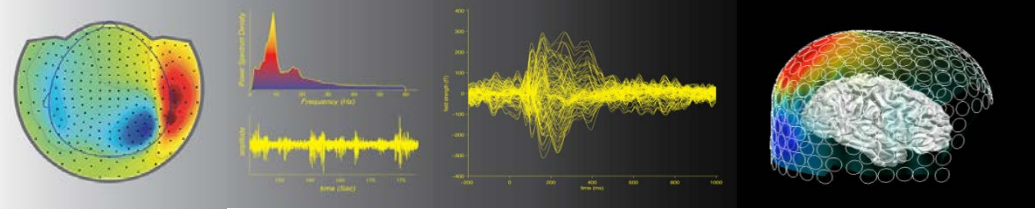




HUMAN
Connectome
PROJECT



Introduction to HCP-MEG Connectome

L.J. Larson-Prior, PhD

Depts. Radiology and Neurology

INTRODUCTION TO HCP-MEG: OUTLINE

I Basics of magnetoencephalography (MEG)

- Strengths of MEG/EEG
- What do we measure
- How do we measure it: SQUIDS
- Analyzing the data

II. HCP Data Collection

- Data acquisition
- Behavioral tasks
- Resting state data
- Assessing data quality: pre-processing
- Physiological artifact removal

III. Data Sharing

- Downloading and unpacking data
- Documentation
- Multi-modal integration

I. The Basics of Magnetoencephalography (MEG)

Strengths of MEG and EEG

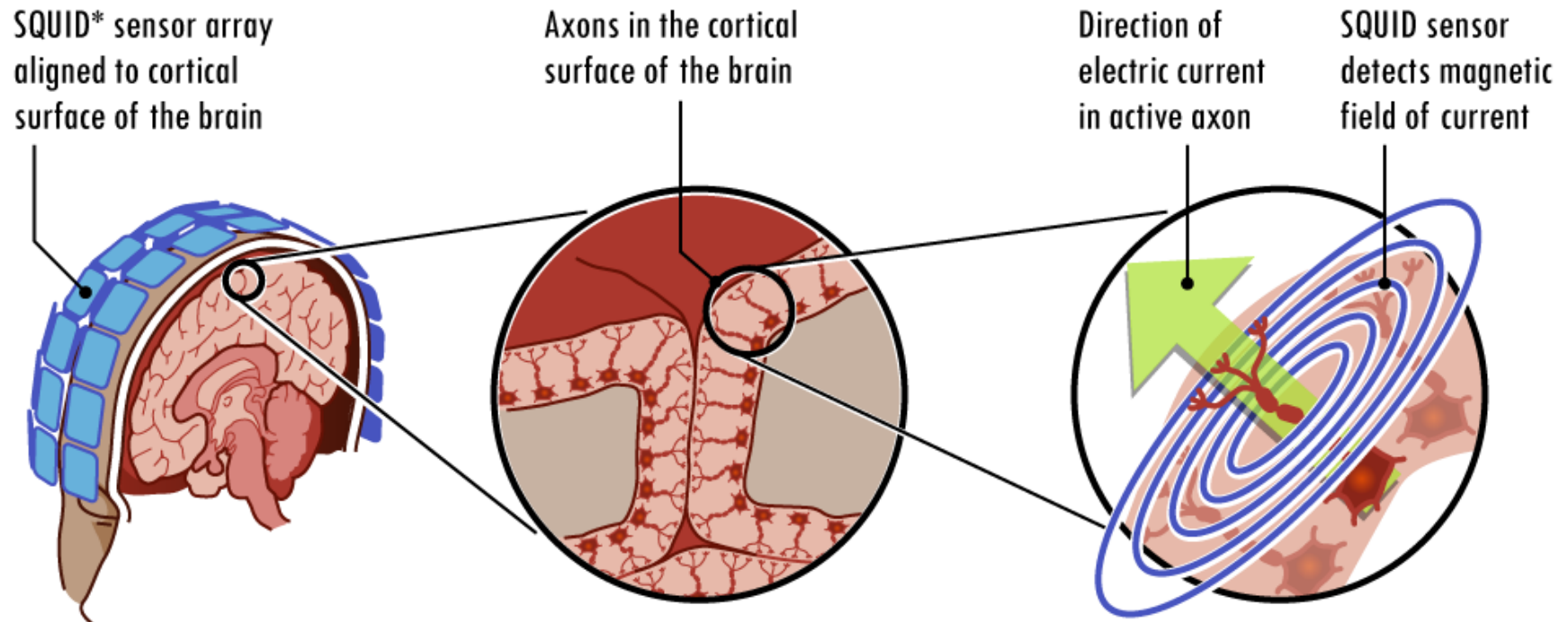
- **Non-invasive**
- **Directly measures neuronal function**
- **High temporal resolution (msec)**
- **Captures oscillatory activity**
- **Time or event – locked activity analyzable for discrete elements**
- **Allows evaluation of brain network dynamics**
 - **Across time**
 - **By frequency**

Drawbacks of MEG and EEG

- **Sensors far from brain sources**
- **Relatively low spatial resolution (high mm – low cm)**
- **Signal overlap**

I. The Basics of Magnetoencephalography (MEG)

MEG and EEG measure



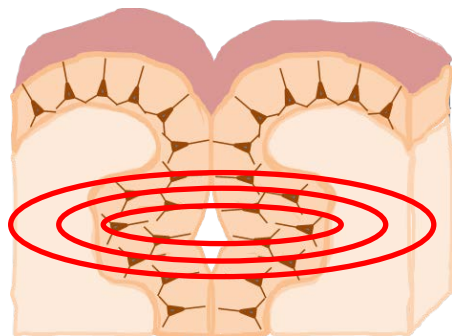
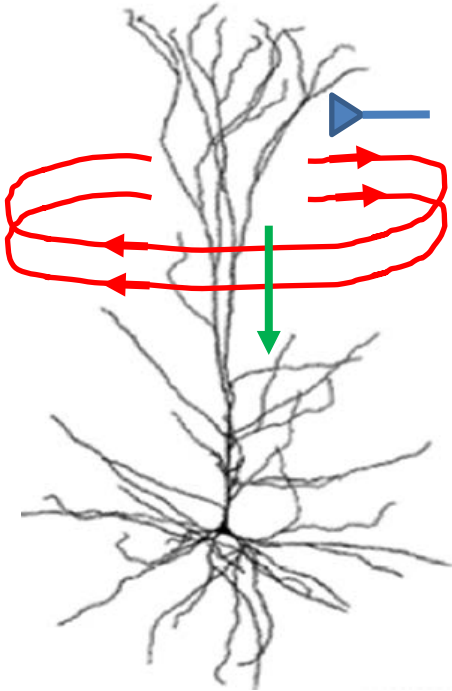
* Superconducting Quantum Interface Device

HUMANCONNECTOME.ORG

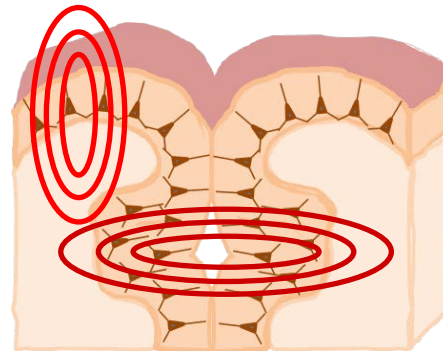
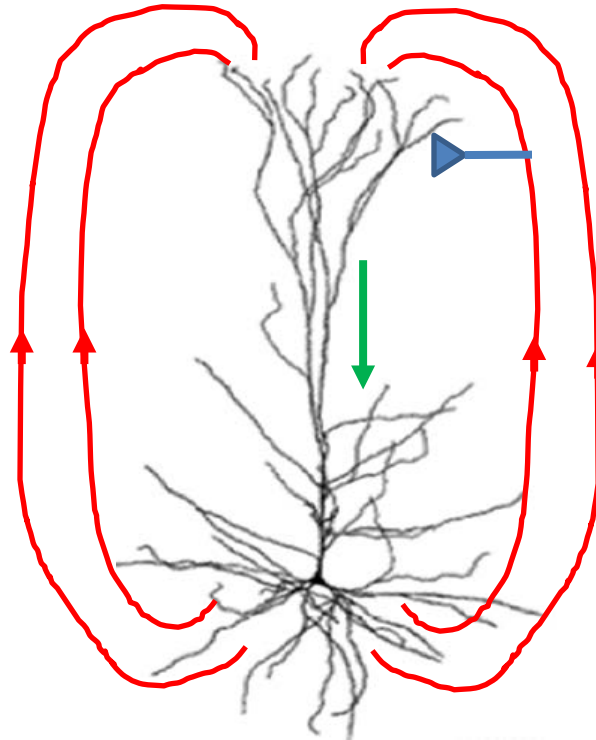
- **POPULATION** potentials from cortical layers
- Electrical and magnetic fields generated by PSPs and not action potentials
- Field alignments are orthogonal to one another (right hand rule)

