

MEA LFP Analysis Toolbox

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Hertie-Institut
für klinische Hirnforschung

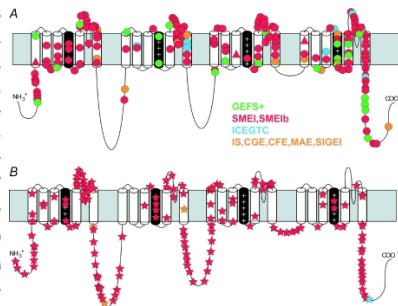
EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN



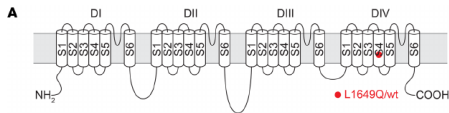
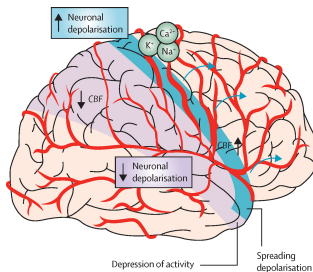
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Introduction

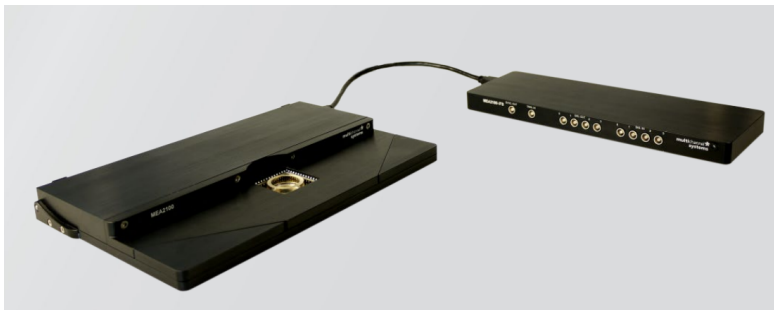
Epilepsy & Migraine as Channelopathies I



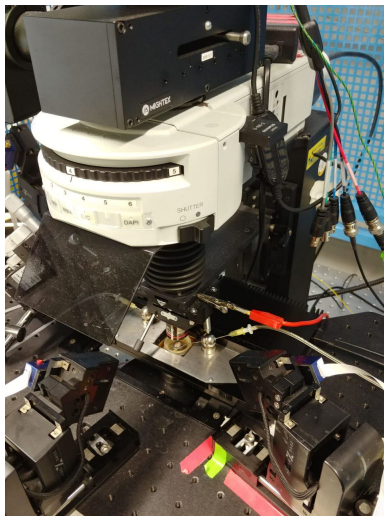
Epilepsy & Migraine as Channelopathies II



