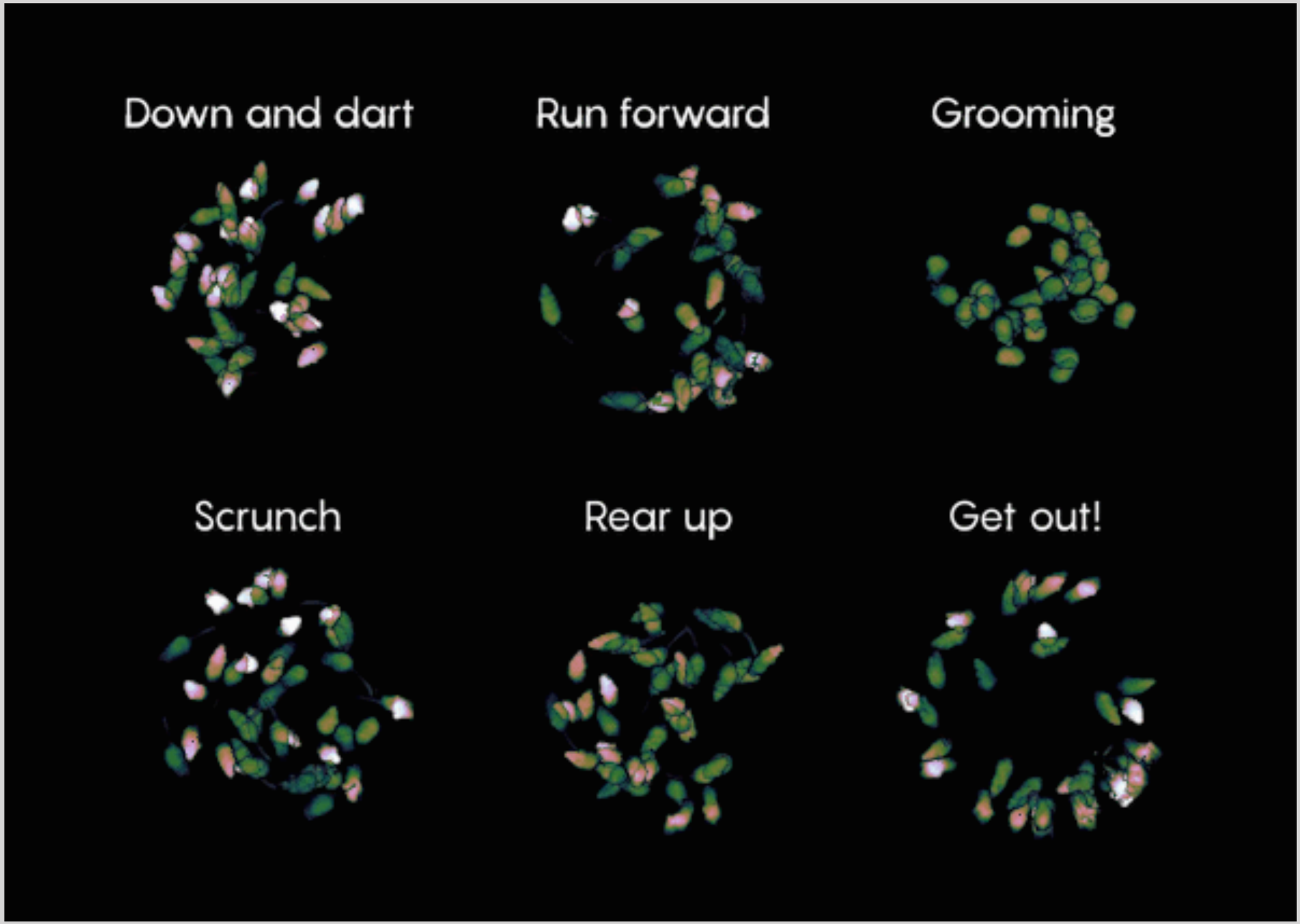
How does the brain create behavior? Are there “grammatical“ patterns in behavior?
Behavioral units as syllabus of behavior?

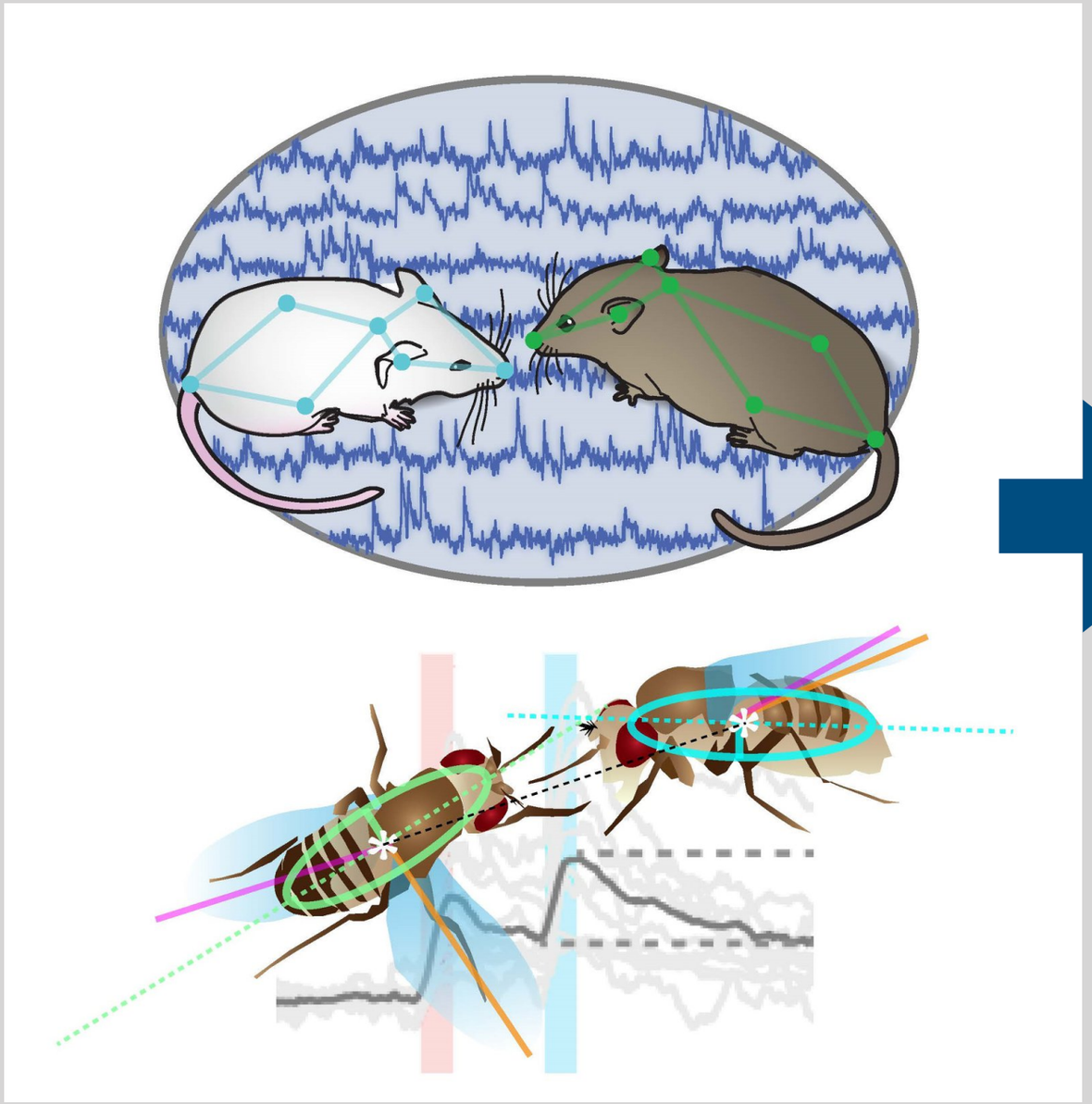


https://www.quantamagazine.org/to-decode-the-brain-scientists-automate-the-study-of-behavior-20191210/

How Does the Brain Create Behavior?

