# משימות

1. לבדוק KMEANS 3 קבוצות ולא 2 - בוצע
2. לצייר 3D גרף של TSNE - בוצע
3. למצוא ערכים סטטיסטיים של ההפרדה של KMEANS ו – MODEL PRED – בוצע
4. להוסיף דאטה של ווקליזציות (כמות ווקליזציות) – לשים לב שיש 2 קבצים על 22 הרץ, אילו חולדות מופיע במאמר של TRACKUSF
5. להריץ את ההקלטות עם TRACKUSF ולחפש ווקליזציות עם תדר נמוך.
6. לחזור על ההשוואה בין BEST AND WORST בלי הספייקים ולראות אם יש שיפור. במידה ויש שיפור, להריץ שוב את המודל של WORST על ה- FREE כדי להראות שזה לא עובד.

# Date: 03/07/2053

In order to have finer clustering, I clustered the behavioral data using kmeans with n\_clusters=4

I used UMAP for dimensionality reduction, it performed better than TSNE.

|  |  |  |
| --- | --- | --- |
|  | model\_pred\_2 | |
| Kmean cluster | affiliative | aversive |
| 0 | 6 | 5 |
| 1 | 3 | 12 |
| 2 | 6 | 11 |
| 3 | 17 | 3 |

Removing cluster 0 from the dataset (11 samples) results in very high scores, but leaving it in and adding it to cluster 3 also yields good results:

|  |  |  |  |
| --- | --- | --- | --- |
| F1 | cappa | auc | desc |
| 0.821 | 0.713 | 0.850 | removed mixed cluster |
| 0.759 | 0.555 | 0.795 | added mixed cluster to affiliative |
| 0.727 | 0.583 | 0.799 | added mixed cluster to aversive |

Statistical significance of each feature - kmeans (mixed group added to averisive)

|  |  |  |  |
| --- | --- | --- | --- |
|  | variable | statistic | pvalue |
| 6 | Intervals\_5\_to\_20\_sec | 75 | 0.000 |
| 0 | Interactions\_Less\_Than\_6\_sec | 181 | 0.000 |
| 8 | Intervals\_All\_intervals | 193 | 0.000 |
| 5 | Intervals\_Less\_Than\_5\_sec | 220 | 0.002 |
| 2 | Interactions\_More\_Than\_19\_sec | 551.5 | 0.017 |
| 3 | Interactions\_More\_than\_6\_sec | 558 | 0.060 |
| 1 | Interactions\_6\_to\_19\_sec | 533.5 | 0.128 |
| 7 | Intervals\_More\_Than\_20\_sec | 486 | 0.395 |
| 4 | Interactions\_Total\_time | 459 | 0.674 |

Statistical significance of each feature - model prediction

|  |  |  |  |
| --- | --- | --- | --- |
|  | variable | statistic | pvalue |
| 4 | Interactions\_Total\_time | 257 | 0.001 |
| 6 | Intervals\_5\_to\_20\_sec | 306.5 | 0.009 |
| 2 | Interactions\_More\_Than\_19\_sec | 371 | 0.022 |
| 3 | Interactions\_More\_than\_6\_sec | 338 | 0.030 |
| 1 | Interactions\_6\_to\_19\_sec | 356.5 | 0.056 |
| 5 | Intervals\_Less\_Than\_5\_sec | 386.5 | 0.134 |
| 7 | Intervals\_More\_Than\_20\_sec | 597 | 0.152 |
| 0 | Interactions\_Less\_Than\_6\_sec | 401 | 0.194 |
| 8 | Intervals\_All\_intervals | 458 | 0.606 |

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# Date: 26/06/2023

A model was trained tested on “chamber” data and later evaluated on “free” data

The model was selected according it roc\_auc\_score. I have also experiments with other metrics such as kappa and f1, and found the roc\_auc\_score works best.

The behavioral data for free rat sessions was extracted. Then, kmeans clustering was used to split the dataset into two classes.

Also, TSNE was used for dimensionality reduction from 6 dimensions to 2.