I. The Basics of Magnetoencephalography (MEG)

MEG

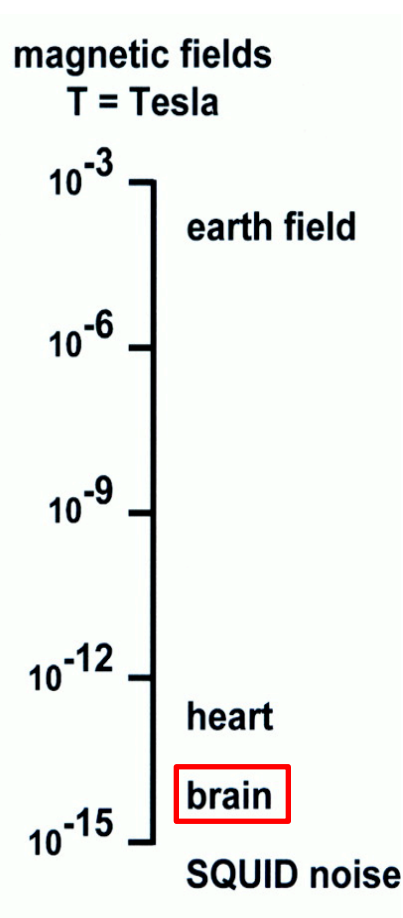


EEG

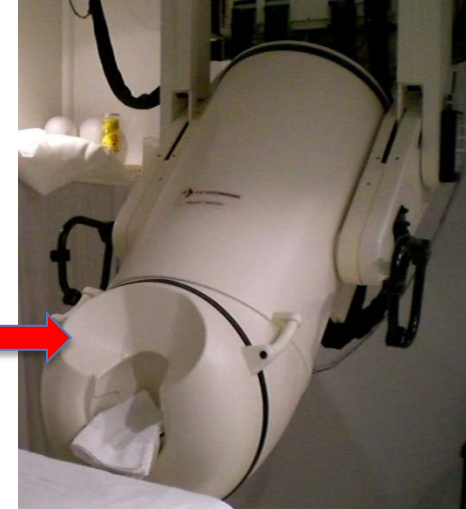
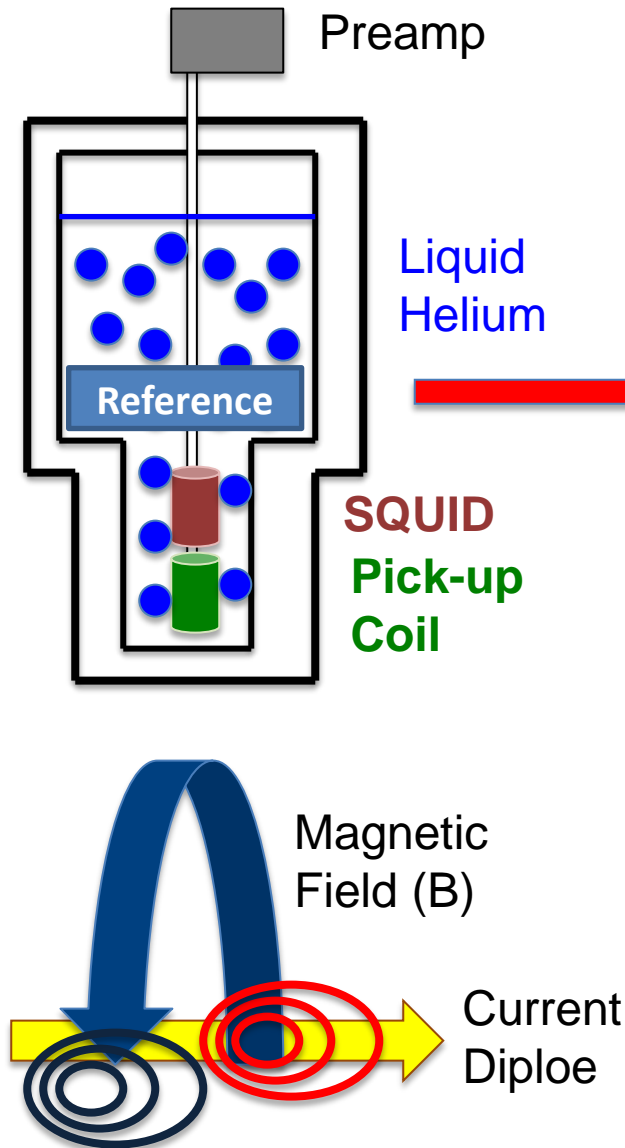


- **MEG** measures fields generated by dendritic current flow
- Signal decreases rapidly with distance
- Sees tangential dipole primarily
- **EEG** measures volumetric return currents generated by dendritic current flow
- Signal is filtered by skull and scalp
- Sees both radial and tangential dipoles

I. The Basics of Magnetoencephalography (MEG)



- Fields generated by brain 50-500 fT
- Fields from eye movements 1-2 orders of magnitude larger



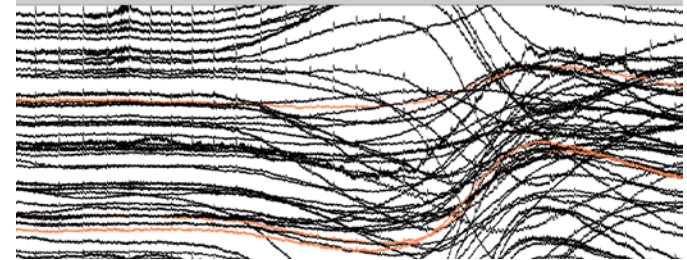
MAGNES 3600
4D Neuroimaging
248 Magnetometers
23 Reference sensors

I. The Basics of Magnetoencephalography (MEG)

Detection and removal of noise and artifacts is an important component of signal processing as SNR can be low

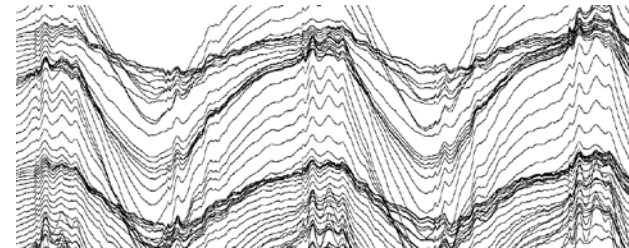
ENVIRONMENTAL NOISE

- Line noise
- Electric appliances
- Vibrational noise (e.g. **truck traffic**)



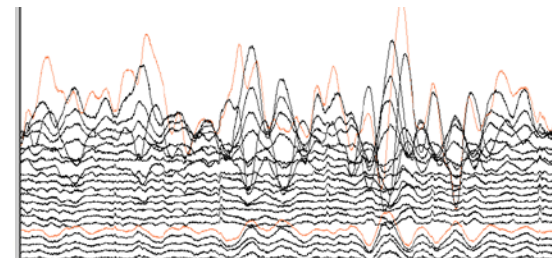
INSTRUMENTATION NOISE

- Electronic noise from amplifiers
- Saturating magnetic signals (e.g. **VNS**)
- Thermal noise



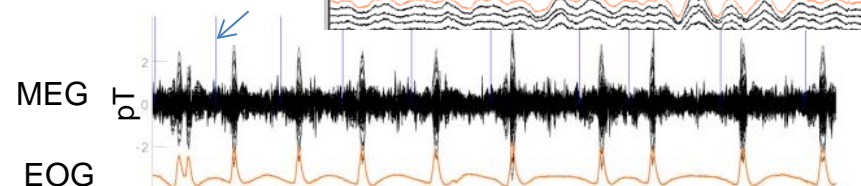
BIOLOGICAL NOISE

- Appliance noise (e.g. **dental appliance**)
- Physiologic signals (eye movements, heart)
- Movement (head, limb, etc)



EXPERIMENTAL NOISE

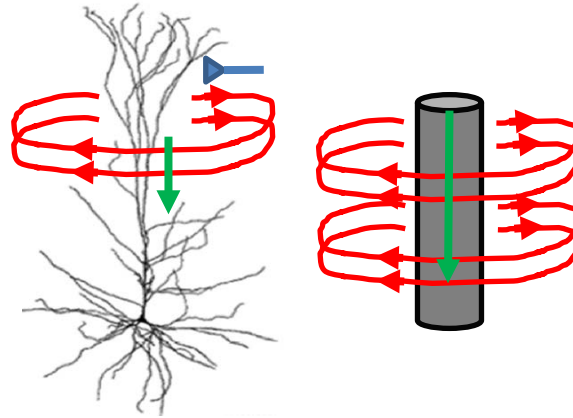
- Startle responses to stimuli
- Stimulus or Event locked artifact



I. The Basics of Magnetoencephalography (MEG)

From sensor space to source space

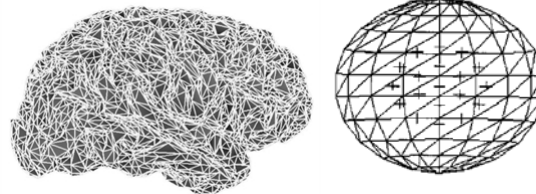
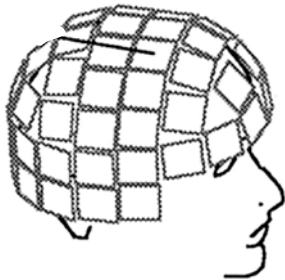
Purpose: To determine the source of magnetic fields recorded from the scalp surface assuming that these sources are generated from distributed cortical generators



Current sources can be modeled as dipoles

**FORWARD
MODEL**

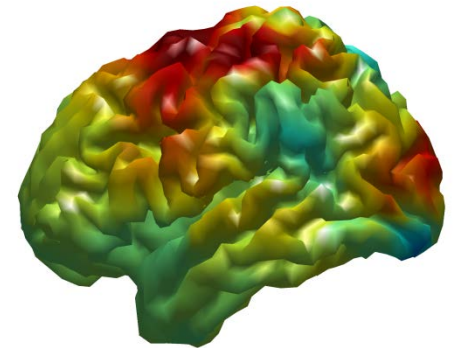
Recorded Data



**Model head and
seed with dipole(s)**

**Lead Field
Matrix (L)**

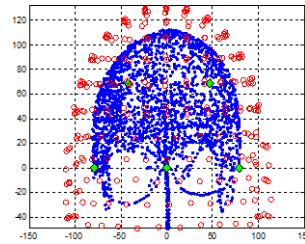
**INVERSE
SOLUTION**



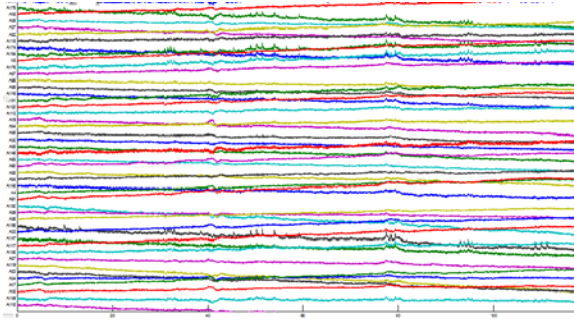
I. The Basics of Magnetoencephalography (MEG)

