# This file describes the basic structure of the saved data, and the codes required to generate the figures

## Data used to generate all figure data and for fitting the models

After segmenting data into each trial, we did fft of each trial for different stimulus conditions. We also calculated the change in amplitude at 2*f* for grating conditions and at 30Hz for plaid conditions. Baseline was averaged across all the trials and a common baseline was used.

– The saved file for protocols that used full-screen stimulus at 0 and 25% contrast is named as **FullScreen\_HighRMSLFP\_sessionWise\_Microelectrode.mat (Experiment 1)**. This protocol was run for M1 and M2. Plaids at both 0° and 90° separation were presented in a single session. This file was generated using codes - runGetDualTF\_FullScreen\_LFPVals\_sessionWise.m and getDualTF\_FullScreen\_LFPVals\_sessionWise.m. These codes need trial-wise segmented rawData files to run.

Organization of the file: The cell array consists of 2 rows corresponding to two monkeys (M1 and M2). Each array has a structure consisting of -

|  |  |
| --- | --- |
|  |  |
| fftST\_plaid | FFT values for plaid stimuli for the analysis period. 5D array – Sessions \* Electrodes \* Delta Orientation (0/90) \* Mask’s Temporal frequency (1 to 29Hz, spacing 1Hz) \* Frequency Values |
| fftBL\_plaid | FFT values for plaid stimuli for the baseline period. 5D array – Sessions \* Electrodes \* Delta Orientation (0/90) \* Mask’s Temporal frequency \* Frequency Values |
| ampDiff\_plaid | 4D array – Sessions \* Electrodes \* Delta Orientation (0/90) \* Amplitude difference at 30Hz for different mask temporal frequencies |
| fftST\_grating | FFT values for grating stimuli for the analysis period. 5D array – Sessions \* Electrodes \* Delta Orientation (0/90) \* Mask’s Temporal frequency \* Frequency Values |
| fftBL\_ grating | FFT values for grating stimuli for the baseline period. 5D array – Sessions \* Electrodes \* Delta Orientation (0/90) \* Mask’s Temporal frequency \* Frequency Values |
| ampDiff\_ grating | 4D array – Sessions \* Electrodes \* Delta Orientation (0/90) \* Amplitude Change at 2f of mask temporal frequency |
| changeInAmpNeg | 4D array – Sessions \* Electrodes \* Delta Orientation (0/90) \* Amplitude Change at 30Hz subtracted from grating condition (15Hz TF at 25% contrast) |
| parameters | Cells correspond to different sessions of the same protocol. Each structure tells the stimulus presented in that session.  Note : Contrast values mentioned are automatically reduced to 50% when stimuli are presented to the monkey (due to the settings in stimulus presentation software for running plaid stimuli) |

– The saved file for protocols that presented stimulus at multiple contrasts (0 to 25% on a log scale is named as **SmallStimPlaid\_HighRMSLFP\_sessionWise\_Microelectrode.mat (Experiment 2)**. Small stimulus was presented for M1 and M2. A full-screen stimulus was presented for M3. Data is only for plaids at 0° and 90° separation. A single session had either plaids at 0° or 90° separation.

Organization of the file: Once loaded, the cell array’s rows correspond to the relative orientation difference between the plaids (0/90), and columns correspond to different monkeys (M1, M2 and M3). Each cell array has a structure. It consists of

