



# ReTune Early Career Methods Workshop:

## Basic introduction to invasive neurophysiology

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# Requirements:

## Software:

Matlab, if you have access, please install Matlab 2020b

Python/Anaconda including Jupyter

## GitHub code repositories:

<https://github.com/retune-commons/InvasiveElectrophysiologyWorkshop> I

<https://github.com/spm/spm12>

<https://github.com/fieldtrip/fieldtrip.git>

## Python packages:

*MNE toolbox, can be installed using the following command in a Jupiter notebook:*

```
import sys
```

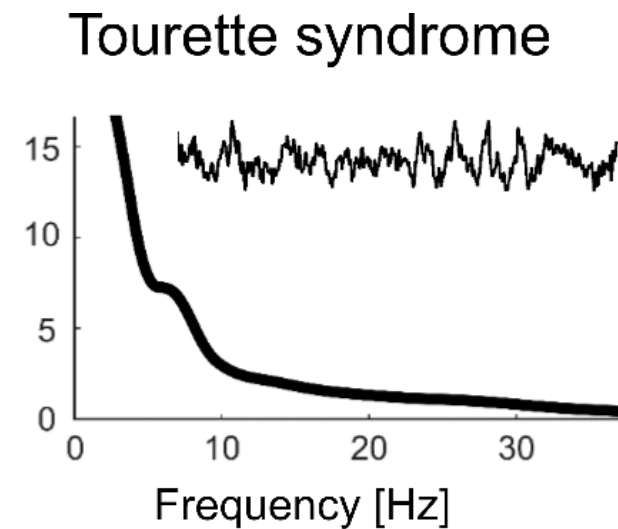
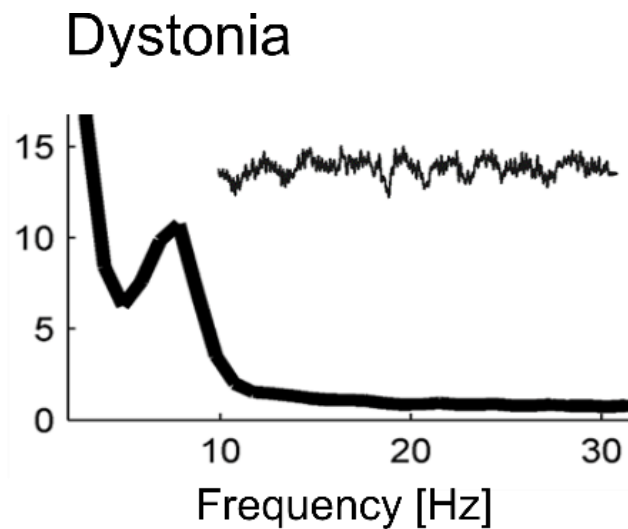
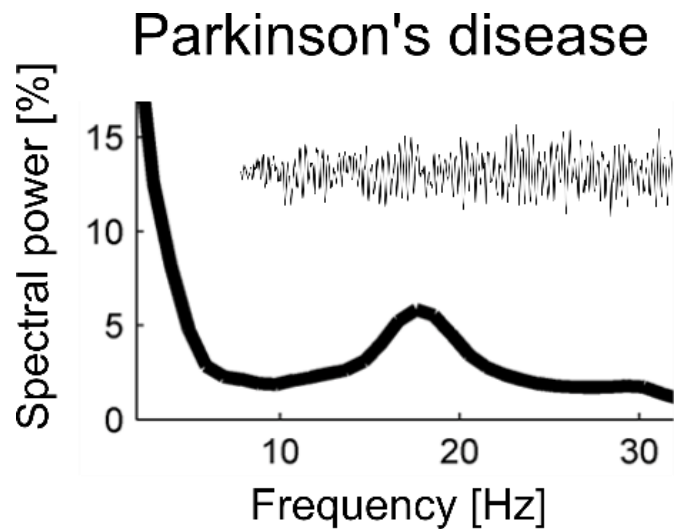
```
!{sys.executable} -m pip install mne
```

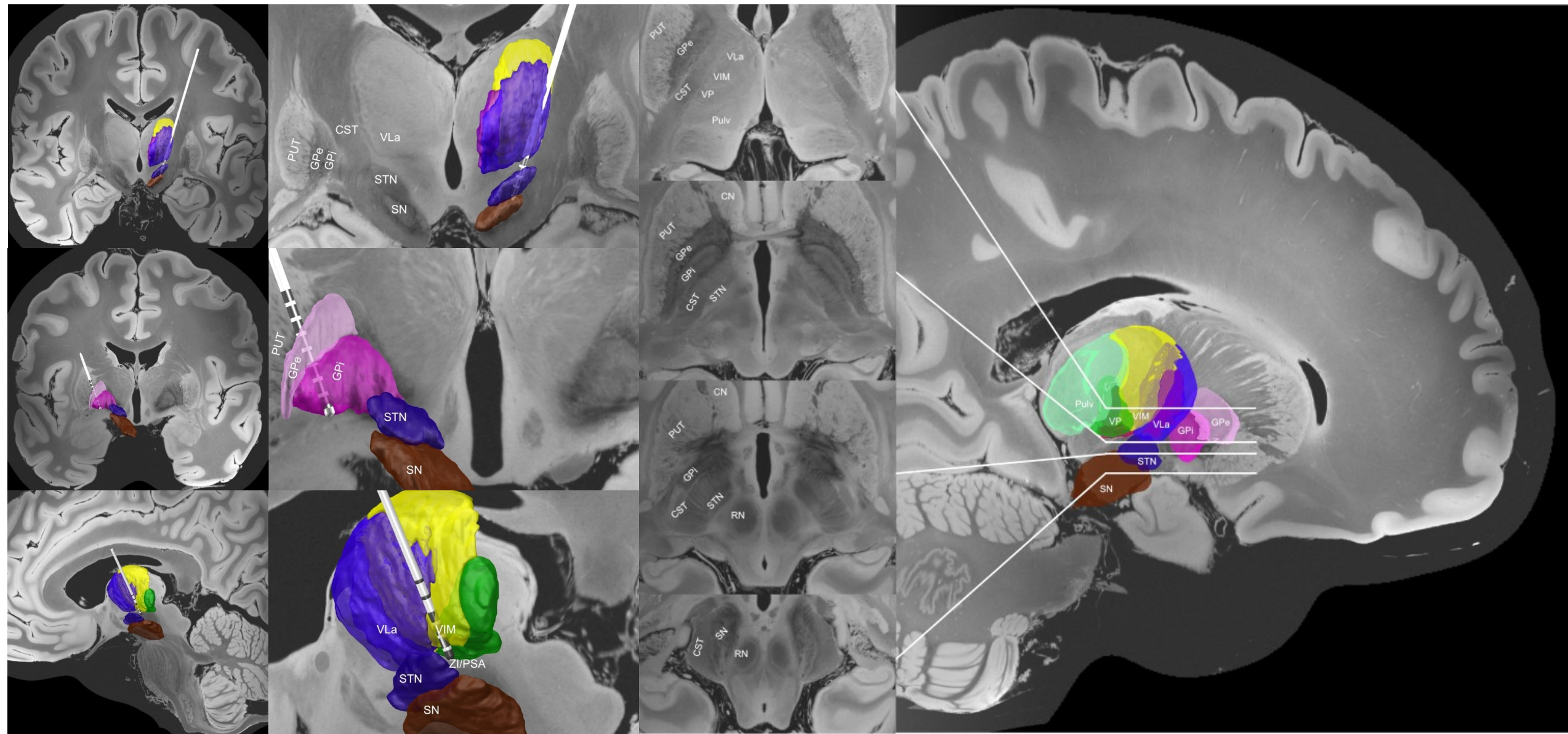
Please have a computer ready with Matlab and Anaconda installed.

