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This document describes the functions of the MATLAB (2021a) codes used in the article: **Restoring interbrain prefrontal theta synchronization reverses social deficits**.

Download the entire folder, add it to the directory (with all the subfolders) in MATLAB.

Sample Data are included within the different parts of analysis.

* MClust\_Spike-Soring\_Toolbox\_master

MClust is used to cut and cluster single neuron data.

* MatlabImportExport\_v6.0.0

Open Resource library of codes that includes codes to import Cheetah collected data to MATLAB

* shadedErrorBar-master

Open Resource library that draws a line plot with shaded error indicating standard error of the mean

1. **Preprocessing**

Codes in this code are used to pre-process the neural data collected from each experimental session.

Behavior\_only\_sessions (codes that are used for behavior only sessions, Fig 1-4, Extended Fig 1-4)

* Shank2\_struct\_[year 2020, 2021, 2023]

Code outputs a K struct that includes mouse ID, genotype, pair type, timestamps, spike data)

* Shank2\_struct\_[year 2020, 2021, 2023]\_behaviortimestamps

Code appends to the K struct social, non-social, immobile (rest) behavior time stamps

* Shank2\_LFPmat\_struct\_save

Code outputs a .mat file that includes rawLFP data, Timestamps, ADMaxValue, InputRange, and Sampling Frequency

OptoStim\_sessions (codes that are used for optogenetics sessions, Fig 5, Extended Fig 5-6)

* Shank2\_struct\_optostim

Code outputs a K struct that includes mouse ID, genotype, pair type, timestamps, spike data)

* Shank2\_struct\_optostim\_behaviortimestamps

Code appends to the K struct social, non-social, immobile (rest) behavior time stamps

* Shank2\_optostim\_LFP\_struct

Code outputs a .mat file that includes rawLFP data, Timestamps, ADMaxValue, InputRange, and Sampling Frequency

Supporting

* Shank2\_socialbehavior\_boutcreation\_mouse1

Code that extracts social behavior data to be included in the K struct

* Shank2\_nonsocialbehavior\_boutcreation\_[year 2020, 2021]

Code that extracts non-social behavior data to be included in the K struct

* Shank2\_immobile\_[year 2020, 2021]

Code that extracts immobile (Rest)data to be included in the K struct

Run time : depending on the number of sessions 5-10 minutes, for one session about 1~2 minutes

1. **Behavior (Fig 1, Extended Fig 1, 2)**

* Xml2struct

This code is a function code imports behavior data annotated using Adobe Premiere Pro. It reads .xml files.

* Xmlcode\_7behaviors

This code imports all the social behavioral data from direct interaction sessions.

* Xmlcode\_nonsocial

This code imports all the non-social and rest behavioral data from the direct interaction sessions.

* Shank2\_solitary\_xml

This code imports all the non-social and rest behavioral data from the solitary recording sessions.

* Shank2\_socialgaze\_total

This code imports gaze data from all the direct interaction sessions (csv output of DeepLabCut) and quantifies it.

* Shank2\_behavior\_total

This code imports all behavioral data from all the direct interaction sessions

Sample Data Folders : GazeData (sample csv outputs from DeepLabCut) BehaviorData (sample xml outputs from Adobe Premiere Pro)

Run time : depending on the number of sessions 5-10 minutes, for one session about 1~2 minutes

1. **InterbrainSynchrony\_PearsonCorrelationCoefficient**

\*Pearson Correlation Coeffcient is referred to as PCC.

Behavior (codes that are used for behavior only sessions, Fig 2-4, Extended Fig 1-4)

* Shank2\_wavelet\_socialbehavior\_pcc\_[year 2020, 2021, 2023]

Code uses wavelet function to calculate PCC values for specific behaviors, social, non-social, and rest

* Shank2\_velocity\_wavelet \_pcc

Code uses wavelet function to calculate PCC values for velocity control epochs

* Shank2\_LFP\_PCC

Code that calculates PCC values for entire LFP recording to make within/between comparisons, direct interaction sessions/solitary recording sessions

* Shank2\_LFP\_pearson\_coeff\_first\_last2min

Code that calculates the PCC values for the 1st and last 2 minutes of direct interaction session (used to draw Fig. 3d-f)

* Shank2\_LFP\_pearson\_coeff\_2min\_timeplot

Code that calculates the PCC values for 2 minute window over time and plots it with behavioral and gaze data (used to draw Fig. 3c)

* Shank2\_LFP\_pearson\_coeff\_linearregression

Code that computes simple linear regression between time and PCC, time and behavior and time and gaze (used to draw Fig. 3c)