|  |  |
| --- | --- |
|  |  |
| ElecIds | Cells correspond to the number of sessions used. It indicates the electrodes used for further analysis for that session (after removing high-impedance electrodes or noisy electrodes) |
| Parameters | Cells correspond to the number of sessions used. Each cell then shows the stimulus parameters presented in that session. |
| fftST\_plaid | FFT values for plaid stimuli for the analysis period. 6D array – Sessions \* Electrodes \* Target Grating Contrast (0 to 25% on a log scale) \*Mask Grating Contrast (0 to 25% on a log scale) \* Mask’s Temporal frequency (1 to 29Hz, spacing 2Hz) \* Frequency Values |
| fftBL\_plaid | FFT values for plaid stimuli for the baseline period. 6D array – Sessions \* Electrodes \* Target Grating Contrast \*Mask Grating Contrast \* Mask’s Temporal frequency \* Frequency Values |
| ampDiff\_plaid | 5D array – Sessions \* Electrodes \* Target Grating Contrast \*Mask Grating Contrast \* Amplitude difference at 30Hz for different mask temporal frequencies |
| fftST\_grating | FFT values for grating stimuli for the analysis period. 6D array – Sessions \* Electrodes \* Target Grating Contrast (at 0%) \*Mask Grating Contrast \* Mask’s Temporal frequency \* Frequency Values |
| fftBL\_ grating | FFT values for grating stimuli for the baseline period. 6D array – Sessions \* Electrodes \* Target Grating Contrast (at 0%) \*Mask Grating Contrast \* Mask’s Temporal frequency \* Frequency Values |
| ampDiff\_ grating | 5D array – Sessions \* Electrodes \* Target Grating Contrast (at 0%) \*Mask Grating Contrast \* Amplitude Change at 2f of mask temporal frequency |
| changeInAmpNeg | 5D array – Sessions \* Electrodes \* Target Grating Contrast \*Mask Grating Contrast \* Amplitude Change at 30Hz subtracted from grating condition (– irrespective of the plaid condition, it was always subtracted from grating with 15Hz TF at 25% contrast) |
| changeInAmpSubtract | 5D array – Sessions \* Electrodes \* Target Grating Contrast \*Mask Grating Contrast \* Amplitude Change at 30Hz subtracted from different grating conditions (Depending upon the plaid condition, it was subtracted from the maximum contrast grating [4 different target contrasts]. For eg., when the target was fixed at 12.5%, and mask grating was varied at four different contrast levels, the amplitude change at 30Hz for each condition was subtracted from the target grating at 12.5% ) |
| ampDiff\_plaid\_F1F2plus | 5D array – Sessions \* Electrodes \* Target Grating Contrast \*Mask Grating Contrast \* Amplitude difference at *f*1+*f*2 (15+ Mask temporal frequency) |
| ampDiff\_plaid\_F1F2minus | 5D array – Sessions \* Electrodes \* Target Grating Contrast \*Mask Grating Contrast \* Amplitude difference at *f*1-*f*2 (|15- Mask temporal frequency|) |
| ampDiff\_plaid\_TwiceF1F2plus | 5D array – Sessions \* Electrodes \* Target Grating Contrast \*Mask Grating Contrast \* Amplitude difference at 2*f*1+2*f*2 (30+ 2\*Mask temporal frequency) |
| ampDiff\_plaid\_TwiceF1F2minus | 5D array – Sessions \* Electrodes \* Target Grating Contrast \*Mask Grating Contrast \* Amplitude difference at 2*f*1-2*f*2 (|15- Mask temporal frequency|) |

For 45° separation plaids – data is saved separately in a file named **SmallStimPlaid\_HighRMSLFP\_sessionWise\_fortyFive\_Microelectrode.mat**. These protocols were run for M2 and M3 only. The file is organized similarly to the one described above. Two columns in the cell array correspond to M2 and M3.

Similar to this, we also saved Spiking data for small sized stimulus – These files are named as **SmallStimPlaid\_GoodSpikeElecsSpike\_sessionWise\_Microelectrode.mat** and **SmallStimPlaid\_GoodSpikeElecsSpike\_sessionWise\_fortyFive\_Microelectrode.mat**.

This file was generated using codes - runGetDualTF\_SmallStim\_LFPVals\_sessionWise.m and runGetDualTF\_SmallStim\_LFPVals\_sessionWise\_fortyFive.m. These codes then use getDualTF\_SmallStim\_LFPVals\_sessionWise.m, getGoodSpikingElecs\_DualTFSmallStim.m and getGoodSpikingElecs\_DualTFSmallStim.m. These codes need trial-wise segmented rawData files to run.

Organization of the file: Once the file is loaded, cell array’s rows correspond to the relative orientation difference between the plaids (0°/90° or 45°), and columns correspond to different monkeys (M1, M2 and only M2 for 45°)

