Quantitative Mouse Engagement Metrics

This document is a summary of analyses on quantitative tools for tracking mouse engagement. The basic analysis considered here is a flash-by-flash rolling reward rate and rolling lick-bout rate. Plotting the distribution of these rates over the entire dataset we quickly see the emergence of a distinct non-engaged state, where the the lick-bout and reward rates are close to 0, and a broad ridge of engaged states that vary in the reward and licking rates. A hard threshold can isolate periods of non-engagement, and the ridge of engaged activity can be continuously tracked using the model free hit-fraction measure, or the behavioral model weights.

Image by Image metrics

I've previously described the development of image by image metrics of mouse behavior. Here, we will use those metrics to develop an engagement metric. Specifically we will use the lick-bout rate and reward rate. These rates are computing on a rolling 320s triangular filter. Licks were segmented into bouts by thresholding inter-lick intervals at 700ms.

By plotting a sample of these rates over the dataset we see that there is a clear division of a non-engaged state and a broad engaged state (Figure 2). In the non-engagement state, both the lick-bout and reward rates are very close to zero. The mouse isn't licking, and is therefore earning no rewards. In the engaged state we see a broad ridge of varying licking rates, and varying reward rates. Previous attempts to use trial wise measures like d' broadly agree with these finer scale measures. We don't see much justification for splitting the engaged ridge into high and low engagement levels, but you can do this if needed (Figure 2, right).

A better way to quantify the mouse's location on the engaged ridge is to use either the behavioral model weights, or the "lick hit-fraction" metric which is defined as the fraction of licking bouts that result in a reward. These metrics nicely tile the engaged state.

Recommendations and Summary

- Mouse behavior is characterized by a non-engaged state, and a broad ridge of engagement with varying performance.
- Thresholding out the non-engaged state is justified and easy
- Quantitative metrics for the engaged state are the lick hit-fraction and behavior model weights.
- These metrics are now included in the visual behavior analysis repo.

  `visual_behavior_analysis/visual_behavior/data_access/loading.py`

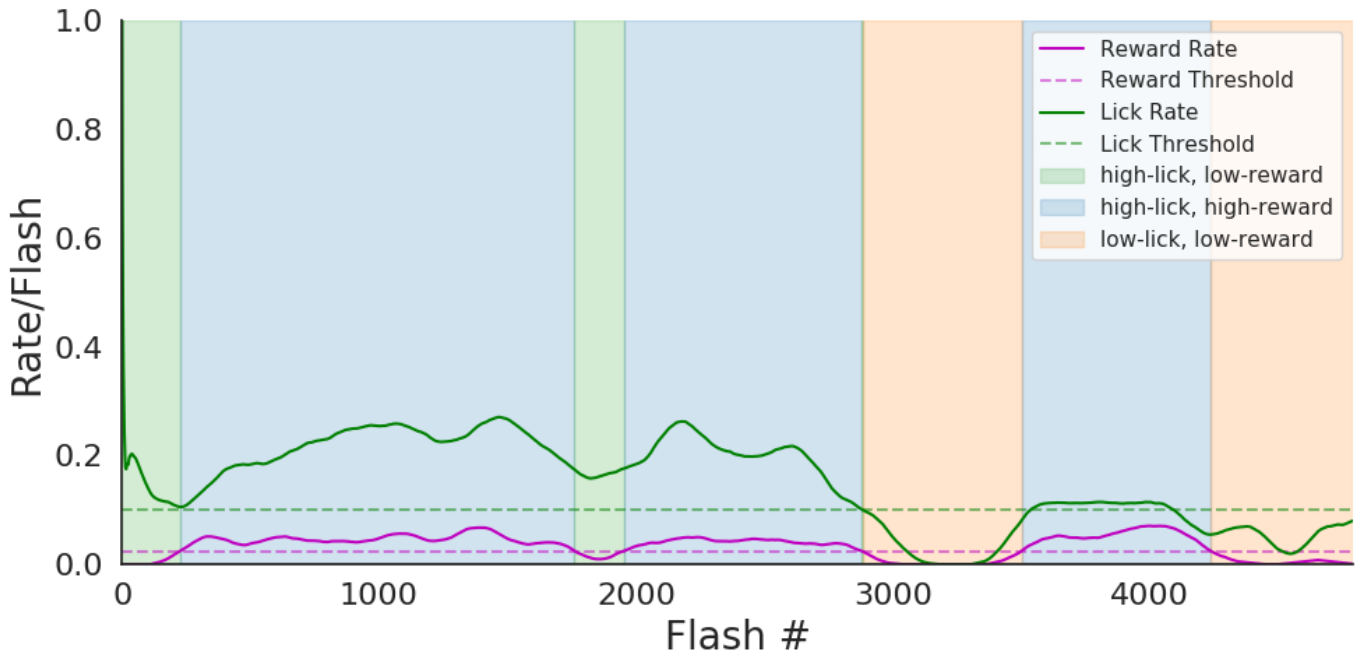

Figure 1: Example lick-bout and reward rate, and thresholding behavior into three classification states.