Clone the identified repositories and create a working directory.




# Invasive neurophysiology research in DBS patients

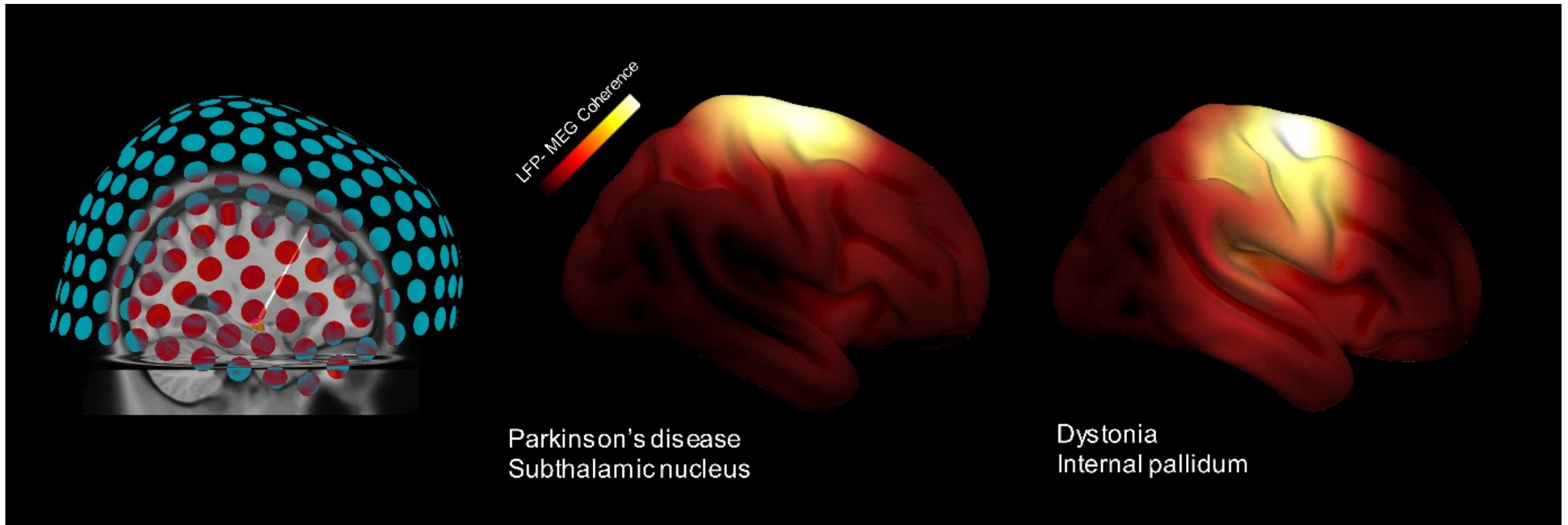


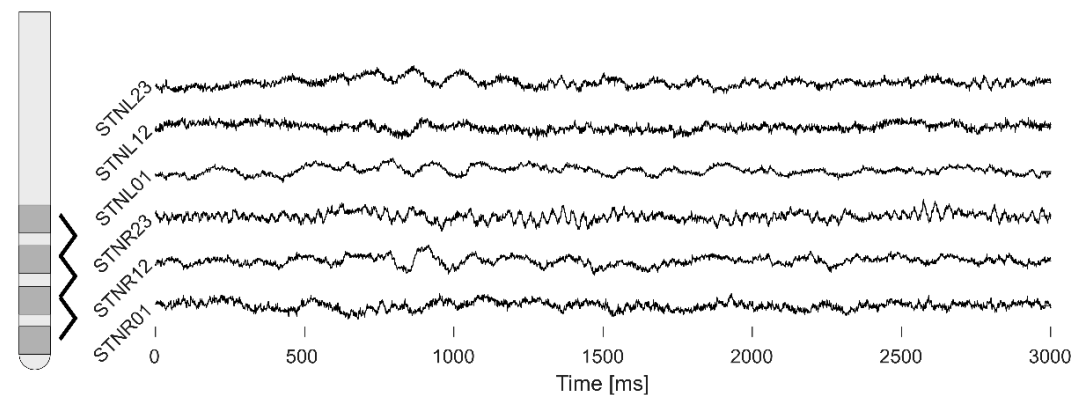
