# Neural Ensemble Dynamics in the Posterior Parietal Cortex During Learning

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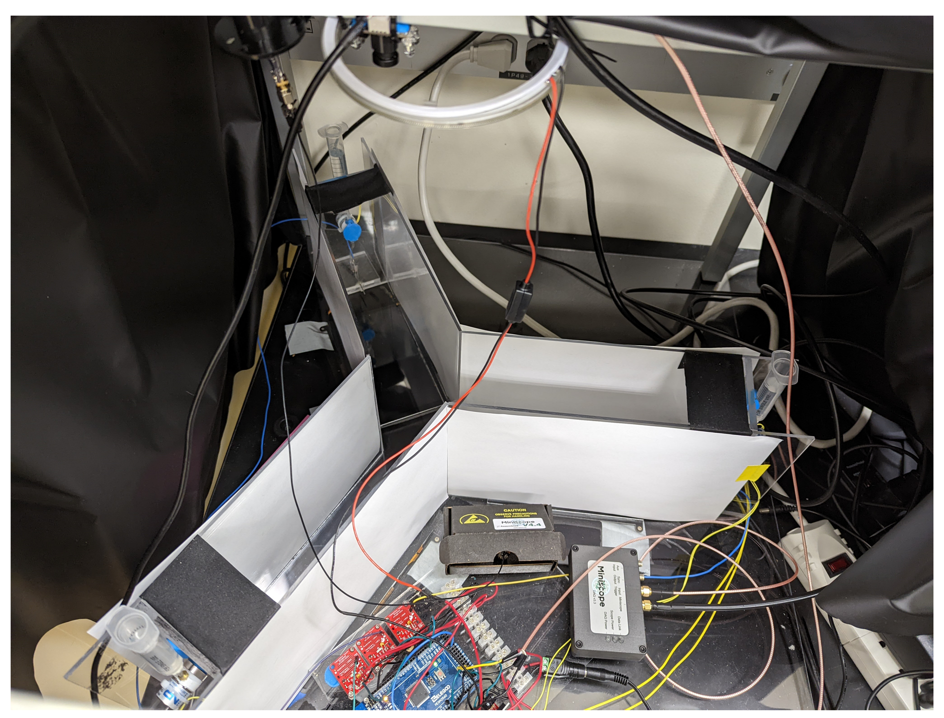
## Background

While the posterior parietal cortex (PPC) is thought to be important for decision-making, it is uncertain whether this is due to its role in motor or cognitive choice encoding. By comparing neural activity in this brain region during naive vs. learned behavioral sessions, we can disambiguate functions of the PPC that were previously inseparable due to task design.

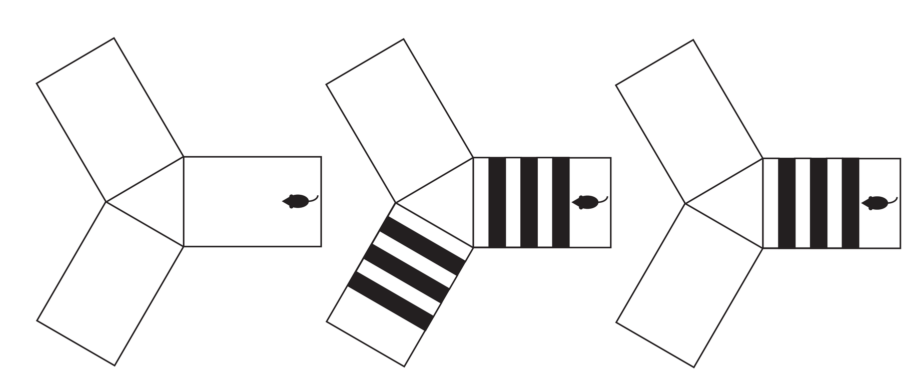
We also follow the neural activity throughout learning. Our goal is to discover commonalities of neuronal population dynamics across mice, which define the learning process of a decision-making task. Lastly, we analyze ensemble stability of learned information.

