Medial Prefrontal Cortex and The Temporal Control of Action

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Temporal control of action

- How is time represented in cortical activity?
- Does the frontal cortex influence the motor system to achieve temporal control?

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Top-Down Control of Motor Cortex Ensembles by Dorsomedial Prefrontal Cortex

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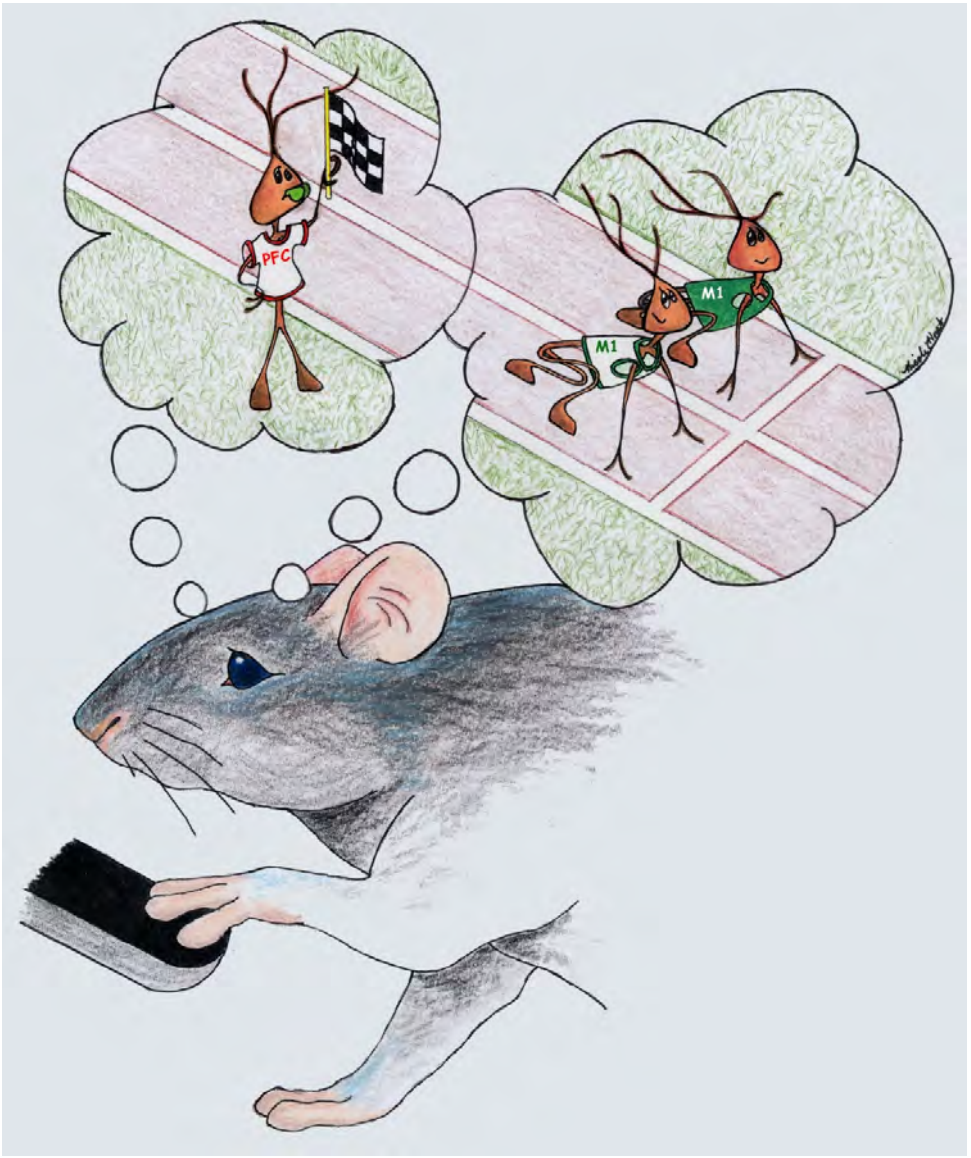
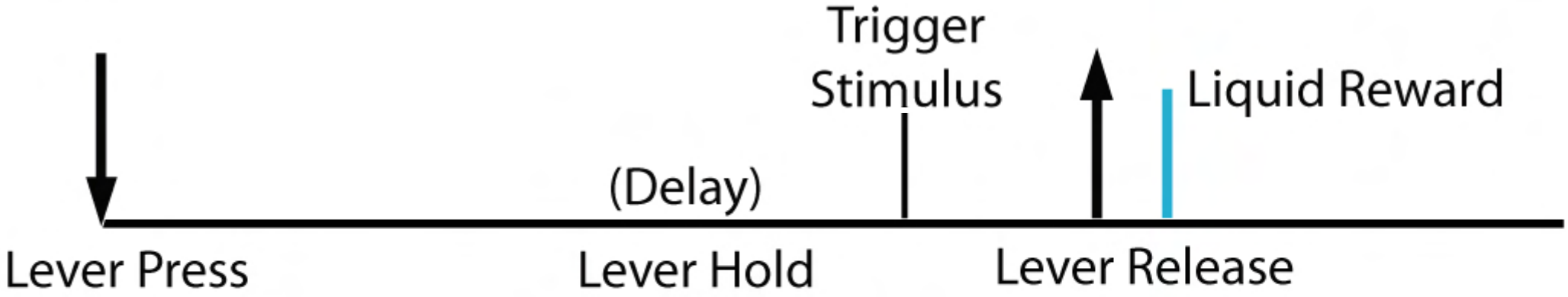
Summary

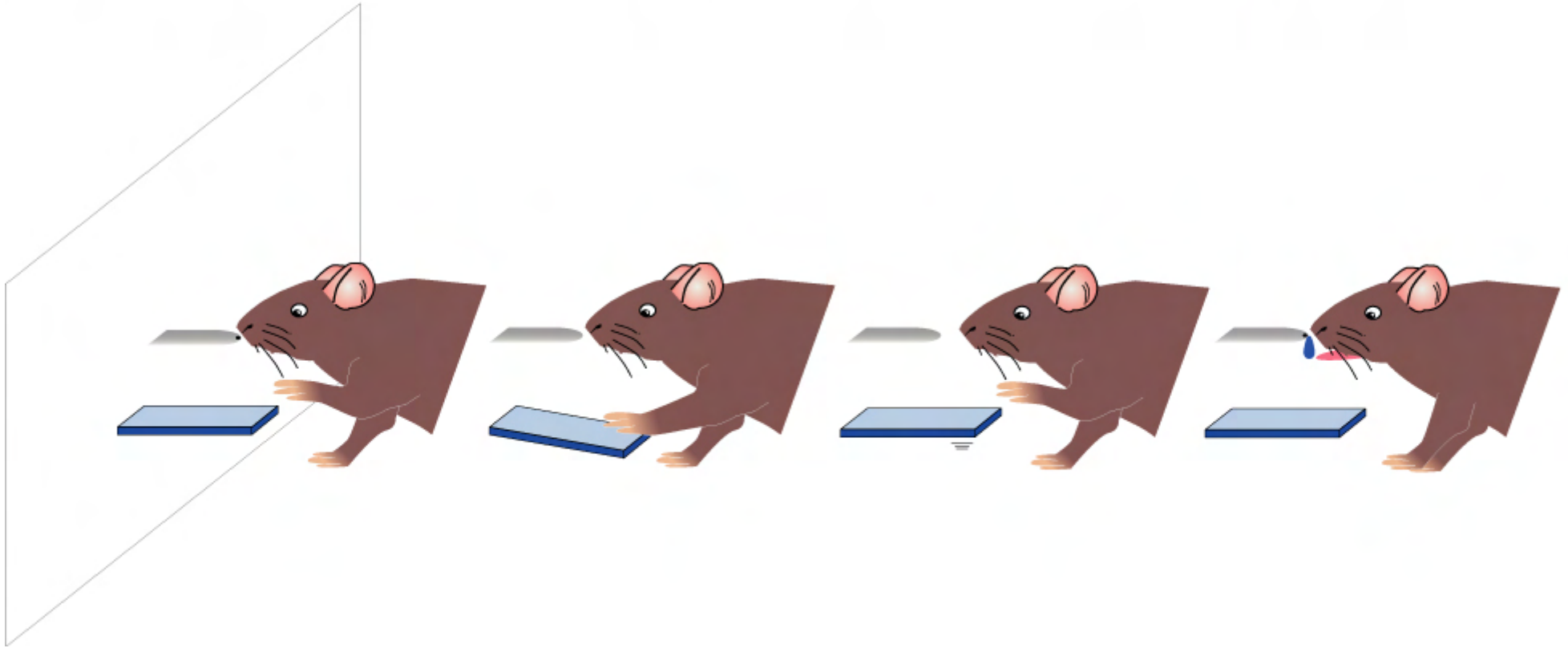
Dorsomedial prefrontal cortex is critical for the temporal control of behavior. Dorsomedial prefrontal cortex might alter neuronal activity in areas such as motor cortex to inhibit temporally inappropriate responses. We tested this hypothesis by recording from neuronal ensembles in rodent dorsomedial prefrontal cortex during a delayed-response task. One-third of dorsomedial prefrontal neurons were significantly modulated during the delay period. The activity of many of these neurons was predictive of premature responding. We then reversibly inactivated dorsomedial prefrontal cortex while recording ensemble activity in motor cortex. Inactivation of dorsomedial prefrontal cortex reduced delay-related firing, but not response-related firing, in motor cortex. Finally, we made simultaneous recordings in dorsomedial prefrontal cortex and motor cortex and found strong delay-related temporal correlations between neurons in the two cortical areas. These data suggest that functional interactions between dorsomedial prefrontal cortex and motor cortex might serve as a top-down control signal that inhibits inappropriate responding.