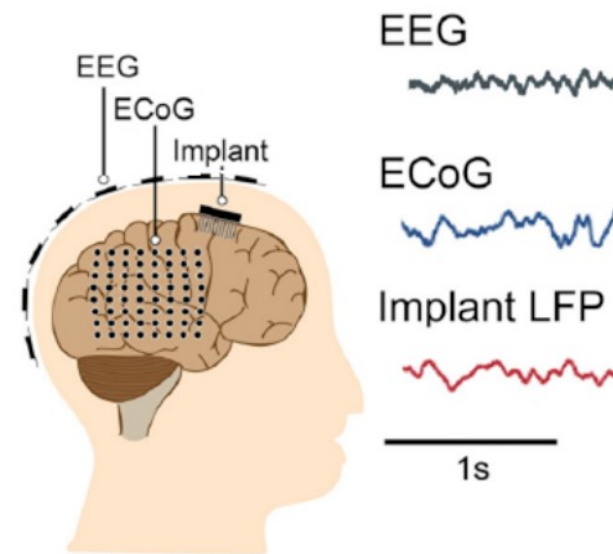
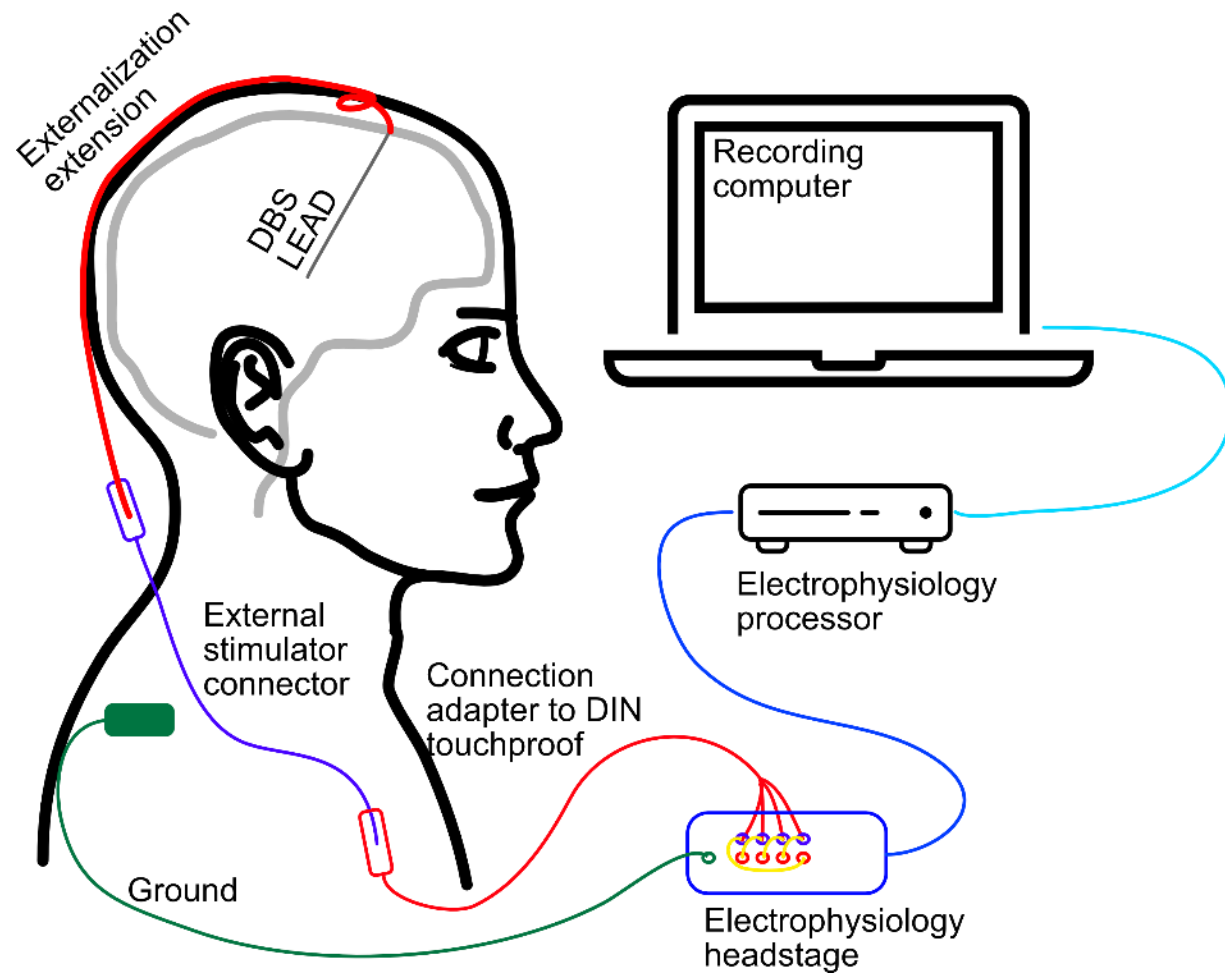


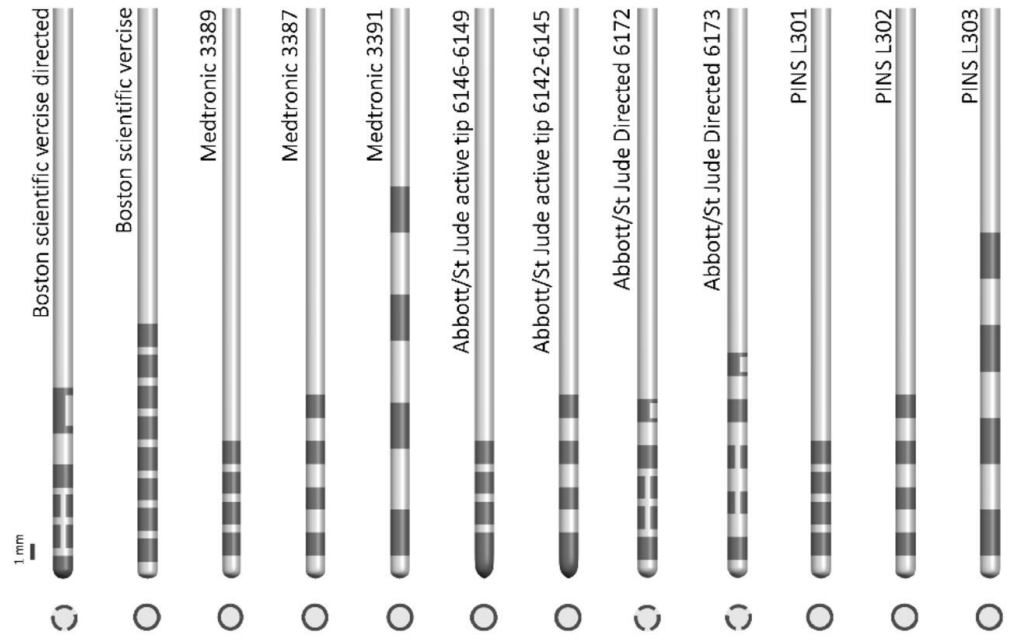
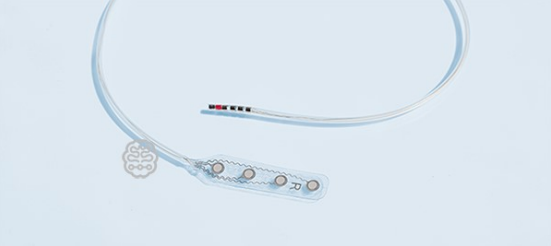
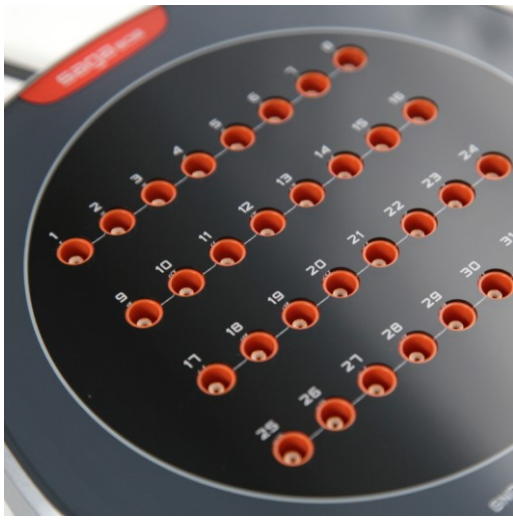