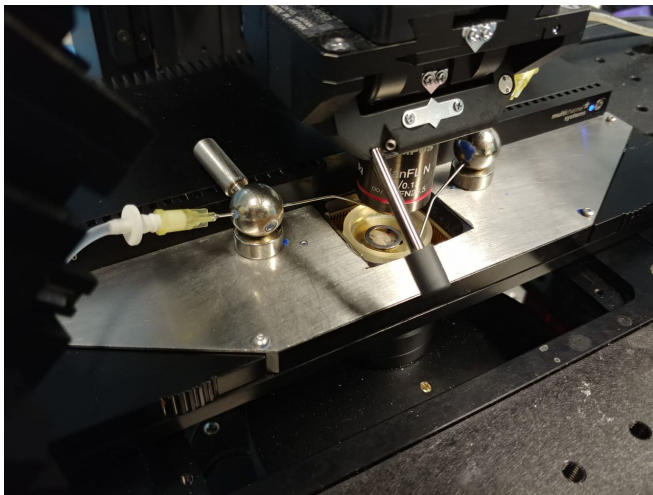
Recording Setup I



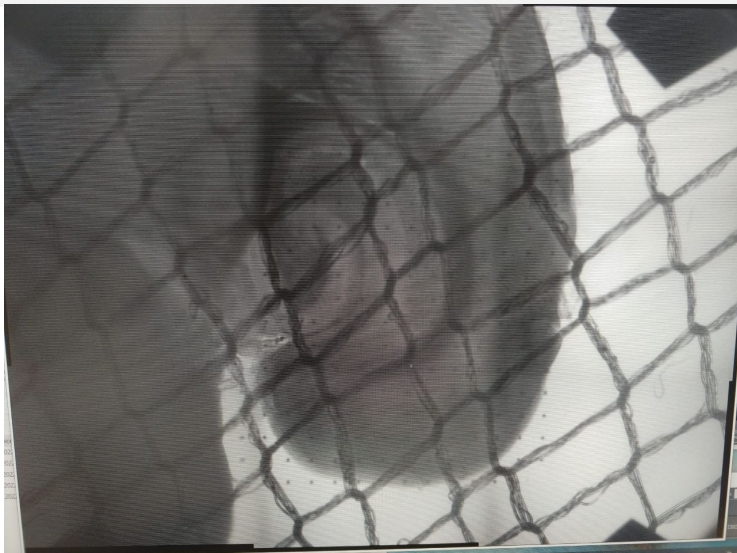
Recording Setup II



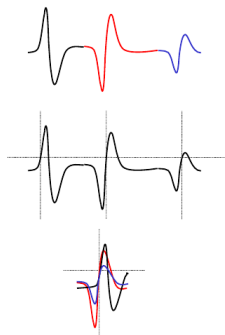
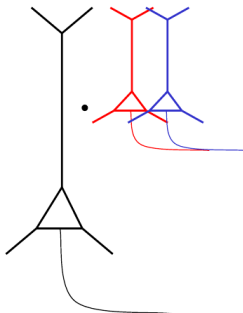
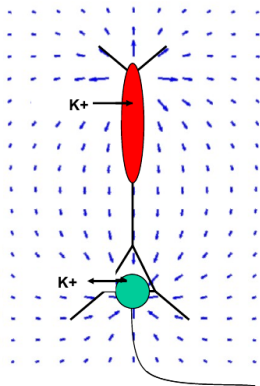
Recording Setup III



Recording Setup V



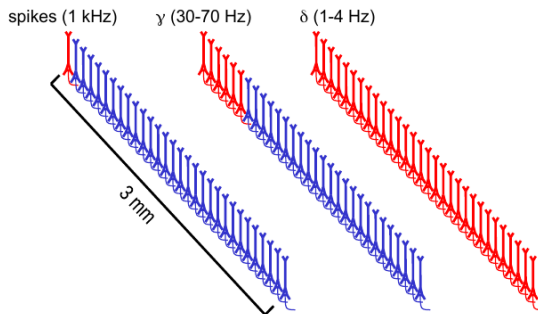
Data I



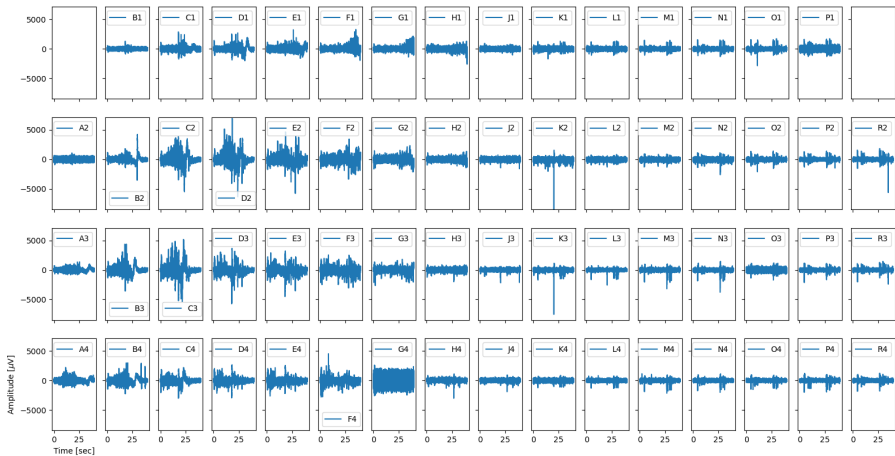
Data II

Local field potential is the sum of all potentials generated by axons, somas and dendrites in the vicinity of the electrode.