|  |  |
| --- | --- |
|  |  |
| ElecIds | Cells correspond to the number of sessions used. It indicates the electrodes used for further analysis for that session (after selecting electrodes based on pre-determined criteria such as the number of total spikes in a session, change in firing rate, SNR values and a strong transient evoked response) |
| Parameters | Cells correspond to the number of sessions used. Each cell then shows the stimulus parameters presented in that session. |
| FiringRate\_grating | It corresponds to the change in firing rate (Stimulus-Baseline period). 4D array – Electrodes\*Target Grating Contrast (at 0%)\* Mask Grating Contrast (0 to 25% on a log scale)\*Mask Temporal Frequency(1 to 29Hz with spacing of 2Hz) |
| psthVals\_grating | 5D array - Electrodes\*Target Grating Contrast (at 0%)\* Mask Grating Contrast\*Mask Temporal Frequency \* Values (time axis saved in Parameters structure) |
| PsthFiringRate\_grating | Change in Firing Rate was calculated by taking the mean PSTH values for the stimulus and baseline period. 4D array – Electrodes\*Target Grating Contrast (at 0%)\* Mask Grating Contrast\*Mask Temporal Frequency |
| rasterData\_grating | 4D array – Electrodes\*Target Grating Contrast (at 0%)\* Mask Grating Contrast\*Mask Temporal Frequency. Each cell corresponds to cells for each trial run for that stimulus condition and tells the time at which the spike was recorded. |
| PsthfftST\_grating | FFT for PSTH during the stimulus period. 5D array - Electrodes\*Target Grating Contrast (at 0%)\* Mask Grating Contrast\*Mask Temporal Frequency \* Values (Frequency values saved in Parameters structure) |
| PsthfftBL\_grating | FFT for PSTH during the baseline period. 5D array - Electrodes\*Target Grating Contrast (at 0%)\* Mask Grating Contrast\*Mask Temporal Frequency \* Values (Frequency values saved in Parameters structure) |
| ampDiff\_spike\_grating | Change in amplitude at the respective 2*f*. 4D array – Electrodes\*Target Grating Contrast (at 0%)\* Mask Grating Contrast\*Mask Temporal Frequency |
| FiringRate\_plaid | 4D array – Electrodes\*Target Grating Contrast(0 to 25% on a log scale) \* Mask Grating Contrast (0 to 25% on a log scale) \*Mask Temporal Frequency (1 to 29Hz, spacing 2Hz) |
| psthVals\_plaid | 5D array - Electrodes\*Target Grating Contrast\* Mask Grating Contrast\*Mask Temporal Frequency \* Values (time axis saved in Parameters structure) |
| PsthFiringRate\_plaid | Change in Firing Rate was calculated by taking the mean PSTH values for the stimulus and baseline period. 4D array – Electrodes \* Target Grating Contrast \* Mask Grating Contrast\*Mask Temporal Frequency. |
| PsthfftST\_plaid | FFT for PSTH during the stimulus period. 5D array – Electrodes \* Target Grating Contrast \* Mask Grating Contrast \* Mask Temporal Frequency \* Values |
| PsthfftBL\_plaid | FFT for PSTH during the baseline period. 5D array – Electrodes \* Target Grating Contrast \* Mask Grating Contrast\*Mask Temporal Frequency \* Values |
| ampDiff\_spike\_plaid | Change in amplitude at the 30Hz. 4D array – Electrodes\*Target Grating Contrast\*Mask Grating Contrast\*Mask Temporal Frequency |
| changeInAmpNeg | 4D array – Electrodes \* Target Grating Contrast \*Mask Grating Contrast \* Amplitude Change at 30Hz subtracted from grating condition (– irrespective of the plaid condition, it was always subtracted from grating with 15Hz TF at 25% contrast) |
| changeInAmpSubtract | 4D array – Electrodes \* Target Grating Contrast \*Mask Grating Contrast \* Amplitude Change at 30Hz subtracted from different grating conditions (Depending upon the plaid condition, it was subtracted from the maximum contrast grating [4 different target contrasts]. |

**Experiment 3** involved presentation of gratings at varying contrasts and temporal frequencies. The trial segmented and Fourier transformed data is stored in two files named as **M1\_ConTF\_GoodSpikingLFP\_sessionWise\_Microelectrode.mat** and **M2\_ConTF\_GoodSpikingLFP\_sessionWise\_Microelectrode.mat ,** corresponding to the two monkeys. To generate these files , trial wise segmented raw LFP data is used by code called runSaveLFPDataConTF\_sessionWise.m (which is further dependent on following codes - saveLFPDataConTF\_sessionWise.m and protocolInformationConTF.m).