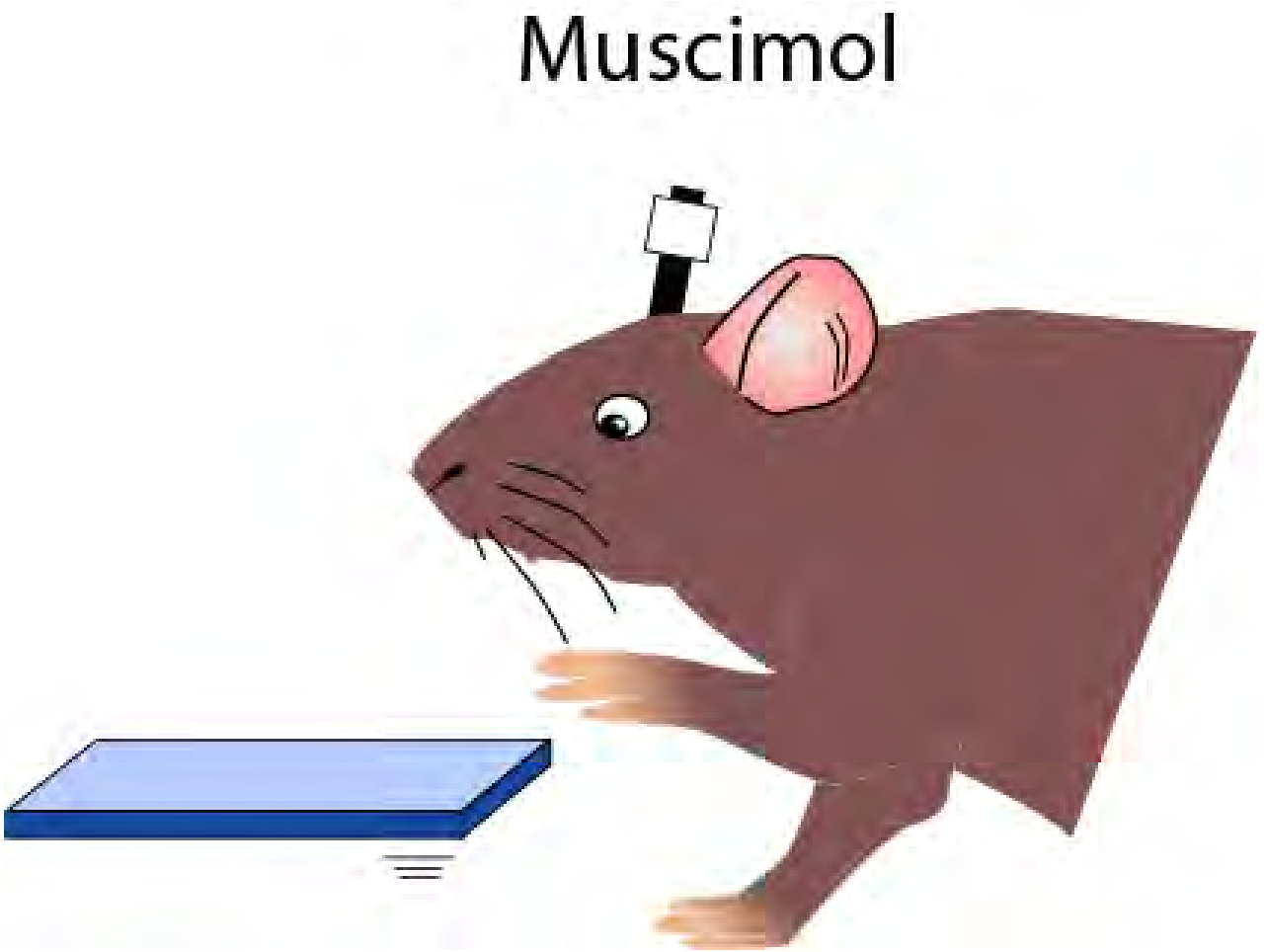
Cartoon by Nicole Horst

Simple Reaction Time Task

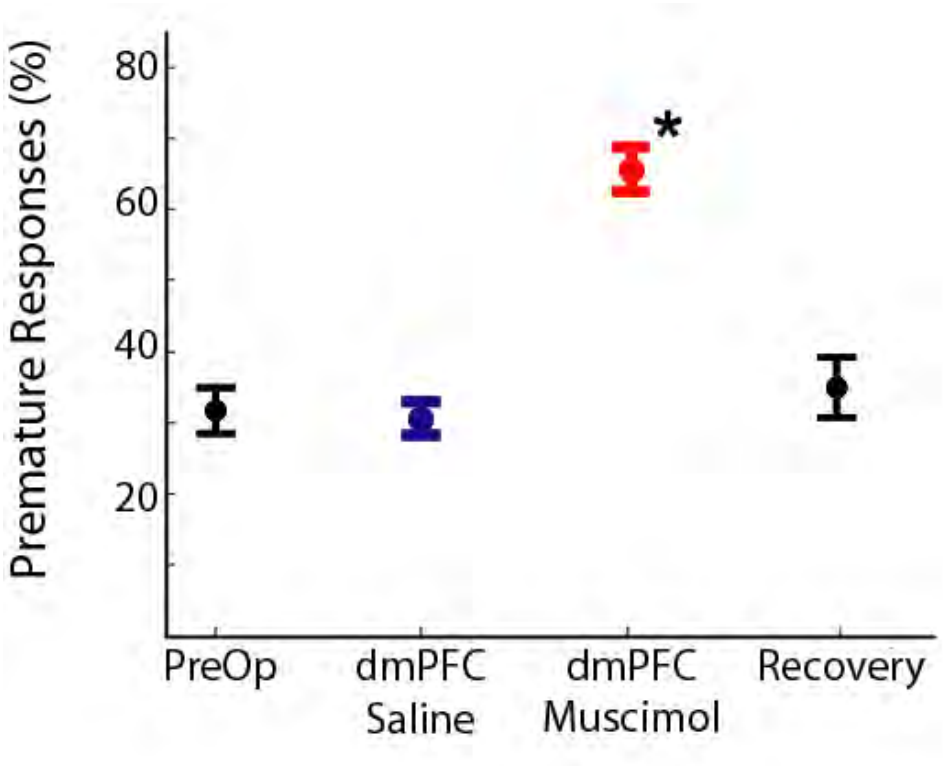


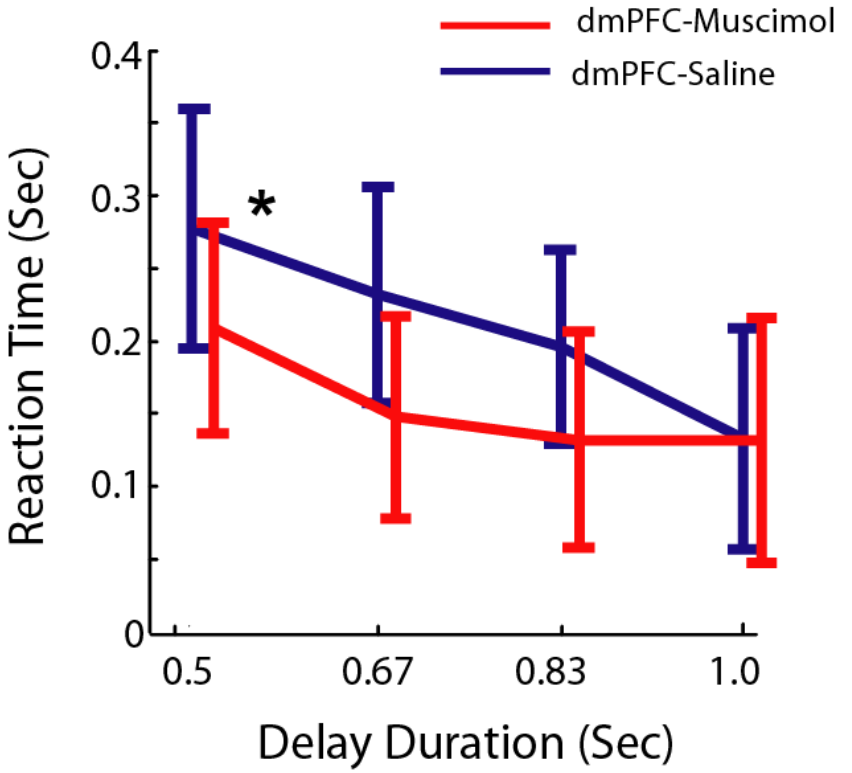


Reversible Inactivation of dmPFC



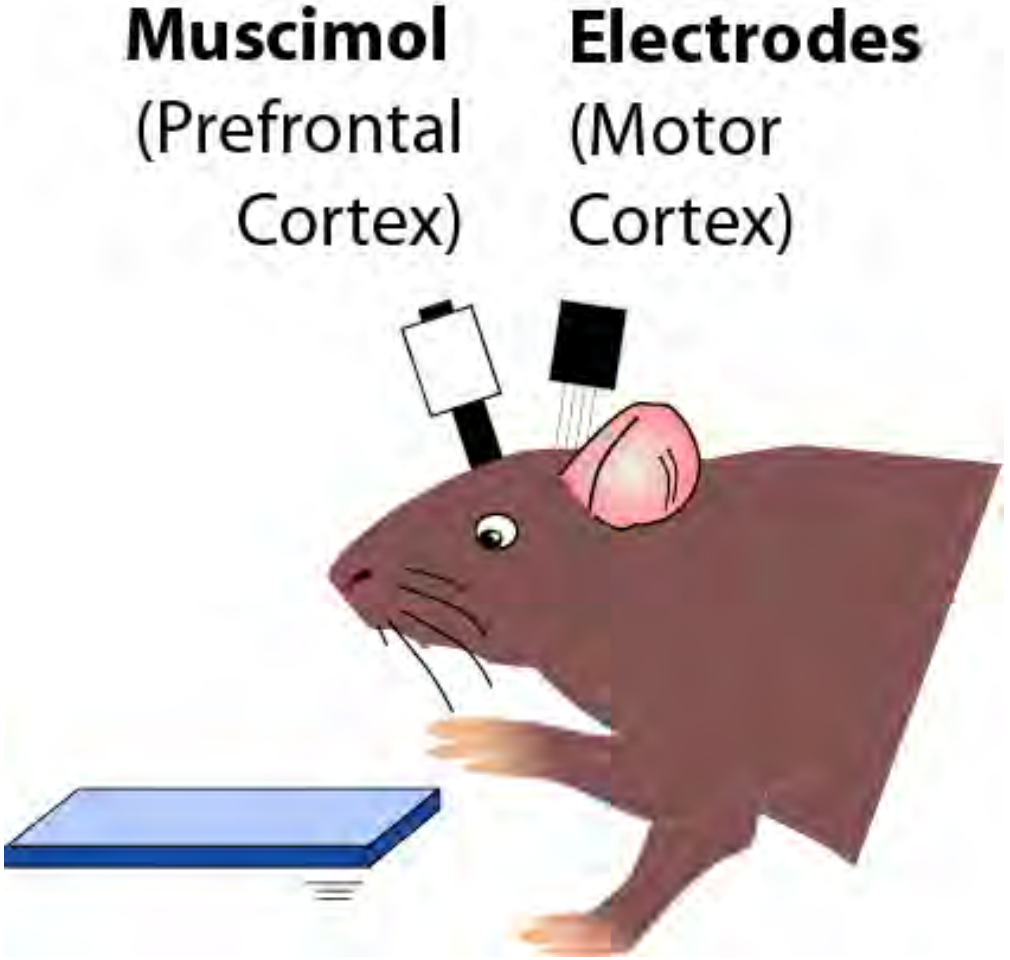
