



December 2024

Instructors: Takfarinas Medani, Yash Vakilna, Chinmay Chinara

Once you have successfully installed and tested Brainstorm, proceed to download the data to be used in the workshop.

- Download the **raw data**:
 - https://box.bic.mni.mcgill.ca/s/vJWC1ak9CW1M6YU
- Unzip the downloaded raw data on your desktop: it will create a new folder named workshopLAX_raw

OUTLINE OF TOPICS COVERED IN THIS WORKSHOP

1. Introduction to Brainstorm Interface

2. EEG and MEG Analysis

- a. Import anatomy
- b. Review Raw recordings
- c. Import events
- d. Frequency filters
- e. Artifact detection and correction
- f. Sensor level analysis
 - i. Import recordings
 - ii. Review trials
 - iii. Trial averages
- g. Source estimation
 - i. Forward model (aka Head model)
 - ii. Noise covariance matrix
 - iii. Computing inverse models
 - iv. Atlases and Scouts

3. SEEG Analysis

- a. Import anatomy
- b. Coregister and Normalize images to standard MNI space
- c. SEEG contact localization
- d. Review Raw recordings
- e. Modeling interictal spikes using Min-Norm Imaging
- f. Modeling ictal onset with Low Voltage Fast Activity (LVFA) using fingerprint analysis (Sensor Space)
- g. Appendix: How to run CAT12 segmentation from Brainstorm
- h. Appendix: Remove power line noise

Preparing your dataset to be imported to Brainstorm

- MRI DICOM files have to be converted to NIfTI format.
- EEG data can be imported to Brainstorm in native format or EDF file conversions.

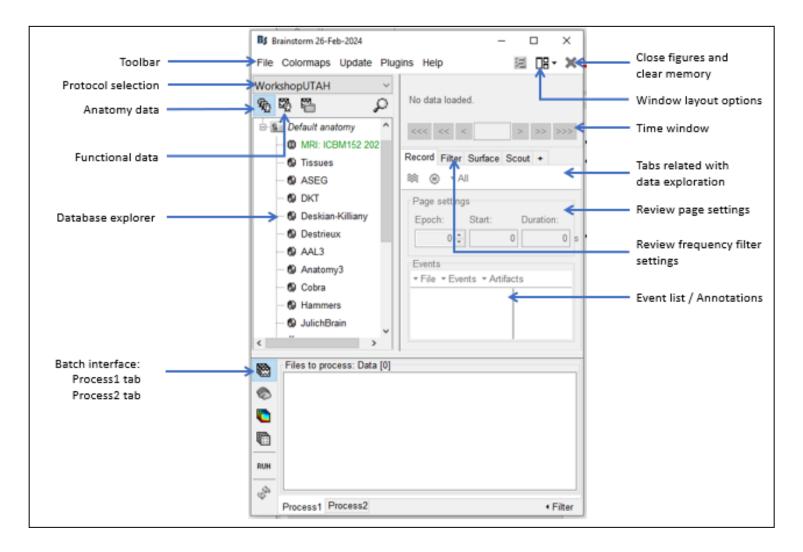




December 2024

1. Introduction to Brainstorm Interface

- CLOSE ALL YOUR APPLICATIONS, INCLUDING WEB BROWSERS
- Start Brainstorm: from Matlab or using the stand-alone application.



** red highlighted texts are processing steps we will be skipping during this workshop to save time

- 2. EEG and MEG Analysis: Import Anatomy
- Select File > New protocol: WorkshopLAX

Create new prote	000	>
Protocol definitio	n	
Protocol name :	WorkshopUTAH	
Anatomy path :	C:\Users\jhampson1\Desktop\WorkshopUTAH\anat	
Datasets path :	C:\Users\jhampson1\Desktop\WorkshopUTAH\data	
Default anatom	s for the subjects ny: ndividual anatomy	
Default anatom No, use i	ny: individual anatomy	
Default anatom No, use i	iy:	
Default anatom	y: ndhridual anstomy protocofs default anatomy I fille: (includes the SSP/CA projectors)	
Default anatom	ny: ndividual anatomy protocol's default anatomy	
Default anatom No, use i Yes, use Default channe No, use o	y: ndhridual anstomy protocofs default anatomy I fille: (includes the SSP/CA projectors)	



USC University of Southern California

Workshop Los Angeles

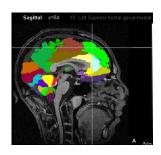
- No, use individual anatomy
- No, use one channel file per acquisition run (MEG/EEG)
- Introduction to database explorer (list of protocols, exploration modes...)
- Switch to anatomy view: 🥸 (1st button, on top of the database explorer)
- Right-click on protocol top node > New subject: **Subject01** (use Defaults)
- Right-click on the created subject > Import anatomy folder (Do not select the (auto) option)
 - Files of Type CAT12
 - Select the anatomy folder in Desktop/workshop_lax/
 - For Number of vertices set 15000
- Once the MRI viewer opens
 - Explain fiducial points and the coordinates (MRI, SCS, MNI)
 - Set coordinates: ⁽¹⁾, set fiducials:
 (MRI coords) NAS [125, 230, 64] LPA [48, 141, 44] RPA [215, 140, 59]
- Exploring MRI (): double-click or right-click > Display > MRI Viewer
 - Exploring the volume (click, mouse wheel, sliders)
 - Anatomical atlases, colormaps, colorbar, figure popup menu
- Exploring MRI (): right-click > Display > 3D orthogonal slices
- Display cortex (()): double-click or right-click > Display
 - 3D figure: rotation, zoom
 - Predefined views and keyboard shortcuts: left, right, top, etc
 - Surface tab: smooth, sulci, edges
 - Scouts tab: atlases and scouts
- Close all figures (button at top-right): close all figures and empty the memory

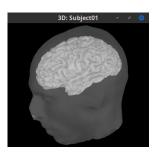
3. EEG and MEG Analysis: Review Raw recordings

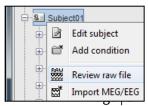
- Switch to functional view: 🙀 (2nd button, on top of the database explorer)
- Create Link to raw file: right-click on Subject01 >
 - Files of Type MEG/EEG: Yokogawa/KIT (*.sqd; *.con; *.raw; *.ave; *.mrk)