Organization of the file: The cell array consists of 2 rows corresponding to two monkeys (M1 and M2). Each array has a structure consisting of -

|  |  |
| --- | --- |
|  |  |
| analogDataAllElec | Evoked response potentials (averaged across all trials). 6D Array- Sessions \* Electrodes \* Stimulus Size (1.5 Degree and Full-Screen) \* Grating Contrast (0 to 100% on log scale) \* Temporal frequency (0,1,2,4,8,16,32,50 Hz) \* Values with time. Time axis stored in params structure. |
| elecfftST | FFT values for analysis period. 6D Array- Sessions \* Electrodes \* Stimulus Size \* Grating Contrast \* Temporal frequency \* frequency values. Frequency axis is stored in params structure. M1 had frequency resolution of 2Hz and M2 had frequency resolution of 1Hz. |
| elecfftBL | FFT values for baseline period. 6D Array- Sessions \* Electrodes \* Stimulus Size \* Grating Contrast \* Temporal frequency \* frequency values. |
| ampDiff | Amplitude change at 2*f.* 5D Array- Sessions \* Electrodes \* Stimulus Size \* Grating Contrast \* Temporal frequency |
| params | Cells correspond to the number of sessions used. Each cell then shows the stimulus parameters presented in that session. |

From all these files, a second file is generated which has data averaged across electrodes and particular conditions which is arranged in such a manner that the figure can be plotted using just that one file.

Figures - It needs **getPlotHandles** code (which can be found in the [Common Programs repository](https://github.com/supratimray/CommonPrograms))**,** which allows custom axes handles to be made.

### Figure 1 –

Figure 1 is generated using dummy data (HypothesisData.mat) and an image file (Figure1 – model.png); both these files are kept in the folder called **Hypothesis.**

***displayHypothesis.m -*** Loads the files and makes the plots.

### Figure 2 –

Codes needed to generate this figure are kept in a folder named **FullScreen.**

**runGetAndPlotDataForFigure2\_sessionWise.m** code searches for the file saved for generating Figure 2 (**Figure2Data\_sessionWise.mat**). If it does not exist in the path, then it generates that file ( using the saved Data files - FullScreen\_HighRMSLFP\_sessionWise\_Microelectrode.mat and SmallStimPlaid\_HighRMSLFP\_sessionWise\_Microelectrode.mat) and then plots the figure. It uses two codes: **getDataForFigure2\_sessionWise.m (**loads the saved file and does averaging across electrodes and saves the data in the desired format to generate the figure**)** and **plotFigure2.m**

### Figure 3 –

The codes needed to generate this figure are kept in a folder named **SmallStimPlaid.**

**runGetDataForFigure3AndPlot\_sessionWise.m** uses three codes called **getDataForFigure3\_sessionWise.m** (for saving LFP data), **getDataForFigure\_Spiking.m** (for saving spiking data) and **plotFigure3\_sessionWise.m**. The main code searches for saved files for generating Figure 3 (**Figure3\_LFPData\_sessionWise.mat** and **Figure3\_SpikingData.mat**). If that does not exist in the path, it generates Figure 3 files and plots them.

### Figure 4 and Figure 6 –

The codes needed to generate this figure are kept in a folder named **Model.**

**runGetResponsefit.m** loads the saved data file (SmallStimPlaid\_HighRMSLFP\_sessionWise\_Microelectrode.mat) and then fits the data using the fmincon function of MATLAB.

**getStartValsDualTFModel.m** is a hardcoded file that gives out the starting values and tells lower and upper bounds for the fmincon function.

**getResponsefit.m** has the equations of the two models (Original Tuned Normalization model and Optimal-Tuned Normalization model).

runGetResponsefit.m saves the model parameters and the obtained fitted curves.

Folder named - exponentModifiedCodes – contains the code files where exponent is also included as a free parameter.

**runPlotModelFitsAllMonkeys.m** loads the saved files (**Model\_LFPData\_for\_all\_elecs\_alldelta\_allSession\_Tuned\_Normalization\_Model.mat** and **Model\_LFPData\_for\_all\_elecs\_alldelta\_allSession\_Optimal\_Model.mat**) and plots the fitted curves for electrodes having explained variance above a pre-determined cutoff. It uses **getAveragedModelData\_AllMonkeys.m** code to find good electrodes and averages their fits (which is saved in files called **PlotDataTunedNormalization\_Model.mat** and **PlotDataOptimal\_Model.mat –** both these files can be loaded to directly generate Figure 4 and 6**)** and then **plotModelFitsAllMonkeys.m** code plots the figure.