"The ultimate goal is to understand how the brain creates behaviour. To my knowledge, nobody has ever tried to model the full 3D pose of the mouse as it evolves over time. Because how your pose changes over time, that is behavior." (Alex Wiltschko, Neurobiology, Harvard Medical School, 2016)

How Can We Objectify Behaviour Without Relying on Human Intuition?



Pose tracking through dividing into body-parts

https://neuroscience.caltech.edu/programs/workshops/chen-institute-workshop-measurement-and-analysis-behavior

Caltech Multi-agent dataset

Jennifer J. Sun, Tomomi Karigo, David J. Anderson, Pietro Perona, Yisong Yue, & Ann Kennedy. (2021). Caltech Mouse Social Interactions (CalMS21) Dataset (1.0) [Data set]. CaltechDATA. https://doi.org/10.22002/D1.1991

trajectory data of freely behaving mice in a standard resident-intruder assay

6 million frames of unlabeled tracked poses of interacting mice, 1 million frames with tracked poses and corresponding frame-level behavior annotations

CalTech Multi-agent Dataset: What are the Labels and Annotations?

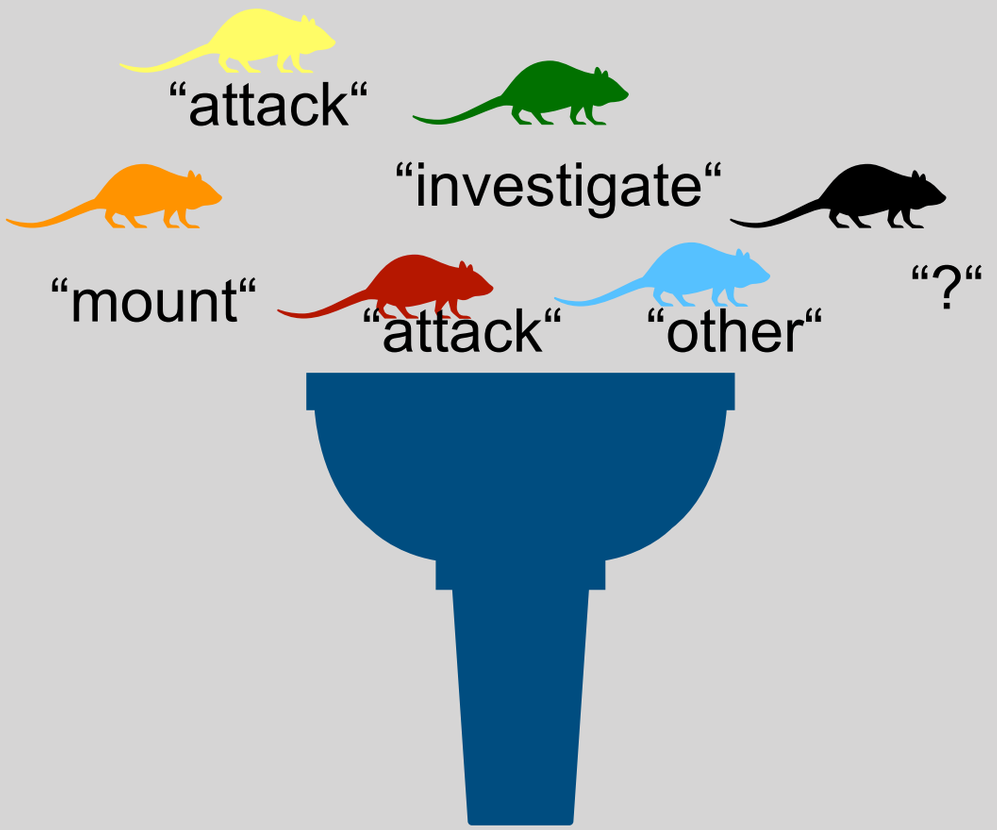
Labels:

- 0 attack
- 1 investigation
- 2 mount
- 3 other

Variables:

- nose, left_ear, right_ear, neck, left_hip, right_hip, tail_base

The "annotation bottleneck problem“ in Neurobiology



Manual annotation to slow, time consuming and brings variability in interpretation

CalTech Multi-agent Dataset: Simplifying the Data

- TrainData: 70 Sequences, 507738 frames
- Test Data: 19 Sequences, 262107 frames

- Converting train and test data into dataframe to check distribution

```
train
label
0      14039
1     146615
2      28615
3     318469
Name: label, dtype:
int64
```

```
test
label
0      12630
1      61275
2      31848
3     156354
Name: label, dtype:
int64
```


Examining Label Distribution and Imbalance in the Dataset Classification

- Imbalanced classification problem, as shown by label distribution in training and test sets

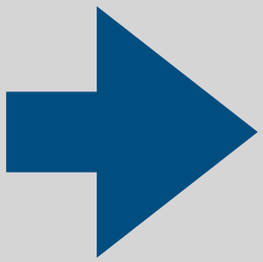
Labels distribution in the training set:

0: 14039

1: 146615

2: 28615

3: 318469



Attack is minority class

Labels distribution in the test set:

0: 12630

1: 61275

2: 31848

3: 156354

Binary Classification for Attack

- Added a binary classification column for attack ('attack') based on the original labels.