Reversible Inactivation of dmPFC

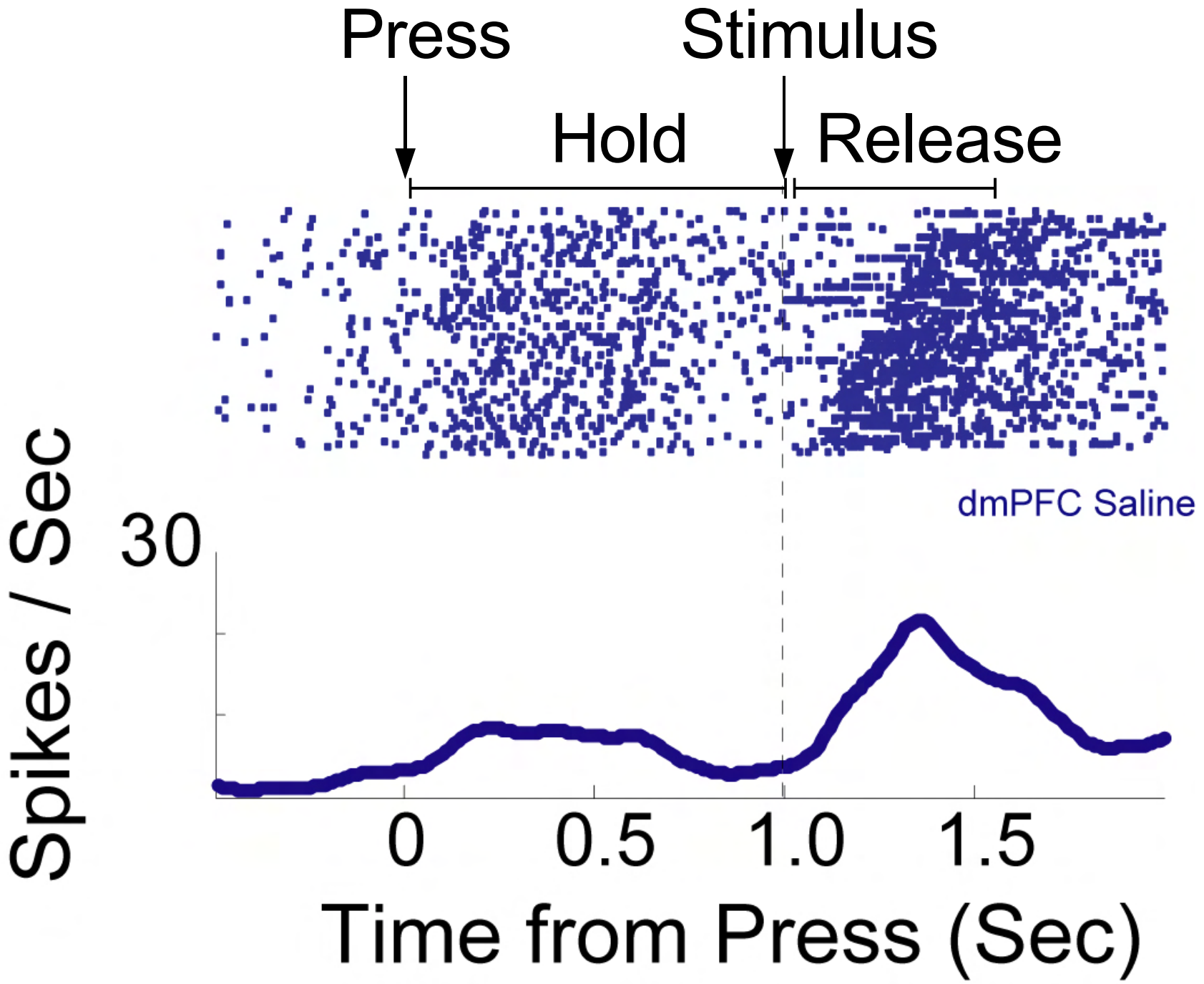


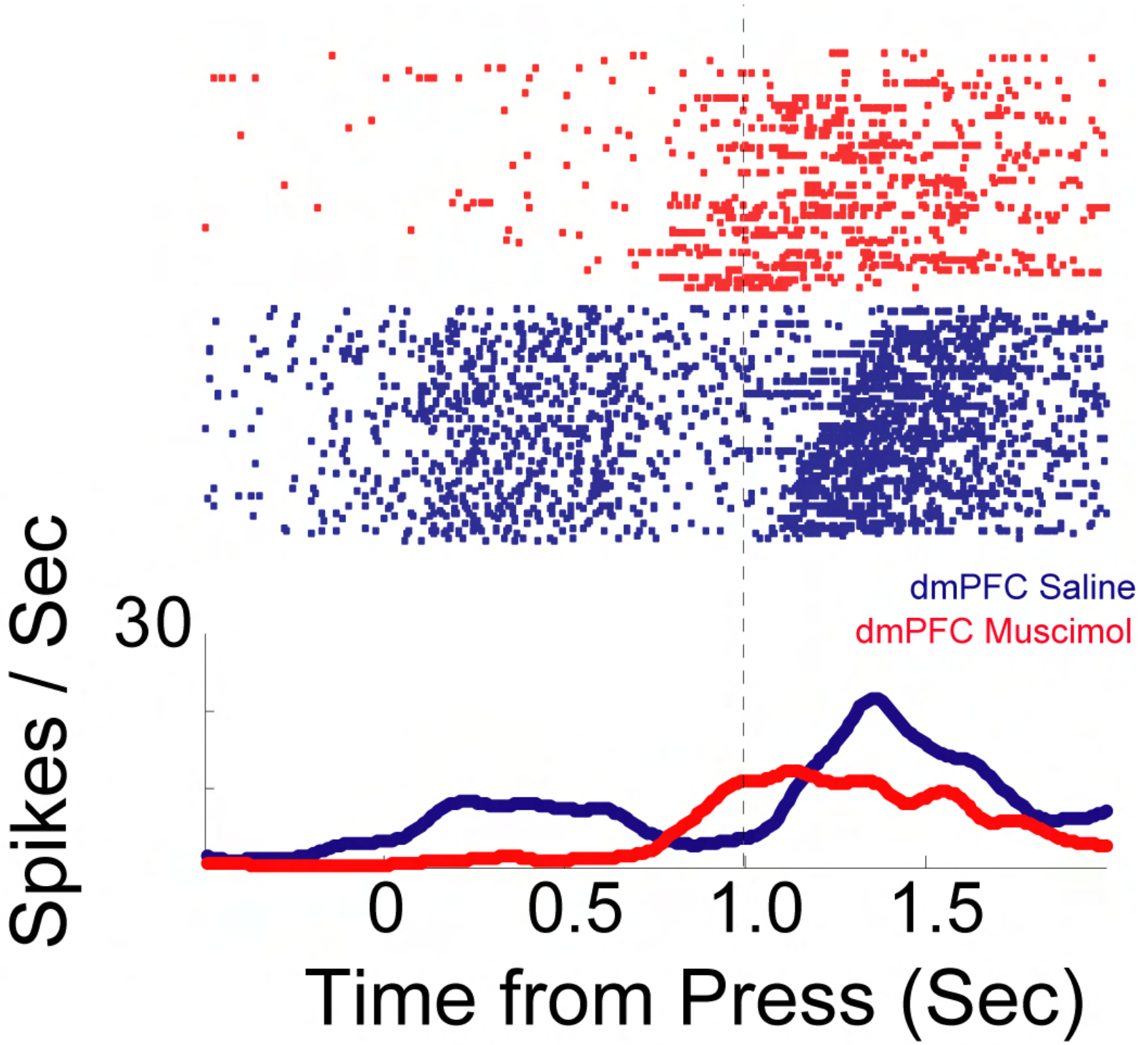


Rats are unable to wait for the stimulus and are quicker to respond at short delays.

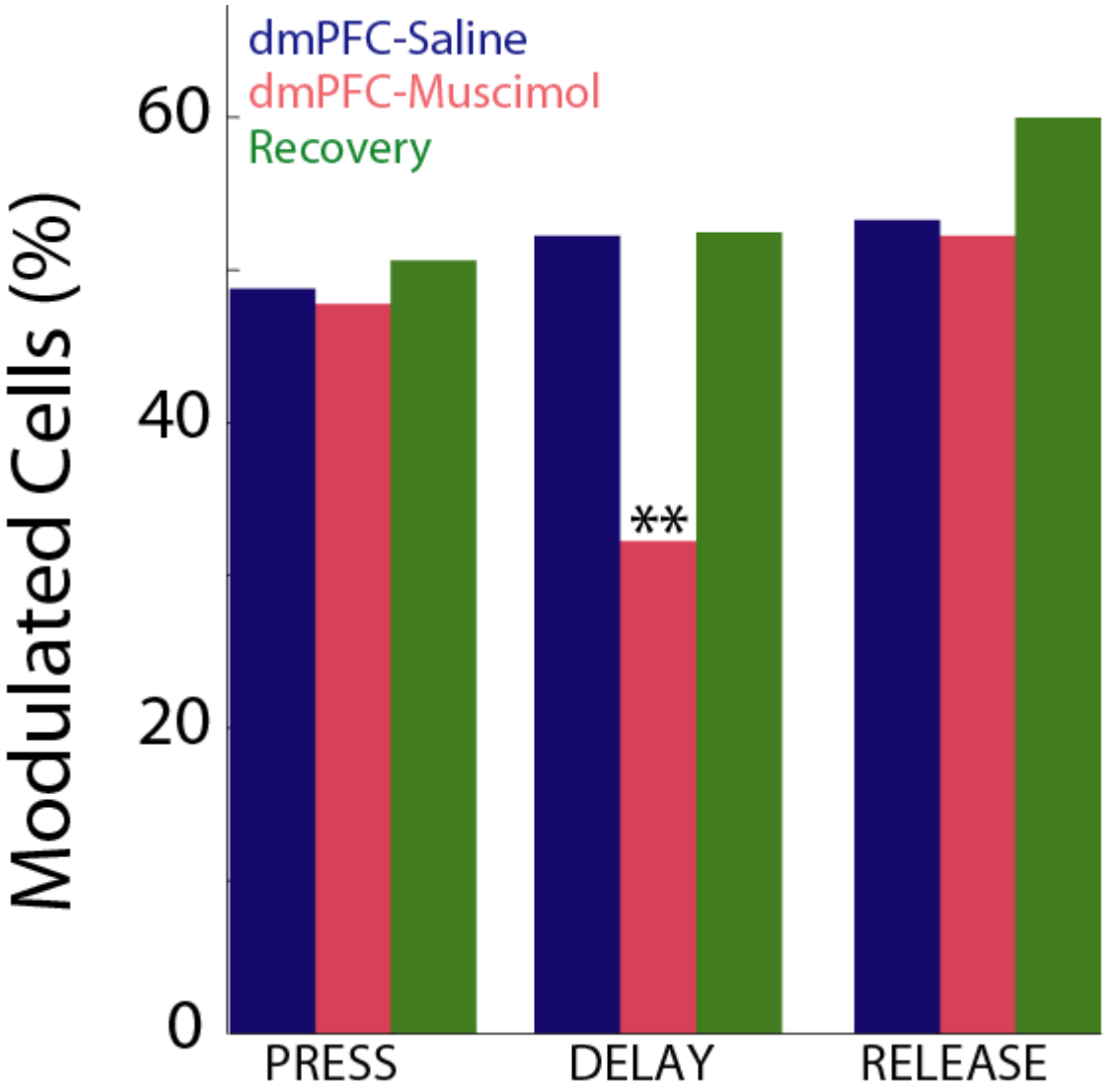