The spatial extend of correlation of these signals is frequency dependent!



Data III



Task

- ▶ Task: Detect peaks, seizure-like bursts & characterize them. Provide GUI.
- ▶ Constraints:
 - ▶ many channels
 - ▶ high sampling rate
 - ▶ high heterogeneity
- ▶ Existing toolboxes are
 - ▶ proprietary or vendor specific
 - ▶ scale specific (Single Unit vs. EEG/MEG)
 - ▶ quality-wise insufficient

Software

MEA LFP Analysis Toolbox I

Semi-automated data analysis pipeline with UI.

- ▶ Currently supports MultiChannel Systems 256 electrode MEA

Input File Path:

File type: ☒ Multi Channel Systems

File path: /home/someusername/sync/workspace/nb_tue/3/1_lerche/data/2022-10-27T15-12-09S2_Epileptiform.h5

| Date | Program | Version | Comment | MEA System Name | MEA Layout |
|---------------------|------------------------|--------------|---------|-----------------|--------------------------|
| 2022-10-27 15:12:09 | Multi Channel Analyzer | 2.16.0.20205 | | 256MEA | MEA_256MEA_MEA2100_252_6 |

| Type | Stream | # ch |
|--------|--|------|
| Analog | Data Acquisition (1) Electrode Raw Data1 | 252 |

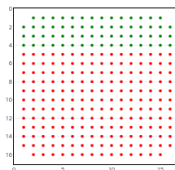
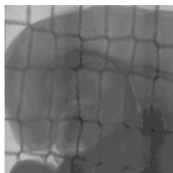
MEA LFP Analysis Toolbox II

- Allows graphical selection of electrodes and time window

Select the desired electrodes and time frame

Select Image File:

/home/someusername/sync/workspace/nb_tue/3/1_lerche/data/Fused_full_contr_gamma_adj_bright.tif



Show selected raw signals

Specify a time range for analysis (s:ms:μs):

0:00:000

39:999:999.9999999925494

Apply electrode and time window selection

MEA LFP Analysis Toolbox III

- Preprocessing: Electrical humming filter, bandpass filter, downsampling

Remove Electrical Humming:

Apply

Successfully removed electrical humming (50 Hz)

Bandpass Filter

☒ Butterworth
☐ Chebyshev

Apply

Successfully applied bandpass filter

Downsampling:

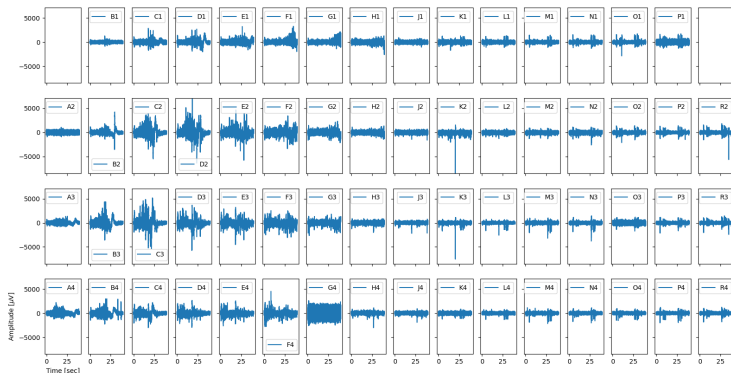
Apply

Successfully downsampled

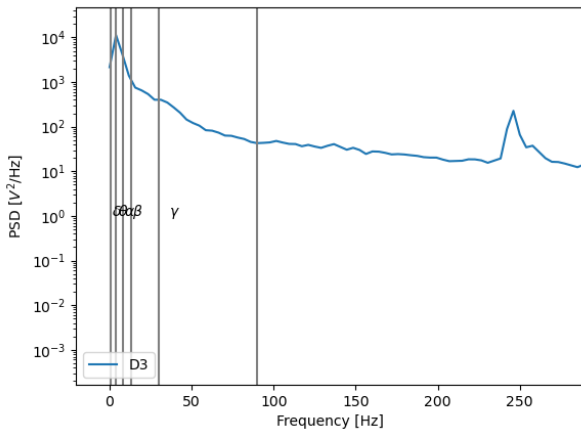
Next

MEA LFP Analysis Toolbox IV

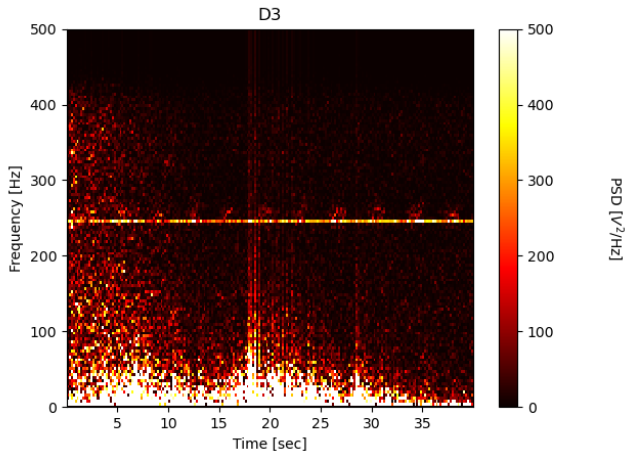
- Exploration: raw signal plots, absolute amplitude video, PSD, Spectrogram



MEA LFP Analysis Toolbox V



MEA LFP Analysis Toolbox VI



MEA LFP Analysis Toolbox VII

- Analysis: Peak detection with threshold based on std or moving average, burst detection based on moving average and moving std (instead of peaks)

Available Analysis Sections:

Electrode Amplitude Activation

Start time (timestamp) Stop time (timestamp)

Playback Speed in FPS

Show data from real-time ☐

Generate filter data: none selected

Moving Average ☐

STD ☐

Transfer Average: PSD decomposition ☐

Transfer gain ☐

Detect peaks by absolute amplitude

Baseline file name

Start

Detect peaks by moving average amplitude

Baseline file name

Start

Detect event by moving std

Baseline file name

Start

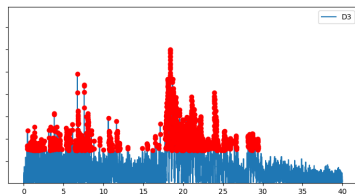
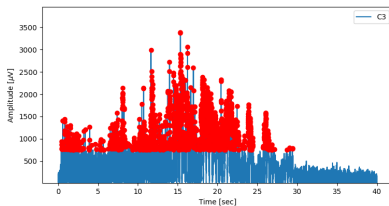
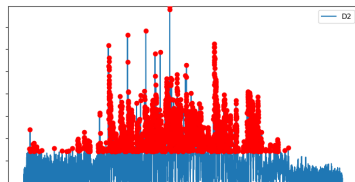
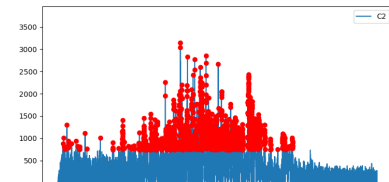
Detect event by moving avg

Home/homepage/home/psychophysic/01b_cue01_benchmark/2022-10-27T01:16:28Z_baseline.b5

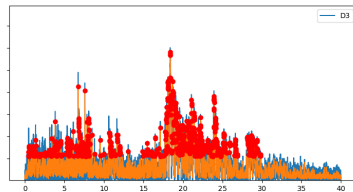
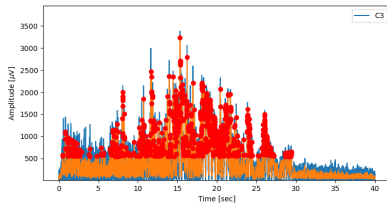
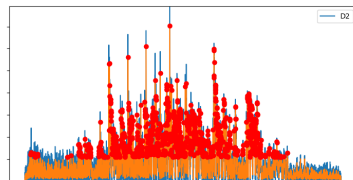
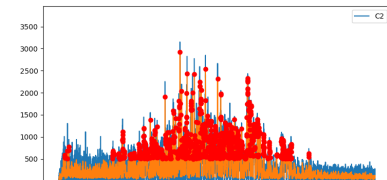
Start