- In the training set: {0 (No attack): 493699, 1 (Attack): 14039}

- In the test set: {0 (No attack): 249477, 1 (Attack): 12630}

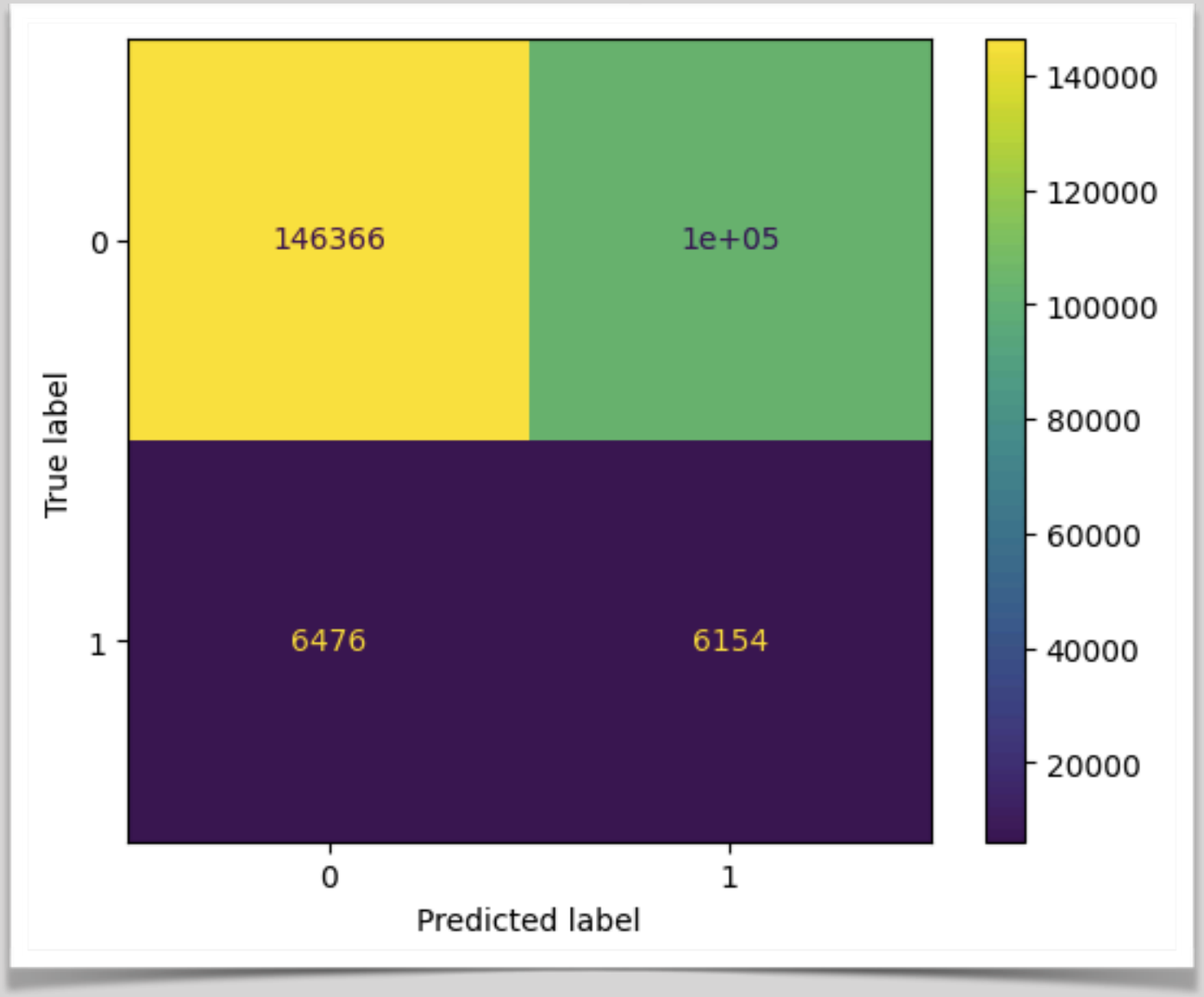
Exploring the Correlation Between Body Parts and Behaviors

- Data shows correlation between body part and behavior
- High correlation between nose, ears, neck and little less for tail
- Reduce features per mouse to nose and tail

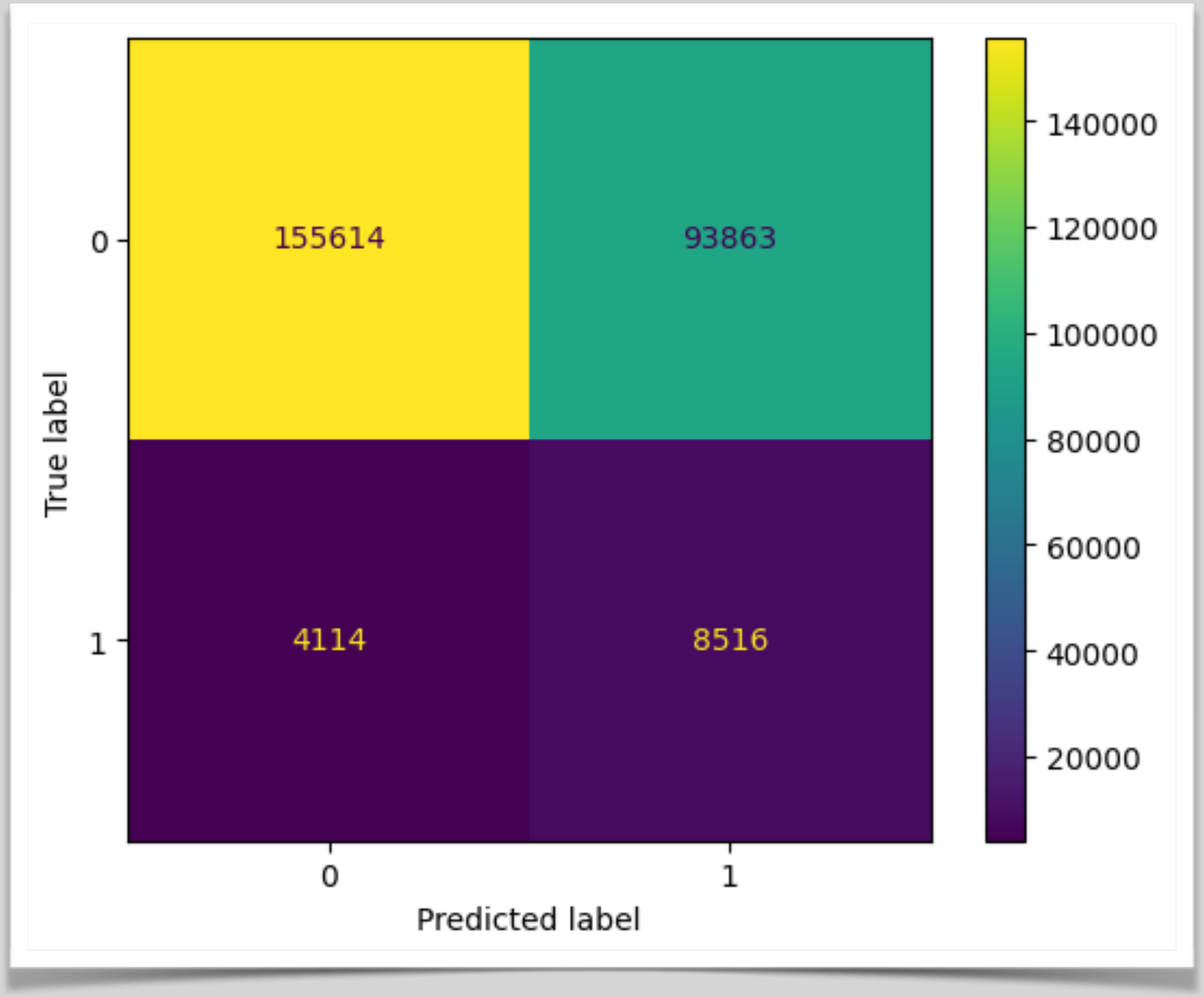
- Can ML classifying help in annotating the frames?

Can ML classifying help associate each frame of a sequence with a specific label or category that describes the behavior exhibited by the mice in that frame?