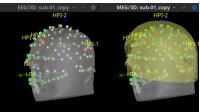
Workshop Los Angeles

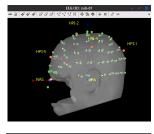
- Select the file SEF_000-export.con in the data folder in Desktop/workshop_lax/
- Click on Open
- In the popup for Refining registration, click on No
- The sensor coregistration will show, close it for now
- Change the type of some channels, right-click on the channel file > Edit channel file:
 - Channel EO1 (208) and EO2 (209): Change the type to EOG
 - Channel EKG+ (214): Change the type to ECG
 - Channel E (231): Change the type to Misc
 - Close the figure and accept to save the modifications
- Check sensor coregistration
 - right-click > MRI registration > EEG:Check
 Some electrodes are above or inside the head surface
 - ☆ right-click > MRI registration > EEG: Edit
 - Select Project electrodes on surface
 - Click OK and save
 - ☆ right-click > *MRI* registration > *MEG:Check*
 - Close figures
- Review EEG signals: 👹 right-click > EEG > Display time series
 - Display in columns (🐲), display windows of 10s
 - Amplitude gain: buttons and shortcuts
 - Add a topography and set the window layout to weighted
- Review MEG signals
- Review EOG signals
- Review EEG and EOG signals simultaneously
- Close all figures

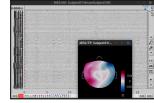
4. EEG and MEG Analysis: Import events

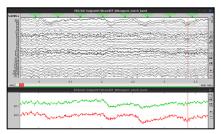
- Different ways of Importing events
- Right-click on Link to *raw file* > *TRIGGER* > *Display time series*
 - Display in columns. Notice that Trigger01 contains the information of the electric stimuli
- In the Record tab, menu *File > Read events from channel*
 - Event channel = Trigger01
 - Option = TTL: detect peaks of 5V/12V on an analog channel
 - Do **NOT** check the option **Accept zeros as trigger values**
- Close the figure with the timeseries to save modifications

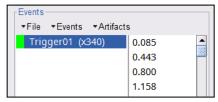
300	EEGODO	EEG
367	EEG061	MISC
368	EEG062	EOG
369	EEG063	ECG
370	EEG064	MISC
371	EEG065	FEG















Workshop Los Angeles

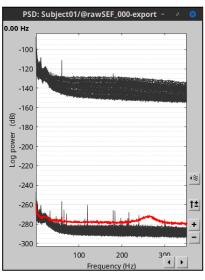
5. EEG and MEG Analysis: Frequency filters

- Process section
 - Tabs Process1, Process2
 - File types:
 [®] recordings,
 [®] sources,
 [®] time-freq, and
 [®] matrices
- EEG and MEG: Filter power line artifact
 - Close all the figures
 - Drag-and-drop ()) raw file in *Process 1*, click [RUN]
 - Add the process: Frequency, Power spectrum density (Welch)
 - Time window = All file, Window length = 5s, Overlap = 50%
 - Units = Physical
 - Sensor types = EEG, MEG
 - Click on Run
- Open the new (L) PSD file
 - Two PSD groups, from top to bottom: **EEG** and **MEG** sensors
 - Peak around 11 Hz: alpha waves from the subject's brain
 - Peaks at 60Hz, 120Hz, 180Hz on EEG and MEG: Power lines (60Hz+harmonics)
 - Smaller peaks at 35Hz, 65Hz, 70Hz, 183Hz, 197Hz on MEG only: Unknown source
 - MEG sensor LC11 appears to have a higher level of noise than all the other MEG sensors.

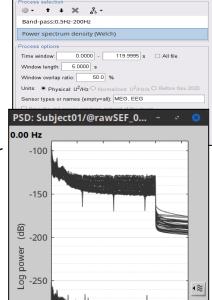
Select the channel (it becomes red), right-click and *Mark selected as bad*

This is often an indication of a bad channel, we can verify this by reviewing MEG signals

- Notch filter the raw file: Select: **Pre-process > Notch filter**
 - Frequencies to remove (Hz) = 60, 120, 180 Hz
 - Sensor types = EEG, MEG
 - Compute the PSD for the notch-filtered raw file, and open the new PSD file
 - EEG and MEG: Bandpass filter
 - Drag-and-drop notch-filtered raw file in Process , click [RUN]
 - Add the process *Pre-process > Band-pass filter*
 - Sensor types = EEG, MEG, Lower cutoff freq = 0.5 Hz, Upper cutoff freq = 200 Hz
 - Click View filter response to see the filter properties
 - Select: Frequency, Power spectrum density (Welch)



Pipeline editor – 🔹 🙁
Process selection
@• † ↓ % _&•
Band-pass:0.5Hz-200Hz
Power spectrum density (Welch)
Input options
□ Process the entire file at once (select to process files with SSP, may require a lot of memory)
Process options
Sensor types or names (empty=all): MEG, EEG
Filtering parameters:
Lower cutoff frequency (0=disable): 0.500 Hz
Upper cutoff frequency (0=disable): 200.000 Hz
Transition band (0=default): 0.000 Hz
Stopband attenuation:
Filter version: 2019 2016-2018 Before Oct 2016
View filter response
Online tutorial Cancel Run





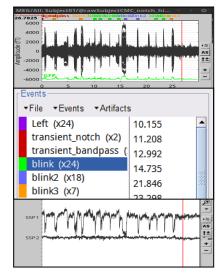


- Add the process: Frequency, Power spectrum density (Welch)
- Run the pipeline
- EEG: re-reference to Average
 - Open the EEG timeseries for the bandpass filtered raw file (in folder _notch_band)
- Click on Artifacts > Re-reference EEG and use AVERAGE as EEG reference channel
- Delete intermediate files that won't be needed anymore:
 - Select folder SEF_000-export_notch
 - Press the Delete key (or right-click > *File* > *Delete*)

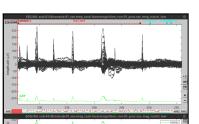
6. <u>EEG and MEG Analysis: Eye-movement related artifacts and other artifacts</u>