The following figure shows side by side the labeling made by kmeans from the behavioral data and the labeling made by the classification model based on lfp and coherence brain activities:

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The model achieved the following scores:

|  |  |
| --- | --- |
| Metric | Score |
| F1 | 0.698 |
| Cappa | 0.4 |
| Auc | 0.735 |

Parameters:

['lfp\_EA\_30\_80Hz\_enc\_pre',

'lfp\_AA\_30\_80Hz\_enc\_pre',

'coherence\_CeA\_MeD\_30\_80Hz\_post\_pre',

'coherence\_AA\_MeD\_4\_12Hz\_enc\_pre',

'coherence\_CeA\_MeD\_4\_12Hz\_enc\_pre',

'coherence\_AA\_MeD\_30\_80Hz\_enc\_pre',

'coherence\_CeA\_MeD\_4\_12Hz\_post\_pre',

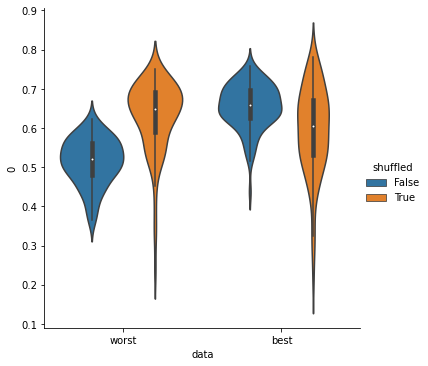
'coherence\_CeA\_STIA\_30\_80Hz\_enc\_pre']

# Date: 21/06/2023

Added model performance when training on top 5% p-value (p-value<=0.05) variables and worst 5% p-value (p value>=0.95)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Variable | Statistic | p-value |
| best | lfp\_EA\_30\_80Hz\_enc\_pre | 12 | 0.011655 |
| lfp\_AA\_30\_80Hz\_enc\_pre | 41 | 0.017954 |
| coherence\_CeA\_MeD\_30\_80Hz\_post\_pre | 61 | 0.018207 |
| coherence\_AA\_MeD\_4\_18Hz\_enc\_pre | 110 | 0.020729 |
| lfp\_AA\_4\_18Hz\_enc\_pre | 43 | 0.02327 |
| coherence\_CeA\_MeD\_4\_18Hz\_enc\_pre | 60 | 0.024456 |
| coherence\_AA\_MeD\_30\_80Hz\_enc\_pre | 108 | 0.028108 |
| lfp\_CeA\_30\_80Hz\_enc\_pre | 20 | 0.03142 |
| spike\_diff\_STIA\_enc\_pre | 66 | 0.044931 |
| worst | coherence\_BMA\_MePV\_30\_80Hz\_enc\_pre | 26 | 0.954645 |
| lfp\_EA\_4\_18Hz\_post\_pre | 41 | 0.965401 |
| coherence\_EA\_MeD\_4\_18Hz\_enc\_pre | 43 | 0.967849 |
| coherence\_EA\_MeD\_30\_80Hz\_enc\_pre | 43 | 0.967849 |
| lfp\_CeA\_30\_80Hz\_post\_pre | 49 | 0.969929 |
| lfp\_MePV\_4\_18Hz\_enc\_pre | 50 | 0.971018 |
| spike\_diff\_CeA\_post\_pre | 55 | 0.971654 |
| coherence\_MeD\_STIA\_4\_18Hz\_enc\_pre | 28 | 1 |

|  |  |  |
| --- | --- | --- |
|  | Data | Shuffled |
| Best | 0.65+-0.006 | 0.59+-0.011 |
| Worst | 0.51+-0.006 | 0.63+-0.009 |



# Date: 18/06/2023

Added multi-spike unit activity to the model,

Increased the number of iterations to 100

Ran the models for each sub-group of data type

Results when shuffling within each class:

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Results when shuffling manually before splitting (this seems like there is no shuffling at all):

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Results when using built-in shuffling but restricting that each rat would be only in one set:

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Correlations between variables:

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# Date: 14/06/2023

The model was expanded to include post-encounter data and single area local field potential (LFP) readings, in addition to coherence between regions. (Logical flow: The model is being enhanced by incorporating additional data sources.)