Logistic Regression



Random Forest



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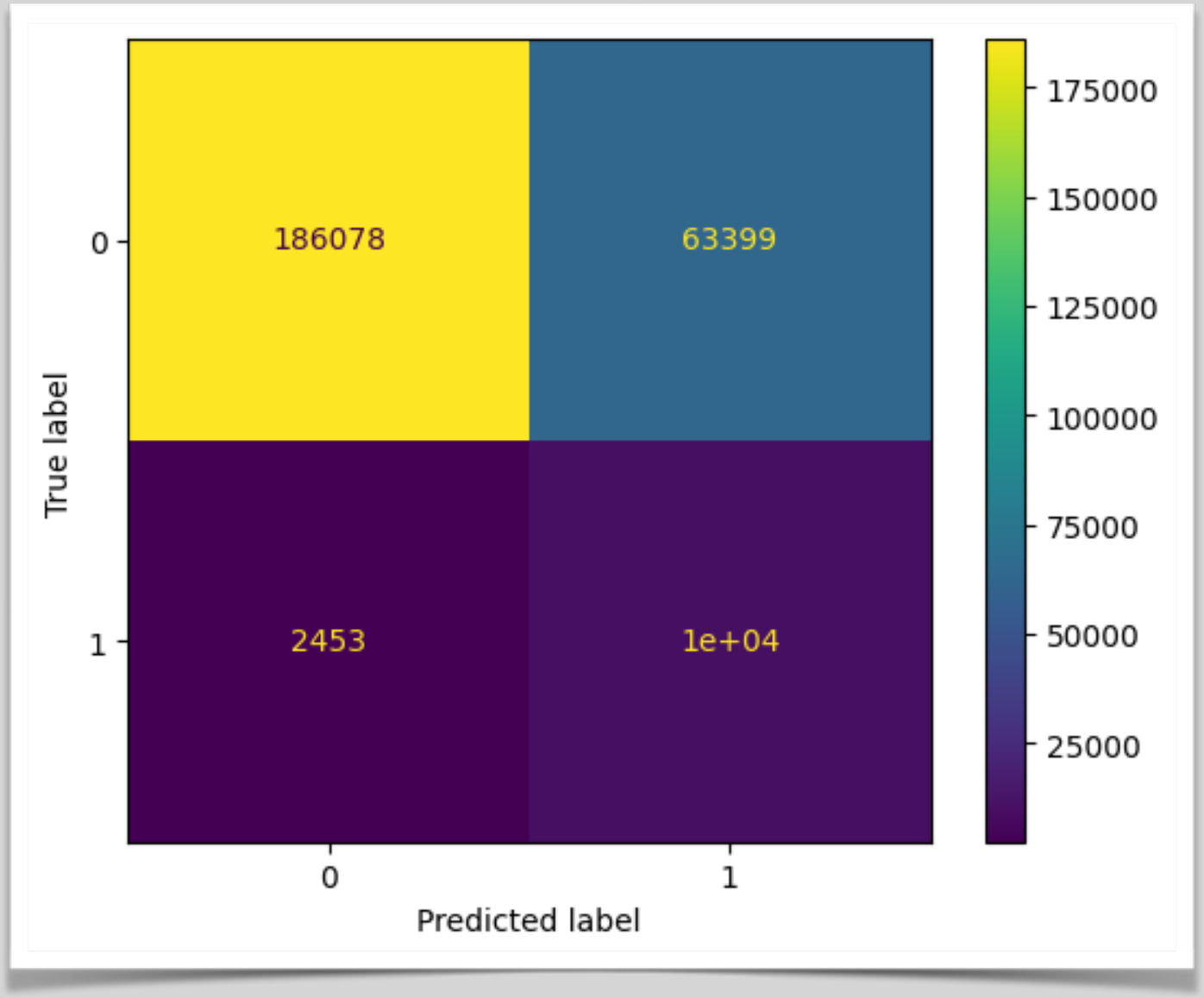
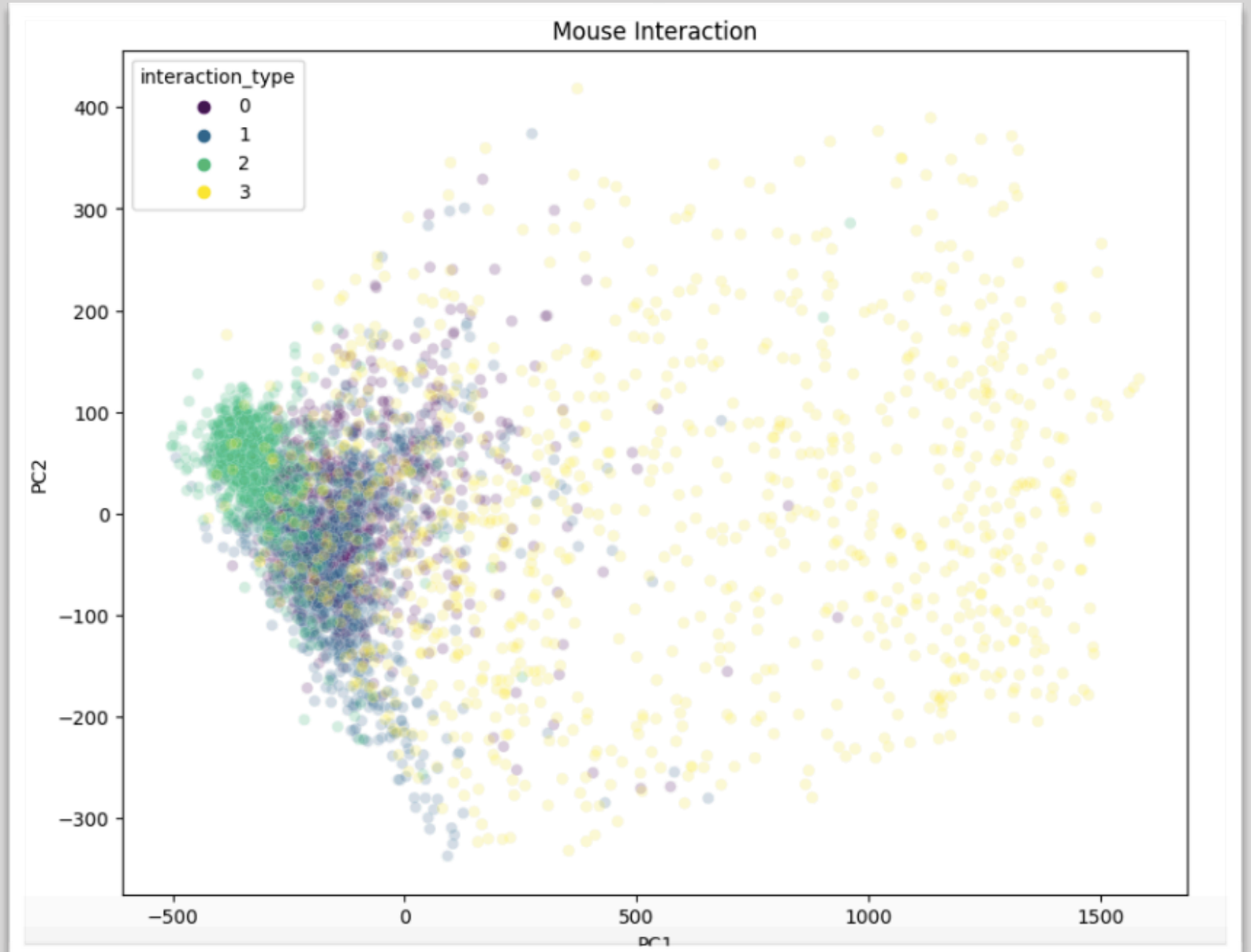
Hist Gradient Boosting