## Behavioral paradigm



Behavioral setup consists of a y-maze with lickspouts, tablets for stimuli presentation, camera, commutator, miniscope, and Arduino.

Visual stimuli: vertical = right, horizontal = left



Mice first learn to navigate the y-maze to obtain reward. Next, mice learn to follow the pattern of visual stimuli in the initiation and goal arms. Finally, mice learn which direction to go when given a visual stimulus in the initiation arm only.

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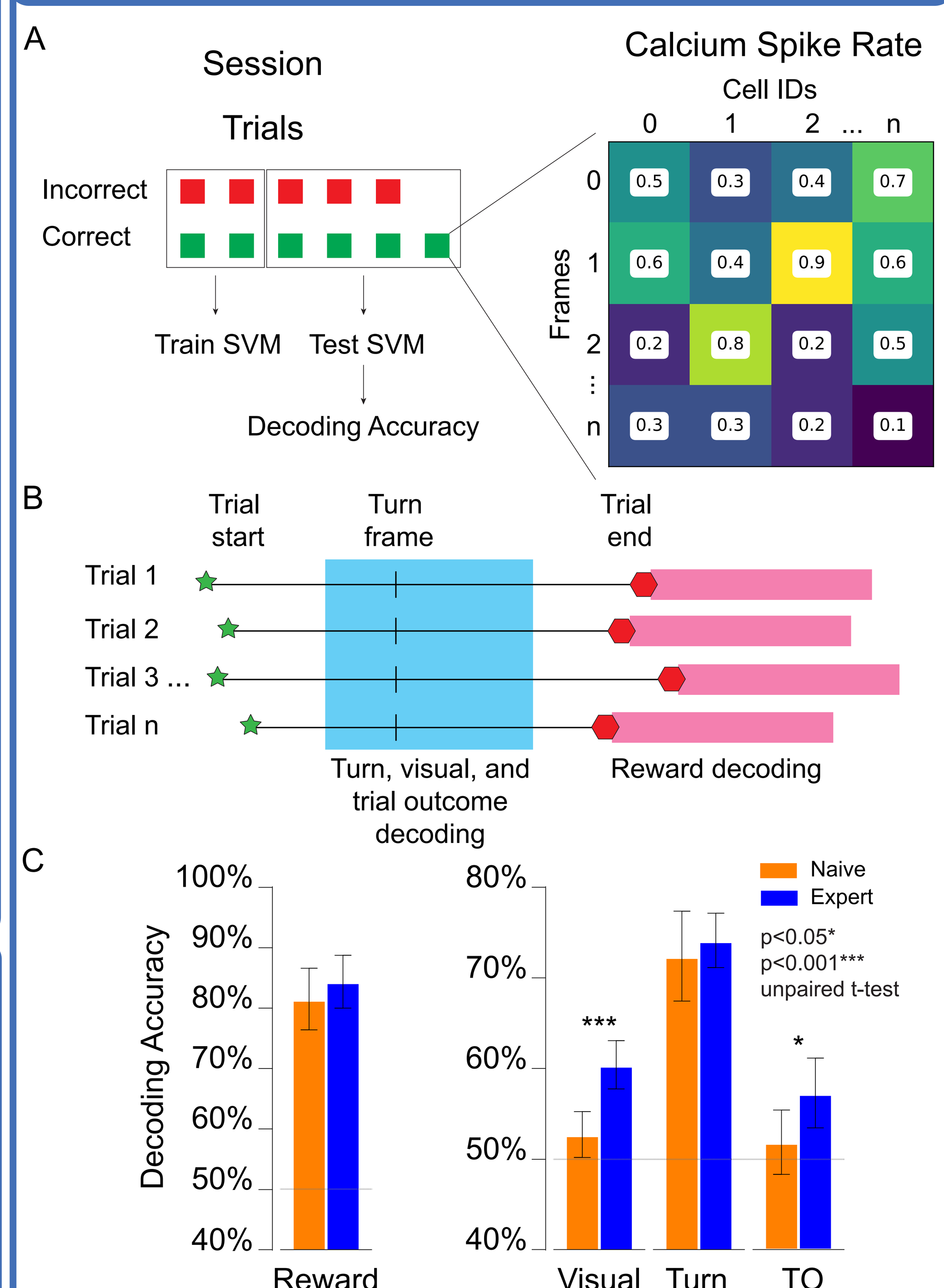
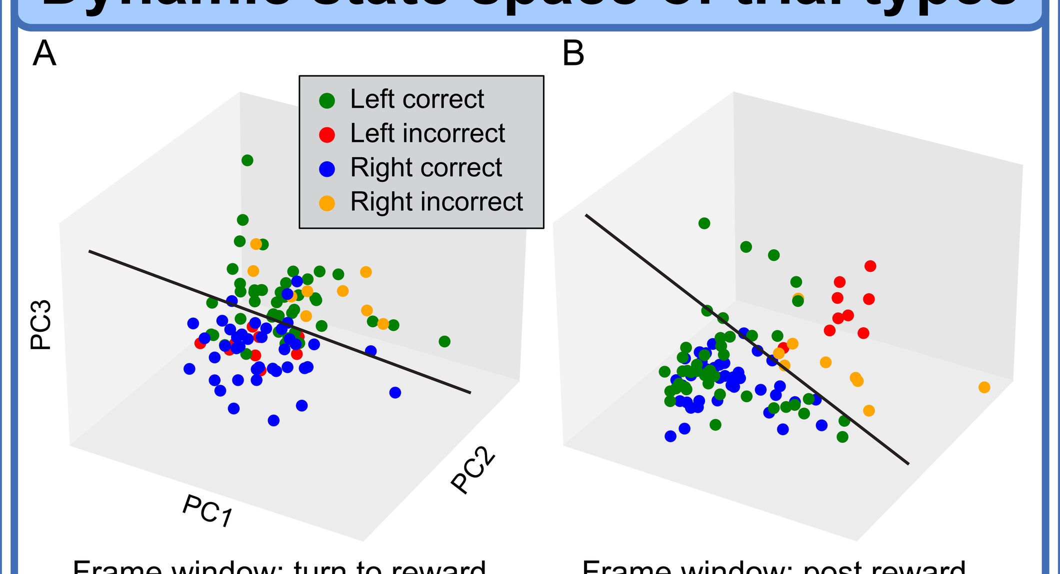
## Changes in decoding with learning