* calculatePCC

function that calculates PCC values for specific windows

Gaze (codes that are used for behavior only sessions, Fig 3, Extended Fig 2)

* Shank2\_socialgaze\_wavelet\_PCC

Code uses wavelet function to calculate PCC values during social gaze epochs

* Shank2\_socialgaze\_excl\_socialbehavior\_wavelet\_PCC

Code uses wavelet function to calculate PCC values during social gaze epochs excluding epochs of social behavior

* Shank2\_headangle\_wavelet\_PCC

Code uses wavelet function to calculate PCC values for headangle control epochs

* excludeInteractionTimes

function that excludes social behavior times from social gaze times

* calculateWaveletCorrelation

function that calculates PCC values for specific epochs for different frequency bands

Sample Data Folder : NeuralData (contains K struct files and LFP struct files in .mat formats), VelocityData (sample csv outputs from DeepLabCut), HeandAngleData (sample csv outputs from DeepLabCut)

Run time : depending on the number of sessions 5-10 minutes, for one session about 1~2 minutes

1. **NeuronProperties (Extended Data Fig. 3)**

* Shank2\_spike\_markEI

This code is categorizes whether a neuron is excitatory or inhibitory based on is half-width and spike to valley ratio

* Shank2\_ISI\_sessiontype

This code calculates the inter-spike-interval for neurons based on session types (baseline, direct interaction, solitary)

* Shank2\_ISI\_sessiontype\_avereage

This code calculates the average inter-spike-interval for neurons based on session types (baseline, direct interaction, solitary)

* Shank2\_ISI\_burstanalysis

This code calculates the proportion of burst spikes for each neuron for each trial type

* Shank2\_ISI\_behaviortype

This code calculates the inter-spike-interval for neurons based on behaviors (social, non-social, rest) during direct interaction sessions

* Shank2\_direct\_interaction\_firingrate

This code calculates average firing rate for all neurons during the direct interaction /solitary recording sessions

* Shank2\_baseline\_firingrate

This code calculates average firing rate for all neurons during baseline.

* Shank2\_averageSesssionFRs\_average

This code calculates average firing rate for all neurons during baseline, direct interaction session, and solitary recording session.

Run time : depending on the number of sessions 5-10 minutes, for one session about 1~2 minutes

1. **auROC (Fig 4, Extended Data Fig. 6)**

* self/otherbehavior\_socialnonsocial

This code runs generates time bins from self/other behavior respectively and use them to calculate firing rates and perform auROC(area under ROC) analysis.

* SDFgen\_self/other

This code generates SDF for all time bins.

* drawing\_SDF

This code draws the average value and s.e.m. of SDF for social neurons in social behavior onsets.

Sample Data Folder: contains .mat files that can be run through Shank2\_auROC code to isolate social behavior encoding neurons

Run time : 30~40 minutes depending on the number of neurons

1. **PhaseLock (Fig. 4, Extended Data Fig. 4)**

* PhaseLock

This code uses spike data and LFP data to calculate Phase to Wave coupling for solitary recording and direct interaction sessions.

* PhaseLock\_optostim

This code uses spike data and LFP data to calculate Phase to Wave coupling for optostimulation sessions

* circularStat

This function code conducts statistical testing that determines if a neuron is phase locked to wave

Wavelet folder contains all the supporting function codes to run PhaseLock analysis

Run time : depending on the number of sessions 5-10 minutes, for one session about 1~2 minutes

1. **Optostimulation (Fig. 5, Extended Data Fig. 5)**

\*Pearson Correlation Coeffcient is referred to as PCC.

Behavior

* Xmlcode\_optostim

This code imports all the social, non-social, immobile (rest) behavioral data from direct interaction sessions.

* Shank2\_behavior\_total\_optostim\_threewindows

Code quantifies social behavioral data in three 5 minutes windows

* Shank2\_behavior\_total\_optostim\_nonsocial

Code quantifies non-social and immobile (rest) behavioral data in three 1 minute windows

* Shank2\_behavior\_total\_optostim

Code quantifies social behavioral data in three 1 minute windows

InterbrainSynchrony

* Shank2\_optostim\_LFP\_thetapower\_threeepoch

Code quantifies theta power in each of the sync, desync, no stim epochs

* Shank2\_optostim\_LFP\_PCC

Code calculates the PCC value for each of the sync, desync, no stim epochs.

Sample Data Folder: OptoStim\_NeuralData (contains K struct files and LFP struct files in .mat formats), Optostim\_BehaviorData (sample xml outputs from Adobe Premiere Pro)

Run time : depending on the number of sessions 5-10 minutes, for one session about 1~2 minutes