- Detect eye-movement events
 - Open the time series for EEG and EOG
 - In the Record tab, select Artifacts > Detect eye blinks, and use the parameters:
 - Channel name = EO2, Time window = All file, Event name = blink
 - Display MEG signals (along EOG) and see some blink occurrences
 - Merge all the **blink** event groups in a **blinks** group
- Detect heartbeat events
 - Open the time series for EEG and ECG
 - In the Record tab, select Artifacts > Detect heartbeats, and use the parameters:
 - Channel name = EKG+, Time window = All file, Event name
 = cardiac
- Handle simultaneous events
 - In the Record tab, select Artifacts > Remove simultaneous:
 - Remove events named: cardiac
 - When too close to events: blinks
 - Minimum delay between events: 250 ms
- Remove blink artifacts from EEG with ICA
 - Open the time series for EEG
 - In the Record tab, select Artifacts > ICA components, and use the parameters:
 - Time window = All file, Band-pass filter = [0, 0], Resample = 0/CA algorithm = Picard, Number of ICA components = 0
 Sort components based on correlation with = EOG, ECG

Events		
▼File ▼Events ▼Artifacts	5	
Left (x24)	10.155	
transient_notch (x2) 11.208		
transient_bandpass (12.992		
blink (x24)	14.735	
blink2 (x18) 21.846		
blink3 (x7)	23.298	



Select active projectors - 🔹		
Projector categories	Projector components	
6 V R X 8 Ø 00	Components to remove:	
EEG reference: AVERAGE	Component #1	
✓ICA_picard: EEG, 20-Jun-2023 15:32:55	Component #2	
blink_bad: SSP_pca, MEG GRAD+MEG MAG, 20-Jun-2023	Component #3	
	Component #4	
	Component #5	
	Component #6	
	Component #7	
	Component #8	
	Component #9	
	Component #10	
	Component #11	
Cancel Save	Component #12	



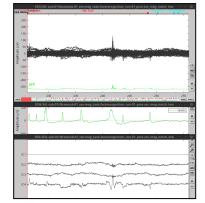


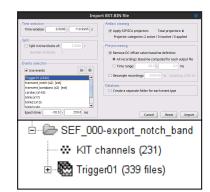
- In the Select active projectors window, uncheck all ICA components, highlight the first eight and plot their time series (), and topologies
- Open EEG and EOG time series and disable auto scaling (AS) plots
- Check Component #1 which is related to the ECG signal and impact
 - of removing it from the EEG signal
- Check Component #2 which seem related to the EOG signal and verify the impact of removing it from the EEG signal
- Click on **Save**, close all figures
- Remove blink artifacts from MEG with SSP
 - Open the time series for MEG
 - In the Record tab, select Artifacts > SSP: Eye blinks, and use the parameters:
 - Event name = blinks, Sensors = MEG

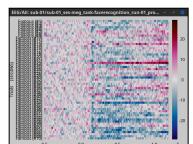
 - Open MEG (all) and EOG time series and disable auto scaling (AS) in the 3 plots
 - Check Component #1 to verify the impact of removing it from the MEG signal
 - Click on Save, close all figures

7. EEG and MEG Analysis: Import recordings

- Import in database
 - Right-click on the pre-processed file > *Import in database*, and use the parameters:
 - *Time window* = 0 119.9995 s
 - Do NOT check Split in time blocks
 - Check Use events and select Trigger01 (x340)
 - *Epoch time* = **-50 to 250 ms**
 - Check Apply SSP/ICA projectors
 - Check Remove DC offset, select All recordings
 - Answer **Yes** to this question to discard the last epoch.
 - A new folder named SEF_000-export_notch_band is created (no more raw indicator)
- Review trials
 - Trials groups (), contain same-name trials (often imported from with the same event)

















USC University of Southern California

)

Workshop Los Angeles

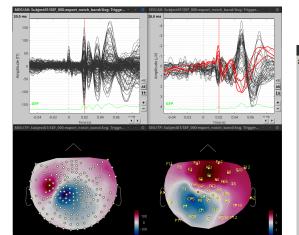
- Trials containing an bad event (with **bad** in its name) are labeled as bad (
- Rastreplots: Right-click on trial group > Display as image > EEG select channel CP5 in the Display Tab
- Average trials
 - Drag and drop all the trial groups in Process1
 - Run process *Average* > *Average files*:

• Group files = Everything, Function = Arithmetic average

- Check different plots for the average somatosensory evoked potential (SEP) in EEG signals, and the somatosensory evoked fields (SEF) in MEG signals. Plot both topographies
- Create a sensor cluster
 - Open the *Cluster* tab by clicking on the plus sign (+) at the right of *Record* tab^{™™}
 - Click on to create a new cluster by indicating the sensor names, use C3, CP5 and P3
 - Plot the cluster time series with on the plot button (
- Observe Components N20, P25, N33 and P45 visible over left somatosensory cortex in EEG and their respective fields in MEG

)

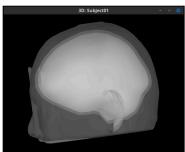
- Close all figures. Do not save the created cluster
- •

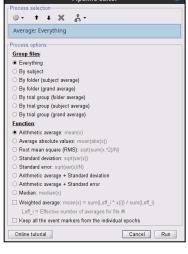




Forward model (aka Head model)

- Computing boundary element (BEM) layers
 - Go to the anatomy view
 - Right-click on Subject01 folder > MRI segmentation > Generate BEM surfaces
 - Select Brainstorm





- Number of vertices: Scalp = 1082, Outer skull = 642 and Inner skull = 642
- Thickness of layers, Skull (mm) 4
- Note: This number of vertices is selected to avoid long computations during the workshop. Otherwise, values of 1922 vertices can be used.
- Right-click on the default cortex (in green) > Force inside skull
- The fix cortex is now selected as default
- Compute the head model for EEG and MEG
 - Go back to the functional data view
 - Right-click on the channel file (*) in the imported data folder > Compute head model
 - Source space = Cortex surface
 - Forward model = MEG: Overlapping spheres and EEG: OpenMEEG BEM
 - Click on OK
 - Use default BEM layers and conductivities
 - Use default OpenMEEG options
 - The process may take up to 5 min
- Demo: the forward model can be computed also using the FEM method
 - Computation of FEM meshes from BEM surfaces. They can be computed from volumes
- Forward model can be computed with the DUNEuro plugin