# Combined LFP and whole-head recordings



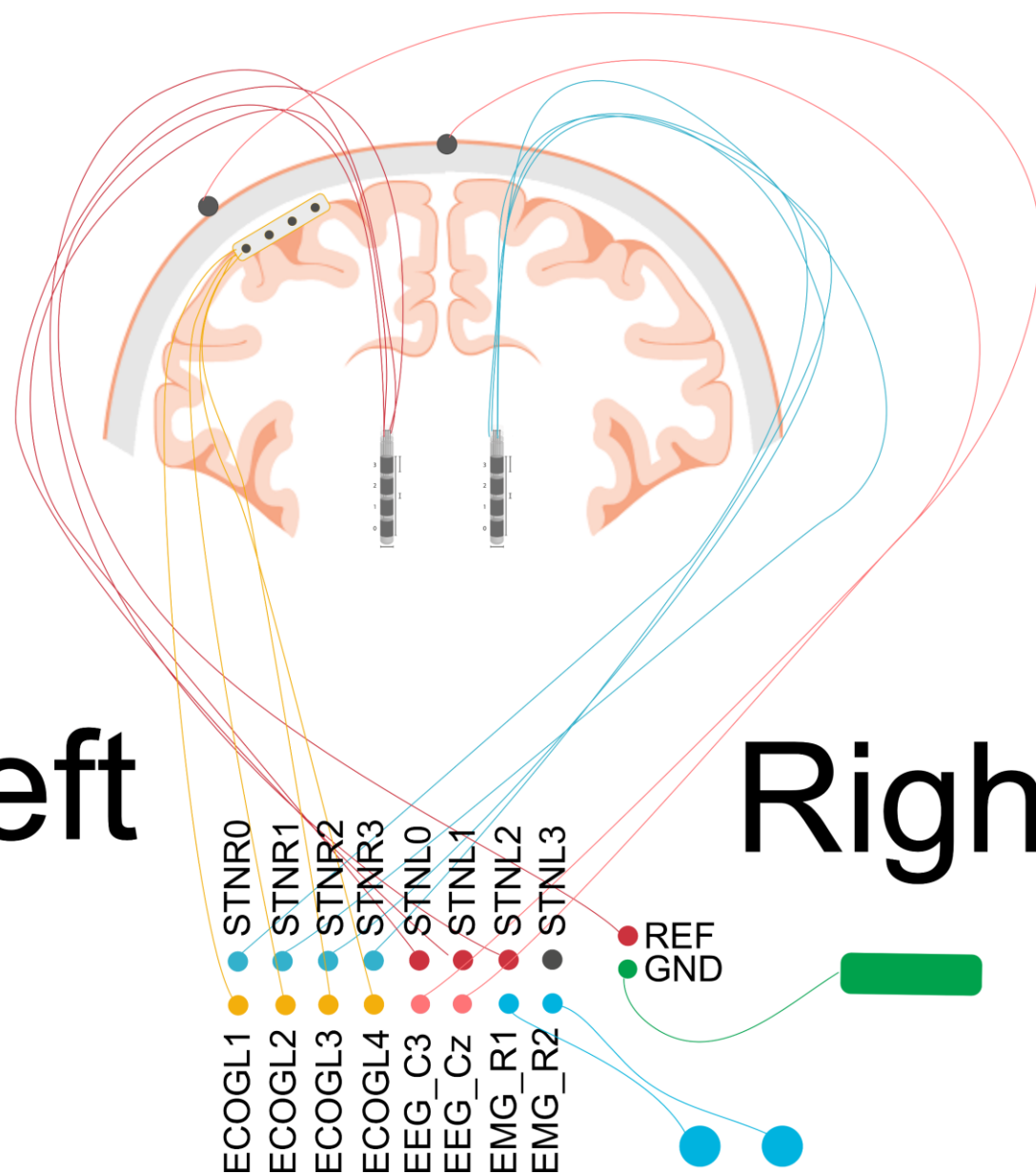






Left

Right



1. STNR0 - REF STNL3
2. STNR1 - REF STNL3
3. STNR2 - REF STNL3
4. STNR3 - REF STNL3
5. STNL0 - REF STNL3
6. STNL1 - REF STNL3
7. STNL2 - REF STNL3
8. Empty (STNL3-STNL3=0)
9. ECOGL1 - REF STNL3
10. ECOGL2 - REF STNL3
11. ECOGL3 - REF STNL3
12. ECOGL4 - REF STNL3
13. EEG\_C3 - REF STNL3
14. EEG\_Cz - REF STNL3
15. EMG\_R1 - REF STNL3
16. EMG\_R2 - REF STNL3





# Practical rules of thumb

- Connectors and adapters can be a source of bad signal quality. Check and replace regularly.
- Turn off any unrequired electric device to reduce 50 Hz noise.
- Ground and reference need to be good, otherwise all signals are bad.
- Smaller contacts have higher impedance and therefore smaller signals.