	Method	DataSet	AUC	F1_w	F1_0	F1_1
0	dummy	Mouse_simple	0.500000	0.928315	0.975312	0.000000
1	lf	Mouse_simple	0.536972	0.697416	0.727612	0.100972
2	rf	Mouse_simple	0.649014	0.731054	0.760567	0.148093
3	hgb	Mouse_simple	0.775826	0.820091	0.849656	0.236109
4	hgb_grid	Mouse_simple	0.751970	0.855761	0.886247	0.253588
5	rf_grid	Mouse_simple	0.742753	0.792370	0.822086	0.205399

Several Maschine learning methods can detect a correlation

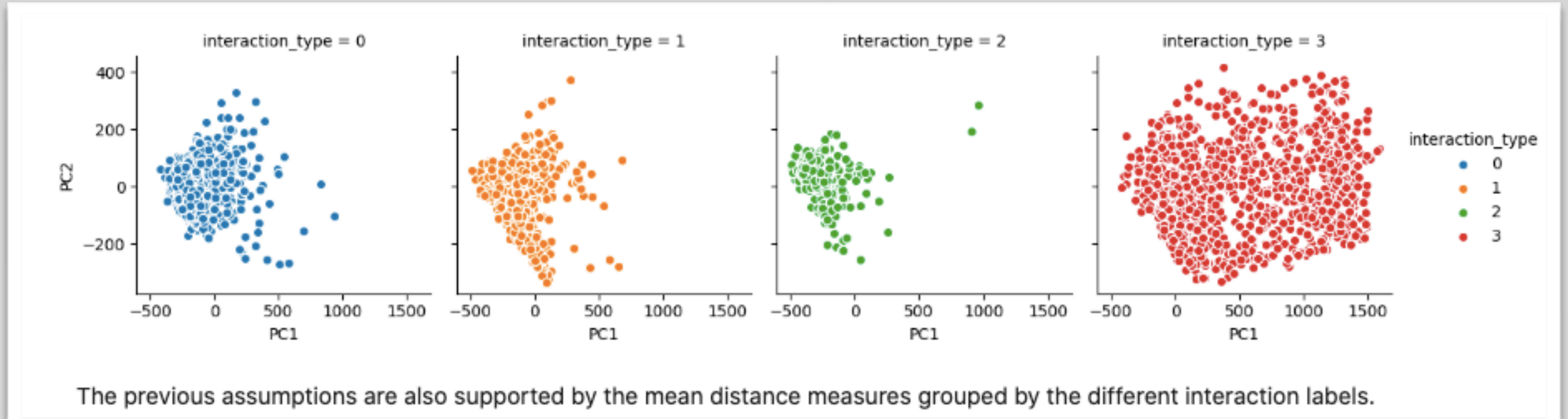
PCA Visualization



©Adam

Interaction types "mount" and "other" exhibit distinct clusters, while "attack" shows less separation