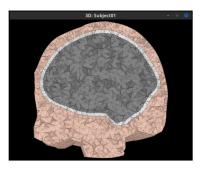
9. EEG and MEG Analysis: Noise covariance matrix

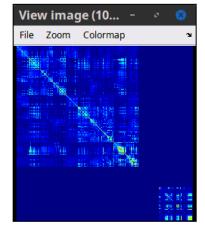
- Compute noise covariance for EEG and MEG from pre-stimulus baselines
 - Select the trial group, right-click > Noise covariance > Compute from recordings:
 - Baseline = [-50, 0] ms, Sensors = EEG and MEG
 - Select **Block by block**

10. EEG and MEG Analysis: Computing inverse models

- Compute inverse model (EEG)
 - Right-click on the head model (
 ⁽
 ⁽⁾
 ⁽
 - Select Minimum norm imaging, Select Current density map
 - Select Constrained: Normal to the cortex
 - Sensors = EEG
 - Compute inverse model (MEG)
 - - Select Minimum norm imaging, Select Current density map

<u>.</u>	🔁 <u>su</u>	b-01_ses-meg_task-facerecognition_run-01_
		Neuromag channels (404)
	- Q	OpenMEEG BEM Overlapping spheres





- Avg: Famous (57 files)

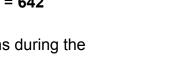
⊷ ₩ Avg: Scrambled (53 files)
 ⊕ ₩ ₩ Avg: Unfamiliar (54 files)

MN: EEG(Constr) 2018

MN: MEG ALL(Constr) 2018

MN: EEG(Constr) 2018

MN: MEG ALL(Constr) 2018





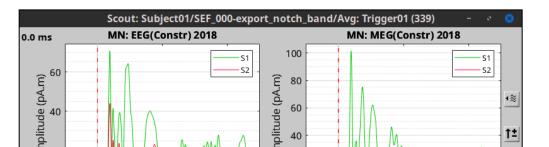


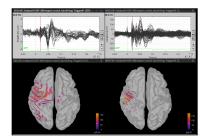


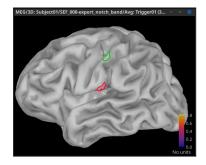
- Select Constrained: Normal to the cortex
- Sensors = **MEG**
- Explanation on the inversion kernel () and link () files in the database
- Explore the estimated average Avg: Trigger (339) at 20ms
 - Display EEG and MEG time series (butterfly mode)
 - Display the sources derived from EEG and from MEG data
 - Set the colormap to local maximum (maximum in that time slice)
 - Right-click on the colorbar > Colormap: sources > Maximum Local
 - Set time to 100 ms
 - Set Smooth = 30% and Amplitude threshold to 40% (both in Surface tab)
- Explore other times, and the evolution of the brain activity

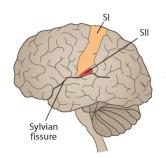
11. EEG and MEG Analysis: Atlases and Scouts

- Display the **sources** derived from EEG and MEG data
 - In the Scout tab, use the dropbox to select different Atlases
 - Operations with Atlases and Scouts
- Create Scouts
 - Open the sources (from MEG) for the average, left view
 - Select the User Scouts atlas
 - Create scout S1 (primary somatosensory cortex) on the left hemisphere
 - Go to Time 20 ms, Amplitude threshold 60% Smooth = 30%
 - Scout tab: Click on Select point (+), then point on activity in the post central gyrus
 - Grow Scout to 20 vertices
 - Rename to S1 (double-click on the scout in the list)
 - Review trace: Absolute values
- Create a second scout S2 (secondary somatosensory cortex) on the left hemisphere
 - Go to Time **50 ms**, Amplitude threshold **20%** Smooth = **30%**
 - Scout tab: Click on Select point (+), then point on activity in the bottom part of the post central gyrus, which is the anatomical location of S2.
- Review S1 and S2 traces together in absolute values. For sources from EEG and MEG









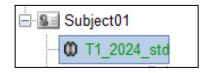




December 2024

12. SEEG Analysis: Import Anatomy

- Import T1 pre-implantation: (5 mins)
 - Right-click on Subject01 > Import MRI
 - Select format: MRI: NifTI
 - Select file: T1_2024_std.nii.gz
 - Introduction to the MRI viewer: Click, mouse wheel, color bar, popup
 - In the MRI Viewer, click on **Compute MNI normalization** and select



the **maff8** algorithm. This sets default positions for the fiducials Coordinate systems: MRI, SCS, World, MNI and also does MNI normalization

- Click Save
- Import post-implant CT: (10 mins)
 - Prerequisites: <u>BrainSuite</u>, ct2mrireg plugin
 - Right-click on the Subject01 > Import CT
 - Select format: MRI: Nifti
 - Select file: CTpost_std.nii.gz (pre registered CTpost_reg.nii.gz)

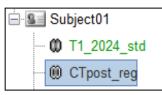
13. <u>SEEG Analysis: Coregister and Normalize images to</u> <u>standard MNI space</u>

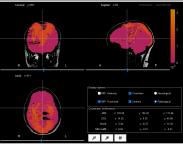
- Select coregister using CT2MRI and select Yes both to reslice volume and clean CT volume. (Select Ignore and select No for reslice volume as the CT is already co-registered.)
- The MRI viewer opens automatically, showing the post-implantation CT volume as a colored layer on top of the previous volume. Use this display to validate that the co-registration of the two volumes is correct (all the parts of the head must align well).

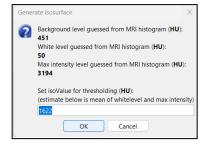
Generate isoSurface (2 mins)

- This creates a thresholded mesh from the CT to separate the contacts from the rest. This aids the user towards localization of the electrodes and its contacts more accurately.
- Right click on CTpost_reg> CT segmentation > Generate threshold mesh from CT
- Set the isoValue for thresholding, the estimation is from the mean of white level and max intensity of the CT. You can leave it as default, select **OK**
- An isosurface is generated showing the contact as blobs overlayed on the 3D MRI slices. The **Thresh** slider under **Surface options** can be used to fine tune and regenerate mesh with different isoValues.