**Let's open Matlab now.**

# Setting the path: change the folders in your version of the code

```
%% CLEAR ALL CLOSE ALL CLC
clear all, close all, clc
%% SET FOLDERS AND PATH
% this is where you are going to work, choose any folder of your liking, we
% will create some files here:
root = 'G:\EphysTutorial'; % This needs to be adapted!
% let's create the directory you specified as root and move there
if ~exist(root, 'dir')
    mkdir(root)
end

cd(root)

% Now add the required code to your path this is where your code
% repositories for wjn_toolbox and SPM are.
addpath('G:\EphysTutorial\code\wjn_toolbox') % This needs to be adapted
addpath('G:\EphysTutorial\code\spm12') % This needs to be adapted
% SPM needs to be initialized to include FieldTrip folders in path:
% Do not initialize FieldTrip yet, as MatLab will get confused!
spm('defaults', 'eeg')
```

Tutorial\_I\_Import\_and\_rereference.m

# Simulate Time-Series Data

Var1	Var2	Var3	Var4	Var5	Var6	Var7	Var8	Var9	Var10	Var11	Var12	Var13	Var14	Var15	Var16
17.44536	-13.0001	15.6813	-6.94418	-21.5084	4.4889	-21.0278	0.982859	30.08133	5.326157	-2.30612	14.27718	-8.85583	-10.6297	16.42631	17.79824
51.90393	5.37778	1.317042	-1.12494	-43.3604	-0.67658	23.41852	0.832861	-52.5087	-28.1725	35.33451	-42.6062	-19.7562	-22.4933	-42.8699	-25.43
-91.8978	15.15133	5.867663	61.01972	-30.3506	8.426437	-22.1146	0.182351	-2.9379	-63.9388	15.90375	-52.8492	-39.3723	-22.7746	-7.98778	30.09908
-72.5365	16.09462	-42.3924	113.7275	-22.8124	-30.2174	34.59551	0.646033	7.429764	-55.0718	12.63944	57.0005	-12.9305	-40.2934	4.812994	-35.0529
75.17835	24.12775	27.68883	11.61614	-48.8152	-25.7187	7.830364	0.617373	-38.5238	-55.1546	64.09477	-72.5609	-43.7526	-56.3797	-36.2747	-75.1297
34.79199	23.4456	-17.2983	-50.9208	-24.4215	-19.6319	0.456993	0.761195	-29.1957	10.01181	58.05339	80.79337	-19.5403	-42.051	20.66676	-24.8653
-61.5551	39.47957	-17.6771	1.255369	-23.351	-33.9789	8.167683	0.727523	-57.8605	-47.2746	55.85162	-18.696	35.6154	-23.869	26.14276	-107.437
36.0438	28.37469	-44.2112	-36.7413	15.07316	-62.6933	-16.9531	0.387199	32.78063	2.312314	53.90074	85.34775	27.66106	-21.0495	57.85951	-99.1668
153.7921	26.23782	-31.976	22.39836	5.253314	-45.7416	43.54859	0.716847	59.36172	-38.3371	44.30501	22.4196	-7.0191	-1.34378	13.65297	-7.73064
17.45117	17.52548	-36.5379	3.767606	29.81859	-4.33784	16.50035	0.701032	37.55614	30.81724	-7.06581	-22.0732	17.88272	12.15191	34.22113	8.48559
29.76182	-0.98175	-26.8312	-108.415	2.687854	9.125535	-3.62467	0.45435	30.2548	46.84432	-16.3401	49.57781	9.337698	8.759205	33.58927	1.965049
-6.36476	-17.8688	33.09917	-83.038	-0.16815	-11.2906	36.24333	0.732844	-11.9892	-10.1684	-14.6021	20.77275	-1.72423	43.9281	-37.5261	19.72874
7.487063	-35.6332	47.51357	-49.752	-14.8916	41.15798	15.10401	0.646537	-6.58481	42.15858	-7.95156	-55.1885	-35.78	45.34515	10.27148	26.80412
20.01179	-45.0391	35.36561	-64.4856	-15.8741	36.38661	37.80298	0.270532	-47.3709	40.72408	-43.7877	18.30379	4.639576	43.8289	20.67567	12.47853
-11.3748	-46.2684	52.73747	-2.63776	-35.9673	32.14233	4.932565	0.285897	29.37526	86.87274	24.138	-44.3159	9.068216	61.2276	-19.7672	78.83935
-11.8261	-38.5289	46.05513	0.082233	-12.1433	9.245147	5.641308	0.193862	3.184588	4.109796	-15.7396	22.47213	-31.9581	51.45656	-39.2911	103.1842
-34.0922	-16.9374	-4.38926	-11.3297	-12.9588	20.53083	-1.48429	0.40899	29.85839	56.89172	-1.28392	68.28397	22.84973	17.935	-34.1983	22.07202
37.68356	0.533614	12.73025	29.75901	-5.43509	0.264179	-9.76934	0.193403	43.05617	11.03539	-6.05721	67.43886	34.16503	18.04861	-34.4119	35.78535
-31.9657	22.22055	-15.3088	80.28134	6.574914	20.06449	34.20739	0.215159	59.11546	-3.12321	-1.56831	42.39405	18.15485	1.089486	4.731444	-38.3134
-31.0677	30.33194	-49.8891	-24.8434	8.838566	24.49235	32.73998	0.812468	-83.0213	-25.5399	-17.8273	43.18268	1.679539	-37.4333	-15.8355	-48.1168
27.6425	39.85008	-35.1991	9.84351	5.73753	36.34956	49.86088	0.459907	-21.1995	-74.3763	4.549324	2.55071	-6.11439	-29.1226	28.73343	-10.4274
29.88149	33.21375	-29.0897	-18.3224	5.604261	9.167906	-54.2746	0.899439	28.82499	-40.3767	-9.48072	-51.0134	-15.2109	-35.9024	-40.3472	-25.5436
-66.0893	19.42211	-29.9614	5.943495	-3.4123	20.29811	-100.501	0.015098	54.04399	-58.8302	38.27845	-34.4326	-35.8176	-45.3434	-47.5275	-86.9544
-11.3684	-3.65518	48.82773	-3.40188	-0.37275	-1.78601	-66.729	0.744351	12.25692	-38.1102	56.71299	-82.0972	-37.4819	-28.0853	-2.67428	-48.3667
-34.2167	-5.40506	11.85179	69.87623	-21.7087	-32.905	-29.2424	0.754856	-61.7641	-34.6055	55.46386	-78.5531	-24.555	-28.6499	-24.3321	-66.2543
16.43898	-13.2297	1.10015	-138.952	10.09671	-33.2883	-36.5844	0.343331	-3.47171	-2.076	40.24761	-4.57457	22.43007	-23.1425	-38.1281	39.54056
16.07016	-12.4444	-11.7876	-36.5838	-6.56562	-54.9113	-58.2282	0.543056	-18.0979	-32.4063	22.7851	-58.8418	43.45751	-6.85928	-22.2435	12.13253
-55.0326	-8.14906	15.86381	-58.6922	38.21364	-73.7752	21.46917	0.577012	18.74397	6.340346	-11.6219	115.9483	24.42737	-27.7732	36.31003	-25.0824
66.38997	-2.86262	-10.8249	-124.56	24.55427	-35.2635	-22.4949	0.172231	-48.1145	6.815774	-19.8621	98.0166	48.77447	-7.21047	42.71241	-70.4991
8.853215	7.288987	-37.6876	-47.8082	37.78739	-19.3908	-8.49496	0.6478	-32.8787	24.49967	-24.2829	62.77574	23.88836	3.014698	36.01303	-70.4949
-5.04604	-1.97609	-14.7075	-34.665	10.60594	6.808931	-20.2666	0.190622	62.53931	34.28518	-24.7601	34.50995	38.38434	31.19845	72.30648	45.11849
-57.1958	-7.18087	-0.28	-90.9189	15.53834	62.28071	-11.3165	0.083458	69.63988	66.23926	-11.333	30.68545	1.492255	42.5674	51.49889	35.54219
-63.515	-6.18045	0.685492	-13.2673	-23.1377	52.12532	5.868337	0.42064	112.3798	14.70433	4.167601	-6.08189	-19.3545	62.19946	-46.8215	42.74239
-62.6236	-7.8435	20.2987	-89.2496	-38.6299	42.16783	-40.0786	0.788193	33.44399	9.740401	-10.6829	-27.6077	-7.57753	69.26978	49.74078	74.45663
25.9154	-8.36571	2.240641	7.874467	-46.2067	31.5143	-43.803	0.041129	59.02993	-18.8199	37.23523	-37.8786	-14.8558	60.89416	-23.077	93.80872

