

# Neural codes for endogenous and exogenous attention in medio-dorsal pulvinar, LIP, and FEF



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## Motivation

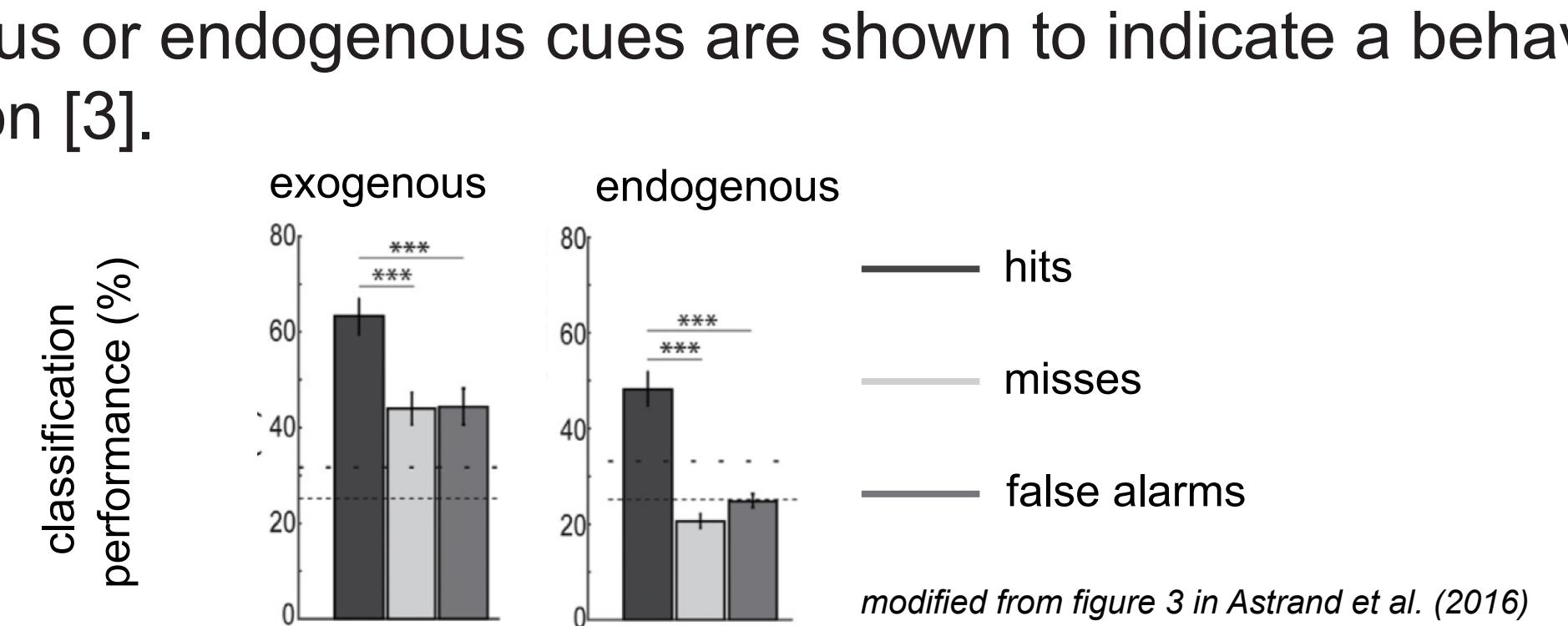
**exogenous attention:**  
involuntary, transient

**endogenous attention:**  
voluntary, sustained

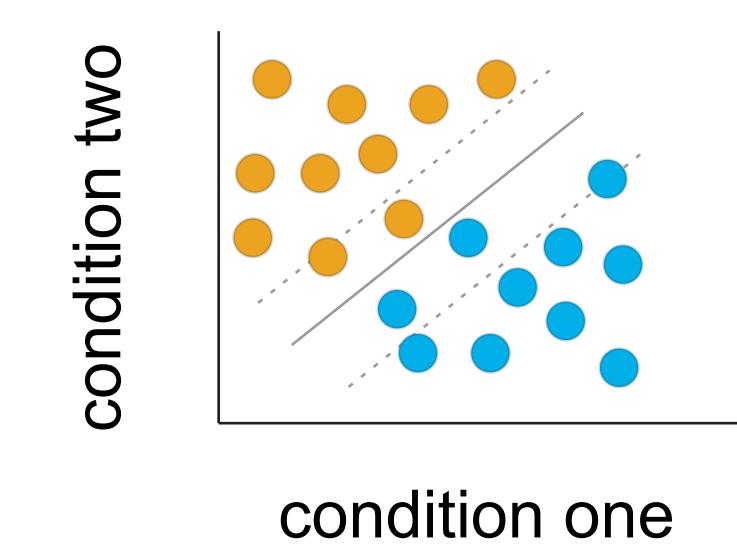
Endogenous and exogenous attention both facilitate the selection and processing of information in the environment but operate on different time scales [1].