14. SEEG Analysis: Contact localization















December 2024

Bs Brainstorm 20-Mar-2024	- 🗆 X	
File Colormaps Update Plugins Help	回 品- ×	
TutorialSeegImplantation	No data loaded	Add new or remove selected electrode
Subject01	Coordinates Second Eliter Surface Scout Coordinates Image: Second Eliter Surface Scout Scou	Used to select contact coordinates from 3D Viz Display contacts as Depth electrodes or Spheres Show/Hide selected electrode Radio Buttons to display contact values in the selected coordinat space
	AH9 12.64 40.23 23.38 AH10 12.73 43.73 23.55 AH11 12.82 47.22 23.73 AH12 12.90 50.72 23.90 AH13 12.99 54.21 24.08 AH14 13.07 57.70 24.25 Electrode configuration Type: ••• SEEG •• ECOG •• ECOG-mid Model: PMT 2102-14-091/2102-14-101	
	Actions: + - Number of contacts: 14 Contact spacing: 3.50 mm Contact length: 2.00 mm Contact diameter: 0.80 mm Electrode diameter: 0.70 mm	Electrode model selection and spacing option
	Electrode length: 47.50 mm	Set coordinates for tip and electrode entry

Manual contact labeling (30 mins)

- Right click on CTpost_reg and choose SEEG/ECOG implantation. This takes you to the functional tab and Subject01 > Implantation > SEEG/ECOG (0) channel gets created. The MRI Viewer (CT overlayed MRI) and 3D Viz (isoSurface+3D MRI Slices) load up as well along with the Panel iEEG.
- Click the + icon from the list of panel tabs and choose Add: Coordinates. This adds the Panel Coordinates which will be used to select points from the 3D Viz.
- On Panel iEEG Click on the + (Add new electrode). This opens up the Add electrode window. Enter anything under the Electrode label based on your convention. For this e.g., enter AH and press OK.
- Select SEEG, and choose the electrode model (PMT

Record Filter			ordinates +	
Coordinates	Coordinates (millimeters)			
	х	Y	Z	
MRI:	-	-	-	
SCS:	-	-	-	
World:	-		-	
MNI:			-	
No vertex s	selected			



USC University of Southern California

December 2024

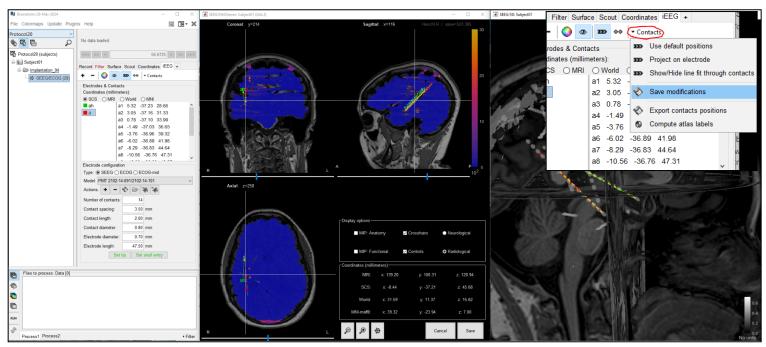
Workshop Los Angeles

2102-14-091/2102-14-101 which is a 14 contact electrode.

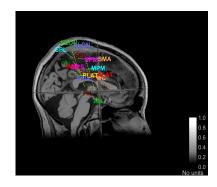
 Switch to the **Coordinates** panel, click **Select** and choose the deepest contact from the isosurface in 3Dviz. This should plot a yellow crosshair marker point on the contact blob and also update the crosshair in the MRI Viewer.

Note: You can play around with the **Thresh** slider under **Surface** tab to get better visibility of the contacts as required

- Switch back to the iEEG panel and click Set tip and the button turns green, indicating that the tip has been set. This point in 3D is at the centroid of the blob, which gives a more accurate location of the contact.
- Go back to the Coordinates tab and repeat the steps above for the skull entry
- Now click Set skull entry and the button turns green indicating that the entry point has been set. The MRI Viewer gets updated with the electrode.



- Click on Save in the MRI Viewer. This saves the new channel file and updates the number of channels in the database explorer. Click Yes for any other Save windows that pop up.
- Double-click the Implantation > SEEG/ECOG channel in the Functional tab to get an updated 3D Viz and MRI Viewer with all the electrodes.
- Repeat these steps for each SEEG electrode except the last step of saving.
- For saving all the further electrodes, click on **Contacts > Save Modifications** to update the







December 2024

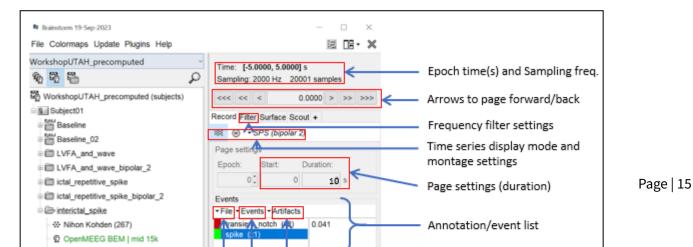
channel information and that saves the changes to the database.

Anatomical labeling (5 mins)

- Switch to the anatomy view.
- Right-click on Subject01 > Add MNI parcellation > AAL3. Repeat with parcellation: Hammers83, Hammers95.
- Close all the figures. Switch back to the Functional view.
- Right-click on the channel file > iEEG atlas labels
- Create Subject01.tsv and click OK. Select all the available options: coordinates in various coordinate systems, volume parcellations, surface parcellations.
- The output is a table, one row per sensor contact in the channel file, for each sensor: coordinate location in the parcellation atlas and probability of the label .