Analytic Results

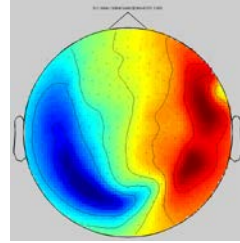
Sensor Space



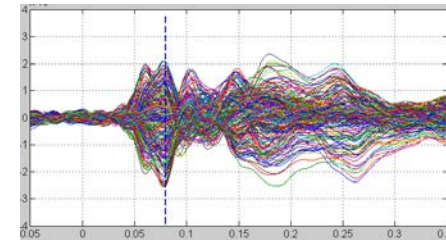
Raw Signal



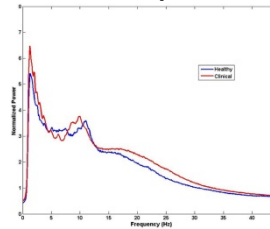
Field topo



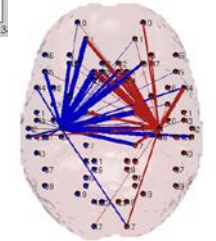
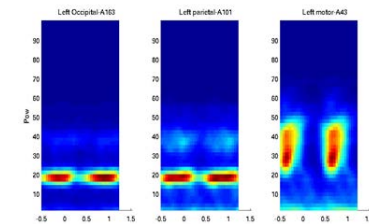
Event Related Field



Spectra

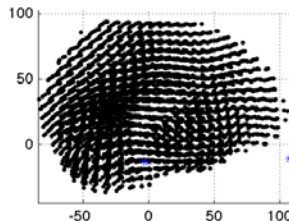


Time-frequency

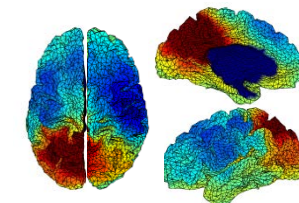
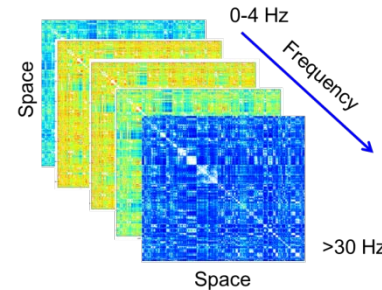


Connectivity

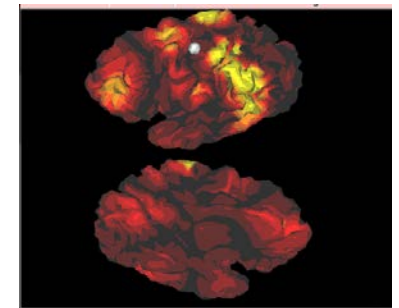
Source Space



Sources



BLP Connectivity



Task connectivity

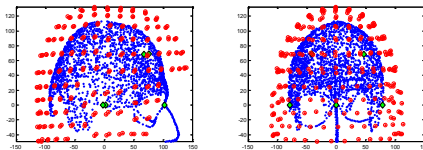
II. Data Collection: Acquisition and Storage

Saint Louis University

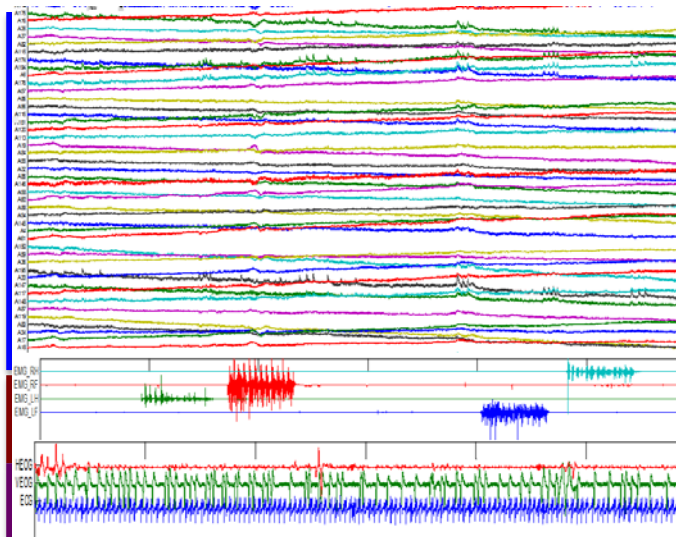


248 magnetometer channels
23 reference channels
Delta encoding
(32 bits/sample)
2034.5101 Hz sampling rate
DC-400 Hz

HEAD SHAPE
Coil Location
Fiducials



MEG



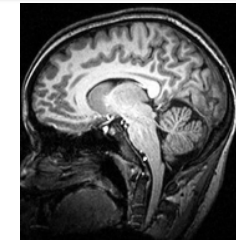
EMG

ECG/
EOG

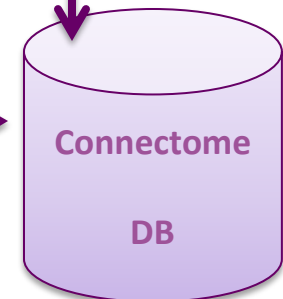


Sun Blade 1500
(1.5 Ghz SPARCv9)
64 bit Solaris 8 Unix
300 Gbyte local storage
capacity

Washington University



MRI/fMRI
Behavioral Data
Health Information

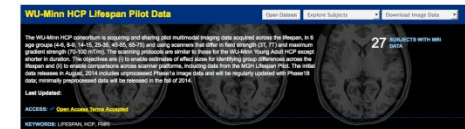


Public Connectome Data

Updated Nov 25, 2014. Unprocessed, source and channel-level processed MEG data from WU-Minn HCP available on over 80 subjects.

[View Data](#)

[View Other Projects](#)



II. Data Collection: Behavioral Tasks

The goal of task acquisition was:

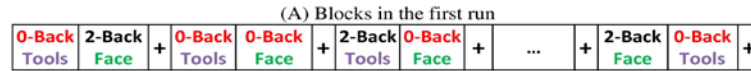
- Identify **NODES** of activation in well-characterized neural systems
- Generate that information in as wide a *range* of systems as possible
- Identify those activations that are both detectable and repeatable in the majority of individuals
- Identify tasks of which a subset can be ported for MEG

Three of the fMRI tasks were chosen for MEG:

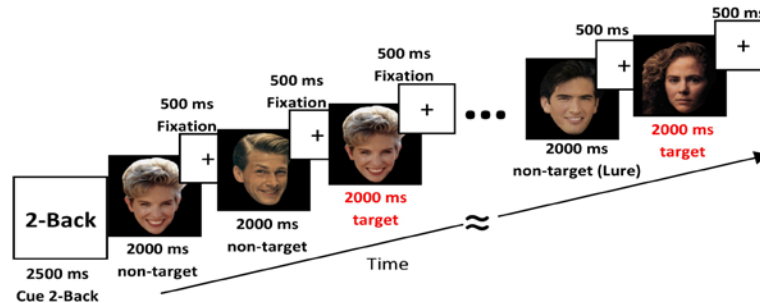
- Motor
 - Left and right hand and foot movements tracked with EMG
- Working memory
 - N-back (0 & 2) working memory task
 - Faces and tools as stimuli
- Language (story-math)
 - 7 story blocks/run
 - 15 math blocks/run
- 2 runs of each task were acquired
- Consistency of acquisition ensured using SOP

II. Data Collection: Behavioral Tasks

N-Back Working Memory Task (Wrkmem)



(B) Example of a 2-Back block

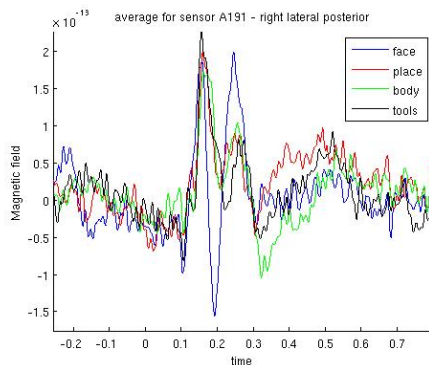


Includes:
0 & 2-back
Face & Tool stimuli

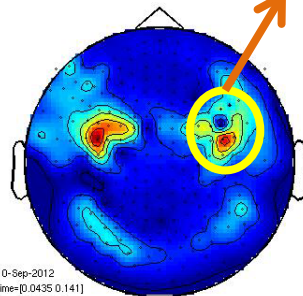
Excludes:
Body parts
Places

Sensor Analyses

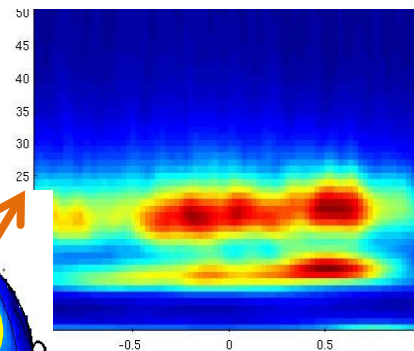
ERF: N170



Topo

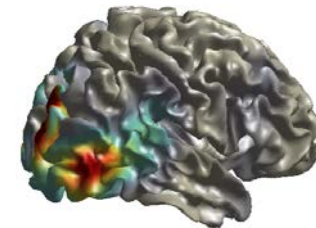


10-Sep-2012
time=[0.0435 0.141]
freq=[8.47 15.4]
powspctrm=[0.317e-23]