Neural activity in LIP, FEF, and medio-dorsal pulvinar (mdPul) modulate during exogenous attention [2].

Multunit activity in FEF has been shown to closely follow the location of attention when exogenous or endogenous cues are shown to indicate a behaviorally relevant location [3].



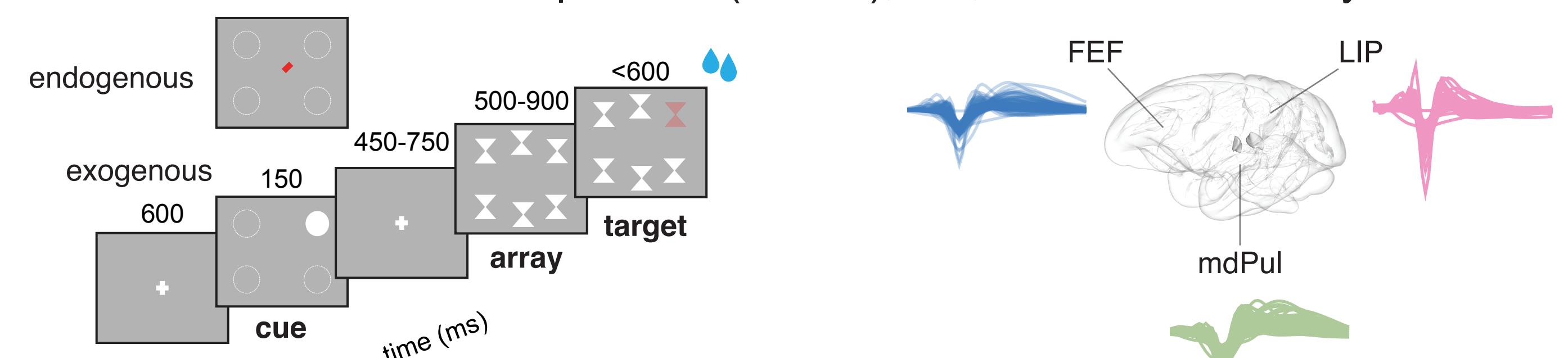
Machine learning classifiers offer an opportunity to study if task-relevant information is present in neural data, and if that information is shared across task conditions or neuronal populations.



**Hypothesis:** Cue location information is distributed differently across pulvinar and cortex when attention is cued exogenously and endogenously.