Reversible Inactivation of dmPFC + Recordings in Motor Cortex



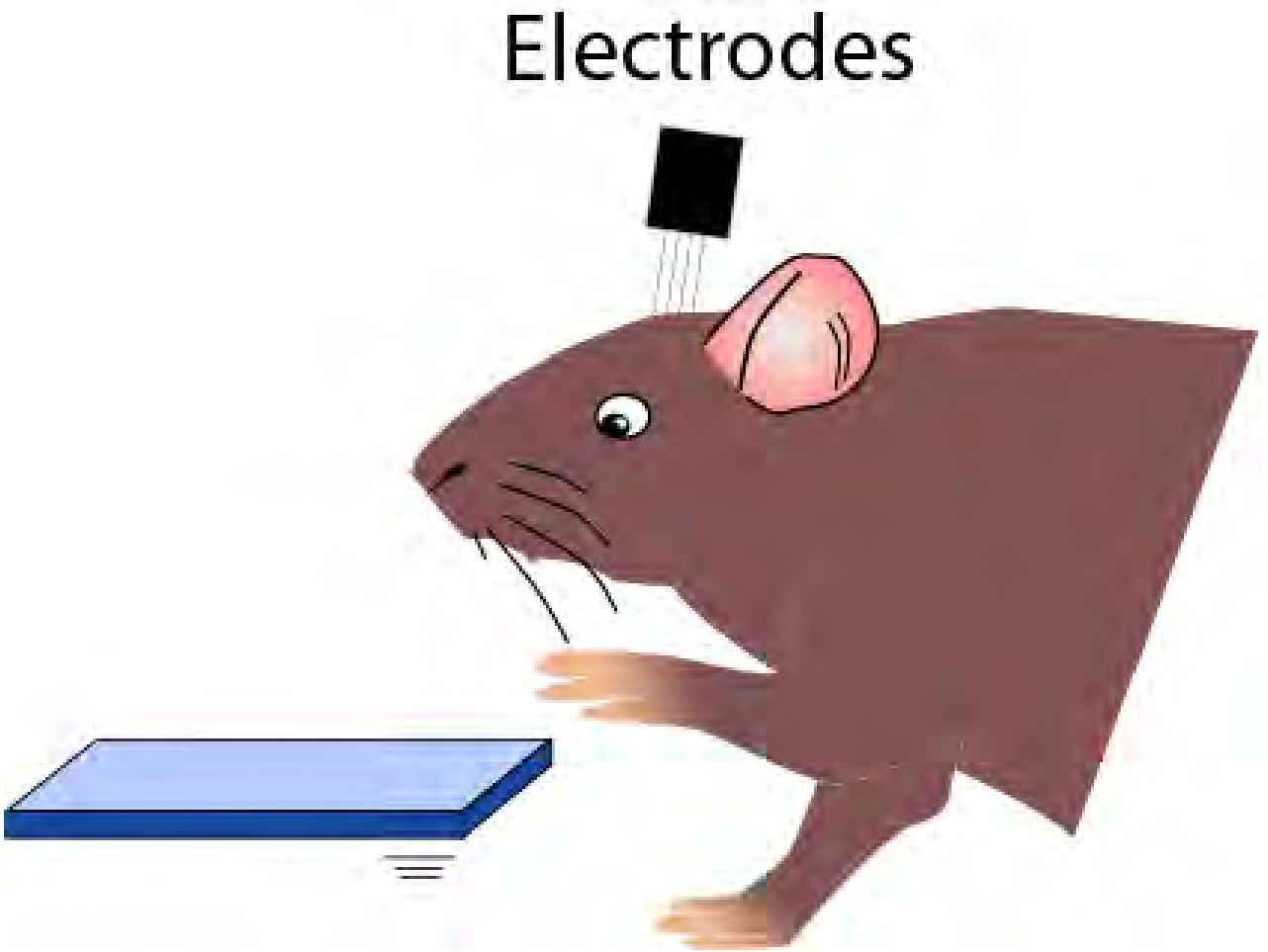

Press
Stimulus
Hold
Release
dmPFC Saline
30
Spikes / Sec
0
0.5
1.0
1.5
Time from Press (Sec)


dmPFC Saline
dmPFC Muscimol
30
Spikes / Sec
0
0.5
1.0
1.5
Time from Press (Sec)