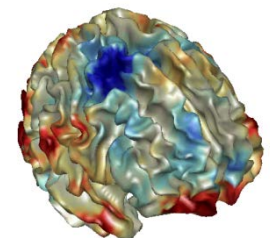
TFA

Source Analysis



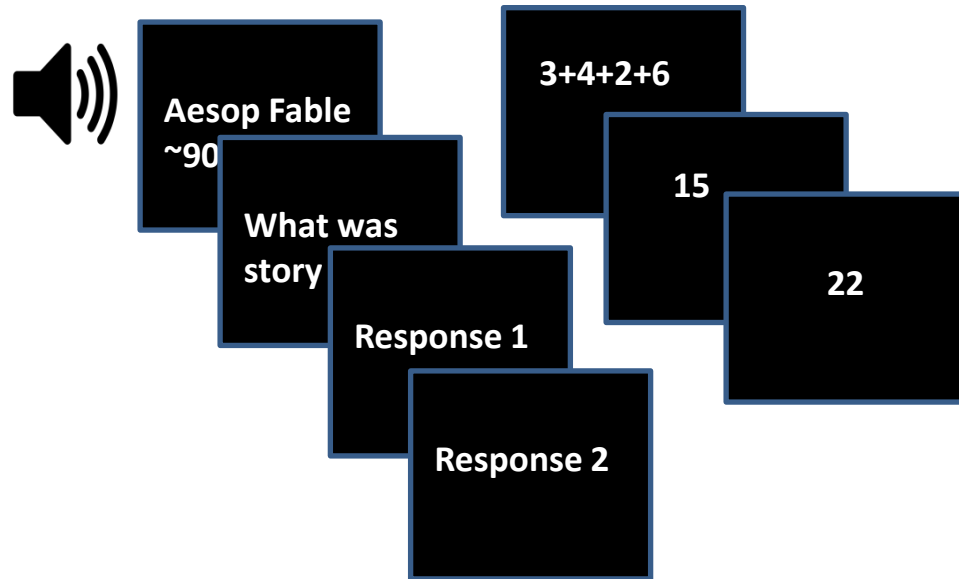
N170

BLP:
Theta
band

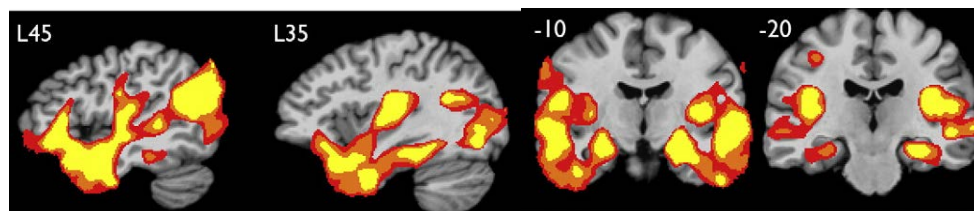


II. Data Collection: Behavioral Tasks

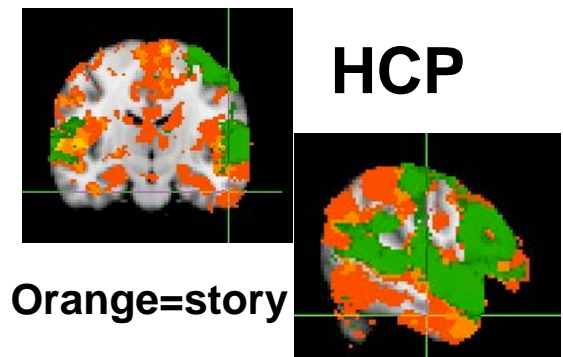
Story-Math Language Task (StoryM)



- Short (5-9 sent) stories adapted from Aesop's fables
- Animal and human subjects in social situations
- Mental arithmetic – serial addition/subtraction
- Button press response to 2 possible answers for each condition
- Difficulty level modulated



Story-Math, Binder et al., 2011

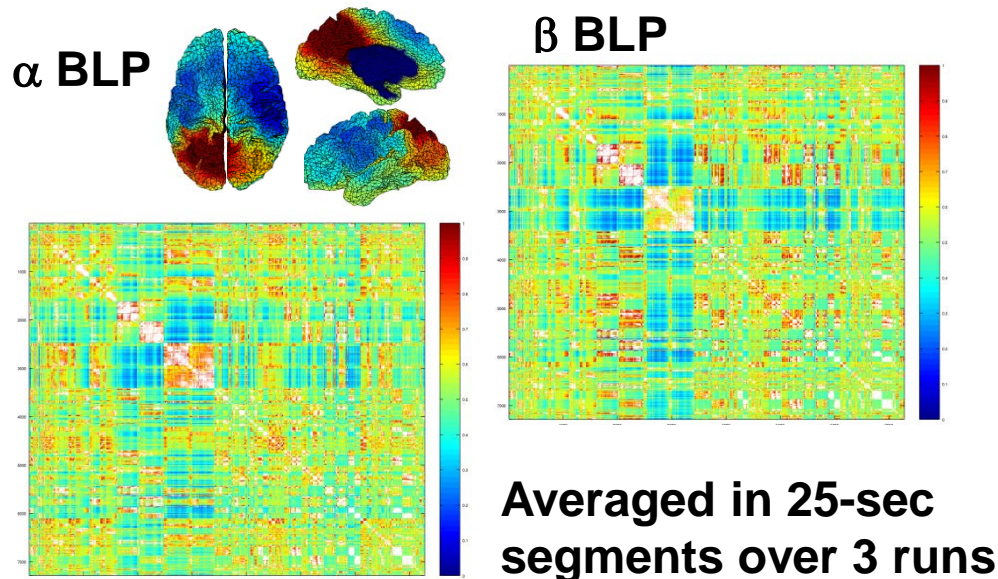


II. Data Collection: Resting State

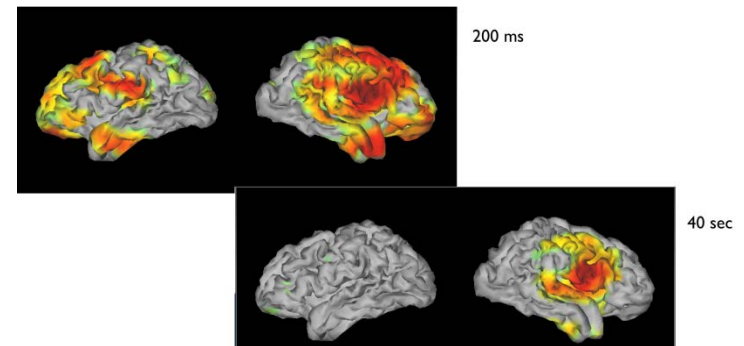


- Supine, eyes fixated on projected cross-hair
- 3 X 6-minute resting state scans
- After noise and before task scans
- ECG and EOG recorded for artifact removal
- Both stationary and non-stationary analyses
- Dense connectome is 8004X8004 nodes

Stationary BLP correlation Source-level dense connectome



Non-stationary BLP correlations

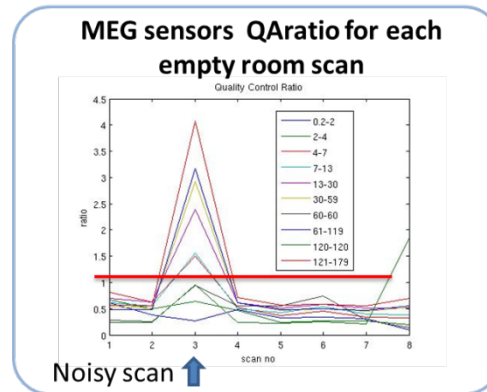
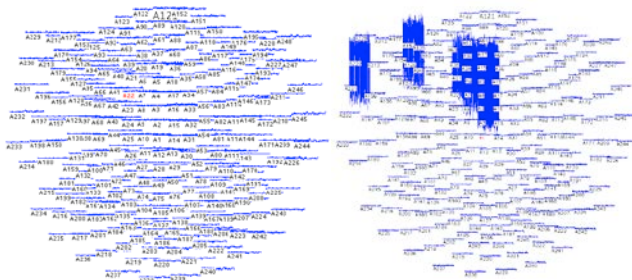


Practical 2.ex5: time windowed seed-based BLP correlations by frequency

II. Data Collection: Pre-scan Quality Control

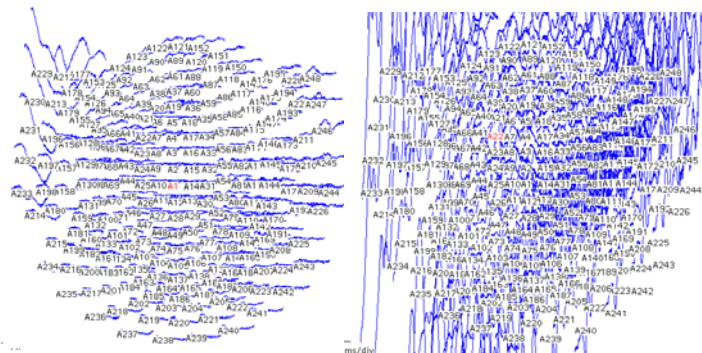
Artifact correction begins before experiments begin