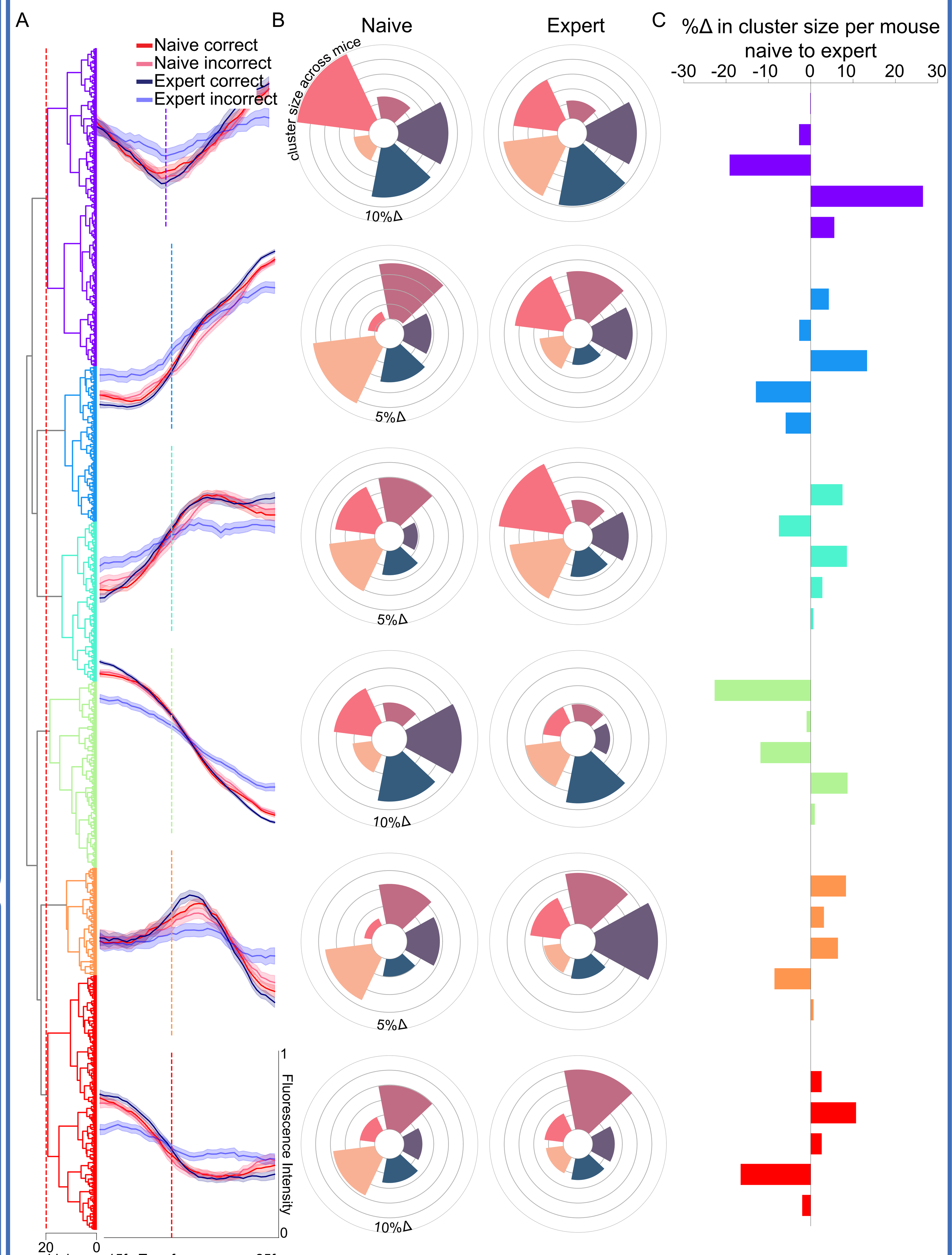

(A) Schematic of data input into the support vector machine.
(B) Illustration of frame ranges used per category of decoding.
(C) Decoding accuracies reward, visual stimuli, turn direction, and trial outcome (n naive = 15, n expert = 22).