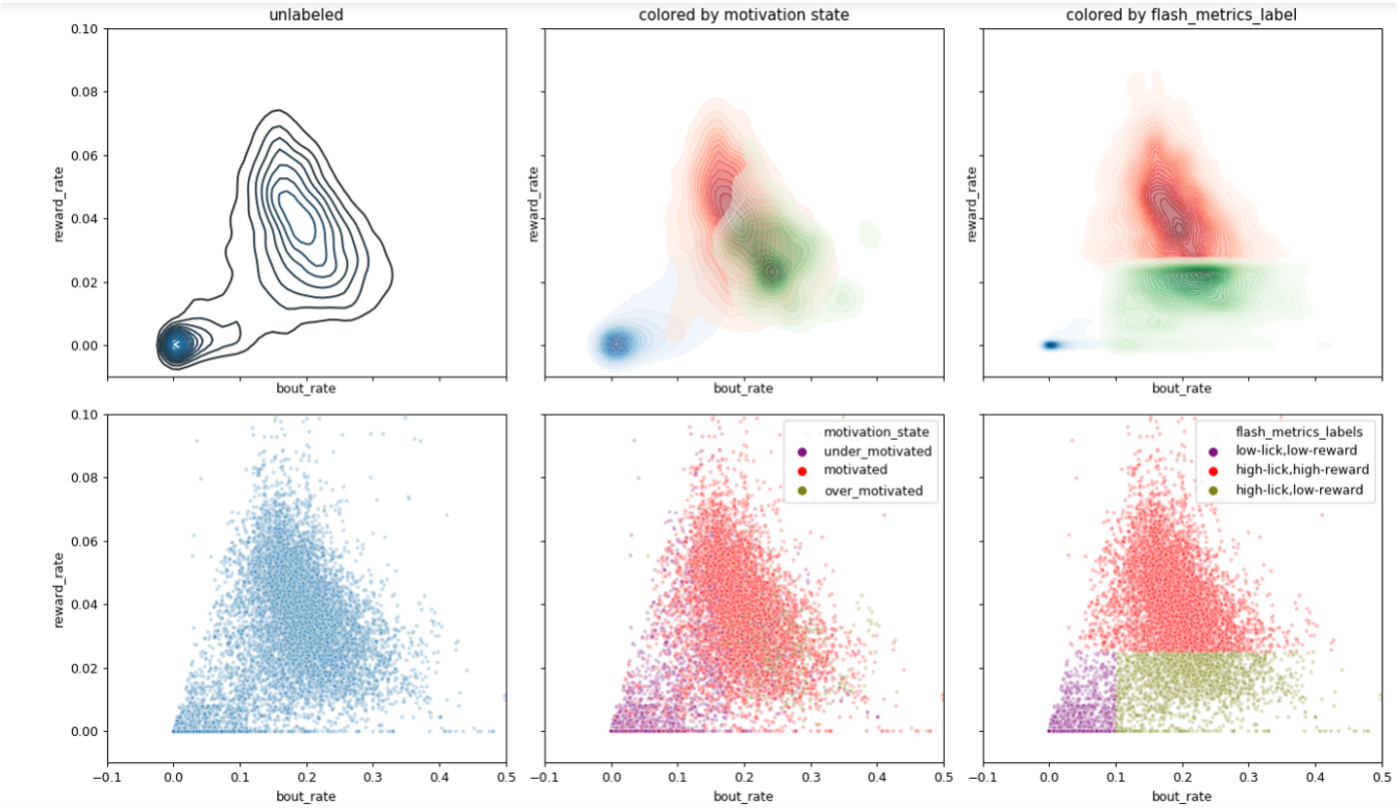

Figure 2: Distribution of lick-bout rate and reward rate over the dataset. **(Left)** Image by image lick-bout and reward rate were sampled across the dataset and are shown as either a distribution (Top) or scatter plot (Bottom). **(Middle)** Same data colored by trial-based d' measure. **(Right)** Same data colored by thresholding the image by image rates.

