The Neural Basis of Decision Making – Part A

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Question 1 – a

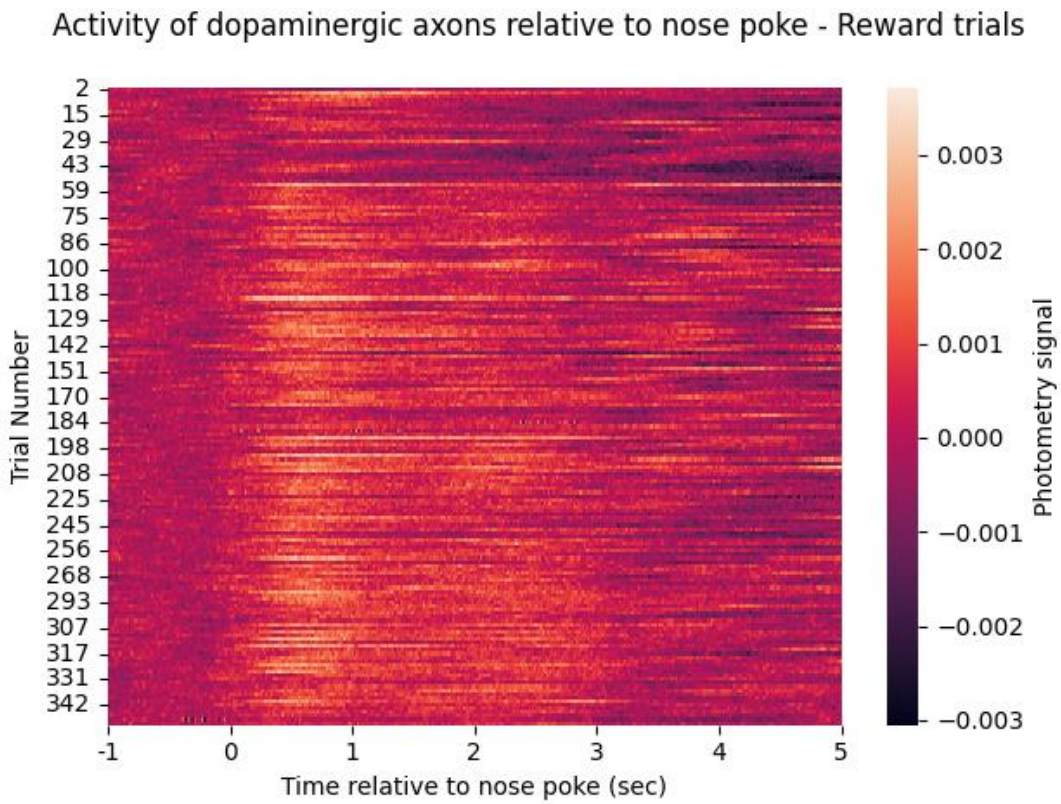


Figure 1: Activity of dopaminergic axons in *reward* trials, relative to nose poke timing. Here we can see a representation of all reward trials (y axis) and the neurons' time dependent response, measured by photometric signal (x axis). We can see a "column" of brighter colors around the time of the poke (0 sec) indicating *increased* activity post the nose poke of the mouse.