| Id | Duration | Start | Stop | Spike count | Spike Rate | RMS | Max_Amplitude | Mean std | Delta | Theta | Alpha | Beta | Gamma | Delta | Transfer entropy |
|----|--------------------|-------------------|--------------------|-------------|--------------------|------------------|-------------------|----------------------|-------------------|--------------------|--------------------|-------------------|--------------------|-------|----------------------|
| C1 | 30.100000000000000 | 0.000000000000000 | 30.100000000000000 | 548 | 47.8962017781965 | 762.762367119010 | 4336.94382610882 | 0.013662203193107613 | 43093.68896320063 | 7621.0861754855963 | 2719.2603032181719 | 863.6878963683847 | 271.87756807121626 | 1 | 0.00986876027718892 |
| C2 | 32.100000000000000 | 0.000000000000000 | 32.100000000000000 | 1762 | 63.80615668918162 | 435.456887198576 | 3773.84629661679 | 0.013020281876816612 | 44176.2407501779 | 5643.48910298417 | 1979.490320623965 | 377.0377646811784 | 184.1862186718776 | 86 | 0.0191987663807628 |
| C3 | 34.100000000000000 | 0.0 | 34.100000000000000 | 3542 | 48.0767871981058 | 595.820568246716 | 3402.854302079702 | 0.0134884171232806 | 31484.71274013389 | 4766.13947026776 | 3205.531100046380 | 381.3822709032383 | 163.5961271881668 | 8 | None |
| C4 | 36.520000000000000 | 0.116800000000000 | 36.643000000000000 | 1036 | 38.462113872510245 | 703.857017710264 | 4168.47784716163 | 0.01032080988765463 | 47768.4086468104 | 7624.84030387393 | 1828.218647020058 | 349.2464478610145 | 128.87789103025884 | 192 | 0.018102602262019478 |

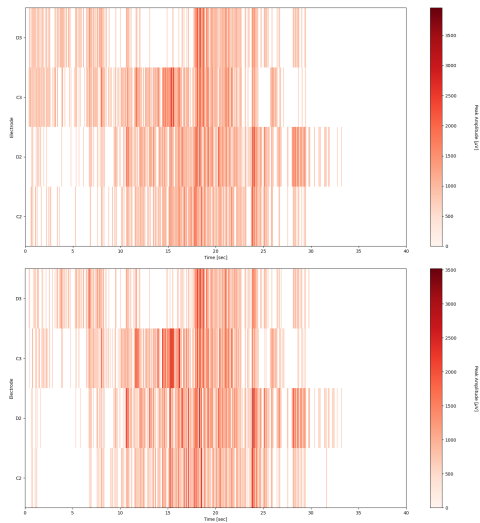
MEA LFP Analysis Toolbox VIII



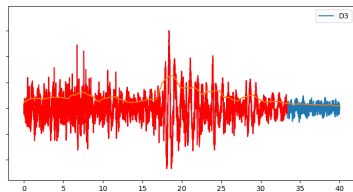
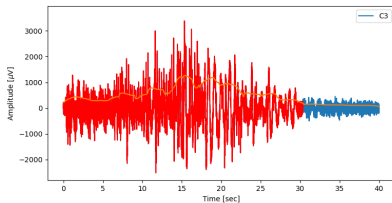
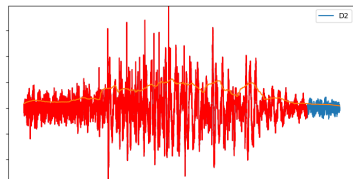
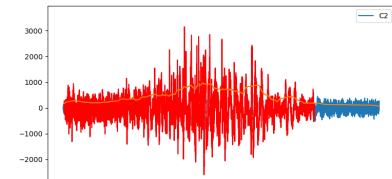
MEA LFP Analysis Toolbox IX