Channel	MNI	AAL3 (MNI-linear)	AAL3 (MNI-linear)_prob	Hammers95 (MNI-linear)	Hammers95 (MNI-linear)_prob
ah1	[39.877,11.669,-5.910]	Insula R	82%	insula_ant_inf_c R	88%
ah2	[40.176,8.912,-3.437]	Insula R	66%	G_insula_mid R	69%
ah3	[40.475,6.155,-0.964]	Insula R	62%	G_insula_post R	62%
ah4	[40.773,3.398,1.509]	Insula R	96%	G_insula_post R	92%
ah5	[41.072,0.641,3.982]	Insula R	89%	G_insula_post R	98%
ah6	[41.371,-2.116,6.456]	Insula R	89%	G_insula_post R	80%
ah7	[41.670,-4.873,8.929]	Rolandic_Oper R	64%	G_insula_post R	60%
ah8	[41.968,-7.630,11.402]	Rolandic_Oper R	52%	PL_postce_G R	86%
ah9	[42.267,-10.387,13.875]	Rolandic_Oper R	59%	PL_postce_G R	94%
ah10	[42.566,-13.144,16.348]	Rolandic_Oper R	88%	PL_postce_G R	98%
ah11	[42.864,-15.901,18.822]	Rolandic_Oper R	100%	PL_postce_G R	100%
ah12	[43.163,-18.658,21.295]	Rolandic_Oper R	82%	PL_postce_G R	97%
ah13	[43.462,-21.415,23.768]	N/A	N/A	PL_supramarginal_gyrus R	99%
ah14	[43.761,-24.172,26.241]	N/A	N/A	PL supramarginal gyrus R	100%

15. SEEG Analysis: Review Raw recordings (15 mins)







- In the functional view: 4 (2nd button, on top of the database explorer) 0
- Create Link to raw file: right-click on Subject01 > Review raw file
- Files of Type EEG: EDF/EDF+
 - Select the file Baseline.edf in the data folder
 - Click on Open
- Review SEEG: Right-click on Link to raw file > SEEG > Display 0 time series
 - Display in columns: Button Image in the Record tab > **Display** . mode > Column
 - Amplitude: Buttons and shortcuts, Display menu
 - Time: Display windows of 15 seconds, Scroll with F3, Auto-Scale button
 - Select bad channels + right click > Channels > Mark selected as bad (if needed)
 - Montages: click **Display configuration > Montage >** Subject01: SEEG > Subject01 SEEG: (bipolar 2)
 - Select the montage for the dataset (Average, Referential, Transversal or longitudinal)
 - For the SEEG dataset, select **bipolar 2** montage for continuous chain.
 - Filter settings for review are set under the Filter tab in t panel
 - this is only for visualization
 - Select the checkbox to turn ON the high or low frequency filter.
 - Add annotations:
 - Got to record view > Events > Add Group > Event A
 - Select 2 peaks and press E
 - Got to record view > Events > Add Group > Extended
 - Drag across the window
 - Press E
 - Save annotation: File > Save modifications

www	Edit montages	Varman mar
	All channels Shift+A	
	Average reference	
M.	Longitudinal 1	- Say and your and
	Longitudinal 2	
	Longitudinal 3	
n_{M}	Transversal 1	WWW WWWW
·	Transversal 2	
	Temporal ring 1	
	Temporal ring 3	
~~1	Referential 3	WWW WWW
	Subject01: All	
	Subject01: ALAT	lu o mod
~~ I	Subject01: ALON	$\mathbb{N} \to \mathbb{V} \to \mathbb{V}$
	Subject01: MC	
	Subject01: MPM	1. K. C
M	Subject01: MPS	
	Subject01: PH	
	Subject01: PIN	
~	Subject01: PLAT	
	Subject01: PLON	
	Subject01: POP	Sise Display mode → 🖄
~	Subject01: PSIN	Time AS
	Subject01: SEEGNOLOGMPS	ty Amplitude → t±
	Subject01: SMA	Lines >
	Subject01: SPL	+
	Subject01: SPM	Subject01: SPM (orig)
_	Subject01: SPS	Subject01: SPM (bipolar 1)
	Subject01: SEEG	Subject01: SPM (bipolar 2)

		2	Edit subject		
	+	e#	Add condition		
the	+	RAU	Review raw file		
	+	₿,	Import MEG/EEG		
Record Filter S	ecord Filter Surface Scout Coordinates +				
Warning: For visualization only Help			р		
Frequency filtering					
High-pass: 1.00 Hz					
Low-pass: 40.00 Hz					
Notch: Hz			Ηz		
Filter all results					

Re





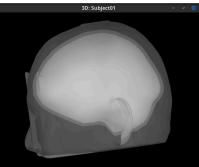
16. <u>SEEG Analysis: Import precomputed Brainstorm</u> protocol (5 mins)

- Prerequisite: Download from the zip file from url: <u>https://box.bic.mni.mcgill.ca/s/Ygit3sciljtHMgF</u>
- Open Brainstorm
- Click File > Load Protocol > Load from zip file
- Click on ..., and point to the downloaded zipped file: WorkshopUTAH_precomputed.zip
- Protocol called WorkshopUTAH_precomputed should appear



17. <u>SEEG Analysis: Modeling interictal spikes using Min-Norm Imaging (Yash</u> <u>Vakilna)</u>

- Compute Forward Model (aka Head Model) (10 mins)
 - Computing boundary element (BEM) layers
 - Prerequisite: OpenMEEG plugin
 - Go to the anatomy view
 - Right-click on Subject01 folder > MRI segmentation > Generate BEM surfaces
 - Select Brainstorm
 - Number of vertices: Scalp = **1922**, Outer skull = **1922** and Inner skull = **1922**
 - Thickness of layers, Skull (mm)= 4
 - DON'T CLICK [OK]
 - Double-click on mid_15002V to make it as the default cortex (in green). If already green, no need to double-click.
 - Compute the head model for SEEG



Comment:	OpenMEEG BEM
Source sp	ace
 Cortex 	surface
	olume
Ocustor	m source model
Forward m	nodeling methods
SEEG	OpenMEEG BEM ~
	Cancel OK





Workshop Los Angeles

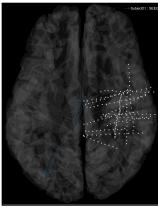
- Go back to the functional data view, navigate to the interictal_spike folder and expand it
- Right-click on the Nihon Kohden channel file (**)> Compute head model
 - Source space = Cortex surface, Forward model = SEEG:
 OpenMEEG BEM, click OK
 - Use default BEM layers and conductivities.
 - Use default OpenMEEG options.
 - DON'T CLICK [OK]
- Copy the head model files to the other folders
 - Right-click on the head-model file (
 OpenMEEG BEM | mid
 15k)> Copy to other folders
- View Leadfield vectors