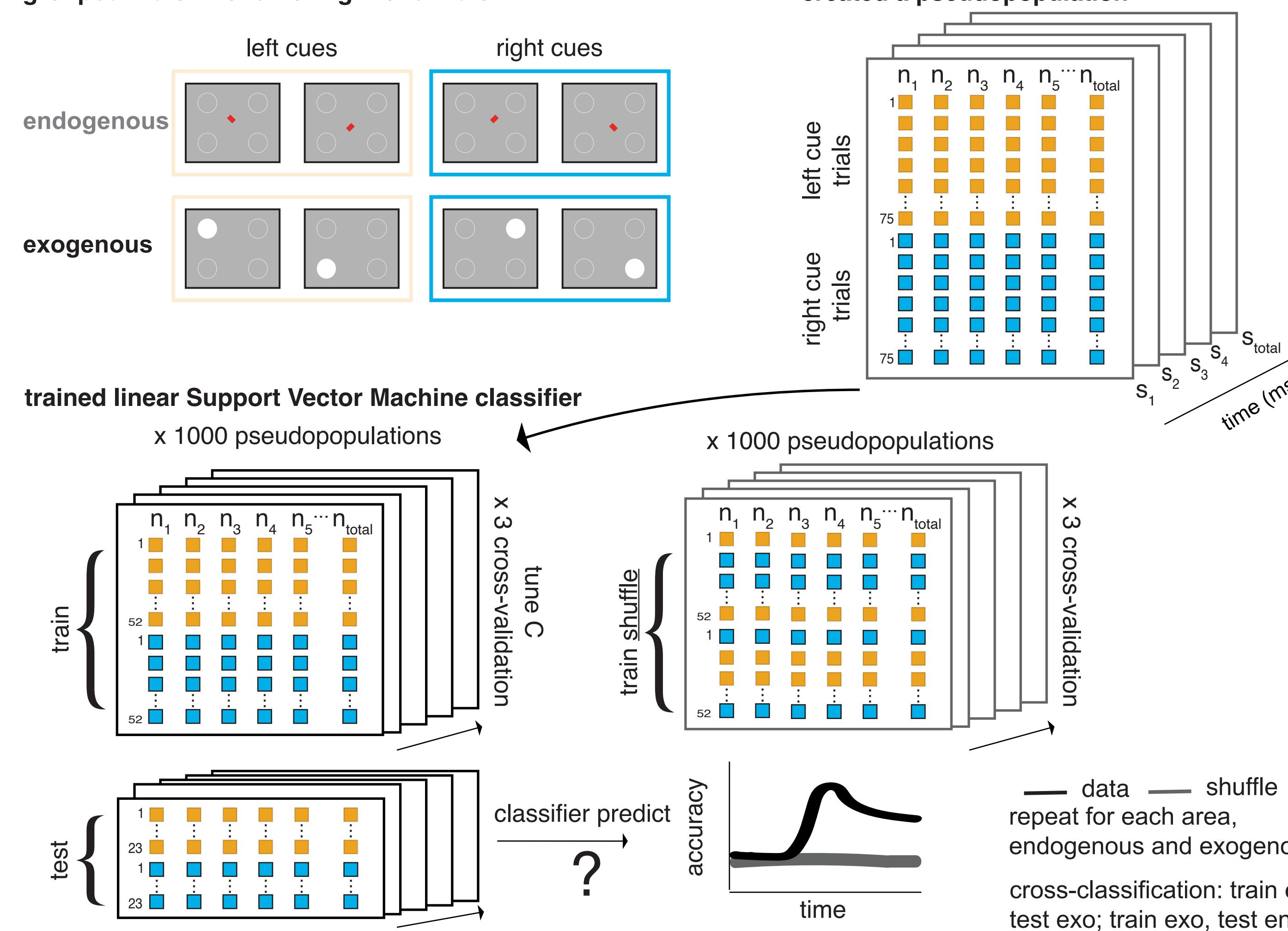
## Methods

Multicontact electrode arrays (Plexon, V-Probe) were inserted into medio-dorsal pulvinar (mdPul), LIP, and FEF each day.