Measures to improve model reliability:

1. The dataset was shuffled before splitting, and this resulted in lower performance. (Remark: Shuffling the dataset before splitting may lead to data leakage between the training and test subsets.)
2. The dataset split was performed using the StratefiedGroupedKfold method, ensuring that the distribution of classes remains the same in the test and train subsets and there is no overlap between groups. (Logical flow: Proper splitting technique is employed to maintain data integrity and prevent leakage.)
3. Each model parameter was evaluated, and the best parameters were chosen. (Logical flow: Parameter tuning is conducted to optimize the model's performance.)
4. The performance of the best model-preprocessing combination was compared to a shuffled data baseline. (Logical flow: The model's performance is evaluated against a baseline to assess its effectiveness.)

Selection of best parameters and variables:

1. The top three (later changed to top 1) variables with the smallest p-values in the Mann-Whitney U test were selected, while variables with high p-values (above 0.1) were rejected. (Logical flow: Variables with significant contributions to the model prediction are chosen, while those unlikely to contribute are excluded.)
2. Models and preprocessing methods were tested using all combinations, and the process was repeated for 10 iterations. (Logical flow: Exhaustive testing of different model-preprocessing combinations is performed.)
3. The mean F1 score was summarized and the best score was extracted. If the best score improved the model, the corresponding variable was added. (Logical flow: The F1 score is used as an evaluation metric, and variables contributing to improved performance are selected.)
4. Steps 7 and 8 were repeated until all variables were either added or rejected. (Logical flow: The variable selection process is iterated until all variables are considered.)

Models and preprocessing algorithms tested:

1. Preprocessing: Three imputation methods (Iterative imputer, Missforest, KNN imputer) and two data scaling options (No scaling, Standard scaler) were tested. The chosen method was Iterative imputer, and Standard scaler was used for data scaling. (Logical flow: Multiple preprocessing methods were compared to select the most suitable ones.)
2. Data splitting: Different values for K-fold (3, 4, 5) were tested, and a K-fold value of 4 was chosen. (Logical flow: Different values for K-fold were explored to determine the optimal value.)
3. Model: Five classification models (Random Forest, Logistic Regression, SVM, Gaussian Naive Bayes, K-neighbors) were tested. The chosen model was Random Forest. (Logical flow: Different classification models were evaluated to select the best one.)

Chosen variables:

The following variables were selected based on the variable selection process:

* AA\_30\_80Hz\_enc\_pre (LFP)
* CeA\_MeD\_30\_80Hz\_post\_pre (Coherence)
* AA\_MeD\_4\_18Hz\_enc\_pre (Coherence)
* AA\_4\_12Hz\_enc\_pre (Coherence)
* MePV\_4\_12Hz\_post\_pre (LFP)

Performance results:

The top results yielded an F1 score of 0.74 ± 0.06 (MEAN ± STD Error), indicating the performance of the chosen model and variables. Additionally, the results of randomized data showed an F1 score of 0.54 ± 0.01 (MEAN ± STD Error). (Logical flow: The F1 score provides an estimate of the model's predictive accuracy, and the randomized data results serve as a comparison.)

The model's performance on real data is significantly better than random.

Effect size (Cohen's d): 3.46

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# Date: 30/05/2023

Methods:

### Experimental Design:

* Rats were subjected to sessions involving the investigation of a novel rat stimulus within a chamber.
* Sociability was determined by measuring the length of bouts exhibited by the subject rat during the investigation.
* Sessions were divided into two groups: affiliative (sessions with longer bouts) and aversive (sessions with shorter bouts).