CSV file with 16  
time-series  
columns in  
forgotten\_trashy\_d  
ataset.csv

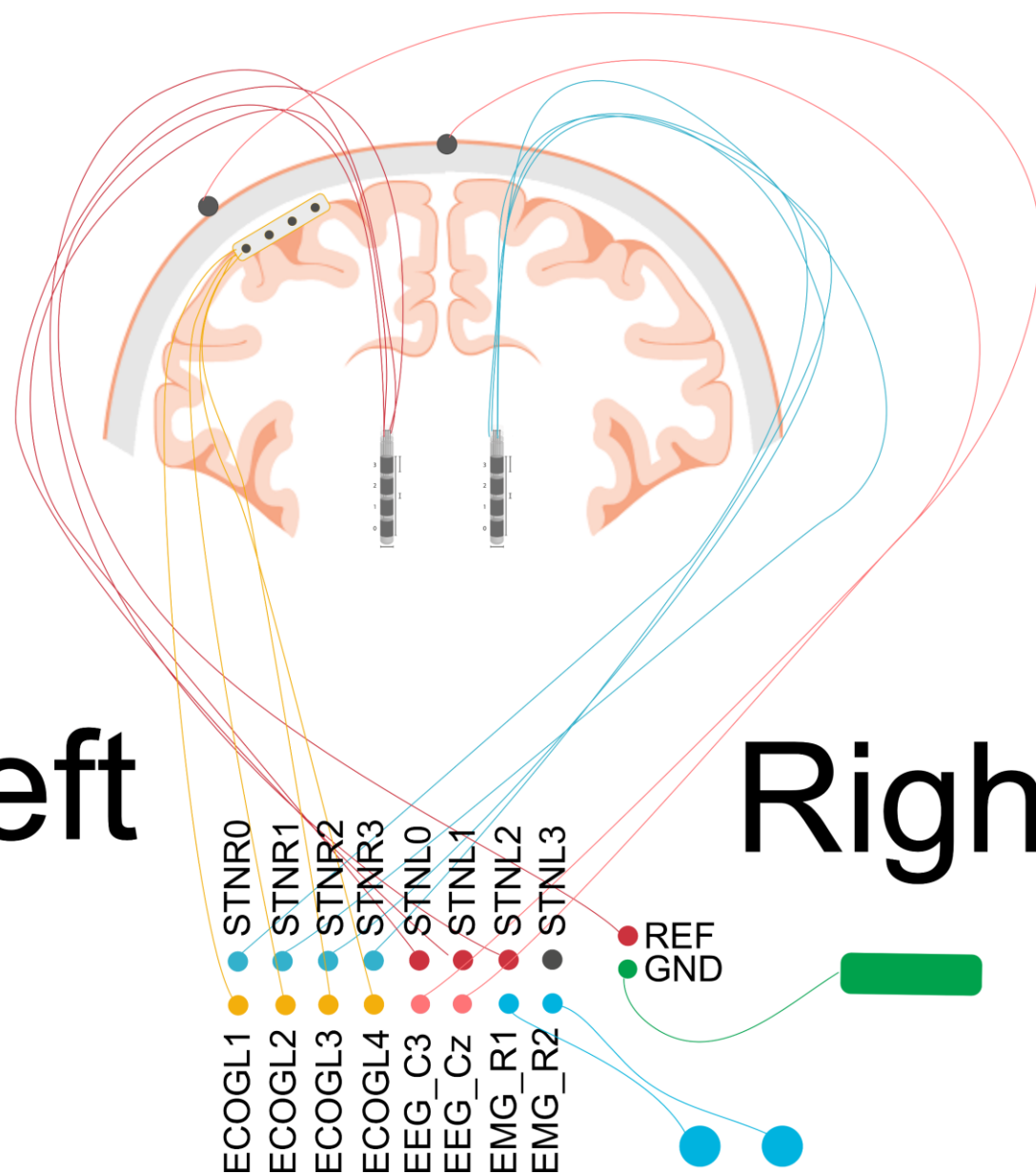
Additional info in  
trashy\_info.txt

 trashy_info.txt	1 KB	23/02/2021 19:16
 forgotten_trashy_dataset.csv	4.49 MB	23/02/2021 19:17