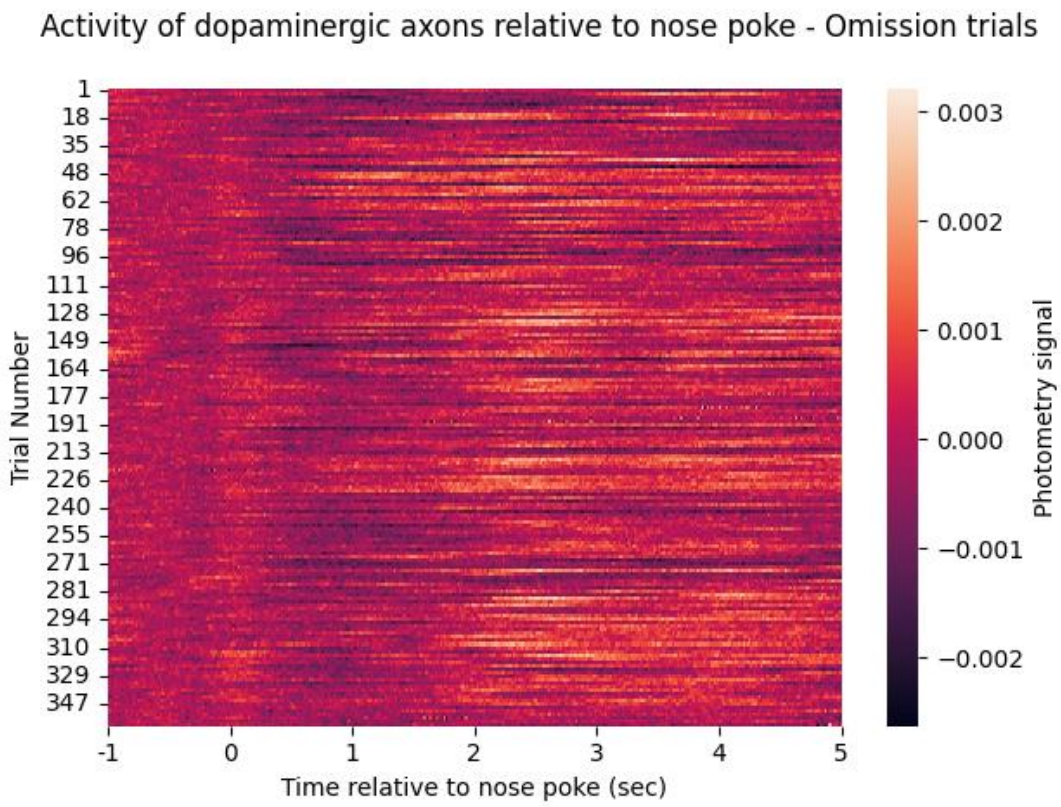


Figure 2: Activity of dopaminergic axons in *omission* trials, relative to nose poke timing. This heatmap represents all omission trials on the y axis and the corresponding neural response on the x axis. Much alike the previous graph, we can see a "column" of color near the time of the mouse nose poke. However, unlike the previous graph, this column is dark, indicating *decreased* activity following the nose poke.

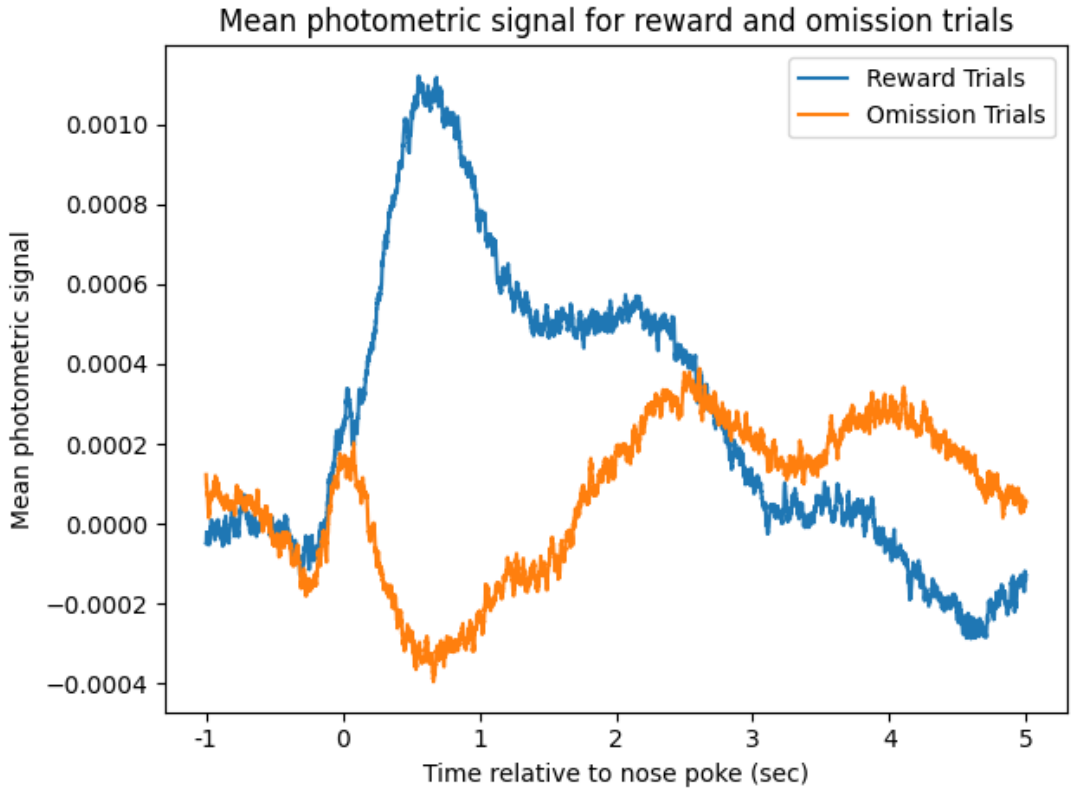


Figure 3: Mean dopamine response traces for reward and omission graph. On this graph we can see the mean dopaminergic response, averaged across all trials. We can see that the mean responses follow the same trend of the heatmaps, where dopaminergic response (measured by photometric signal) increases after the nose poke for reward trials and decreases for omission trials.