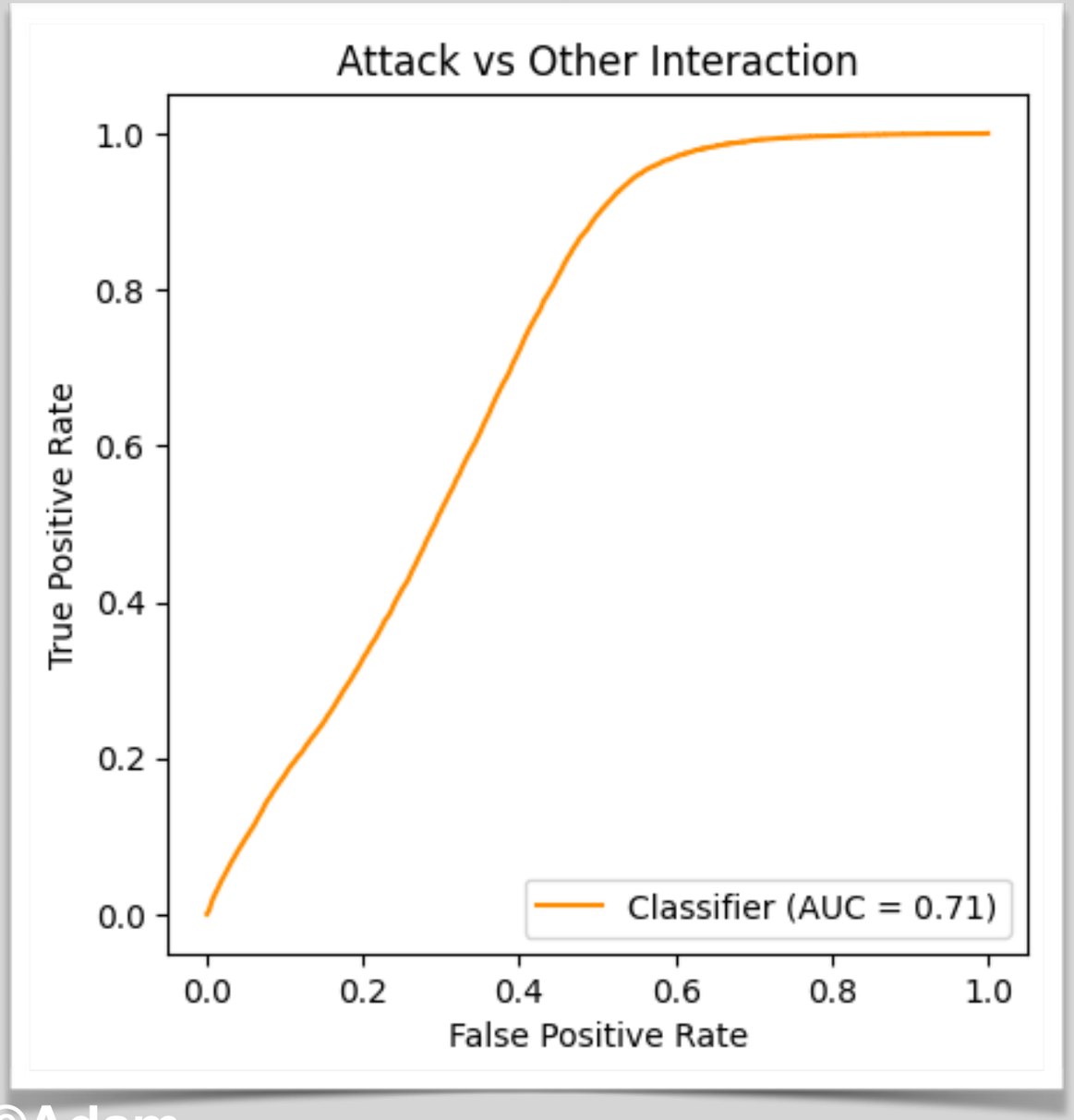
Mean Distances Measure

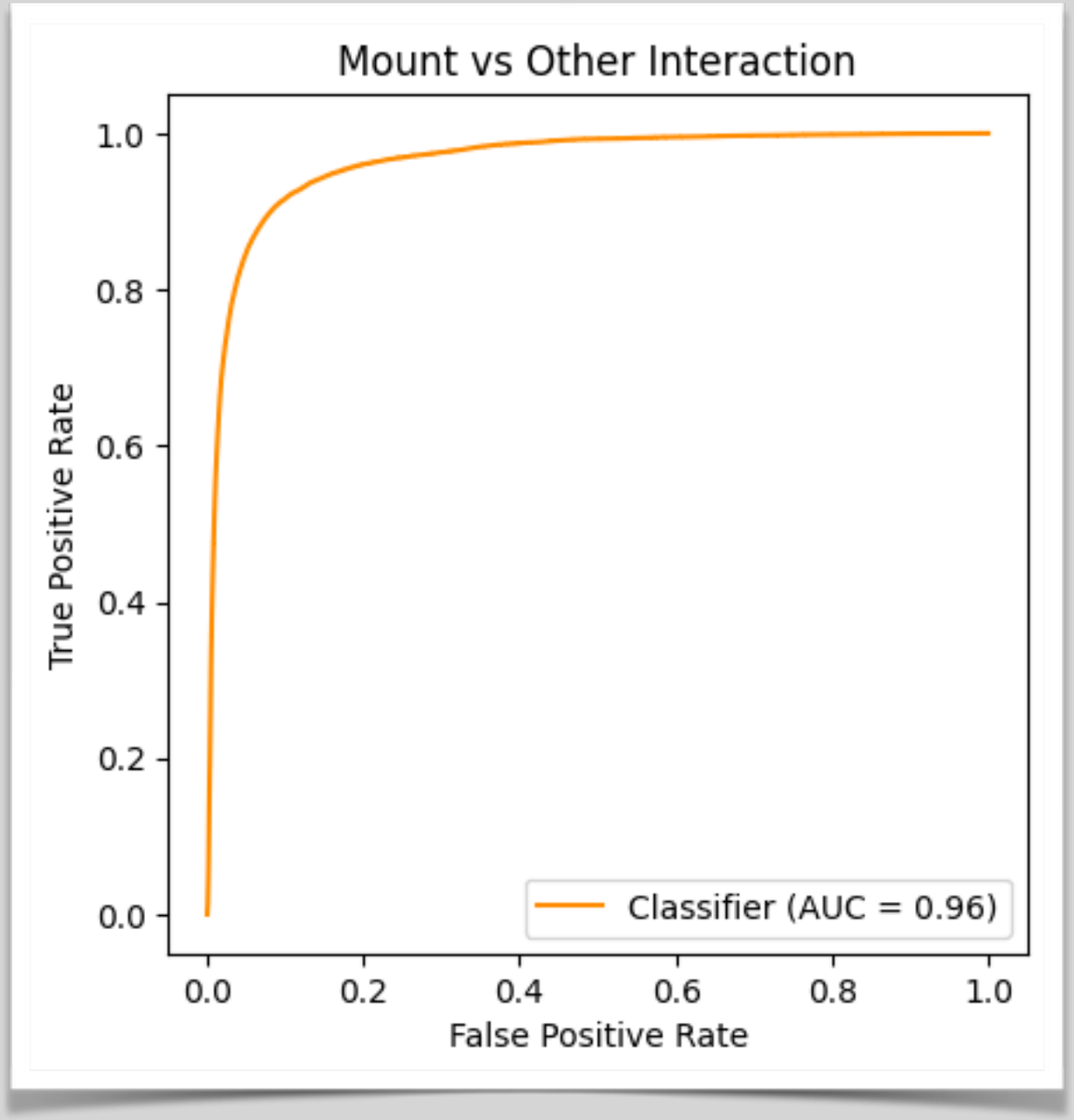


The previous assumptions are also supported by the mean distance measures grouped by the different interaction labels.

"Attack" instances have higher average distances compared to "mount" and "other."

