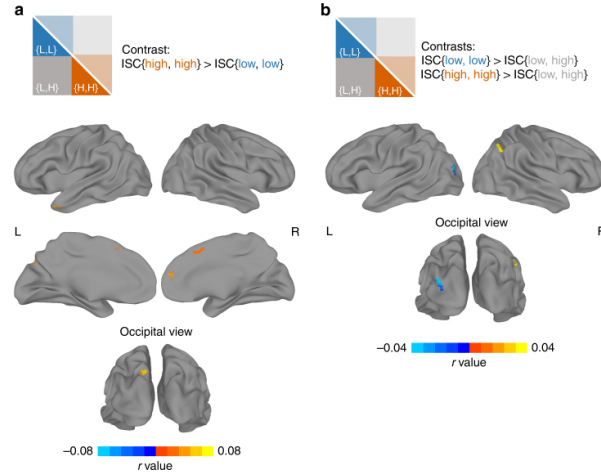
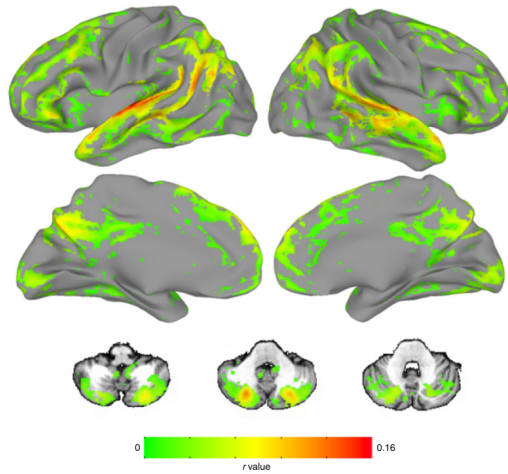


# Trait Paranoia

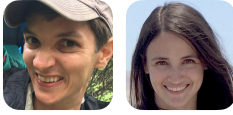
Finn et al. (2018) in Nat Comm.



Listening to an ambiguous story  
Possible suspicious events

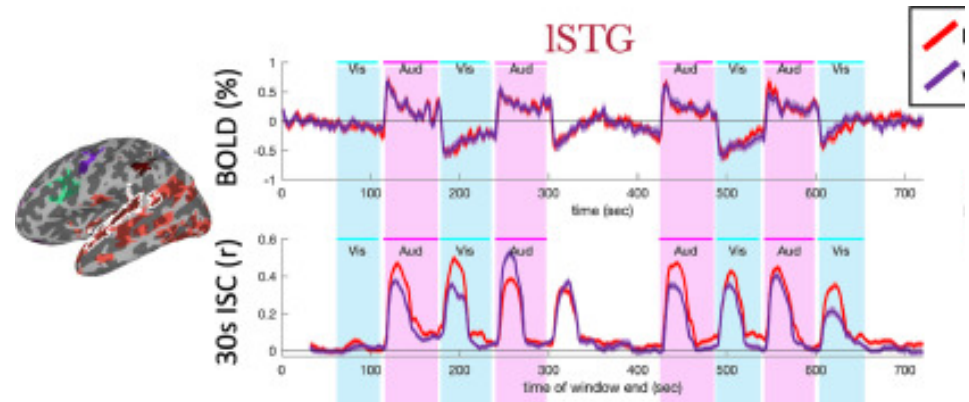
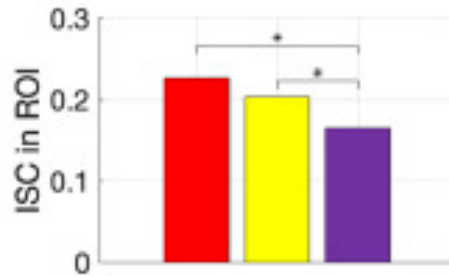
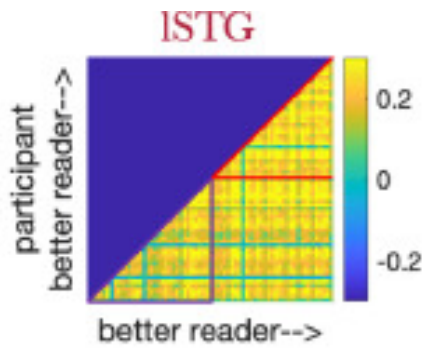
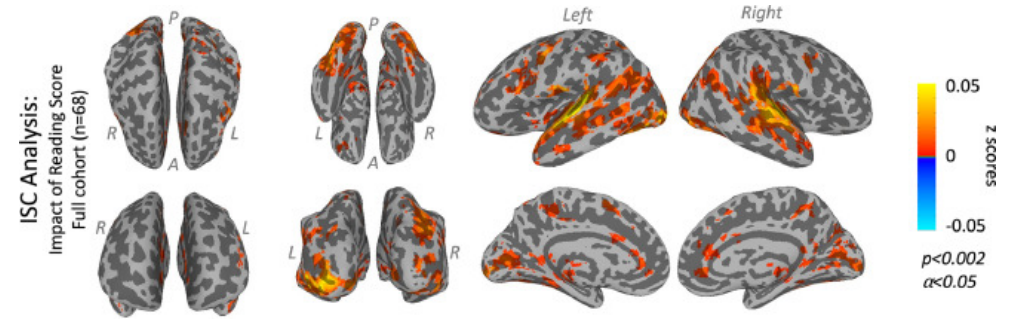
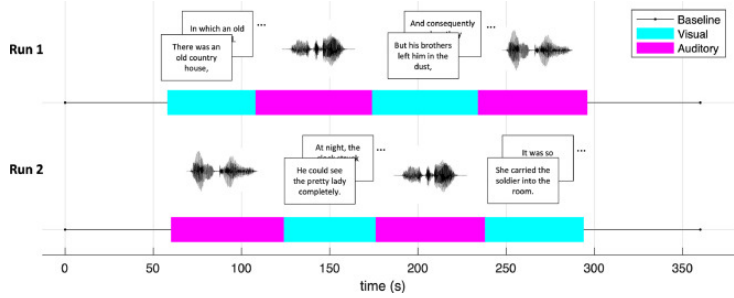