 - Select reference=MC2, click OK
 - Make sure scouts are unselected
 - Go to the Scout tab, and make sure **ALL** and **SEL** are unselected
 - Go back to the Surface tab
 - Select Transparency = 90, and Press Shift+Up arrow till the arrows are visible
 - Press E to show the electrode
 - Press Up/down to change the Reference electrode, right/left to change the Target
 - Press × to close all figures

Compute Noise Covariance Matrix (for SEEG) (15 mins)

- Explain Process section
 - Tabs Process1, Process2
 - File types:
 [®] recordings,
 [®] sources,
 [®] time-freq, and
 [®] matrices
- Switch to Baseline folder
- Compute Link to raw file | copy (ﷺ) for sEEG from Baseline recording
 - Select the trial group, right-click > Noise covariance > Compute from recordings:
 - Baseline = [0, 301] s
 - Select Block by block
 - DON'T CLICK [OK]

BEM Layers & conductivit	ties
Scalp 1922 vertices:	1
Skull 1922 vertices:	0.0125
Brain 1922 vertices:	1
OpenMEEG options	
Use adjoint formulation	(less memory, longer)
Use adaptive integration	(more accurate, 3x longer)
Process dipoles by block	ks of: 4000
Estimated resources	
Memory: 5384 Mb Hard drive: 6074 Mb	
	Cancel OK



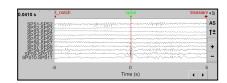
Files		
Number of files :	1	
Time window :	[0.0000, 300.9995] s	
Frequency :	2000 Hz	
Baseline samples :	602000	
Options		
Baseline: 0	0.0000 - 300.9995 s	
Block by blo	: (subtract average computed over the baseline) ck, to avoid effects of slow shifts in data bal average and remove it to from all the blocks	

- Copy the Noise Covariance ()across other folder
 Right-click noise covariance file > Copy to other folders
- Compute Inverse Model (5 mins)
 - Switch to the interictal_spike folder,
 - Right-click on the head model ($^{\textcircled{0}}$) > Compute sources, use these parameters:
 - Click on Show Details
 - Select Minimum norm imaging, Select Measure: sLORETA
 - Select Constrained: Normal to Cortex
 - Select Noise covariance regularization: Diagonal noise covariance
 - Sensors = SEEG
 - DON'T CLICK [OK]
 - Explanation of the inversion kernel (\bigcirc) and link (\clubsuit) files in the database
 - Display sensor time series (5 mins)
 - Display time series
 - Right-click on Recording ([®] Spike (#1) ...)> SEEG> Display time series
 - On the right side of the figure,

Select () > Montage > Subject01: SPS > Subject01: SPS (bipolar 2)

- Select the first peak of SPS10-SPS11 (Time 0.041s)
- Display 2D Layout of the spike
 - Right-click on **Recording** (¹/⁽¹/₁)> SEEG> 2D Layout
 - Click on the corner and select [-500, 500]

Method	Noise covariance regularization
Minimum norm imaging IO//V beamformer	ORegularize noise covariance: 0.1 OMedian eigenvalue
O Dipole modeling MEM: Max entropy on the mean	Diagonal noise covariance No covariance regularization
Measure Corrent density map OdSPM Warning: unscaled values © stORE1A	Automatic strinkage Regularization parameter: 1 / λ ③ Signal-to-noise ratio: 3.00
Source model: Dipole orientat © Constrained: Normal to cortex O Loose constraints 0.2 O Unconstrained	RMS source emplitude: 1000.00 nAir Output mode @inverse kamel only Full results (Kamel*Recordings) Full results (Kamel*Recordings)
Sensors SEEG	









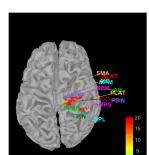


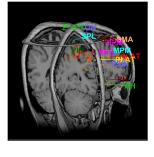
View Inverse Modeling results (10 mins)

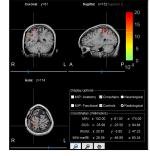
- Display on Cortex
 - Right-click on link (SLORETA ...) > Cortical activations > **Display on cortex**
 - Show sensors:
 - **Ctrl+L** SEEG contacts, **Ctrl+E** for sensors
 - Show colormap Bar: Right Click on Colorbar > Colormap: Sources > Permanent menu
 - Select Maximum: Custom [0, 2]
 - Contrast: -18, Brightness: 99
 - Switch to Surface tab, Select Amplitude: 56%
- Display on 3D MRI Viewer
 - Right Click on link (💭) > Cortical activations > Display on MRI . (3D)
 - Right Click and drag to select Axial, Coronal, and Sagittal slices
 - Press M to go to voxel with Maximum Intensity
- Display on MRI viewer
 - Right Click on link (🍈) > Cortical activations > Display on MRI (MRI Viewer)
 - Right Click on Colorbar > Electrodes > SEEG contacts
 - Show colormap Bar: Right Click on Colorbar > Colormap : Sources > Permanent menu
 - Explain Radiological and Neurological view
 - Explain MIP function and MIP anatomical .

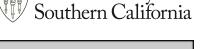
Atlases and Scouts (5 mins)

- Display sources on the Cortical surface
 - Right-click on link (()) > Cortical activations > Display on cortex
 - In the Scout tab, use the dropbox to select different Atlases
 - Display Desikan-Killiany and Destrieux
 - Subdivided Desikan-Killiany
 - Atlas > Subdivide atlas> Area > Area of the sub-regions (cm²): 5
 - DON'T CLICK [OK]









December 2024

USC University of









Workshop Los Angeles

Press × to close all figures

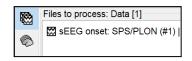


18. <u>SEEG Analysis: Modeling ictal onset with Low Voltage Fast Activity (LVFA)</u> using fingerprint analysis (Sensor Space) (Yash <u>Vakilna)</u>