Daily empty room scans
(Rnoise)



Automated QA tests of spectral content are calculated and assessed over days/scans to determine if corrections are needed

Patient noise scans
(Pnoise)



Pnoise scans are acquired prior to all experiments and visually examined for artifact. Adjustments are made, and new scans acquired until noise levels are reduced, or an equipment problem identified

II. Data Collection: Artifact Detection

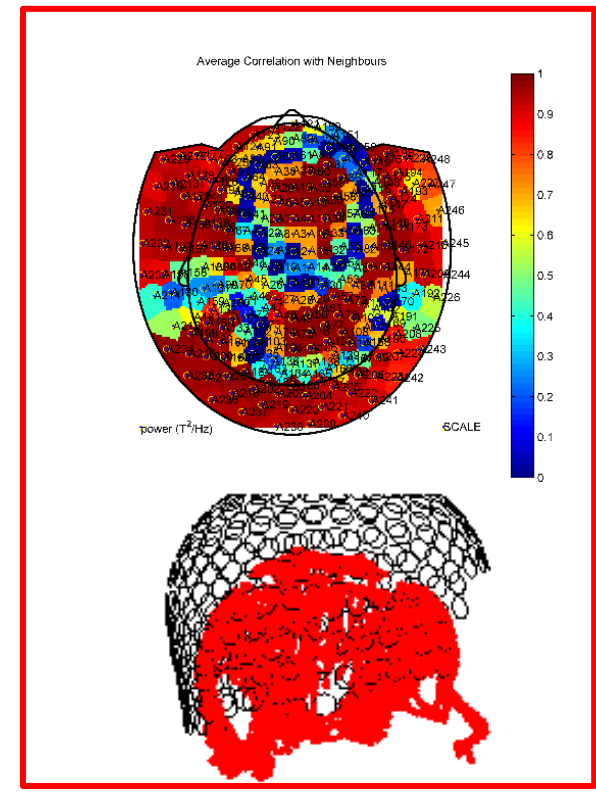
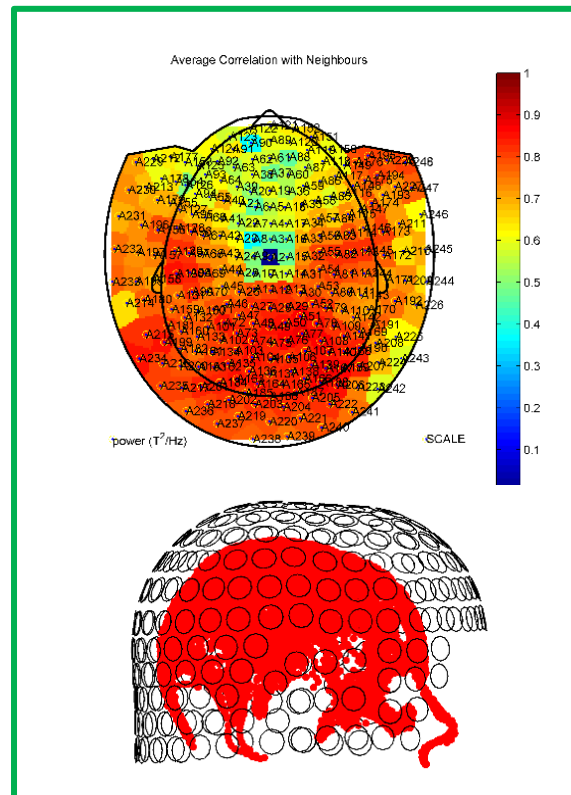
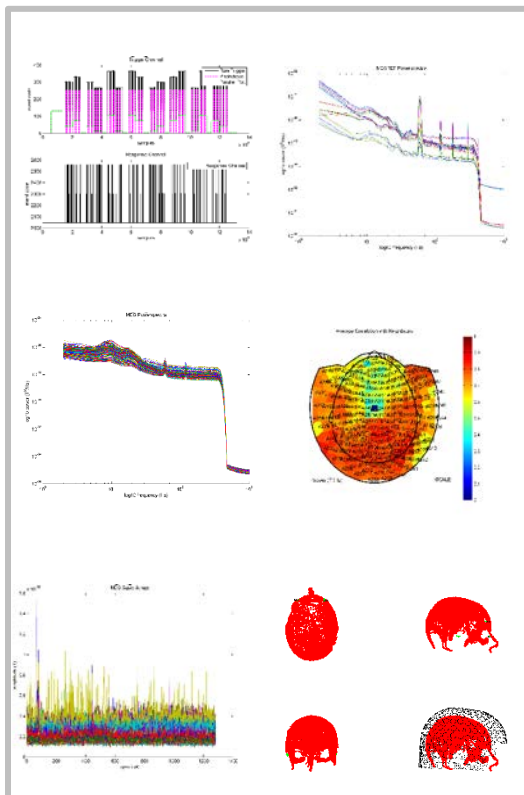
Baddata pipeline detects and records bad channels and segments to ASCII text file

Assessments include channel and reference spectral power, sensor correlations to neighbors, head-shape and sensor placement, and bad segments and are fully described in the HCP Reference Manual

Assessment

PASS

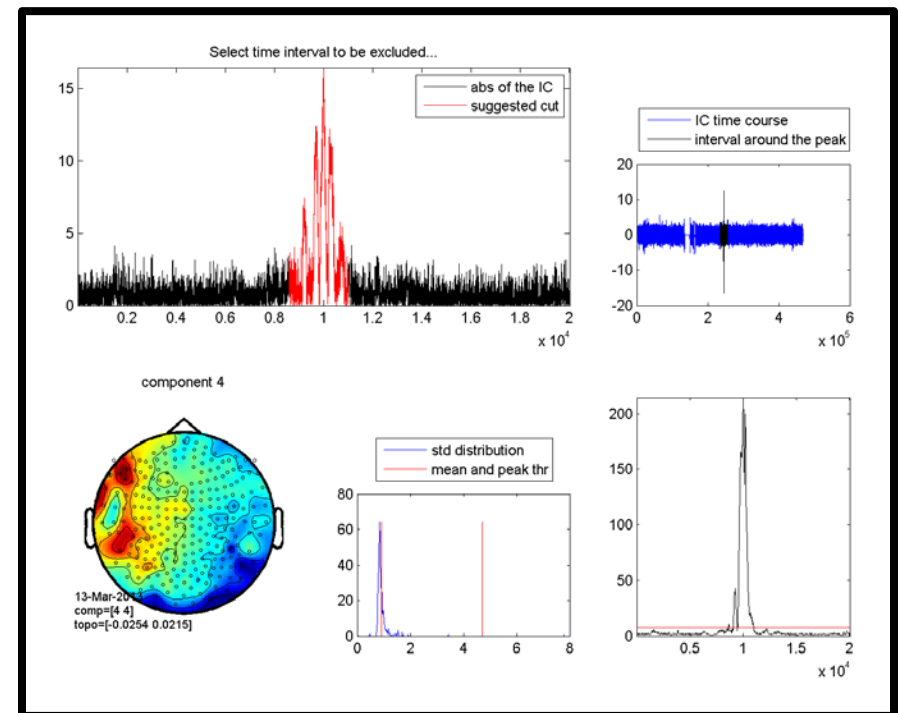
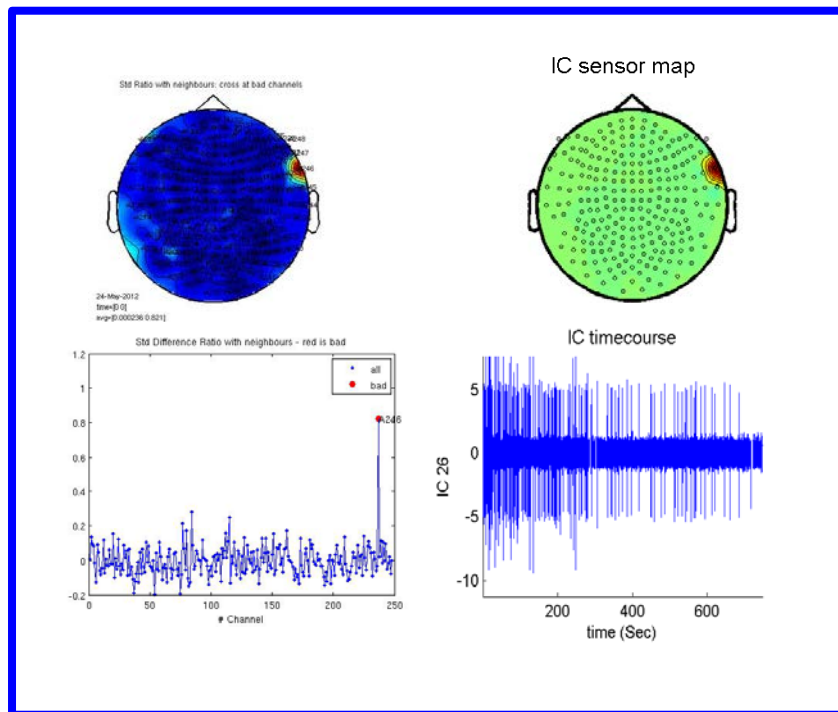
FAIL



II. Data Collection: Artifact Correction

Baddata pipeline detects and records bad channels and segments to ASCII text file

ICA is used to identify bad channels and bad data segments in addition to previously noted QA metrics, providing maximal ability to identify poor quality data or data that needs to be removed from further processing



Artifact removal is carried out in rest/task preproc pipelines

II. Data Collection: Released data sets

Only the highest quality collected data is released. In some cases, released data will exclude some scan types.