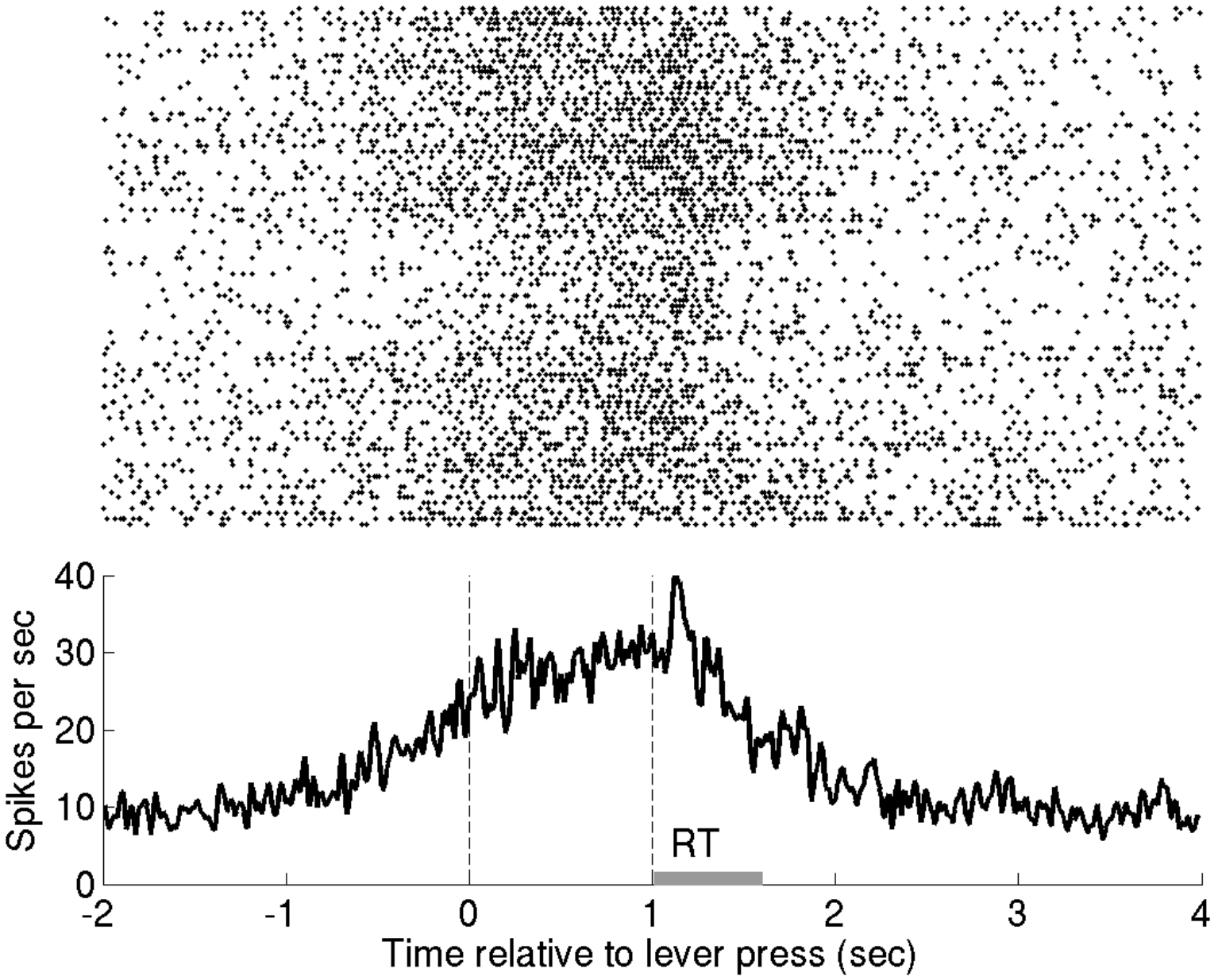
Inactivating dmPFC reduced delay period firing in motor cortex