## Dynamic state space of trial types



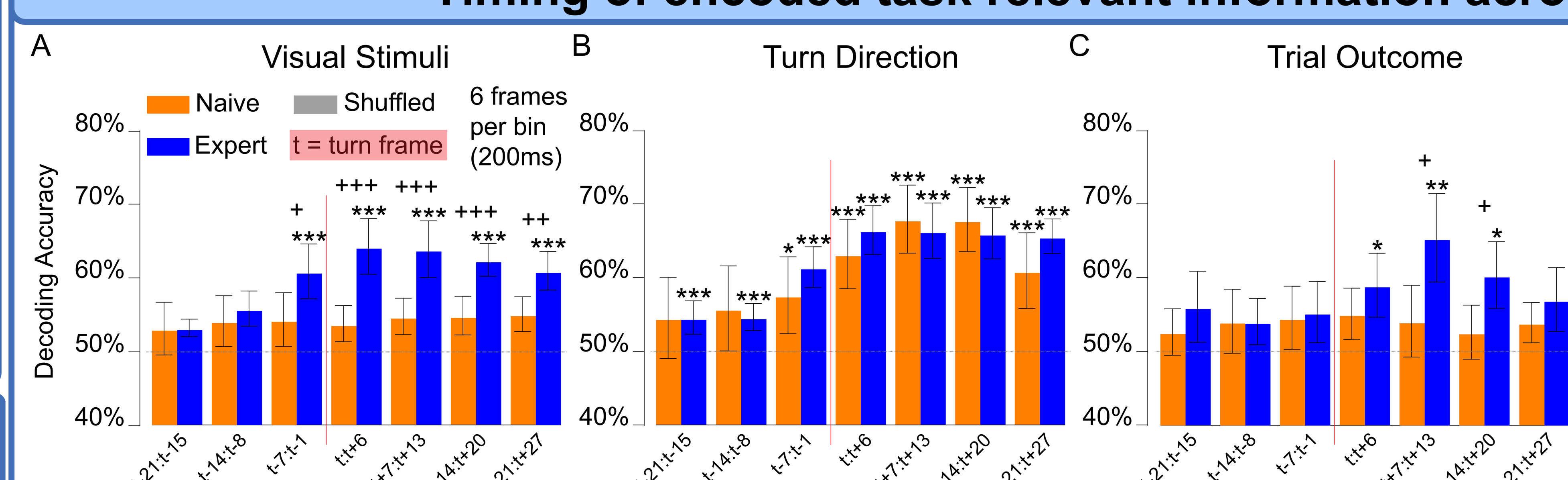

(A) In an expert mouse, turn direction can be separated using PCA when analyzing the neural activity between turn onset and reward frames.
(B) When the analysis is shifted several milliseconds later to after the reward frames, the neuronal firing preferentially shifts to reward encoding.

## Differences in naive vs. expert average trial activity




(A) Neurons across 5 mice are used for unsupervised hierarchical clustering, based on the average trial activity for each neuron. After the clusters are determined, the average trial activity is displayed for naive and expert trials, per trial outcome along with the 95% confidence intervals. (B) Each bar represents the percentage of cells for a single mouse within the given cluster, for both its naive and expert sessions. (C) The percent change in cluster size per mouse is determined by subtracting the percentage of cells in the given cluster for the expert session from the naive session.

## Timing of encoded task relevant information across a trial




Within group: p<0.05*, p<0.01**, p<0.001***
Between groups: p<0.05+, p<0.01++, p<0.001+++
A one-sample t-test was first used to test whether the decoding accuracy is greater than the shuffled decoding accuracy at 50%. Due to the large number of tests conducted, we accounted for multiple comparisons by computing adjusted p-values using false discovery rate (FDR).