FINAL QUALITY ASSESSMENT

6-Wrkmem	USABLE	USABLE Invalid response channel value near beginning of time course. Possible power line noise artifact on A246 and A248. Coil#3 replaced just before this acquisition.	USABLE Head Positioning: GOOD Triggers: OK Electrodes: Seem OK Average coil movement: 1.752 mm Scan time: 637.08 s	USABLE Bad channels in total: 4 Bad segments: 83.3306 sec (0 zscore / 12.2491 ica / 71.0815 manual) Channels in the frontal part have low correlation with neighbors. Also sensors on the bottom show low values.	USABLE Number of Independent Components Brain related: 30 Artifacts: 5 Total: 35
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Assigned QA score
0 = poor
1 = good
2 = excellent

All data is evaluated and assigned a final QA score.
Only QA2 data is released.

The Subject Dashboard in ConnectomeDB, when the tab ‘MEG Sessions’ is included, provides information on which data sets are available for each subject

DATA FILTERS

Subject Information Demographics Subject = 100307|102816|1040 Edit Remove

Add New Filter

Subject Information MR Sessions MEG Sessions Add Tab < prev next >

<< first < prev 1 2 3 4 5 next > last >> 20 1 of 28 Pgs (542 Rows)

Subject	MEGsession_Scanner	MEGsession_Scans	MEGsession_Label
100307	SLU MEG	Pnoise(1), Restin(3), Rnoise(1), StoryM(2), Wrkmem(2)	100307_MEG
102816	SLU MEG	Pnoise(1), Restin(3), Rnoise(1), StoryM(2), Wrkmem(2)	102816_MEG
104012	SLU MEG	Motort(2), Pnoise(1), Restin(3), Rnoise(1), StoryM(2), Wrkmem(2)	104012_MEG
105923	SLU MEG	Motort(2), Pnoise(1), Restin(3), Rnoise(1), StoryM(2), Wrkmem(2)	105923_MEG
106521	SLU MEG	Motort(2), Pnoise(1), Restin(3), Rnoise(1), StoryM(2), Wrkmem(2)	106521_MEG
108323	SLU MEG	Motort(2), Pnoise(1), Restin(3), Rnoise(1), StoryM(2), Wrkmem(2)	108323_MEG
109123	SLU MEG	Motort(2), Pnoise(1), Restin(3), Rnoise(1), StoryM(2), Wrkmem(2)	109123_MEG
111514	SLU MEG	Pnoise(1), Restin(3), Rnoise(1), StoryM(2), Wrkmem(2)	111514_MEG
113922	SLU MEG	Motort(2), Pnoise(1), Restin(3), Rnoise(1), StoryM(2), Wrkmem(2)	113922_MEG
116524	SLU MEG	Pnoise(1), Restin(3), Rnoise(1)	116524_MEG
125525	SLU MEG	Motort(2), Pnoise(1), Rnoise(1), Wrkmem(2)	125525_MEG

III. Data Sharing: ConnectomeDB

CONNECTOMEdb All Datasets HCP Subject Keys Search by ID Search

Current Project: WU-Minn HCP Data - 500 Subjects + MEG2 Logged in as: [jlrort](#) | Auto-logout in: 0:29:23 - [renew](#) | [Logout](#)

Public Connectome Data

Updated Nov 25, 2014: Unprocessed, source and channel-level processed MEG data from WU-Minn HCP available on over 60 subjects.

[Update Log](#) [View Other Projects](#)

amazon web services Public Data Sets

HCP Data now mirrored on Amazon Web Services

WU-Minn HCP Data – 500 Subjects + MEG2

[Open Dataset](#) [Explore Subjects](#) [Download Image Data](#)

HCP public data releases include high-resolution MR scans from healthy adults and four imaging modalities: structural images (T1w and T2w), resting-state fMRI (rsfMRI), task-fMRI (tfMRI), and high angular resolution diffusion imaging (dMRI). Behavioral data is also largely available, with some restrictions. Furthermore, MEG data is available for some subjects. The Open Access Dataset includes imaging data and most behavioral data. To protect subject privacy, some of the data (e.g., which subjects are twins) are part of a Restricted Access dataset.

Last Updated:

ACCESS: [Restricted Access Terms Accepted](#) [Data available on Amazon S3](#)

KEYWORDS: HCP, MRI, CONNECTOME, MEG, RESTING STATE, DIFFUSION, RfMRI, DMRI, FMRI

526 SUBJECTS WITH MRI DATA
67 SUBJECTS WITH MEG DATA
542 SUBJECTS WITH BEHAVIORAL DATA

CONNECTOMEdb All Datasets HCP Subject Keys Search by ID Search

Current Project: WU-Minn HCP Data - 500 Subjects + MEG2 [Open Access](#) [Open Access](#) Logged in as: [jlrort](#) | Auto-logout in: 0:28:38 - [renew](#) | [Logout](#)

Dataset: WU-Minn HCP Data – 500 Subjects + MEG2

Dataset ID: HCP_500

DESCRIPTION	CONTENTS	ACTIONS
HCP public data releases include high-resolution MR scans from healthy adults and four imaging modalities: structural images (T1w and T2w), resting-state fMRI (rsfMRI), task-fMRI (tfMRI), and high angular resolution diffusion imaging (dMRI). Behavioral data is also largely available, with some restrictions. Furthermore, MEG data is available for some subjects. The Open Access Dataset includes imaging data and most behavioral data. To protect subject privacy, some of the data (e.g., which subjects are twins) are part of a Restricted Access dataset.	526 Subjects with MRI Data	Browse Subjects
	67 Subjects with MEG Data	Open Group
	542 Subjects with Behavioral Data	Download Images
		AWS Public Data Set

[Documentation](#) [Permalink](#)

Data Reference

[Known Data Issues and Planned Fixes](#)

[HCP Data Reference Manual](#)

[HCP Users FAQ](#)

[MEG Data FAQ](#)

[HCP Data Dictionary](#)

Pipeline Software

[HCP MR Pipelines Software](#)

[MegConnectome Software](#)

Purchase data and storage

[Order Connectome in a Box](#)

Quick Downloads

[March 2014 Data Patch](#)

[E-Prime fMRI scripts](#)

[In-Scanner Performance Data](#)

[Download Behavioral Data](#)

Group Average Functional Connectivity - Updated April 2015

The dense connectome file can be downloaded or accessed directly via Connectome Workbench. [See Documentation](#)

[468 Subjects \(Many Related\) Dense Connectome \(33GB\)](#)

[468 Subjects Group-PCA Eigenmaps](#)

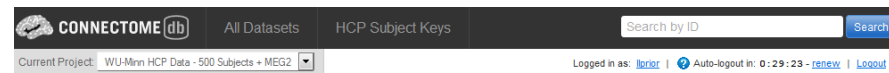
This is identical to the previously released file named `HCP_Q1-Q6_R468_fmri_groupPCA_q4500_Eigenmaps.dtseries.nii`

HCP500 Parcellation+Timeseries+Netmats (PTN)

[468 Subjects \(Many Related\)](#)

- HCP reference manual
- MEG FAQ
- Megconnectome Software
- Behavioral Data

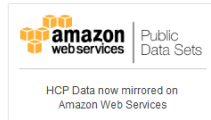
III. Data Sharing: ConnectomeDB



Public Connectome Data

Updated Nov 25, 2014: Unprocessed, source and channel-level processed MEG data from WU-Minn HCP available on over 60 subjects.

[Update Log](#) [View Other Projects](#)



WU-Minn HCP Data – 500 Subjects + MEG2 [Open Dataset](#) [Explore Subjects](#) [Download Image Data](#)

HCP public data releases include high-resolution MR scans from healthy adults and four imaging modalities: structural images (T1w and T2w), resting-state fMRI (rfMRI), task-fMRI (tfMRI), and high angular resolution diffusion imaging (dMRI). Behavioral data is also largely available, with some restrictions. Furthermore, MEG data is available for some subjects. The Open Access Dataset includes imaging data and most behavioral data. To protect subject privacy, some of the data (e.g., which subjects are twins) are part of a Restricted Access dataset.

Last Updated:

ACCESS: [Restricted Access Terms Accepted](#) [Data Available on Amazon S3](#)

KEYWORDS: HCP, MRI, CONNECTOME, MEG, RESTING STATE, DIFFUSION, RFMRI, DMRI, FMRI

526 SUBJECTS WITH MRI DATA
67 SUBJECTS WITH MEG DATA
542 SUBJECTS WITH BEHAVIORAL DATA

- Three processing levels
 - Unprocessed
 - Preprocessed
 - Source Level
- Three modalities
 - Anatomy
 - Resting State
 - Task
- Includes QA figures

Session Type
MEG

Processing Level
Unprocessed

Modalities
[Resting State](#)
[Task](#)
[Noise](#)

[Reset Filters](#)

Noise 67 of 67 subjects OK – 2,479 files, 48.21 GB
This package contains baseline scans with empty room and participant noise: file types c_rDC (raw, binary, 16-bit data) and config (metadata). Noise scans do NOT have head localization information.
keywords: MEG, noise, unprocessed [+ queue for download](#)

Resting State 61 of 67 subjects OK – 793 files, 137.26 GB
This package contains unprocessed resting-state data: each scan in this series will have its own folder (3-Restin, etc.) each containing 5 files: c_rDC (raw, binary, 16-bit data), config (metadata), e_rhfp1.0HzCOH (start position) and e_rhfp1.0HzCOH1 (final position).
keywords: MEG, resting state, unprocessed [+ queue for download](#)