Neural Recording in dmPFC

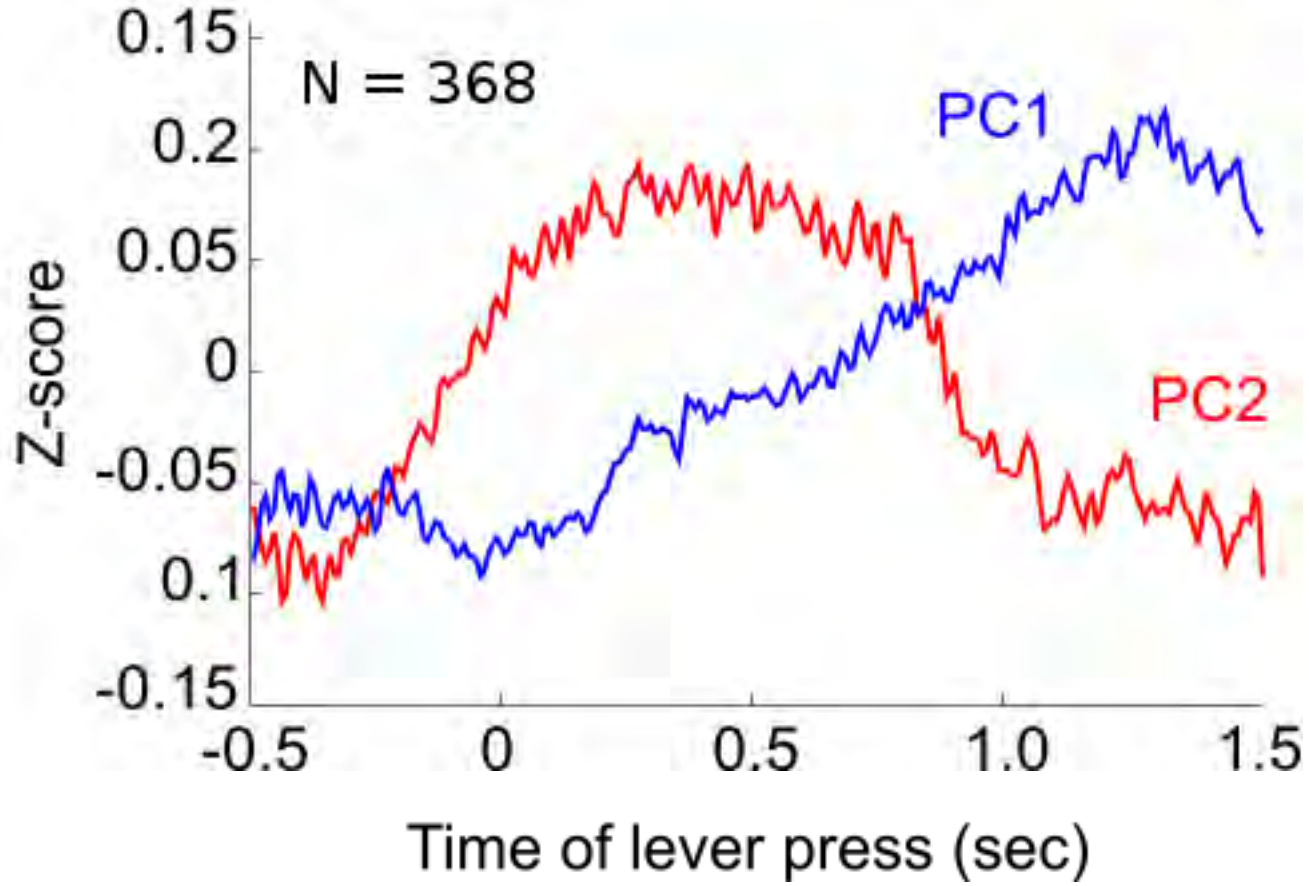


Persistent task-modulated activity



Population Activity in dmPFC

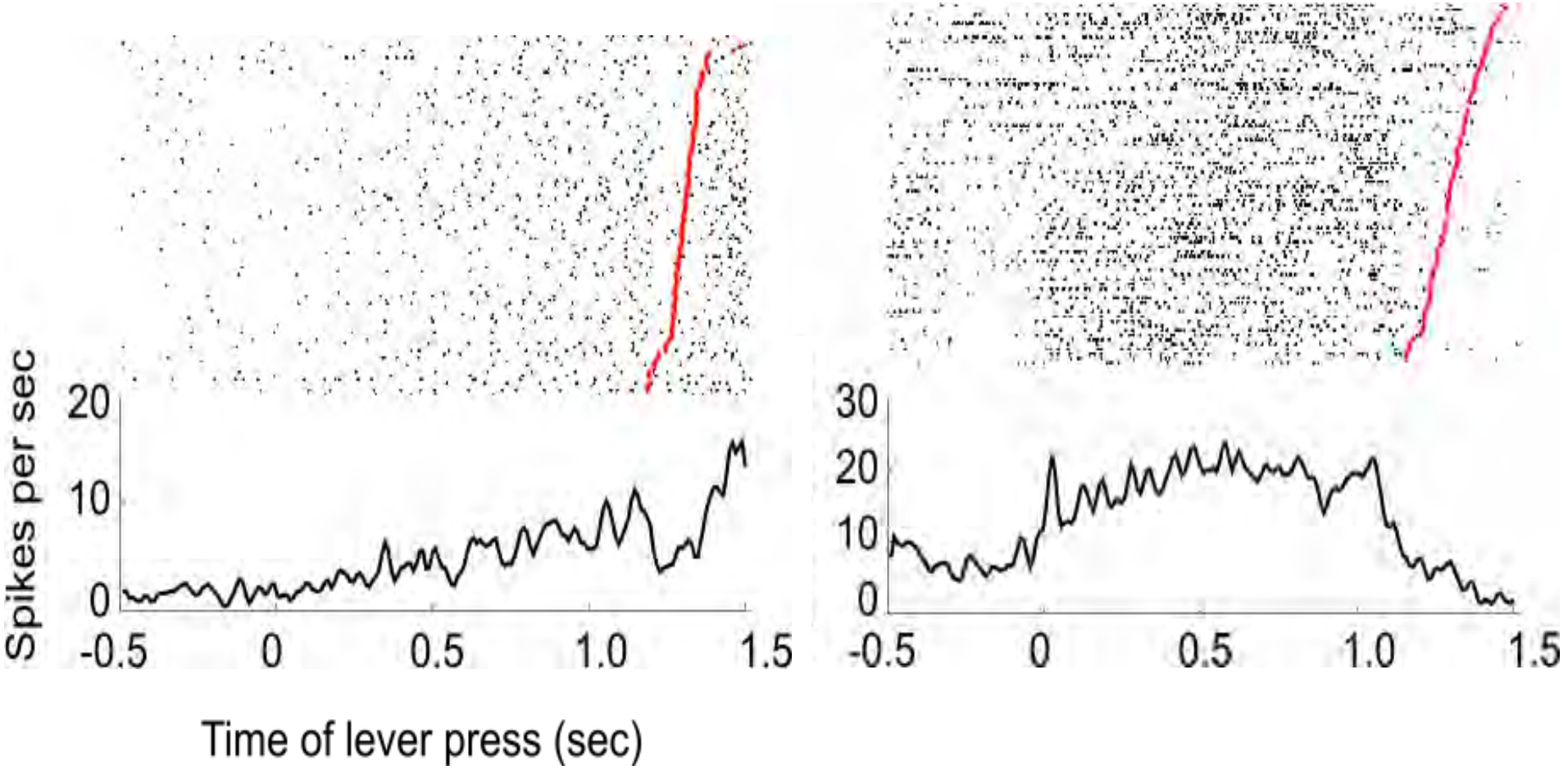
Principal Component Analysis of trial-averaged activity