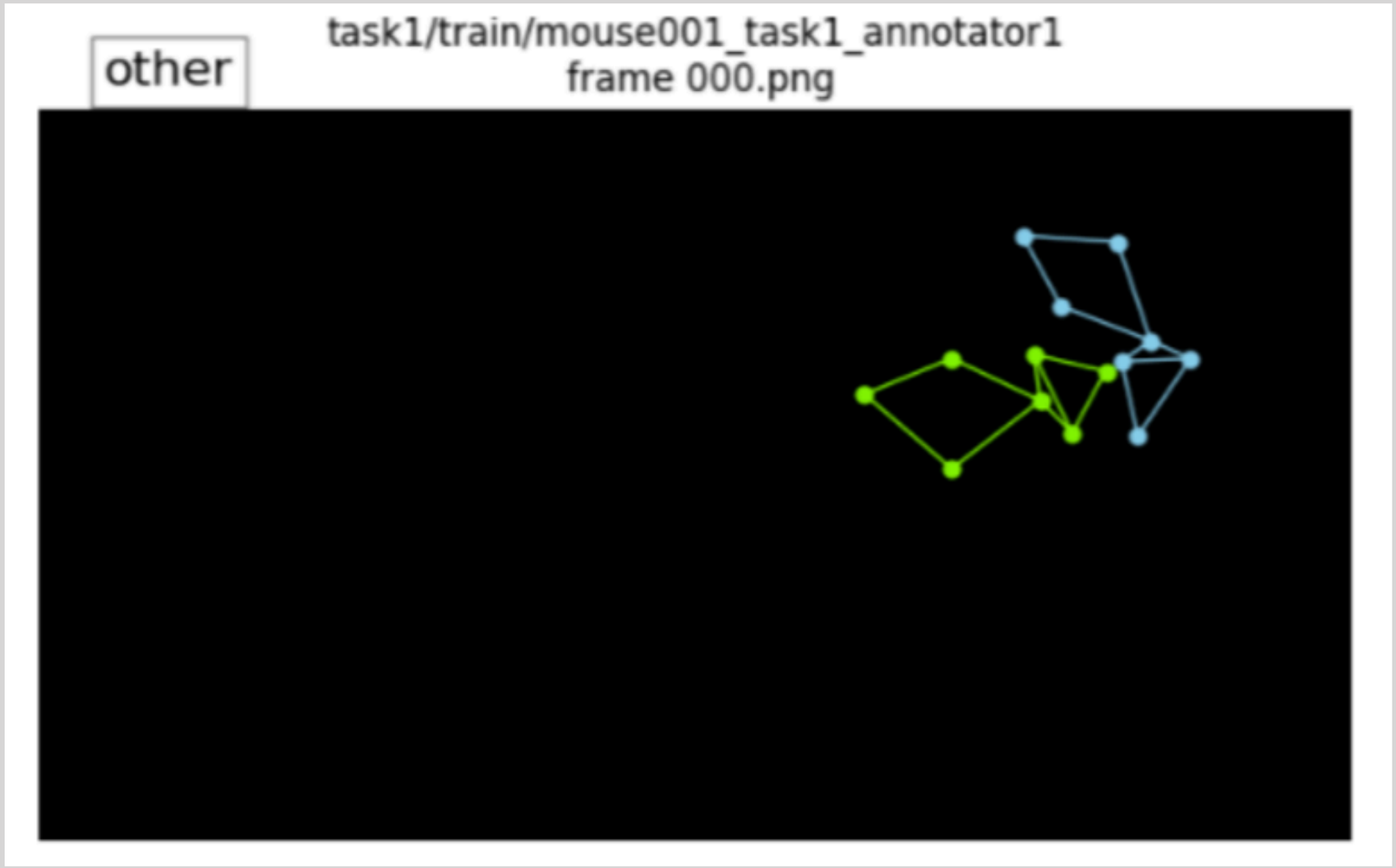
Prediction





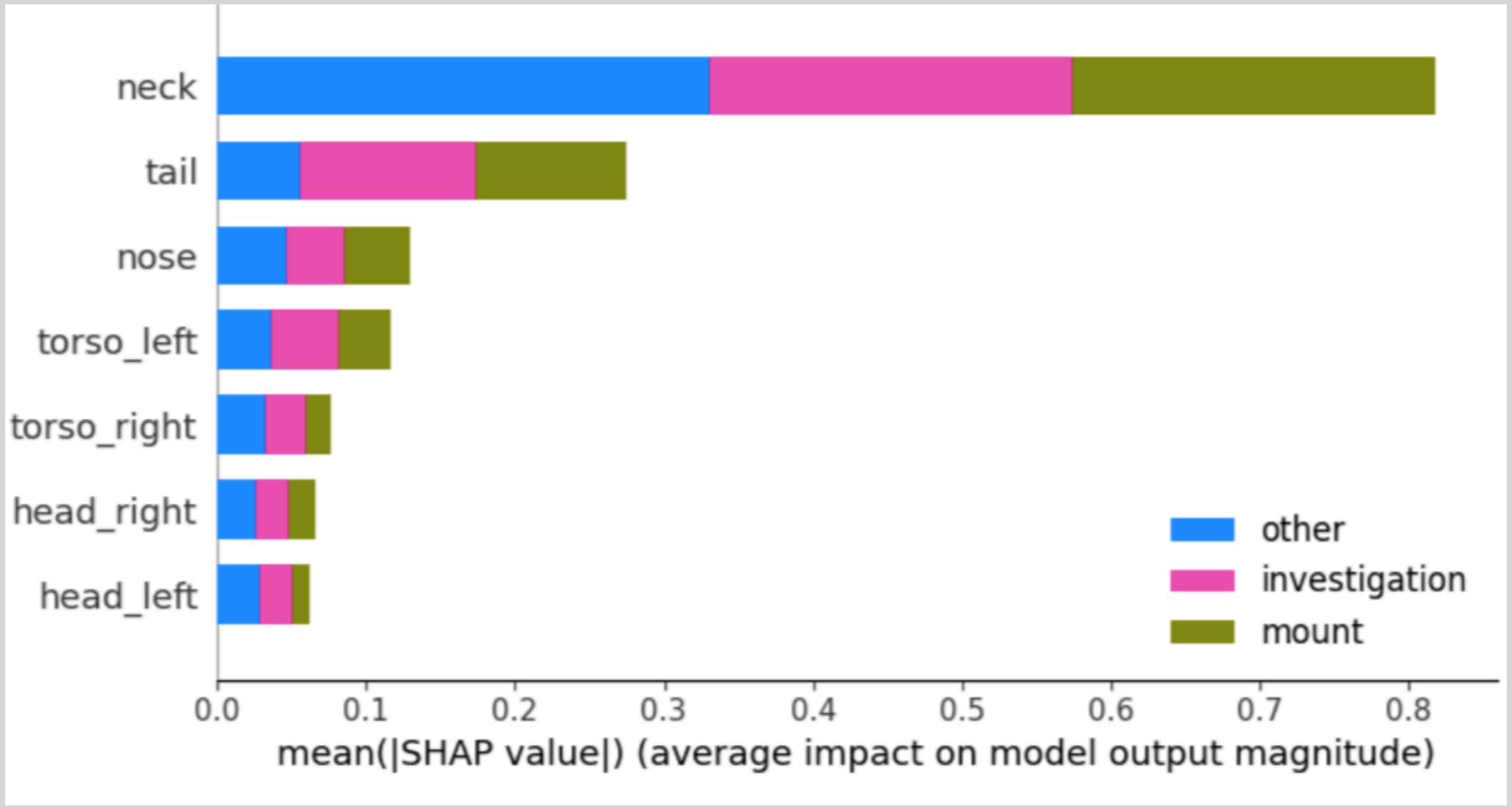
The logistic regression model performs better than random chance for "attack", better performance for the "mount" label

Visualization of the Animals' Movements



©Manu

SHAP Values for Feature Contributions and Relations



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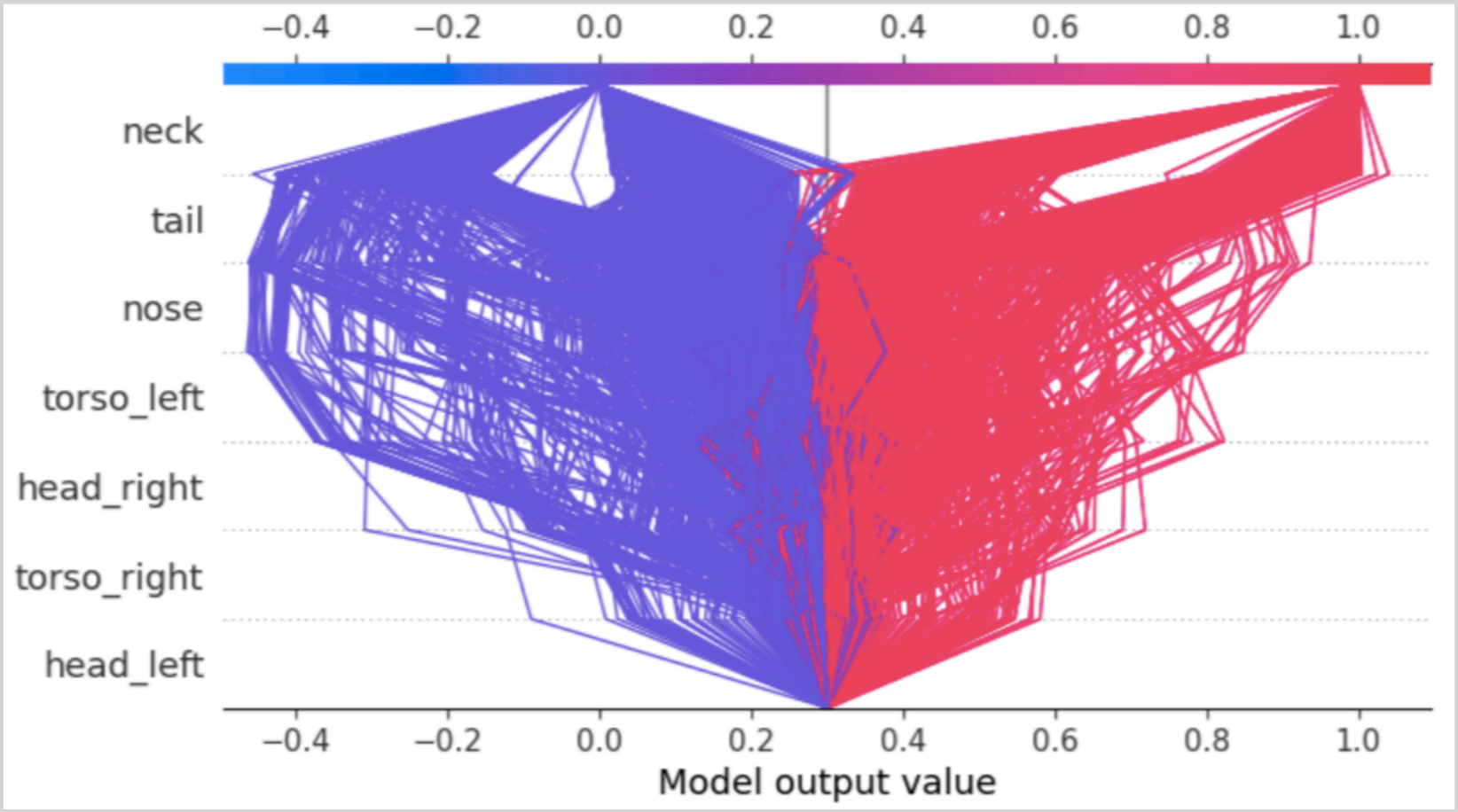
neck has a high contribution in determining behavior of "investigation" and "mount"