Task: Working Memory 58 of 67 subjects OK – 754 files, 143.84 GB
This package contains unprocessed Working Memory task data: each scan in this series will have its own folder (6 Workmem, 7 Workmem, e.g.) containing 7 files: c_rDC (raw, binary, 16-bit data), config (necessary metadata), hs_file (shape), e_rhfp1.0HzCOH (start position) and e_rhfp1.0HzCOH1 (final position), and stimulus/response sync files (tab-delimited excel and text files processed from E-Prime).
keywords: MEG, task, unprocessed [+ queue for download](#)

Task: Story Math 57 of 67 subjects OK – 741 files, 103.79 GB
This package contains unprocessed Story-Math (Language processing) task data: each scan in this series will have its own folder (8-StoryM, etc.) containing 7 files: c_rDC (raw, binary, 16-bit data), config (metadata), e_rhfp1.0HzCOH (start position) and e_rhfp1.0HzCOH1 (final position), and stimulus/response log files (tab-delimited excel and text files processed from E-Prime).
keywords: MEG, task, unprocessed [+ queue for download](#)

Task: Motor 42 of 67 subjects OK – 546 files, 121.62 GB
This package contains unprocessed Motor task data: each scan in this series will have its own folder (9-Motort, etc.) containing 7 files: c_rDC (raw, binary, 16-bit data), config (metadata), e_rhfp1.0HzCOH (start position) and e_rhfp1.0HzCOH1 (final position), and stimulus/response log files (tab-delimited excel and text files processed from E-Prime).
keywords: MEG, task, unprocessed [+ queue for download](#)

[Select All](#) [Clear Selection](#) [Download Packages](#)

III. Data Sharing: ConnectomeDB

To download EPRIME result files as tab delimited ASCII, navigate to MEG Subjects from the splash page, click on subject of interest and navigate to MEG Session in Data/Type of Data

CURRENT SELECTION

SLU MEG , SLU

Accession ID: ConnectomeDB_E10375 | Operator:

Last Updated: 2014-07-29 14:10:31.271

ACTIONS

Go to Dashboard

Download CSV

Get Files

Download Images

Session Quality: 3T Summary

T1 Count	T2 Count	Resting State	T:Memory	T:Gambling	T:Motor	T:Language	T:Social	T:Relational	T:Emotional	Diffusion
1	2	4	1	1	1	1	1	1	1	1

Session Quality: Behavioral Summary

HCPPNP	DDISC	SPCPTNL	CPW	PMAT24A	VSPLOT24	ER40	NEO	ASR	ASR DSM
1	1	1	1	1	1	1	1	1	1

Acquisition Details

Scan	Type	Description	Files	Note
1	Rnoise	Rnoise	668.4 MB in 2 files	
2	Pnoise	Pnoise	133.9 MB in 2 files	
3	Restin	Restin1	820.2 MB in 5 files	
4	Restin	Restin2	846.9 MB in 5 files	
5	Restin	Restin3	822.0 MB in 5 files	
6	Wrkmem	Wrkmem1	1.4 GB in 7 files	
7	Wrkmem	Wrkmem2	1.3 GB in 7 files	
8	StoryM	StoryM1	1.0 GB in 7 files	
9	StoryM	StoryM2	973.2 MB in 7 files	

CONNECTOMEdb

All Datasets

HCP Subject Keys

Search by ID

Search

Current Project: WU HCP Data

DSM Subjects

MOD2

Open Access

Logged in as: [BIOB](#)

Auto-logout in: 0:29:05

Logout

Session

Project: HCP

SLU

Accession: Last Update

File Manager

scans

1 Rnoise

4D: 2 files, 668.44 MB 4D RAW

2 Pnoise

4D: 2 files, 133.96 MB 4D RAW

3 Restin

4D: 5 files, 820.22 MB 4D RAW

4 Restin

4D: 5 files, 846.99 MB 4D RAW

5 Restin

4D: 5 files, 822.0 MB 4D RAW

6 Wrkmem

4D: 5 files, 1.40 GB 4D RAW

LINKED_DATA: 2 files, 111 KB MISC RAW

7 Wrkmem

4D: 5 files, 1.31 GB 4D RAW

LINKED_DATA: 2 files, 115 KB MISC RAW

8 StoryM

4D: 5 files, 1.01 GB 4D RAW

LINKED_DATA: 2 files, 65 KB MISC RAW

9 StoryM

4D: 5 files, 1.01 GB 4D RAW

zip

Download

Close

6 Wrkmem

4D: 5 files, 1.40 GB 4D RAW

LINKED_DATA: 2 files, 111 KB MISC RAW

7 Wrkmem

4D: 5 files, 1.31 GB 4D RAW

LINKED_DATA: 2 files, 115 KB MISC RAW

104012_MEG_Wrkmem_run2lab.xml 75 KB

104012_MEG_Wrkmem_run2.xlsx.xml 40 KB

8 StoryM

4D: 5 files, 1.01 GB 4D RAW

zip

Download

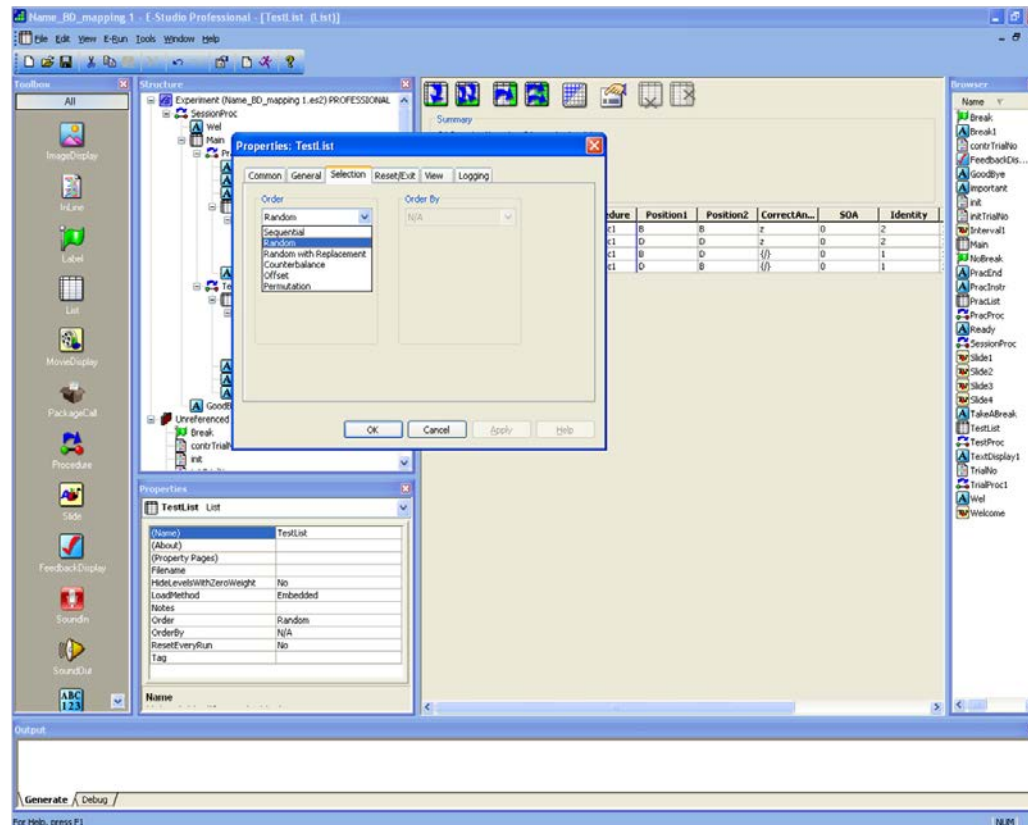
Close

Found in LINKED_DATA for task of interest

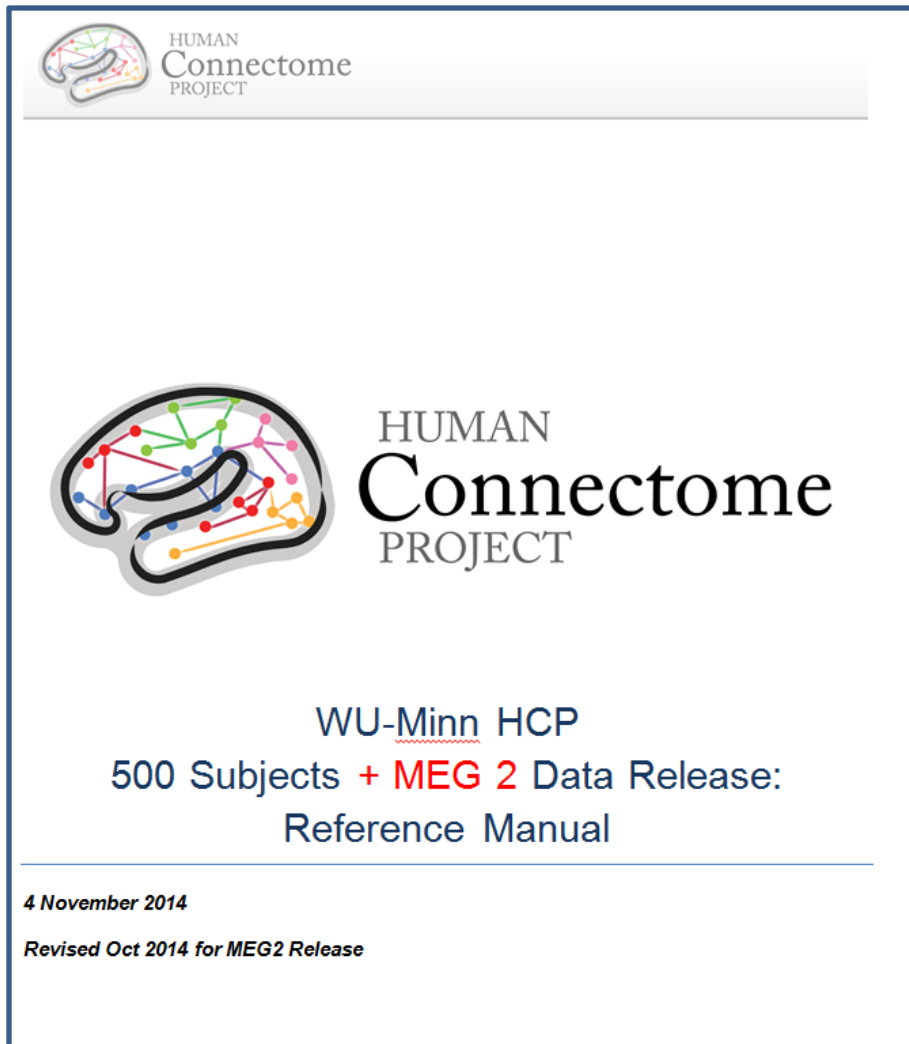
III. Data Sharing: ConnectomeDB

To obtain EPRIME program files you need to contact Tracy Nolan and request them. Her contact information is provided here:

Tracy S. Nolan
Washington University
tracyn@npg.wustl.edu

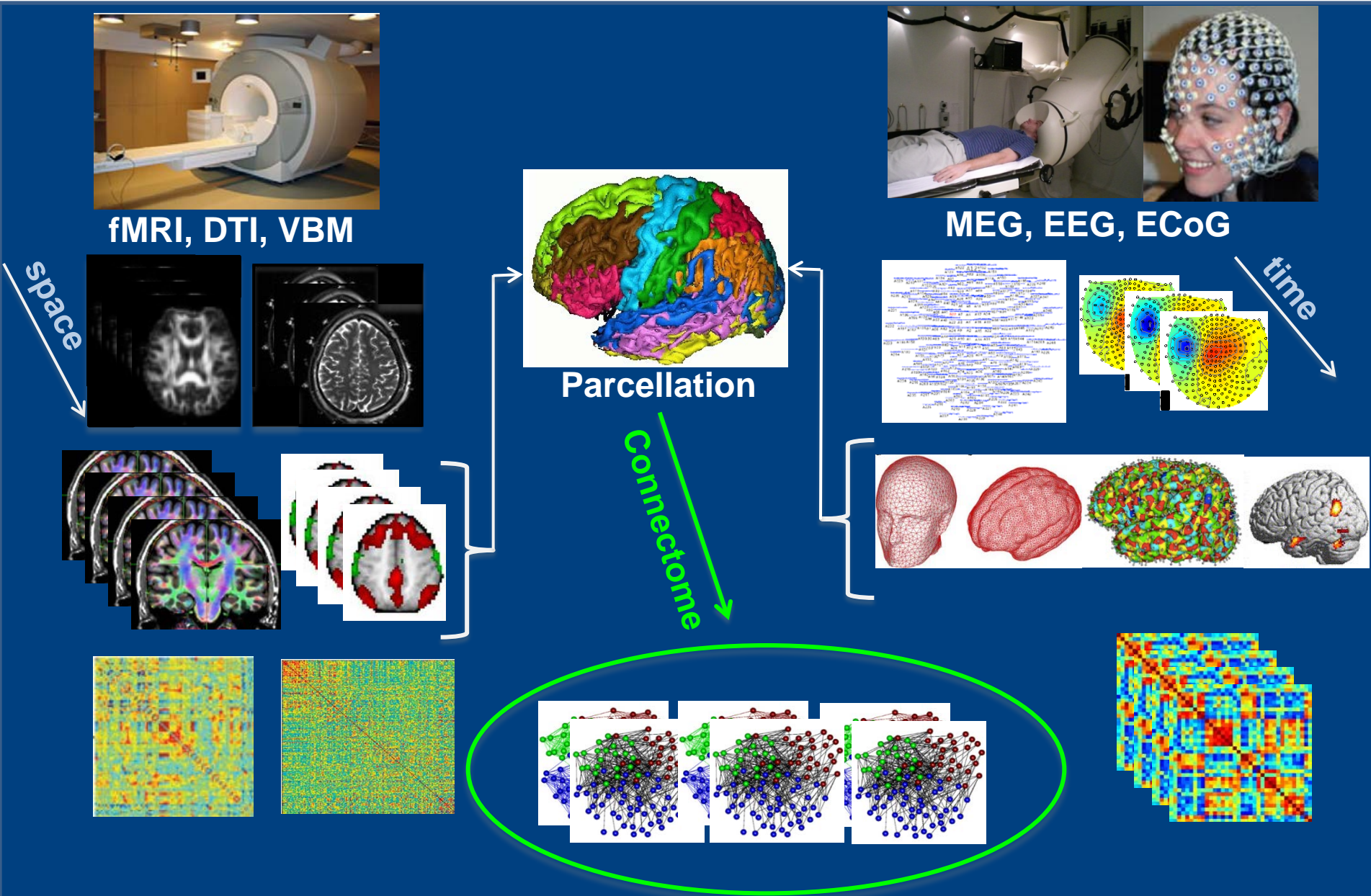


III. Data Sharing: Documentation

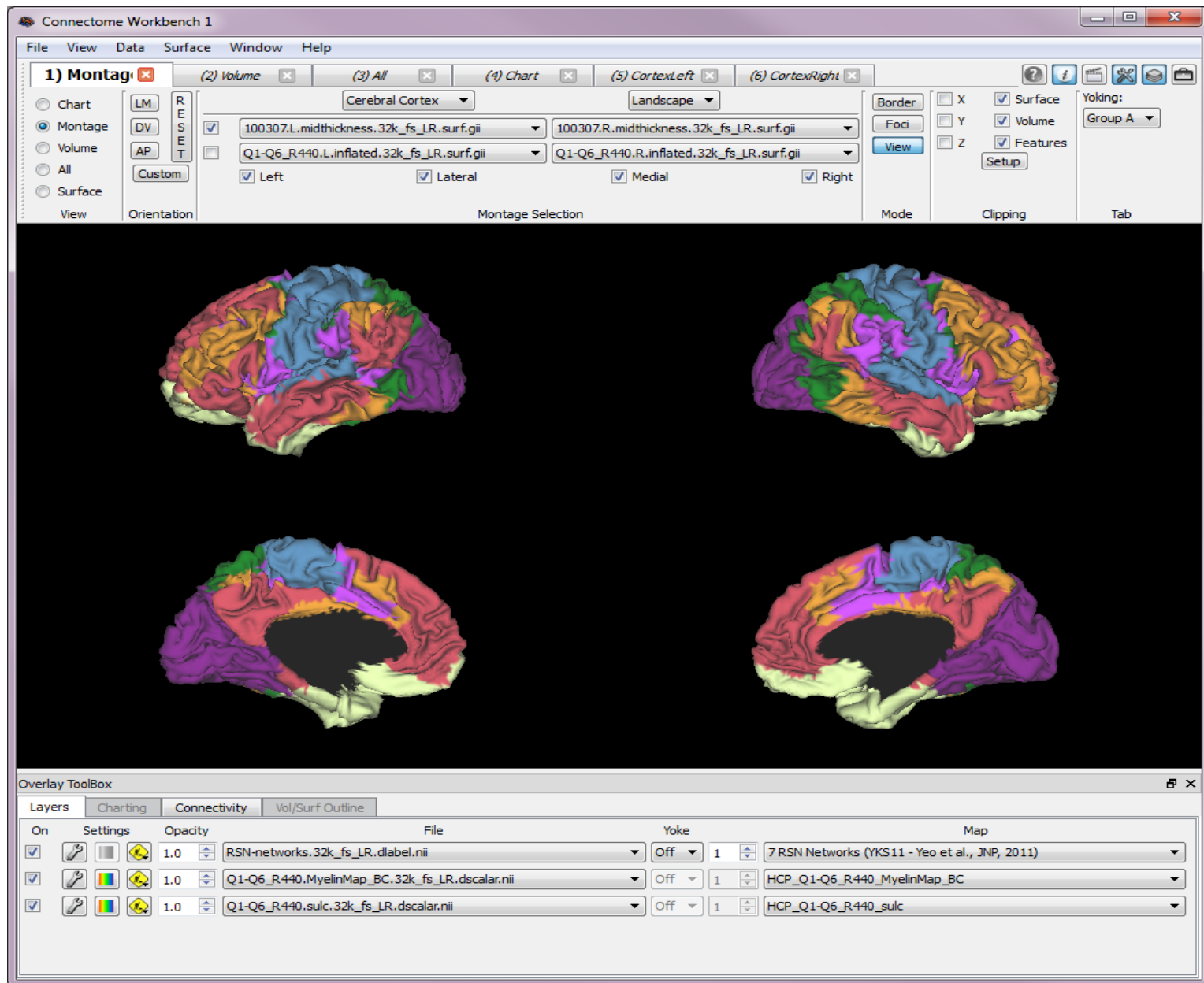


- **Full description of task protocols**
- **Complete description of all processing pipelines**
- **Information on MEG directory structures for raw and processed data**
- **Complete description of all events used in task processing**
- **Appendix containing all HCP SOPs**

III. Data Sharing: Multi-modal Integration



III. Data Sharing: Connectome Workbench



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Tera Kiser



HUMAN
Connectome
PROJECT

Mapping structural and functional connections in the human brain

The “WU-Minn” HCP consortium

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Saint Louis University

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Indiana University, Warwick University

Ernst Strungmann Institute (Frankfurt)

Radboud University (Nijmegen), Duke University

Advanced MRI Technologies (Sebastopol CA)

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