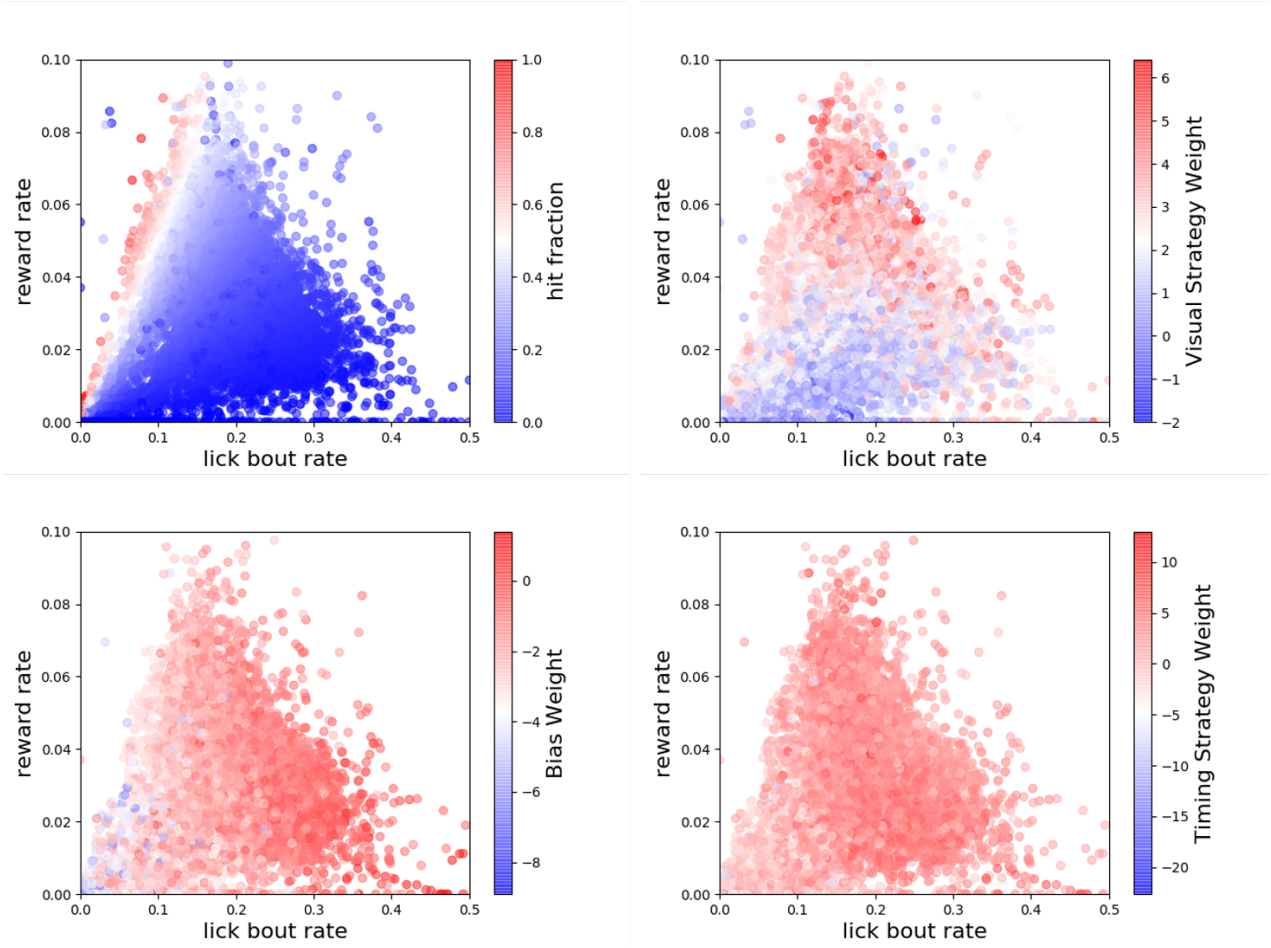

Figure 3: Lick-bout and reward rate scatter plot colored by various metrics. **(Top Left)** Lick hit fraction. **(Top Right)** Behavior model visual strategy weight. **(Bottom Left)** Behavior model bias weight. **(Bottom Right)** Behavior model timing strategy weight.