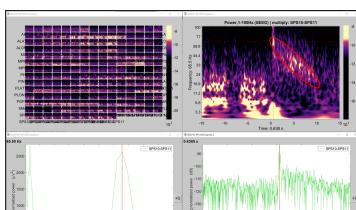
- Compute Bipolar Montage (5 mins)
 - Navigate and expand LVFA_and_wave folder
 - Press imes to close all figures
 - Drag-and-drop (
) recording file in **Process 1, click [RUN]**
 - Add the process: Standardize>Apply Montage
 - Montage name: Subject01: SEEG (bipolar 2)[tmp]
 - Select Create new folders
 - DON'T CLICK [RUN]
 - A new folder with **bipolar_2** suffix will appear
- Compute Time-Frequency decomposition (5 mins)
 - Navigate and expand LVFA_and_wave_bipolar_2 folder
 - Delete any previous recordings in the Process 1 tab below
 - Drag-and-drop ([®]) recording file in **Process 1, click [RUN]**
 - Add the process: Frequency>Time-Frequency (Morlet wavelets)
 - Sensor type: SEEG
 - Select Spectral flattening: Multiply output power values by frequency
 - Click Edit ...
 - Frequency definition: Log (start:N:stop), 1:25:100
 - Central Frequency: 1 Hz, Time resolution (FWHM): 6s
 - Click [OK]
 - DON'T CLICK [RUN]
- View Time-frequency maps (10 mins)
 - Expand ([®] sEEG onset ...) recording file, right-click on **Power (**, and select **All channels**
 - Click on Smooth display, Log(Power)
 - Click on SPS8-SPS9
 - Right-click on Colorbar>Colormap: Timefreq >Permanent menu
 - Set Turn-off [Absolute Value](if on),
 Maximum: Local, Contrast: 49,
 Brightness: -65
 - Demonstrate Left-click and Drag on colorbar to select appropriate Brightness and Contrast

<	>	
	Files to process: Data [1]	
٢	SEEG onset: SPS/PLON (#1) notch(180Hz 300Hz 420Hz 540Hz 660Hz 780Hz 900Hz)	[1]
6		
•		
RUN		
S.		
	Process1 Process2	

Bs Pipeline editor	_		\times
Process selection			
◎· ↑ ↓ X 읂·			
Apply montage			
Process options			
Montage name: RP1: SEEG (bipolar 2)[tmp]	~		
Create new folders			
Online tutorial	Cance	I R	un



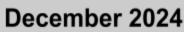
	Frequency definition
Time definition ® Semo as input filos [+15.000s - 0.50ms - 15.000s] © Group in time bands (ms)	C Linear (start:stop:stop)
	1:4:600
	Elog (start:N:stop)
	1:50:100
	Group in frequency bands (Hz)
Generate	dota / 2, 4 / mona troba / 2, 4 / mona bela / 1, 2 / mon garma / 20, 3 / mon garma / 20, 39 / mona garma / 20, 50 / mona
	Roset
Model wavelet options	
Central frequency:	1 Hz (default-1) Display
Time resolution (FWHM):	6 s (default=3)
Processing options	
Processing options Compute the following measure	
Compute the following measure	ione (save complex values)







- Right-click on the colored time-frequency plot > **Power Spectrum, Time Series**
- Click to ¥ close all figures







Workshop Los Angeles

SEEG Analysis: Appendix

- How to run CAT12 segmentation from Brainstorm
 - Display cortex:
 - Close figure, double-click on cortex_15002V (low-resolution pial surface)
 - 3D figure: Rotation, zoom, predefined views
 - Surface tab: Smooth slider, sulci, edges
 - Scout tab: Parcellations of the surface vertices
 - Volume parcellations: AAL3, Hammers, tissues
 - Adjust transparency, change the atlas, non-linear MNI transformation
 - Add MNI parcellation: Schaefer2018_100_7net

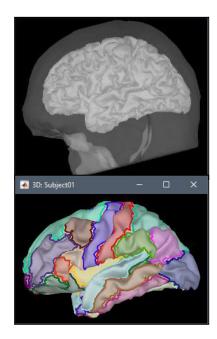
Import T1 post-implantation:

- Right-click on Subject01 > Import MRI
- Select file: /xxx/xxxx/xxxx.nii.gz
- Apply transformation: YES
- How to register: IGNORE (volumes are already co-registered with SPM)
- Reslice the volume: YES (so we can overlay them)
- Surface tab: Adjust threshold with slider **Data options: Amplitude**

Close all: Big cross on the top-right, close all the figures and empty memory.

Remove power line noise.

- Compute Periodogram
 - Close all the figures
 - Drag-and-drop () raw file in Process 1, click [RUN]
 - Add the process: Frequency, Power spectrum density (Welch)
 - Time window = All file, Window length = _s, Overlap = 50%
 - Units = Physical
 - Sensor types = SEEG
 - Click on Run
- Review Periodogram
 - Peaks at 60Hz, 120Hz, 180Hz on EEG and MEG: Power lines (60Hz+harmonics)





	Files to process: Data [1]
ß	Link to raw file [1]
ē	
Ē	
RUN .	Process1/Process2/





Workshop Los Angeles

- Process Notch filter
 - Select: Pre-process > Notch filter
 - Frequencies to remove (Hz) = 180, 300, 420, 540, 660, 780, 900Hz
 - Sensor types = SEEG

Import recordings

- Import in database
 - Right-click on the pre-processed file > Import in database, and use the parameters:
 - Time window = 0 119.9995 s
 - Do NOT check Split in time blocks
 - Check Use events and select sEEG onset
 - Epoch time = -15000 to 15000 ms
 - Check Remove DC offset, select All recordings
 - A new folder named _ is created (no more raw indicator)

lime selection	Pre-processing
Time window: 0.0000 - 3599.9995 s	Remove DC offset: select baseline definition
5-14	All recordings: Baseline computed for each output file
Split	OTime range: -15000.0 -0.5 ms
Split in time blocks of: 0.1000 s	0 Time range: -13000.00.3 ms
Number of blocks: 300	Resample recordings: 1000.00 HzSampling: 2000 I
Events selection	Database
Use events 🗢 🚸	Create a separate folder for each event type
A1+A2 OFF (x1)	
sEEG onset: SPS/PLON (x1)	
MARK ON (x2)	
MARK OFF (#2)	
SENSATION IN HER HAN (x1)	
SpO2 UNSTABLE (x2)	