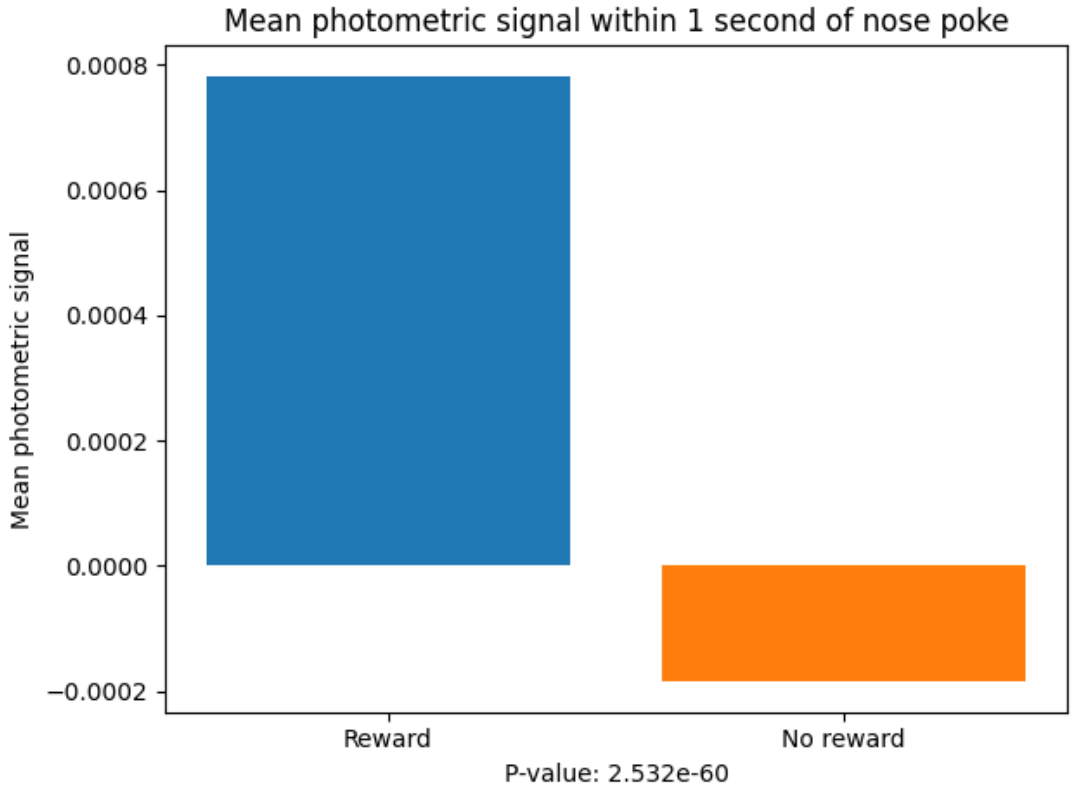


Figure 4: Mean photometric signal within 1 second of nose poke. This bar plot shows the average signal in the 1-second window after the mouse nose poke, for reward and omission trials. To make this plot, the time-course signal for each trial was averaged, resulting in a single value for each trial. Then, these values were used in a t-test to calculate the p-value between the reward and omission trials. Finally, trial averages were combined to get one overall value for reward trials and one for omission trials, which are displayed in the graph above.

As can be seen, the signal increase and decrease following the nose poke, for the reward and omission trials, respectively is also statistically significant.

Question 1 – b

Reward prediction error (RPE) of dopamine theory hypothesize that dopaminergic neurons encode the *expectation* of reward. For this reason, the mouse needs to *expect* reward for increased photometric signal and to *expect* reward and get none for decreased signal. In order to align with our results, it means that following the nose poke, the mouse indeed expected reward for rewarded trials and expected reward but got none for omission trials. The size of the effects (as in the absolute value of the signal change) would suggest that the mouse's expectation of reward during rewarded trials was larger than its expectations for reward during omission trials. Assuming the mouse managed to get the hang of the probability of reward in respect to the port side, and managed to track the change between the probabilities and sides these results fairly align with the RPE theory.