### Selection of LFP Pairs:

* LFP recordings were obtained from various brain regions.
* A minimum of five sessions were required for each LFP pair in both the affiliative and aversive groups.
* Change in coherence between each pair was calculated by subtracting the mean coherence before interaction before stimulus insertion and the mean coherence during the interactions after stimulus insertion and before stimulus removal
* Mann-Whitney U tests were conducted to compare the coherence of each pair between the two groups.
* The following pairs were selected for analysis:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **area1** | **area2** | **stat** | **pval** | **freq** |
| CeA | MeD | 12 | 0.024456 | 4-12 |
| BMA | MePV | 36 | 0.327672 | 4-12 |
| MeD | STIA | 27 | 1 | 4-12 |
| AA | BMA | 7 | 0.177489 | 4-12 |
| AA | MeD | 30 | 0.020729 | 4-12 |
| EA | MeD | 45 | 0.967849 | 4-12 |
| BMA | MeD | 60 | 0.629796 | 4-12 |
| CeA | STIA | 17 | 0.370962 | 4-12 |
| CeA | MeD | 17 | 0.083064 | 30-80 |
| BMA | MePV | 28 | 0.954645 | 30-80 |
| MeD | STIA | 32 | 0.661172 | 30-80 |
| AA | BMA | 10 | 0.428571 | 30-80 |
| AA | MeD | 32 | 0.028108 | 30-80 |
| EA | MeD | 45 | 0.967849 | 30-80 |
| BMA | MeD | 54 | 0.945211 | 30-80 |
| CeA | STIA | 9 | 0.055278 | 30-80 |

### Data Filtering and Subset Selection:

* The significant area pair-frequency range combinations were identified as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **freq** | **area1** | **area2** | **stat** | **pval** |
| 4--12 | AA | MeD | 30 | 0.020729 |
| 4--12 | CeA | MeD | 12 | 0.024456 |
| 30-80 | AA | MeD | 32 | 0.028108 |

* The dataset was filtered to include only sessions that contained measurements from at least one of these area pairs.
* After filtering, a total of 31 sessions remained for further analysis.

### Train-Test Split:

* The 31 sessions were divided into two subsets: train and test, based on the following criteria:
* Sessions containing recordings from all three areas (CeA, AA, MeD) were selected for the test subset (n=11).
* Sessions with missing files were chosen for the training subset (n=20).
* To facilitate data imputation for missing values, all recordings from rat number 23 (with 2 sessions) and rat number 4 (with 3 sessions), which contained measurements from all areas, were moved from the test set to the training set.
* Additionally, recordings from rat number 19 (with 4 sessions, 1 aversive and 3 affiliative) were transferred from the training set to the test set to balance the distribution of classes in the test set.

To summarize:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **test** | | **train** | |
|  | **affiliative** | **aversive** | **affiliative** | **aversive** |
| **Rat number** |  |  |  |  |
| 3 | 0 | 0 | 2 | 2 |
| 4 | 0 | 0 | 1 | 2 |
| 10 | 0 | 4 | 0 | 0 |
| 12 | 0 | 1 | 0 | 0 |
| 15 | 0 | 0 | 1 | 2 |
| 16 | 0 | 0 | 1 | 2 |
| 17 | 0 | 0 | 0 | 3 |
| 19 | 3 | 1 | 0 | 0 |
| 20 | 1 | 0 | 0 | 0 |
| 21 | 0 | 0 | 1 | 0 |
| 23 | 0 | 0 | 1 | 1 |
| 26 | 0 | 0 | 2 | 0 |
| sum | 4 | 6 | 9 | 12 |

To impute missing data in both the training and test subsets, we employed the MissForest algorithm. MissForest is a machine learning algorithm specifically designed for imputing missing values in datasets. It utilizes a random forest approach to predict missing values based on the observed values and other variables in the dataset. The algorithm iteratively imputes missing values until convergence is achieved.

Remark: The MissForest algorithm was introduced by Stekhoven and Buehlmann in their paper titled "MissForest—Non-parametric missing value imputation for mixed-type data" (2012).

After imputing the missing data, we trained a random forest classifier using the imputed training set and evaluated its performance on the imputed test set. It is important to note that imputation was performed separately for each dataset (training and test) to prevent data leakage and maintain the integrity of the evaluation.