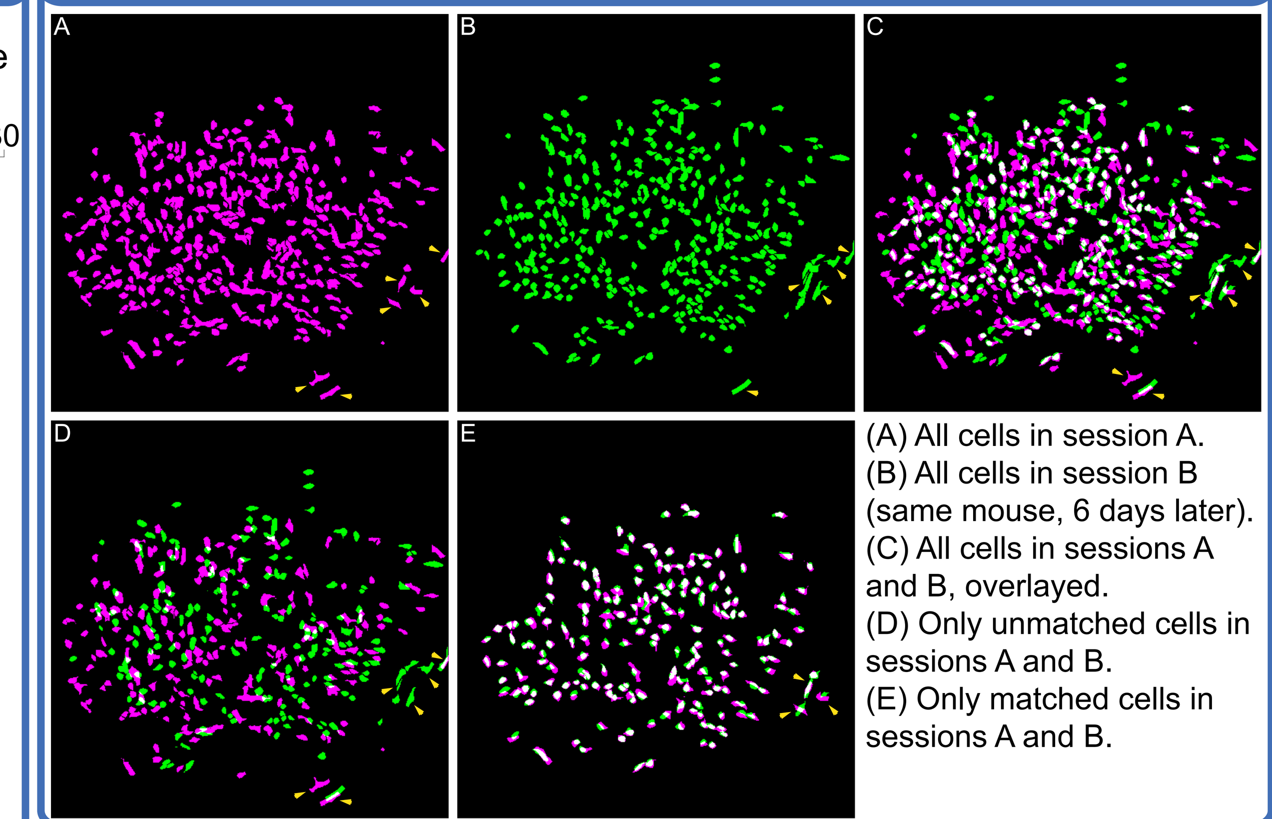
Decoding accuracy within 200ms timebins across a trial (n naive = 15, n expert = 22).

(A) Decoding accuracy for visual stimulus identity.

(B) Decoding accuracy for turn direction.