Participants free recall narration of story



# ISC during long narratives

## Adolescent reading ability

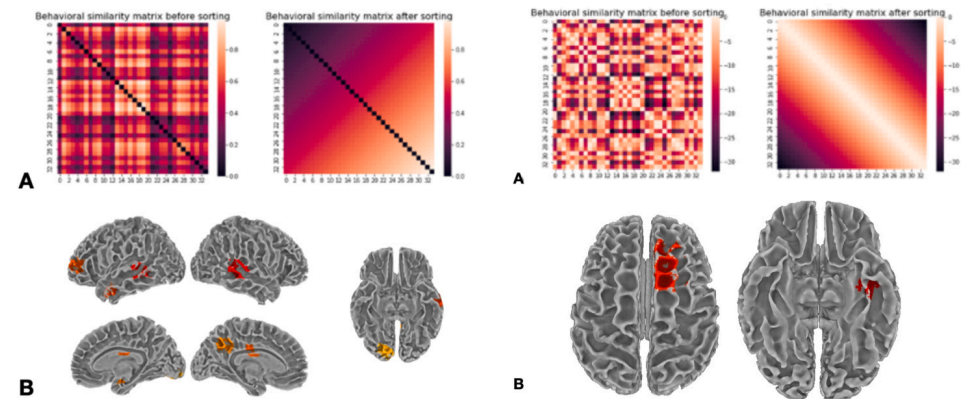
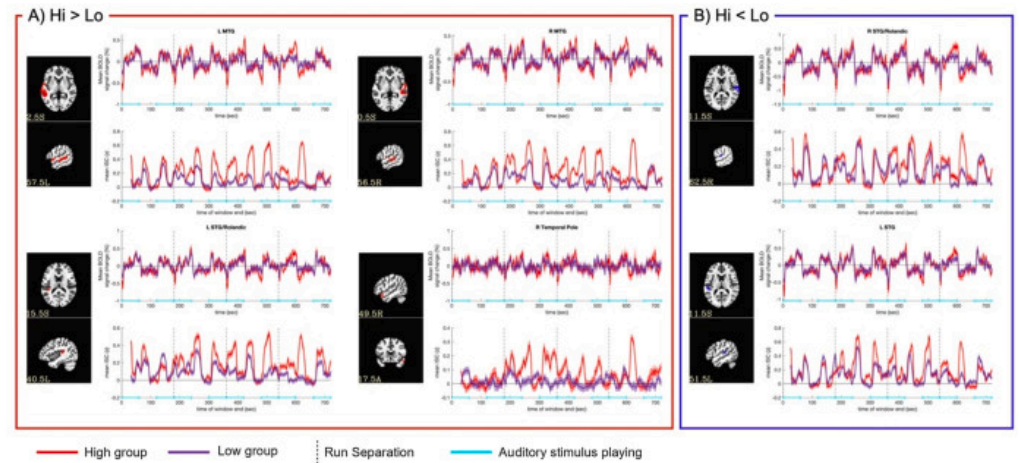
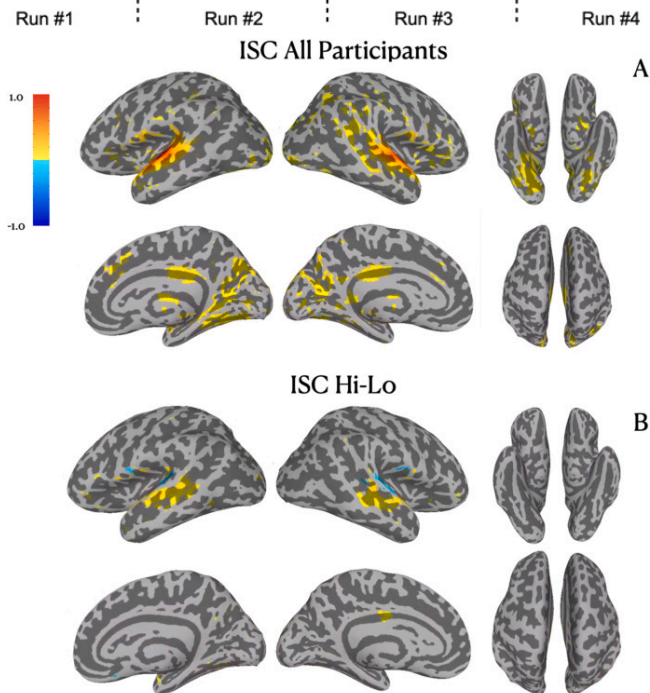
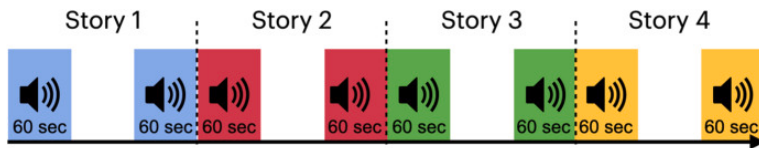






# ISC during long narratives

## Emergent Reading cohort



Wat, Jangraw, Finn, ... & Molfose (2024)



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# Questions?

[peter.molfese@nih.gov](mailto:peter.molfese@nih.gov)