The following table presents the results obtained from the random forest classifier on both the training and test sets:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Accuracy** | **Precision** | **Recall** | **F1 Score** |
| Test | 0.8 | 0.667 | 1.0 | 0.8 |
| Train | 1 | 1 | 1 | 1 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **index** | **files** | **GT** | **predicted** | **correct** | **confidence** |
| 3 | chamber\_Rat10-probe13-day1\_Behavior\_and\_Optogenetics\_TimeStamps.mat | aversive | aversive | TRUE | 0.59 |
| 4 | chamber\_Rat10-probe13-day2\_Behavior\_and\_Optogenetics\_TimeStamps.mat | aversive | aversive | TRUE | 0.82 |
| 5 | chamber\_Rat10-probe13-day3\_Behavior\_and\_Optogenetics\_TimeStamps.mat | aversive | aversive | TRUE | 0.94 |
| 6 | chamber\_Rat10-probe13-day4\_Behavior\_and\_Optogenetics\_TimeStamps.mat | aversive | affiliative | FALSE | 0.64 |
| 7 | chamber\_Rat12-probe16-day2\_Behavior\_and\_Optogenetics\_TimeStamps -.mat | aversive | aversive | TRUE | 0.64 |
| 17 | chamber\_Rat19-Probe18-day1-Behavior\_and\_Optogenetics\_TimeStamps.mat | aversive | affiliative | FALSE | 0.68 |
| 18 | chamber\_Rat19-Probe18-day3-Behavior\_and\_Optogenetics\_TimeStamps.mat | affiliative | affiliative | TRUE | 0.83 |
| 19 | chamber\_Rat19-probe18-Day2-Behavior\_and\_Optogenetics\_TimeStamps.mat | affiliative | affiliative | TRUE | 0.81 |
| 20 | chamber\_Rat19-probe18-day6-Behavior\_and\_Optogenetics\_TimeStamps.mat | affiliative | affiliative | TRUE | 0.81 |
| 21 | chamber\_Rat20-Probe19-day1-Behavior\_and\_Optogenetics\_TimeStamps.mat | affiliative | affiliative | TRUE | 0.81 |

## Figures:

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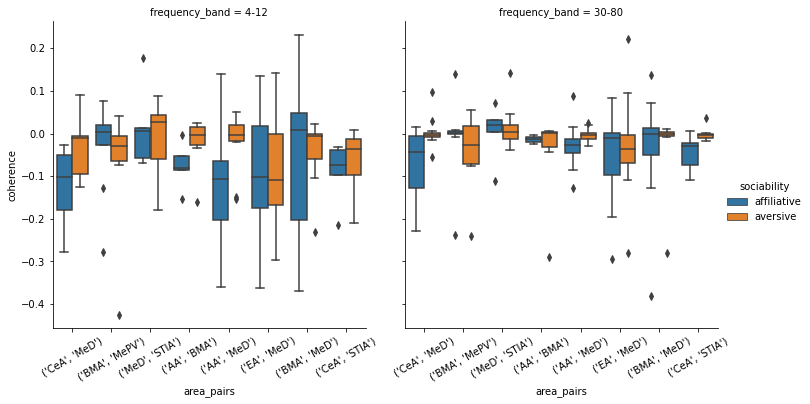


Figure 1. Coherence in LFP changes before and during stimulus insertion between pairs of brain regions.

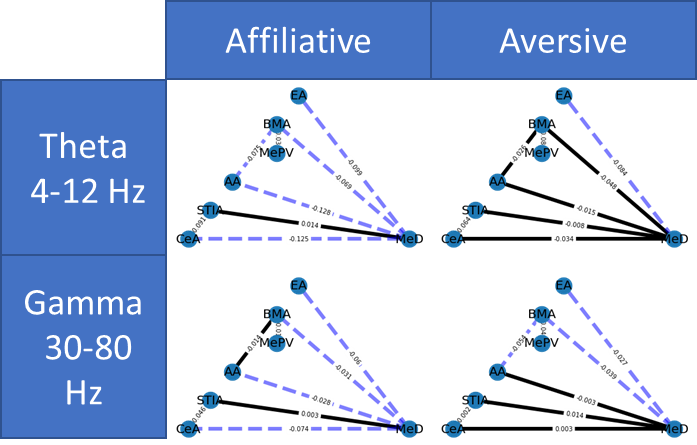


Figure 2. Network graph of the coherence between each pair of regions, dashed lines indicate lower values than the median, and solid lines indicate higher than or equal to the median coherence.

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Figure 3. Visualization of parameters of the training dataset before (nan values removed) (top) and after (middle) imputation using miss forest algorithm and after dimensionality reduction of the imputed dataset using tsne algorithm (bottom).