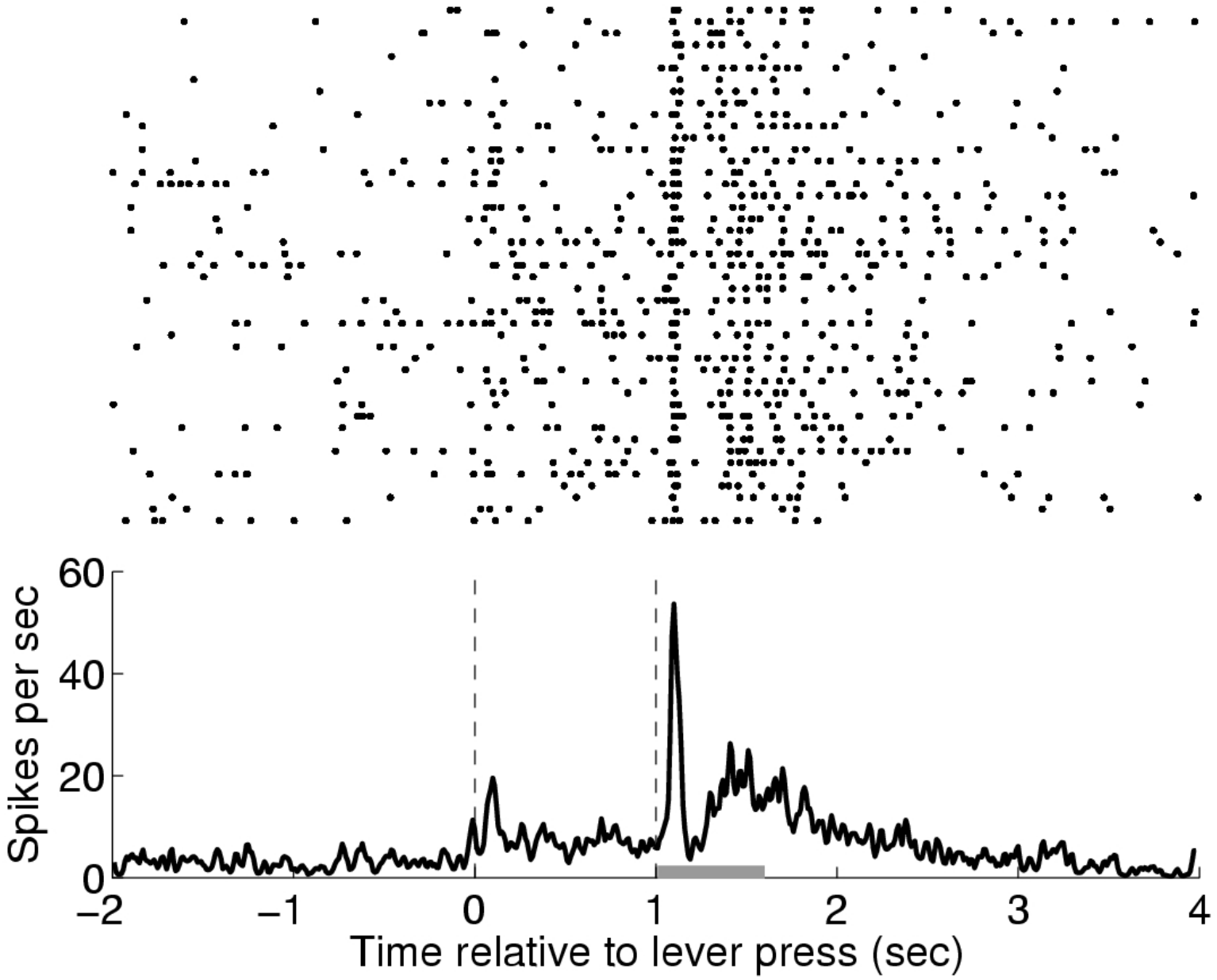
Population Activity in dmPFC

Largest loading on PC1

Largest loading on PC2

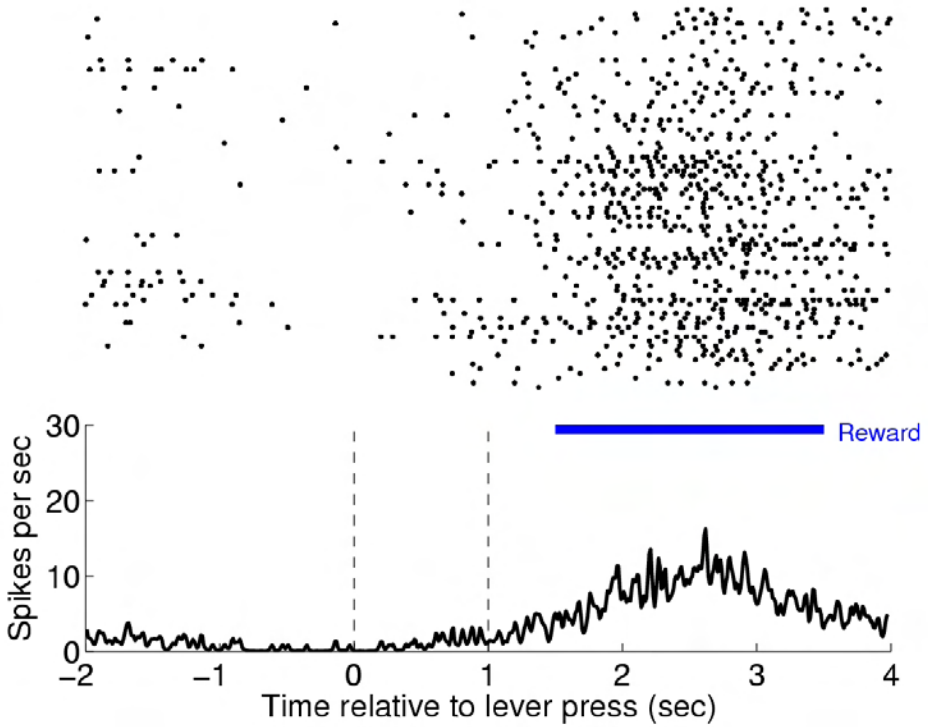


Stimulus-evoked activity



Reward-related activity

04-KJ2-020606



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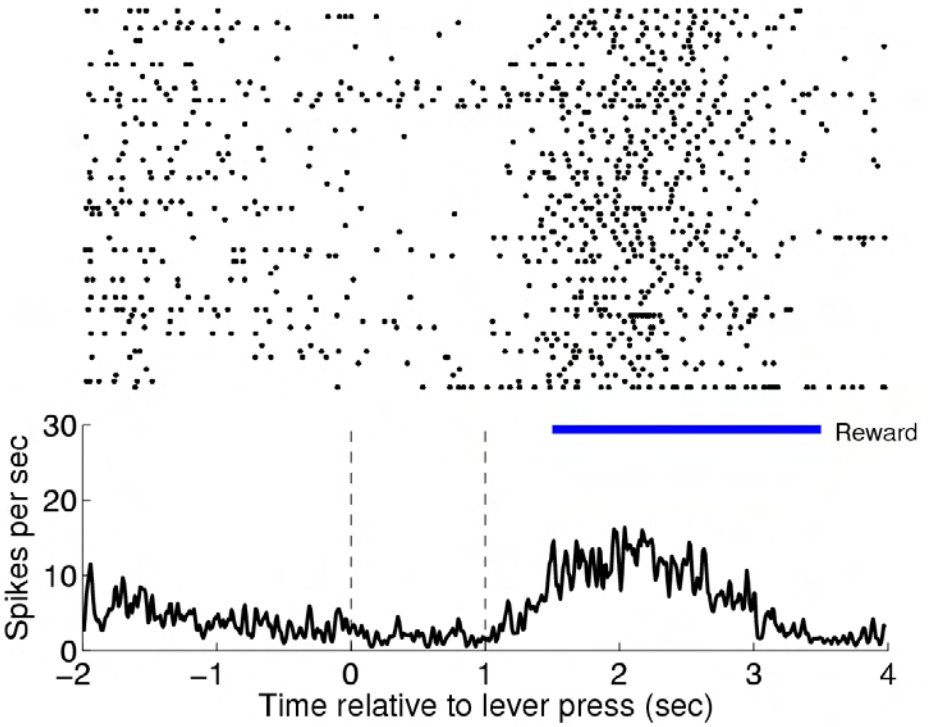

Reward-related activity

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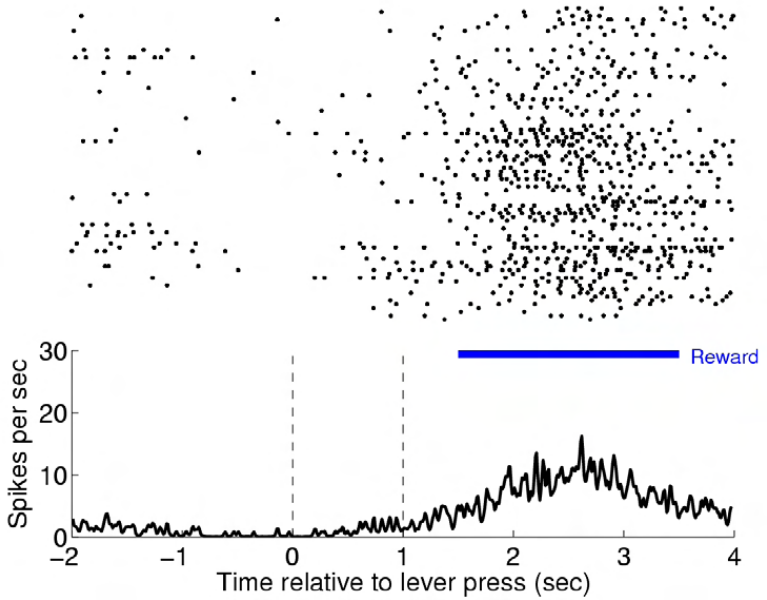