Question 2 – a1

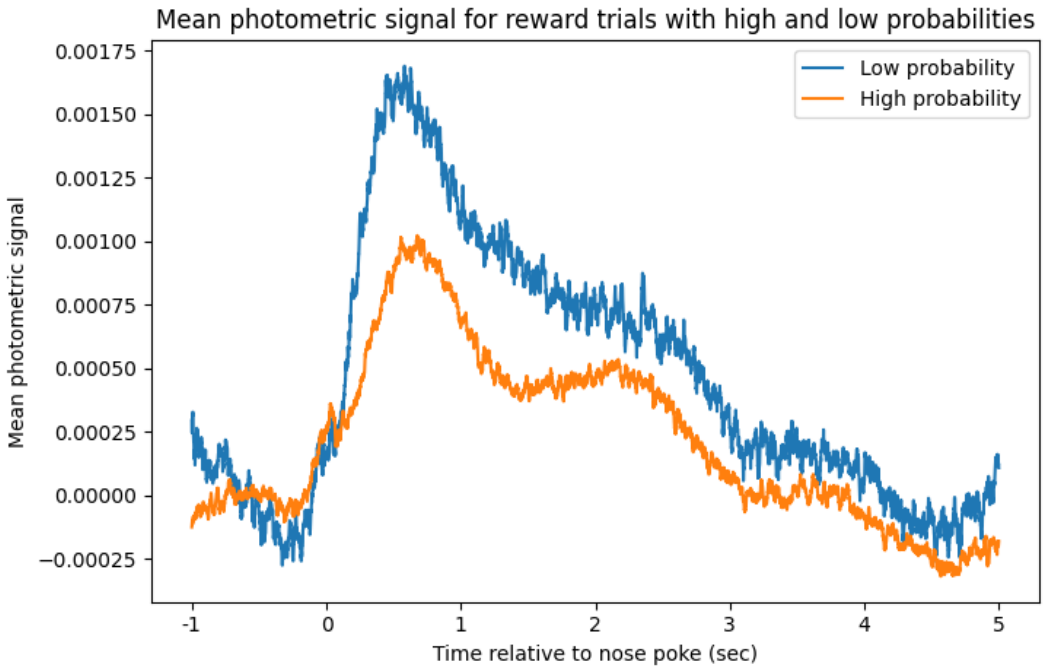


Figure 5: Mean photometric signal of reward trials, for high and low probabilities. The graph above shows the signal change (measured in mean photometric signal) for reward trials, relative to the mouse nose poke timing. Blue curve indicates low reward probability (20%) and orange curve indicates high reward probability (80%).

We can see signal increases for reward trials, with low reward probability trials increasing higher than high probability trials, then both decrease towards 0.