Visualizing Summed SHAP Values for Weighted Contributions of Features Through Decision Plots



©Manuel

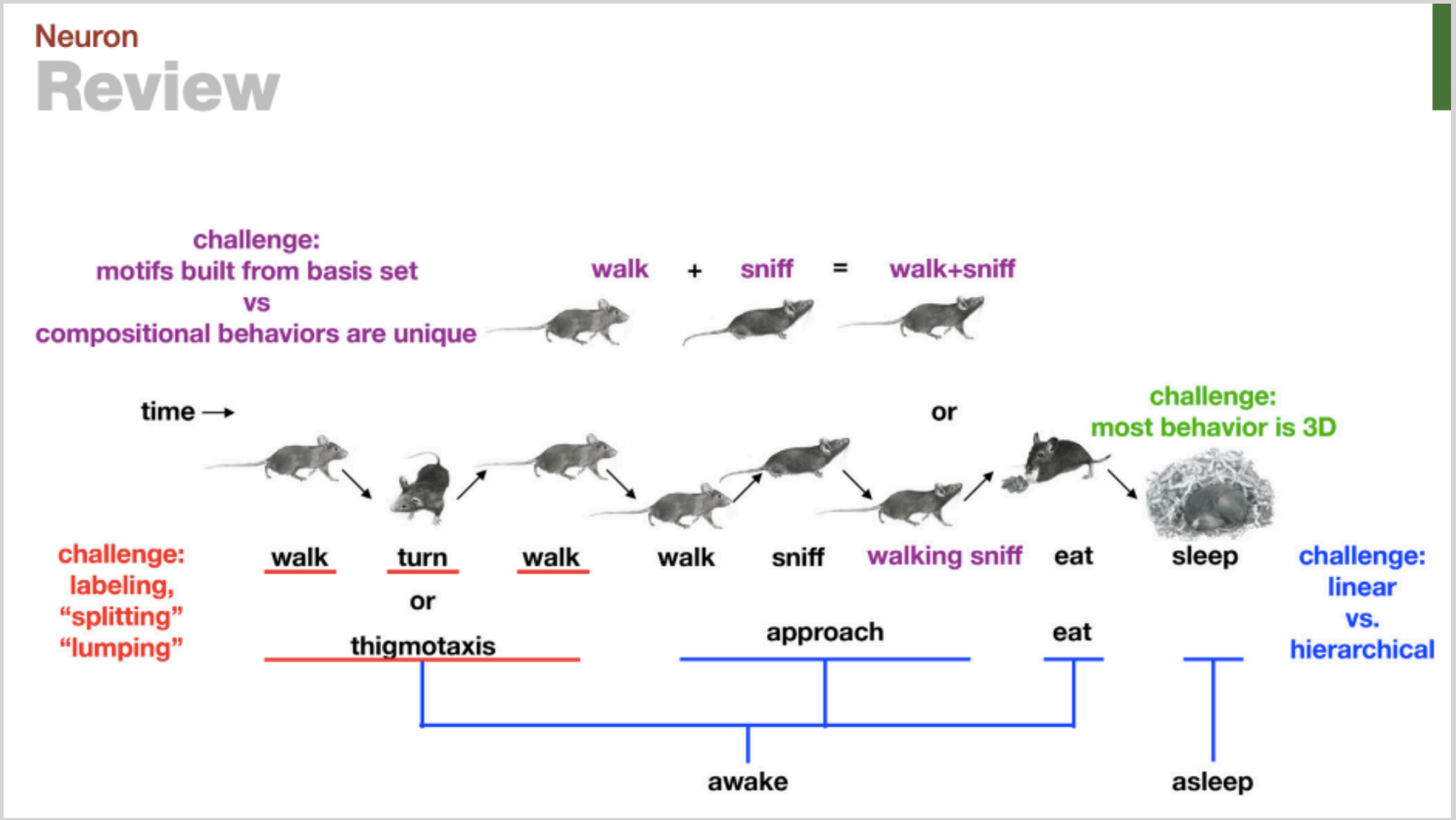
Average Distribution in Training Set

	Behavior	Percentage Frames
0	attack	2.765009
1	investigation	28.876113
2	mount	5.635781
3	other	62.723097

©Manuel

"investigation" is the most frequently observed behavior, "other" a substantial portion of frames, "mount" occurs moderately, and "attack" is the least common among the observed subjects.

Because pose-tracking software has simplified data collection, “now we can think about other problems,” said Benjamin de Bivort, a behavioral biologist at Harvard University. Starting with: How do we define the building blocks of behavior, and how do we interpret them?



Datta, S. R., Anderson, D. J., Branson, K., Perona, P., & Leifer, A. (2019). Computational neuroethology: a call to action. Neuron, 104(1), 11-24.

Glossary

- Preprocessing: clean, organize, and transform the data into a format that is more suitable for further analysis or model training
- Plot( ): function draws a line from one point to another, takes parameters for specifying points in a diagram, parameter 1 array containing points on x-axis and parameter 2 is an array containing points on y axisCross-Validation
- Trajectory Data: course of a variable over time
- ROC-Curve: to compare true-positive and true-negative rates
- Minority class: underrepresented label, in ML oversampling might be necessary
- Prinzipal Component Analysis (PCA): A technique for dimensionality reduction that identifies the principal components capturing the most variance in the data.
- Cross - Validation: A resampling technique to assess model performance by partitioning the data into training and testing subsets.
- Logistic Regression: A regression model for binary classification that estimates the probability of an instance belonging to a particular class.
- Mean Distance Measures: Average distances between specific points or locations, providing a summary measure of spatial relationships.
- Threshold: A value used to convert continuous model predictions into binary classifications.