Left

Right

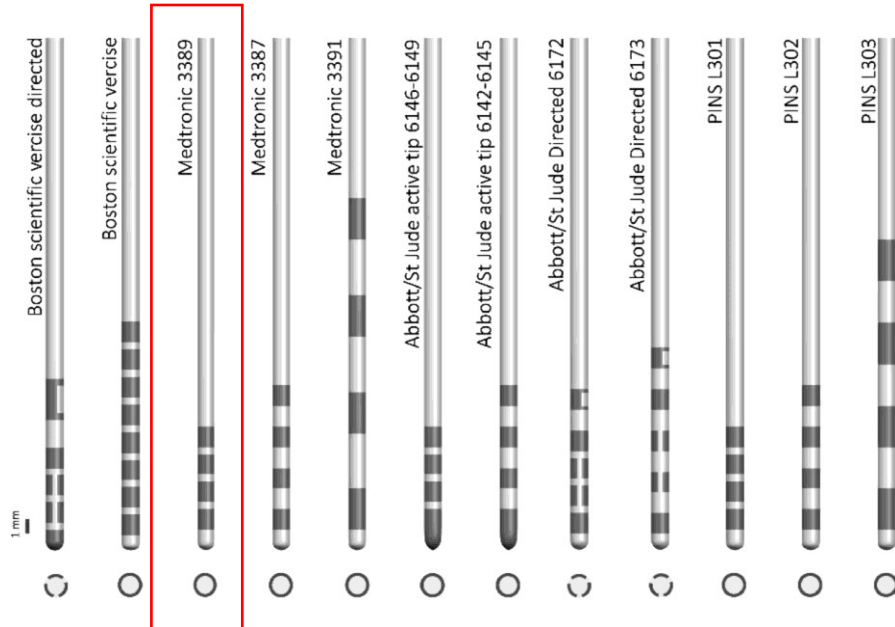
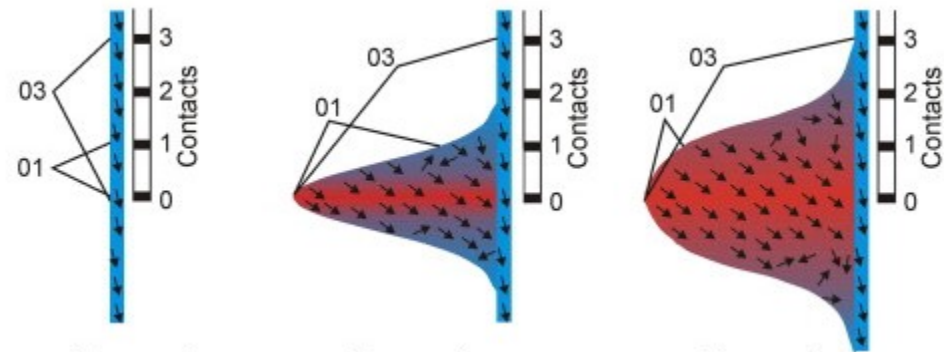
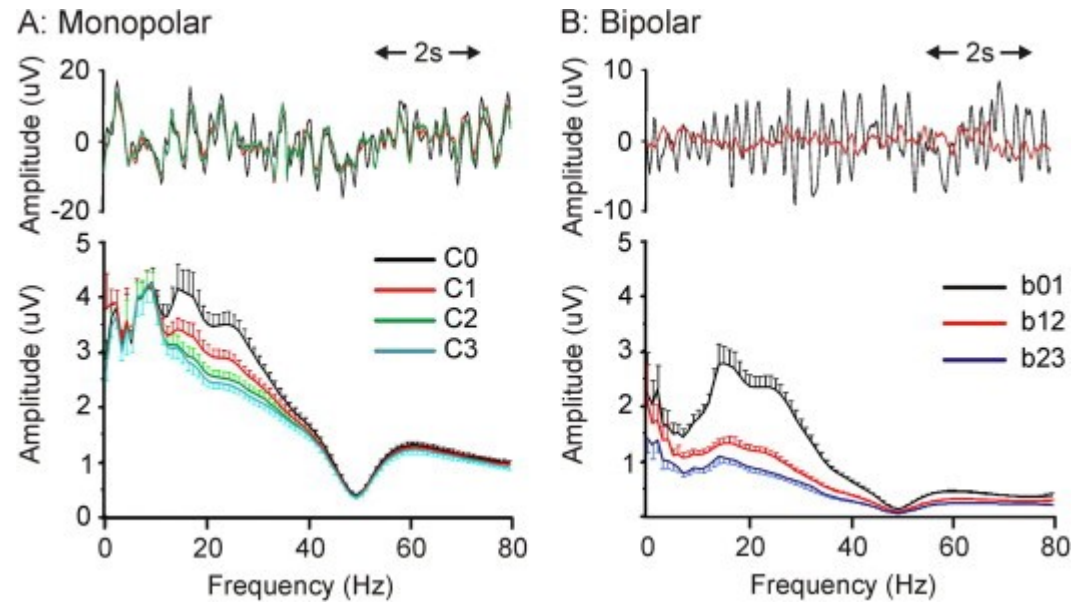


1. STNR0 - REF STNL3
2. STNR1 - REF STNL3
3. STNR2 - REF STNL3
4. STNR3 - REF STNL3
5. STNL0 - REF STNL3
6. STNL1 - REF STNL3
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9. ECOGL1 - REF STNL3
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12. ECOGL4 - REF STNL3
13. EEG\_C3 - REF STNL3
14. EEG\_Cz - REF STNL3
15. EMG\_R1 - REF STNL3
16. EMG\_R2 - REF STNL3



# Rereferencing LFP

Bipolar rereferencing serves a more focal analysis.