Question 2 – a2

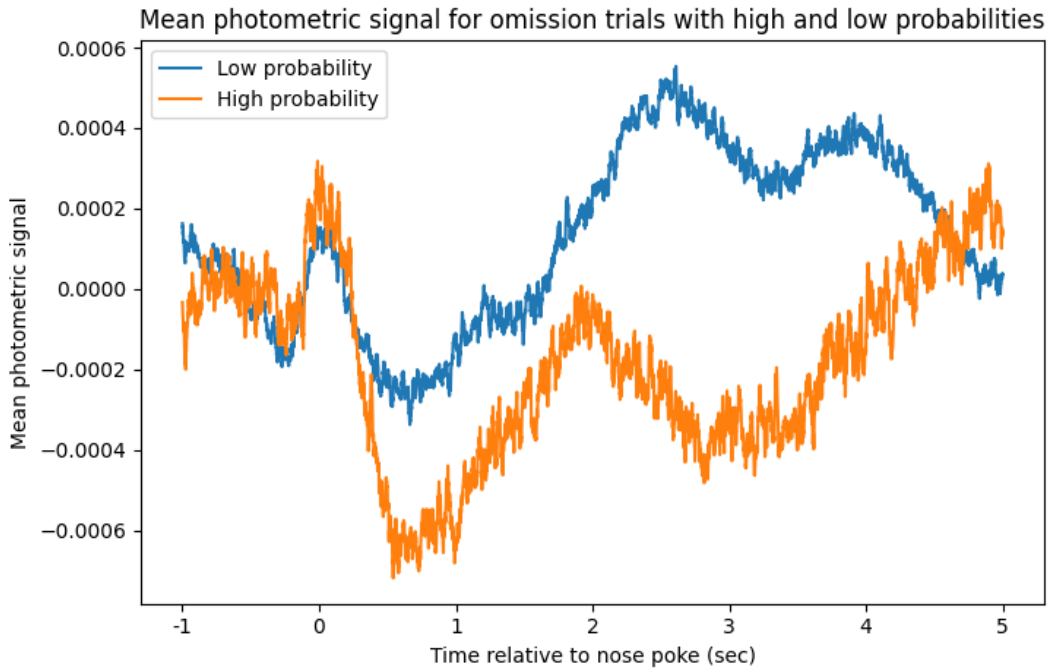


Figure 6: Mean photometric signal of omission trials, for high and low probabilities. This graph presents the signal change (measured in mean photometric signal) for omission trials, relative to the mouse nose poke timing. Blue curve indicates low reward probability (20%) and orange curve indicates high reward probability (80%).

Unlike the reward trials, we see signal *decreases* for omission trials, with low probability trials decreasing lower than high probability trials. The two curves behave similarly until around 2 seconds post nose poke, then diverge.

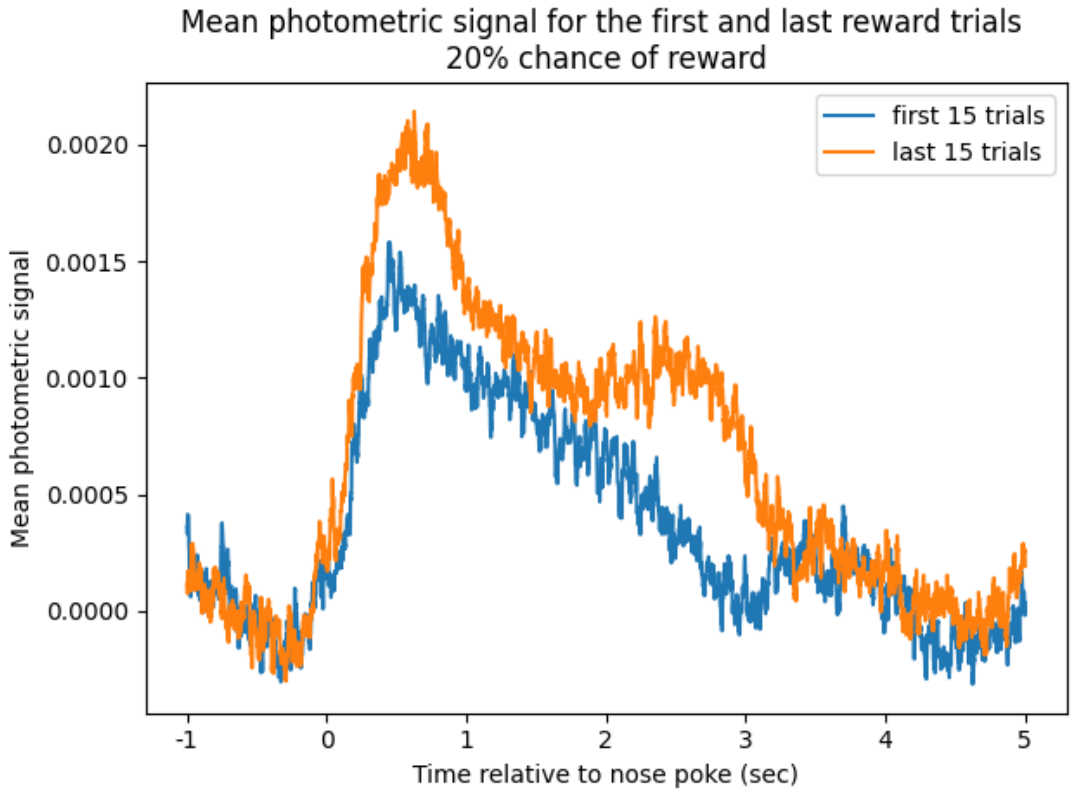
Question 2 – a3

Those results align with the predictions of RPE.