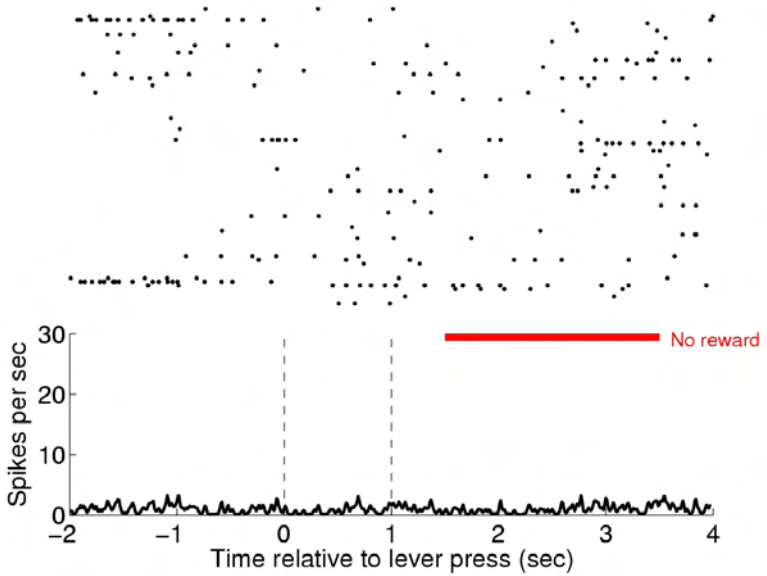

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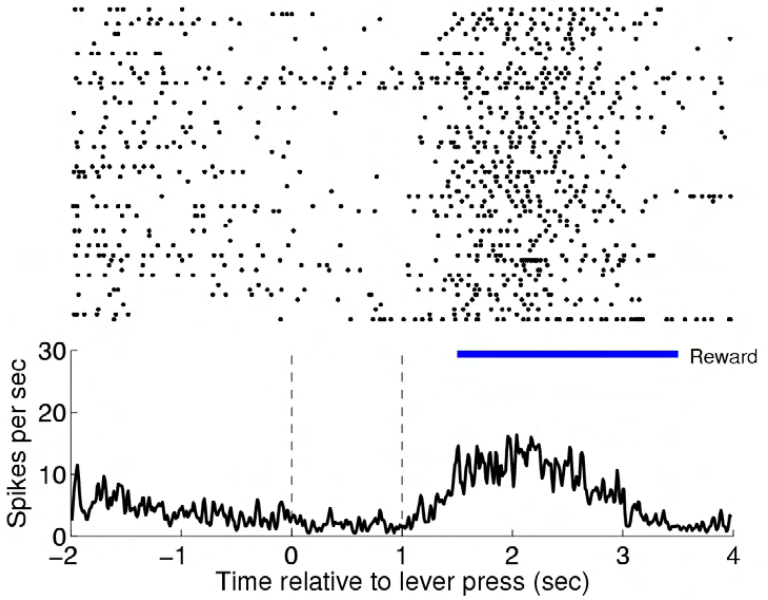
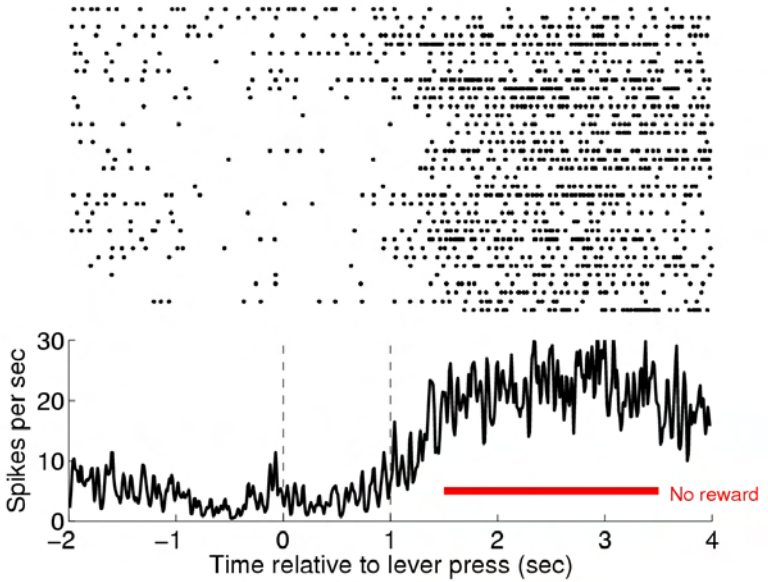
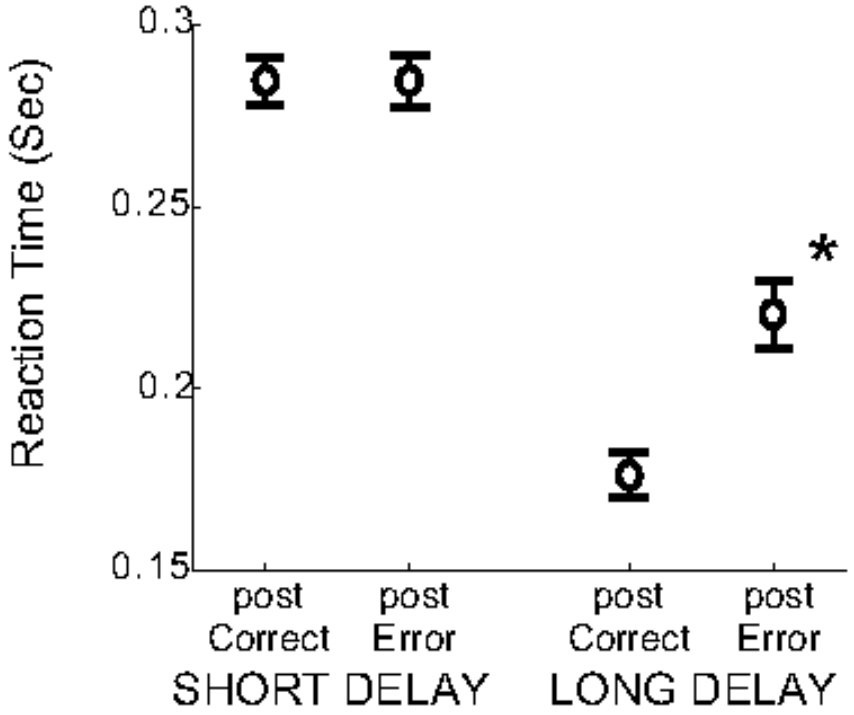
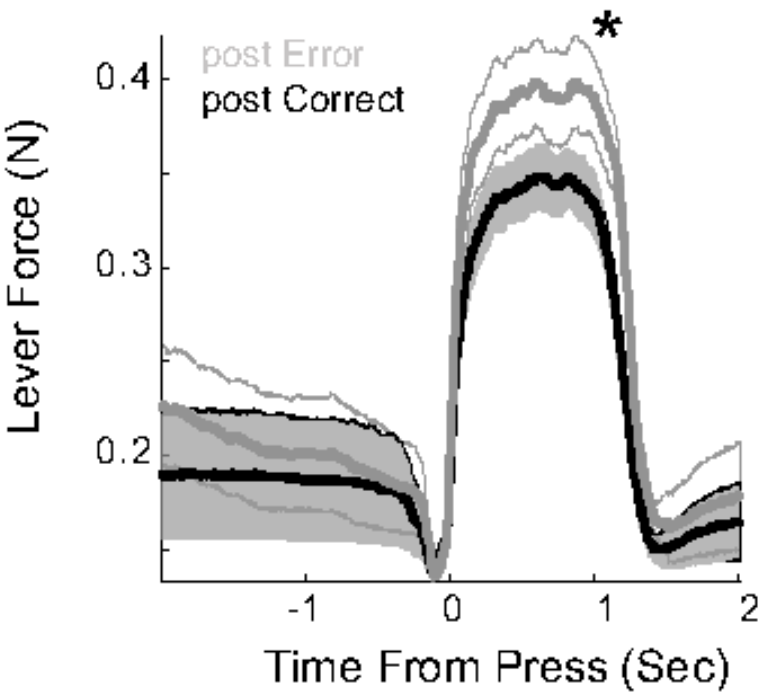


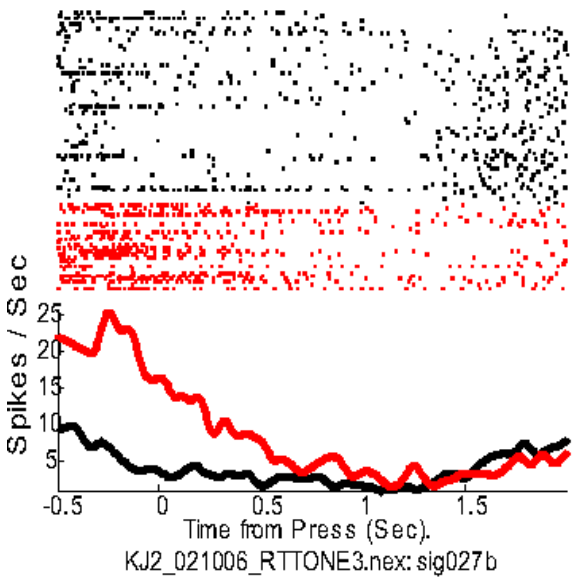


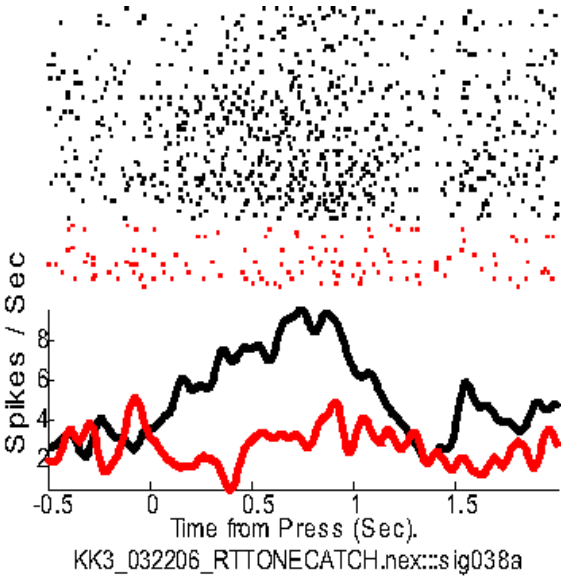
Sequential effects of trial outcome

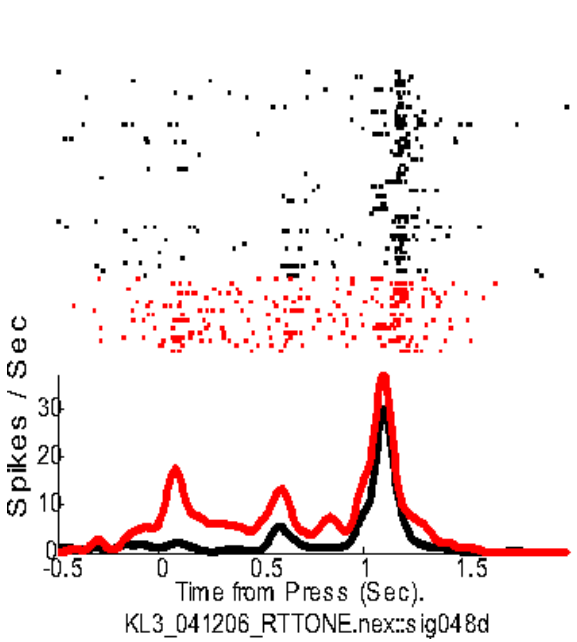


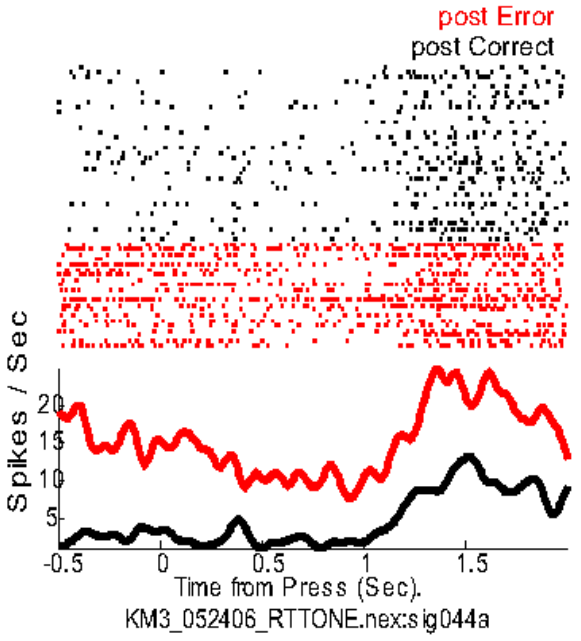


Sequential effects of trial outcome









Summary

- dmPFC inactivations impair the ability to wait for stimuli
- dmPFC activity controls delay period activity in motor cortex
- There is a subpopulation of dmPFC neurons that exhibit slow, persistent activity over the entire trial
- Some dmPFC neurons exhibit error/reward sensitivity and lasting effects of errors across trials

What is the role of dmPFC in the temporal control of action?

- Response inhibition
- Motor preparation
- Performance monitoring

What is the role of dmPFC in the temporal control of action?

- Response inhibition
- Motor preparation
- Performance monitoring
  - Rules (How long to wait)
  - Response-Reward Association
  - Recent reward history

Temporal control of action

Future directions of our research

- Model persistent activity and examine effects of task parameters and reward history.
- Quantitative analysis of behavioral and neuronal data: Effects of reward history.