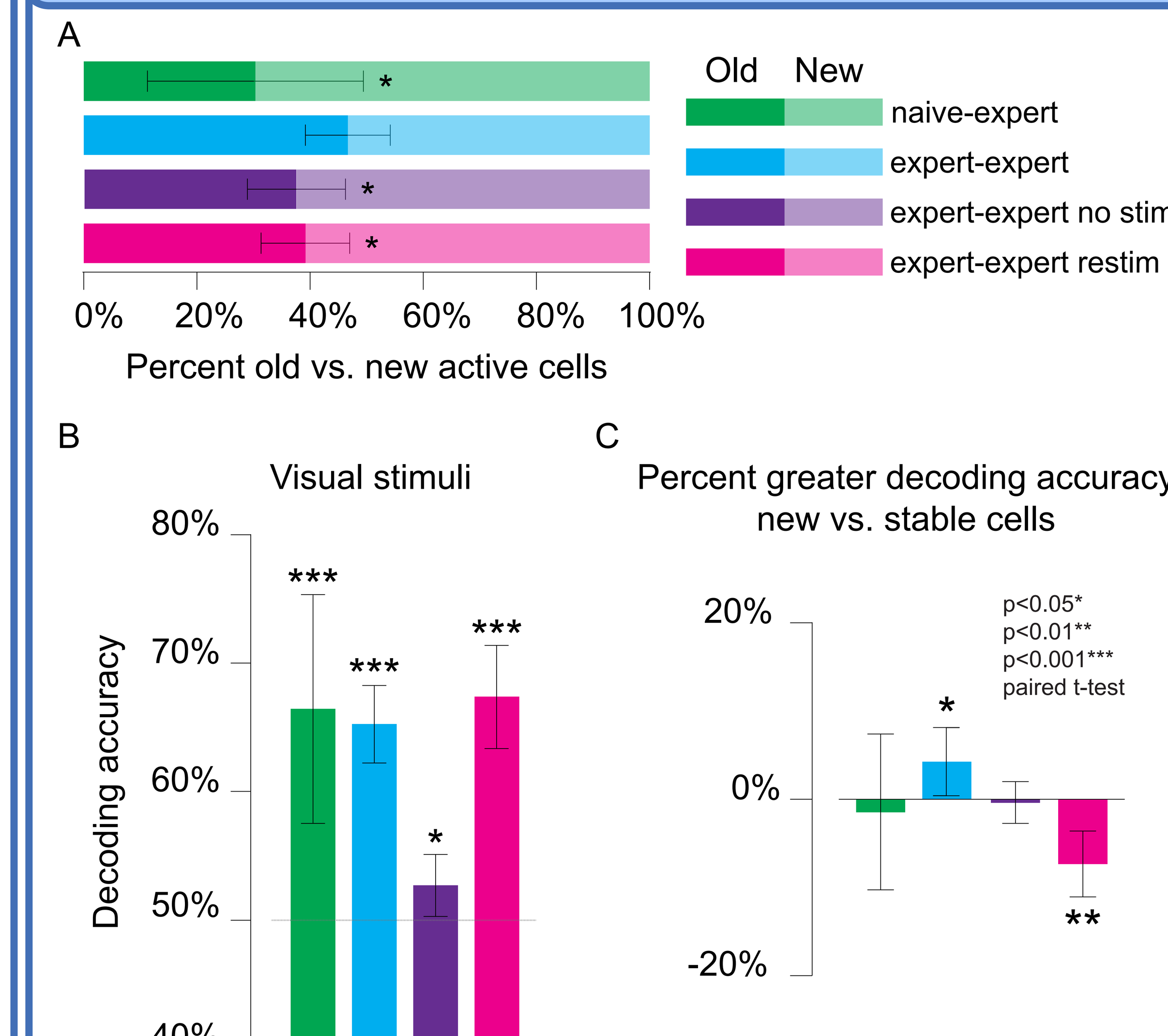
(C) Decoding accuracy for trial outcome.

## Cell tracking



(A) All cells in session A.
(B) All cells in session B (same mouse, 6 days later).
(C) All cells in sessions A and B, overlayed.
(D) Only unmatched cells in sessions A and B.
(E) Only matched cells in sessions A and B.

## Ensemble stability




(A) Analysis is done across 4 different types of paired sessions. Percent old active cells refers to the percentage of cells in the second session pairing that were also actively present in the first session. Percent new active cells refers to the percentage of cells in the second session pairing that was not actively present in the first session.
(B) Decoding accuracy of visual stimulus identity for the second session in the pairing, using all cells in each session.
(C) Decoding accuracy of visual stimulus identity difference between using only newly active cells vs. only old active, stable cells for the second session in the pairing. The first session in the pairing is used to determine the matched and unmatched cells.

## Summary

- The PPC encodes information for both navigation and decision-making.
- There is a learned effect in decoding task variables (visual stimulus identity and trial outcome), while turn direction is constant.
- The neuronal reprentations of trials changes from turn direction to trial outcome within milliseconds.
- There is pre-turn trial decoding of task variables.
- Clustering reveals a difference in average trial activity dynamics for correct vs. incorrect trials in expert but not in naive mice.
- The relative turnover rate of active cells diminishes between expert-to-expert sessions.
- Using only the neurons present in both the previous and current sessions yielded significantly better results in expert-to-expert sessions compared to strictly using the newly active cells only. This provides further evidence for the stabilization of neuronal ensemble with learning.