As described earlier RPE encodes for expectations, rather than actual outcome. This can explain why there's a higher increase in dopaminergic axons for the *low probability* reward trials – as the mouse expectation for reward was low, yet, it got a reward, creating a surprise and elevated neuronal activity.

On the other hand, it can also explain why there was a higher decrease for high probability omission trials. The mouse was expecting a reward but was surprised and got none. This resulted in higher, negative effect.

Question 2 – b



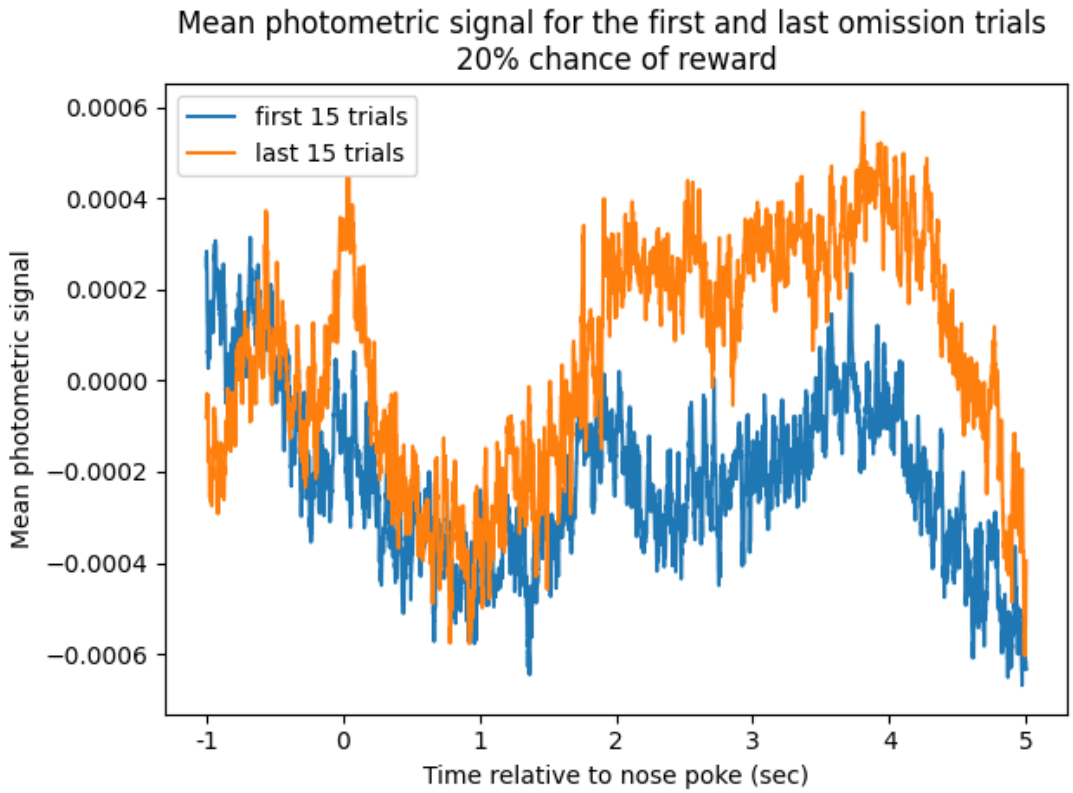


Figure 7+8:

Mean photometric signal for the first 15 (blue) and last 15 trials (orange) for reward probability of 20%. The upper graph shows signal for rewards trials, lower graph shows signal for omission trials.

During reward trials of low probability, we see a higher increase in signal for the last 15 trials than the first 15 trials. During omission trials, it seems the decrease in activity for the first 15 trials is bigger.

In this analysis, I sorted the data by reward/omission, low/high reward probability and the first/last 15 trials. If the mouse had access to the port probabilities from the start of the experiment, we probably wouldn't see a difference between the first and last trials. Instead, the mouse's cell responses were clearly influenced by experience. The graphs above support this claim. For example, in the rewarded 20% reward probability trials (figure 7), the change of signal amplitude implies that mouse was more surprised (had greater reward prediction error) during the *last* trials. This shows that the mouse learned to identify which ports were less likely to give reward, so it was more surprised to get a reward from them later on than compared to the beginning, when it had no clue about the probabilities. Additionally, the second graph (figure 8) shows a smaller decrease in prediction error during the last trials compared to the first, indicated by lower decrease in photometric signal. This further supports the idea that the mouse developed some understanding of the experiment's model through trial and error.