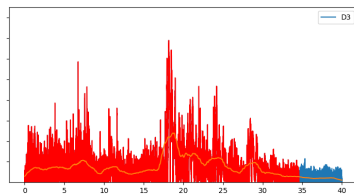
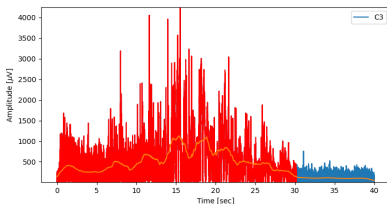
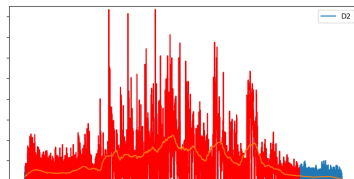
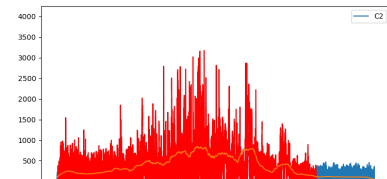
MEA LFP Analysis Toolbox X



MEA LFP Analysis Toolbox XI



MEA LFP Analysis Toolbox XII



MEA LFP Analysis Toolbox XIII

► seizure-like event quantification:

| Name | Duration | Start | Stop | Spike Count | Spike Rate | RMS | Max. Amplitude | Mean ISI | Delta | Theta | Alpha | Beta | Gamma | Delay | Transfer Entropy |
|------|--------------------|---------------------|--------------------|-------------|--------------------|-------------------|--------------------|----------------------|--------------------|--------------------|--------------------|-------------------|--------------------|-------|----------------------|
| C3 | 30.343999999999994 | 0.0 | 30.343999999999994 | 1218 | 40.130731083575015 | 676.204258400888 | 3385.735854954693 | 0.0165068638783894 | 52884.79088679831 | 4046.105660920222 | 1424.1835364867688 | 405.9470872255121 | 159.57460302189006 | 0 | None |
| C2 | 31.723999999999993 | 0.06099999999999998 | 31.814999999999994 | 1532 | 48.291514310931795 | 544.7914957818647 | 3149.600545015607 | 0.014235140431090788 | 40544.402819089424 | 3827.1513524540896 | 1101.0128282182766 | 337.4613468369034 | 138.7614903056342 | 91 | 0.012157223268195239 |
| O3 | 33.337999999999994 | 0.0 | 33.337999999999994 | 1357 | 40.704301397804315 | 530.6768306622532 | 3009.0049199776963 | 0.016622418879056043 | 26148.683175379446 | 2760.411662431562 | 842.9915044156808 | 254.7014992913317 | 109.27190403526385 | 0 | None |
| O2 | 35.872999999999999 | 0.0 | 35.872999999999999 | 1224 | 34.120369079800336 | 657.6218603310972 | 3957.810312831967 | 0.018857726901062955 | 52983.509791213124 | 4511.064715611301 | 1229.3361816008162 | 290.0630620383728 | 95.1573607267399 | 0 | None |

| Name | Duration | Start | Stop | Spike Count | Spike Rate | RMS | Max. Amplitude | Mean ISI | Delta | Theta | Alpha | Beta | Gamma | Delay | Transfer Entropy |
|------|--------------------|-----------------------|--------------------|-------------|--------------------|-------------------|--------------------|----------------------|--------------------|--------------------|--------------------|--------------------|--------------------|-------|----------------------|
| C3 | 30.189999999999994 | 0.0009999999999999998 | 30.190999999999999 | 1449 | 47.99602517389865 | 750.7524676119893 | 4244.96180674892 | 0.013642265193370163 | 65093.688065240865 | 7821.5860154805965 | 2119.2603037218773 | 463.68789636083847 | 211.87758807127628 | 1 | 0.003946878437774082 |
| C2 | 32.559999999999995 | 0.08399999999999998 | 32.643999999999999 | 1752 | 53.808353808353814 | 605.858887580576 | 3173.934296651159 | 0.012532838378069472 | 49175.25075011739 | 5843.409320084117 | 1579.4592556529865 | 377.0317764461704 | 184.18403278451776 | 84 | 0.019556078608207628 |
| O3 | 34.501999999999999 | 0.0 | 34.501999999999999 | 1542 | 44.5767807585569 | 586.8204058346716 | 3442.9554328375702 | 0.01546841012329656 | 31404.71274313209 | 4104.136470026716 | 1205.5311939090395 | 281.39227000325263 | 143.50612711897404 | 0 | None |
| O2 | 34.528999999999999 | 0.11499999999999998 | 34.643999999999999 | 1336 | 38.692113875293245 | 753.857511715354 | 4168.477847766143 | 0.016352808988764043 | 67744.46964846194 | 7424.840305397393 | 1926.2188479702058 | 349.24643786195145 | 128.81739103358484 | 115 | 0.018192693296591678 |