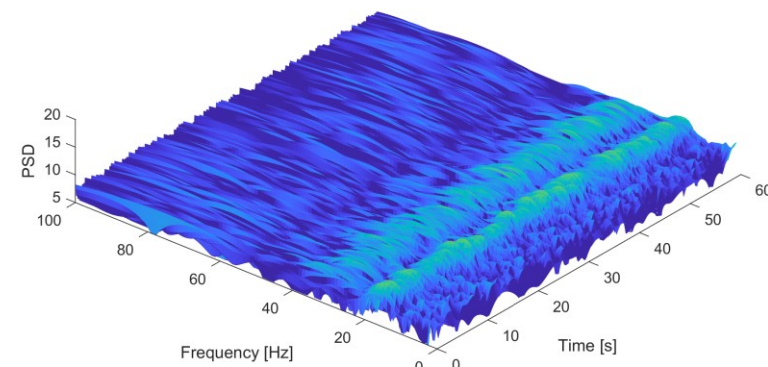
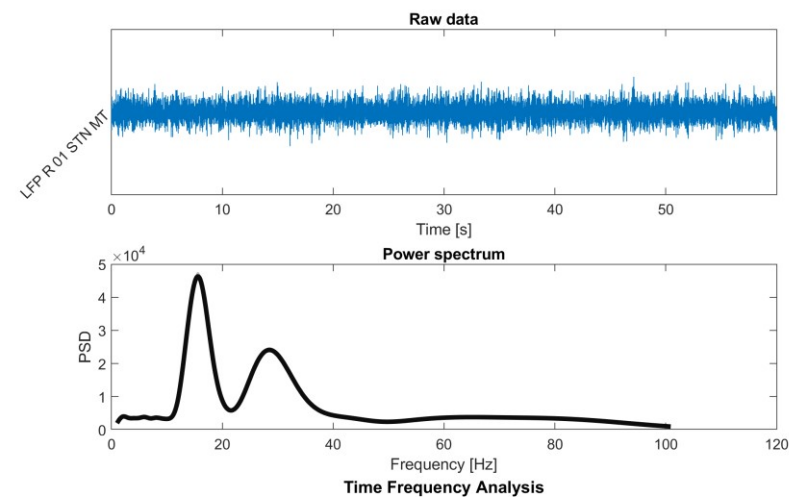
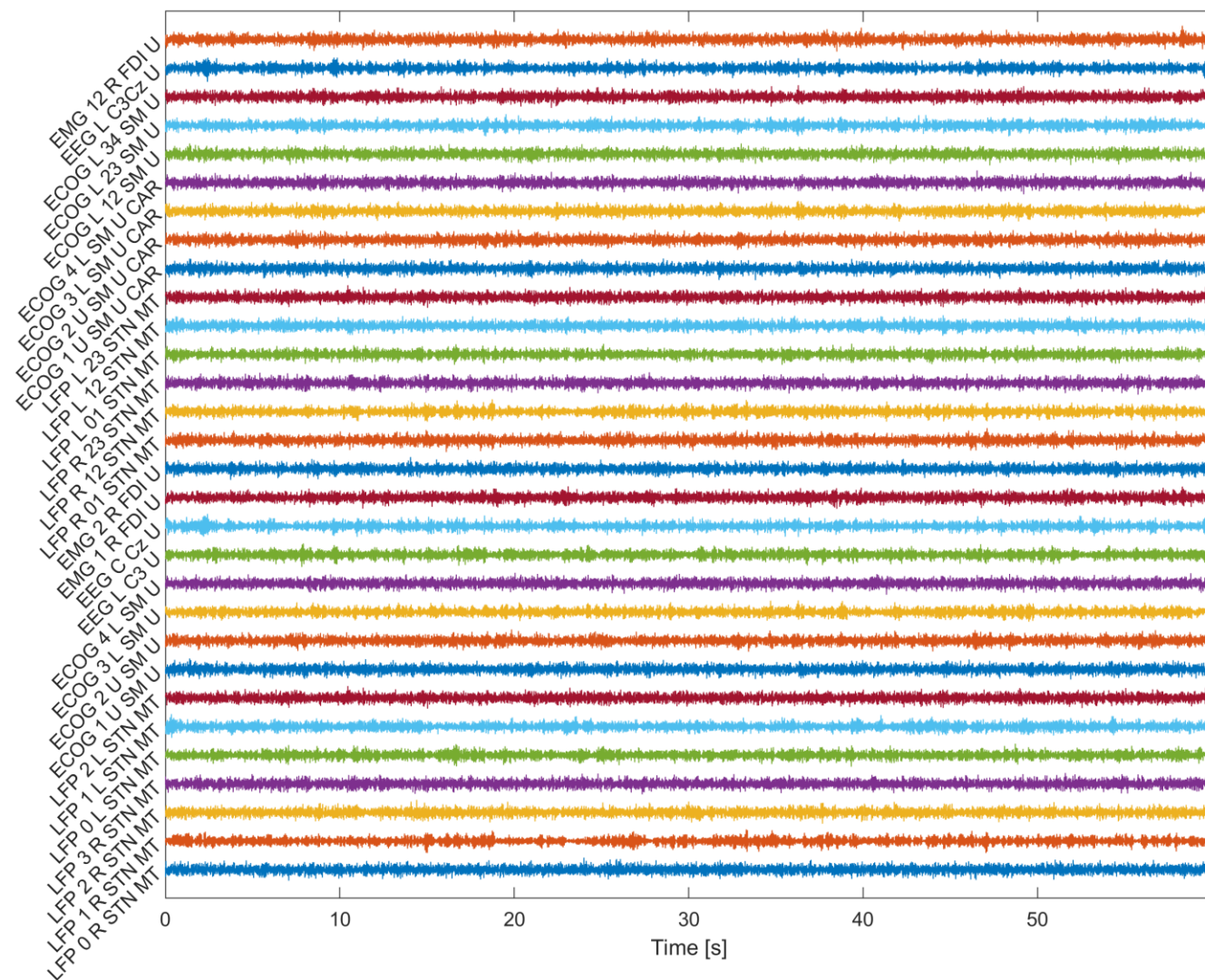
Rereferencing should always be done as the first step of any further processing!

For bipolar rereferencing subtract adjacent recordings.

- |                      |   |                      |
|----------------------|---|----------------------|
| 1. STNR0 - REF STNL3 | > | Channel 1-2 = STNR01 |
| 2. STNR1 - REF STNL3 | > | Channel 2-3 = STNR12 |
| 3. STNR2 - REF STNL3 | > | Channel 3-4 = STNR23 |
| 4. STNR3 - REF STNL3 |   |                      |
| 5. STNL0 - REF STNL3 | > | Channel 5-6 = STNL01 |
| 6. STNL1 - REF STNL3 | > | Channel 6-7 = STNL12 |
| 7. STNL2 - REF STNL3 | = | Channel 7 = STNL23   |

Note that Channel 7 is already hardware bipolar.

# Dataset milestone: Rereferenced and clean.







# SCIENTIFIC DATA

OPEN

COMMENT

## iEEG-BIDS, extending the Brain Imaging Data Structure specification to human intracranial electrophysiology

Received: 29 January 2019

Accepted: 24 May 2019

Published online: 25 June 2019

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The Brain Imaging Data Structure (BIDS) is a community-driven specification for organizing neuroscience data and metadata with the aim to make datasets more transparent, reusable, and reproducible. Intracranial electroencephalography (iEEG) data offer a unique combination of high spatial and temporal resolution measurements of the living human brain. To improve internal (re)use and external sharing of these unique data, we present a specification for storing and sharing iEEG data: iEEG-BIDS.

bids		23/02/...
sub-001		23/02/...
ses-MedOff		23/02/...
ieeg		23/02/...
sub-001_ses-MedOff_task-Rest_ieeg.eeg	1.0...	23/02/...
sub-001_ses-MedOff_task-Rest_ieeg.vhdr	1 KB	23/02/...
sub-001_ses-MedOff_task-Rest_ieeg.vmrk	1 KB	23/02/...
sub-001_ses-MedOff_task-Rest_ieeg.json	1 KB	23/02/...
sub-001_ses-MedOff_task-Rest_channels.tsv	1 KB	23/02/...
sub-001_ses-MedOff_scans.tsv	1 KB	23/02/...
dataset_description.json	1 KB	23/02/...
participants.tsv	1 KB	23/02/...
trashy_info.txt	1 KB	23/02/...
forgotten_trashy_dataset.csv	4.4...	23/02/...



Let's move to Python now