### Figure 5 –

The code needed to generate this figure is kept in a folder named **Model.**

**ModelSimulatedPlots.m** – It simulates the summation of sinusoids in various ways and plots it.

### Figure 7 –

The codes needed to generate this figure are kept in a folder named **Model.**

**runGetAndPlotAicAndExpVar.m**loads the saved model files (Model\_LFPData\_for\_all\_elecs\_alldelta\_allSession\_Tuned\_Normalization\_Model.mat and Model\_LFPData\_for\_all\_elecs\_alldelta\_allSession\_Optimal\_Model.mat) as these list the explained variance and squared sum of errors for each electrode. This code uses **getAicAndExpVar.m** code to calculate AIC for each electrode. **plotAicAndExpVar.m** plots the figure and also does the statistics (signrank test).

### Figure 8 –

The codes needed to generate this figure are kept in a folder named **ConTF.**

**runGetDataforFigure8\_sessionWiseAndPlot.m** code searches for the file saved for generating Figure 8 (**Figure8Data\_sessionWise.mat**). If it does not exist in the path, then it generates that file ( using the saved Data files - M1\_ConTF\_GoodSpikingLFP\_sessionWise\_Microelectrode.mat and M2\_ConTF\_GoodSpikingLFP\_sessionWise\_Microelectrode.mat) and then plots the figure. It uses two codes: **getDataForFigure8\_sessionWise.m** and **plotFigure8\_ConTFSize.m.**

### Figure S1 –

The codes needed to generate this figure are kept in a folder named ReceptiveFieldData**.**

**getReceptiveFieldPlots.m** plots the receptive field centers and sizes for the electrodes that had stable receptive field across days. These files for the three monkeys are kept in three folders named coco (M1), dona (M2) and alpaH(M3). For more details about how RF centers were calculated refer to methods section of the paper.

### Figure S2 –

The codes needed to generate this figure are kept in a folder named Supplementary\_FortyFive**.**

**runGetDataForFortyFiveSupplementaryFigure\_sessionWise.m** searches for the file saved for generating Figure S2 (**FigureFortyFiveSupplementary\_FigureData\_sessionWise.mat**). If it does not exist in the path, then it generates that file (using the saved Data files - SmallStimPlaid\_HighRMSLFP\_sessionWise\_fortyFive\_Microelectrode.mat) using code **getDataForFigure3\_sessionWise.m (**kept in SmallStimPlaid Folder**).**

**runGetResponseFit\_FortyFive.m** fits the model on this dataset and saves the model fits in Model folder (**Model\_LFPData\_for\_all\_elecs\_FortyFivedelta\_allSession\_Tuned\_Normalization\_Model.mat** and **Model\_LFPData\_for\_all\_elecs\_FortyFivedelta\_allSession\_Optimal\_Model.mat**).

**runPlotFigure\_Supplementary\_FortyFive\_sessionWise.m** loads the saved files to generate the figure. It uses **getAveragedModelData\_AllMonkeys.m** code to find electrodes which had fits with a good explained variance and averages their fits (which is saved in files called **PlotData\_FortyFivedeltaTuned\_Normalization\_Model.mat** and **PlotData\_FortyFivedeltaOptimal\_Model.mat –** both these files can be loaded to directly generate this figure along with **FigureFortyFiveSupplementary\_FigureData\_sessionWise.mat** **)** and then **plotFigure\_Supplementary\_FortyFive\_sessionWise.m** code plots the figure.

### Figure S3 –

The code needed to generate this figure are kept in a folder named **Model.**

**ModelSimulatedPlots\_ExponentVariant.m** – It simulates the summation of sinusoids followed by non-linearity for different exponents.

ModelSimulatedPlots\_TauVariant.m – Changes the cutoff of low-pass filter.

### Figure S4 and S5 –

The codes needed to generate this figure are kept in a folder named Supplementary\_IMComponents**.**

**runPlotIMComponents.m** loads the saved data file named SmallStimPlaid\_HighRMSLFP\_sessionWise\_Microelectrode.mat (for S4) and SmallStimPlaid\_HighRMSLFP\_sessionWise\_fortyFive\_Microelectrode.mat (for S5) to generate data for making the figure. This data is saved and is used for plotting. (Figure\_IMData\_0\_90\_sessionWise.mat and Figure\_IMData\_45\_sessionWise.mat) Codes used for plotting are called plotFigureIM\_sessionWise.m (for S4) and plotFigureIM\_sessionWise\_45.m (for S5)