Outlook

Outlook

- ▶ Transfer Entropy, Granger Causality and CSD
- ▶ Group analysis
- ▶ Other setups: CMOS, deep brain stimulation electrodes
- ▶ in-vitro/MEA - in-vivo/Tetrode correlation
- ▶ 2-Photon Ca^{2+} imaging

References

- [1] E. L. Nylén und P. Wallisch, *Neural Data Science: A Primer with MATLAB® and Python™*. Academic Press, 2017.
- [2] P. Virtanen, R. Gommers, T. E. Oliphant u. a., „SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python“, *Nature Methods*, Jg. 17, S. 261–272, 2020. DOI: [10.1038/s41592-019-0686-2](https://doi.org/10.1038/s41592-019-0686-2).
- [3] C. R. Harris, K. J. Millman, S. J. van der Walt u. a., „Array programming with NumPy“, *Nature*, Jg. 585, Nr. 7825, S. 357–362, Sep. 2020. DOI: [10.1038/s41586-020-2649-2](https://doi.org/10.1038/s41586-020-2649-2). Adresse: <https://doi.org/10.1038/s41586-020-2649-2>.
- [4] J. D. Hunter, „Matplotlib: A 2D graphics environment“, *Computing in Science & Engineering*, Jg. 9, Nr. 3, S. 90–95, 2007. DOI: [10.1109/MCSE.2007.55](https://doi.org/10.1109/MCSE.2007.55).
- [5] T. Donoghue, M. Haller, E. J. Peterson u. a., „Parameterizing neural power spectra into periodic and aperiodic components“, *Nature neuroscience*, Jg. 23, Nr. 12, S. 1655–1665, 2020.
- [6] K. Ikegawa, J. Trauger, J. McMullin und R. Brunner, „PyIF: A Fast and Light Weight Implementation to Estimate Bivariate Transfer Entropy for Big Data“, English (US), in *IEEE SoutheastCon 2020, SoutheastCon 2020*, Ser. Conference Proceedings - IEEE SOUTHEASTCON, Publisher Copyright: © 2020 IEEE.; 2020 IEEE SoutheastCon, SoutheastCon 2020 ; Conference date: 28-03-2020 Through 29-03-2020, United States: Institute of Electrical und Electronics Engineers Inc., März 2020. DOI: [10.1109/SoutheastCon44009.2020.9249650](https://doi.org/10.1109/SoutheastCon44009.2020.9249650).
- [7] A. Mahadevan, N. K. Codadu und R. R. Parrish, „Xenon LFP Analysis Platform is a Novel Graphical User Interface for Analysis of Local Field Potential from Large-Scale MEA Recordings“, *bioRxiv*, 2022.
- [8] V. A. Unakafova und A. Gail, „Comparing open-source toolboxes for processing and analysis of spike and local field potentials data“, *Frontiers in Neuroinformatics*, Jg. 13, S. 57, 2019.
- [9] E. Cotterill und S. J. Egle, „Burst detection methods“, *In Vitro Neuronal Networks*, S. 185–206, 2019.
- [10] O. Herreras, „Local field potentials: myths and misunderstandings“, *Frontiers in neural circuits*, Jg. 10, S. 101, 2016.
- [11] G. T. Einevoll, C. Kayser, N. K. Logothetis und S. Panzeri, „Modelling and analysis of local field potentials for studying the function of cortical circuits“, *Nature Reviews Neuroscience*, Jg. 14, Nr. 11, S. 770–785, 2013.
- [12] W. Van Drongelen, *Signal processing for neuroscientists*. Academic press, 2018.