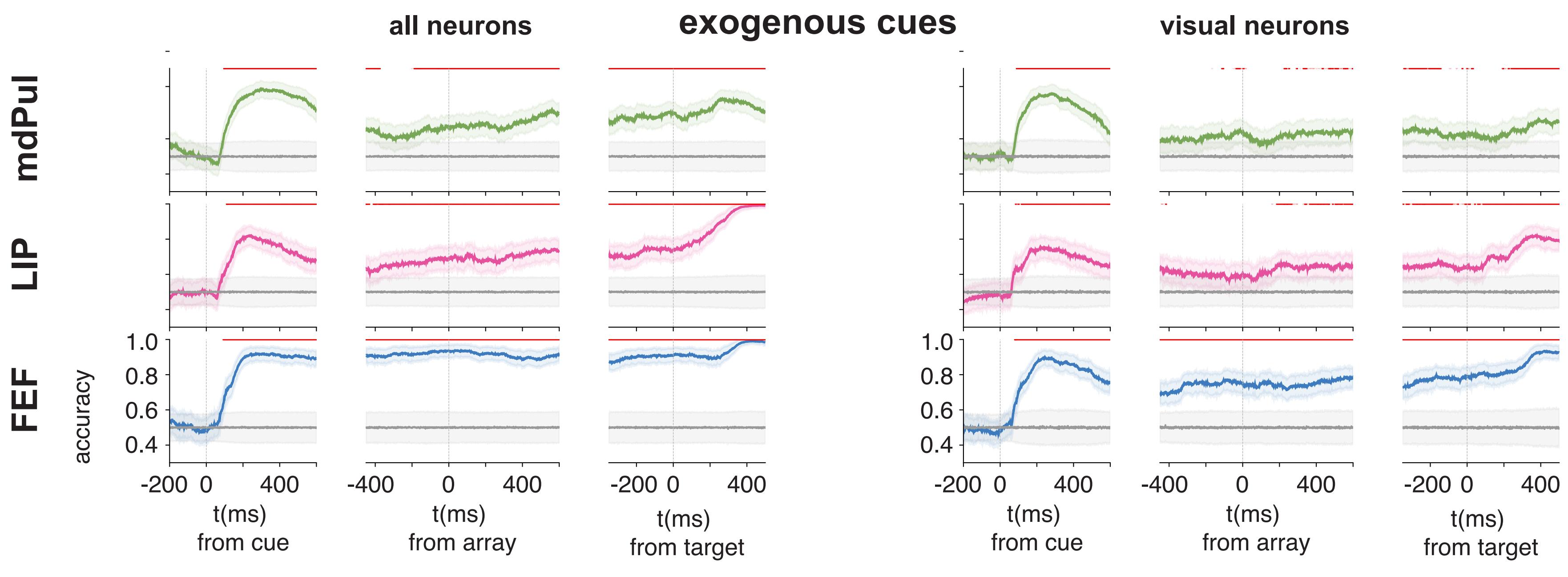


Single neuron activity was decoded to investigate which neuron populations carried information about the location of endogenous and exogenous cues.

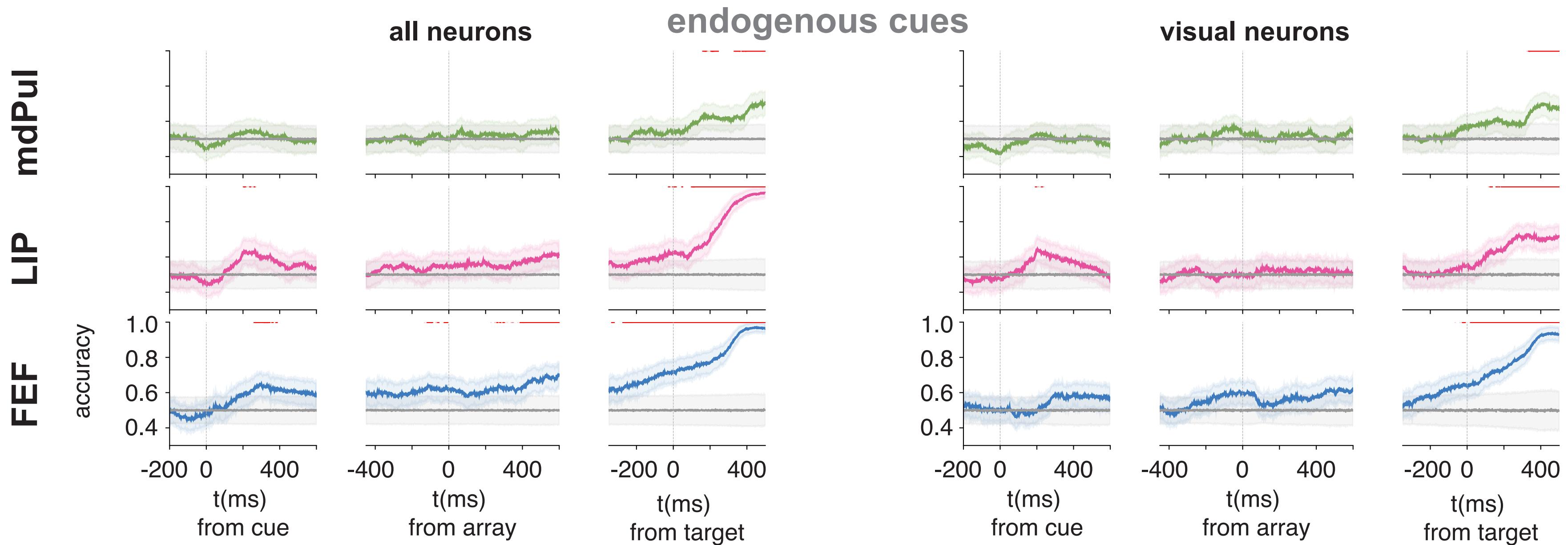
grouped trials into left or right cue trials



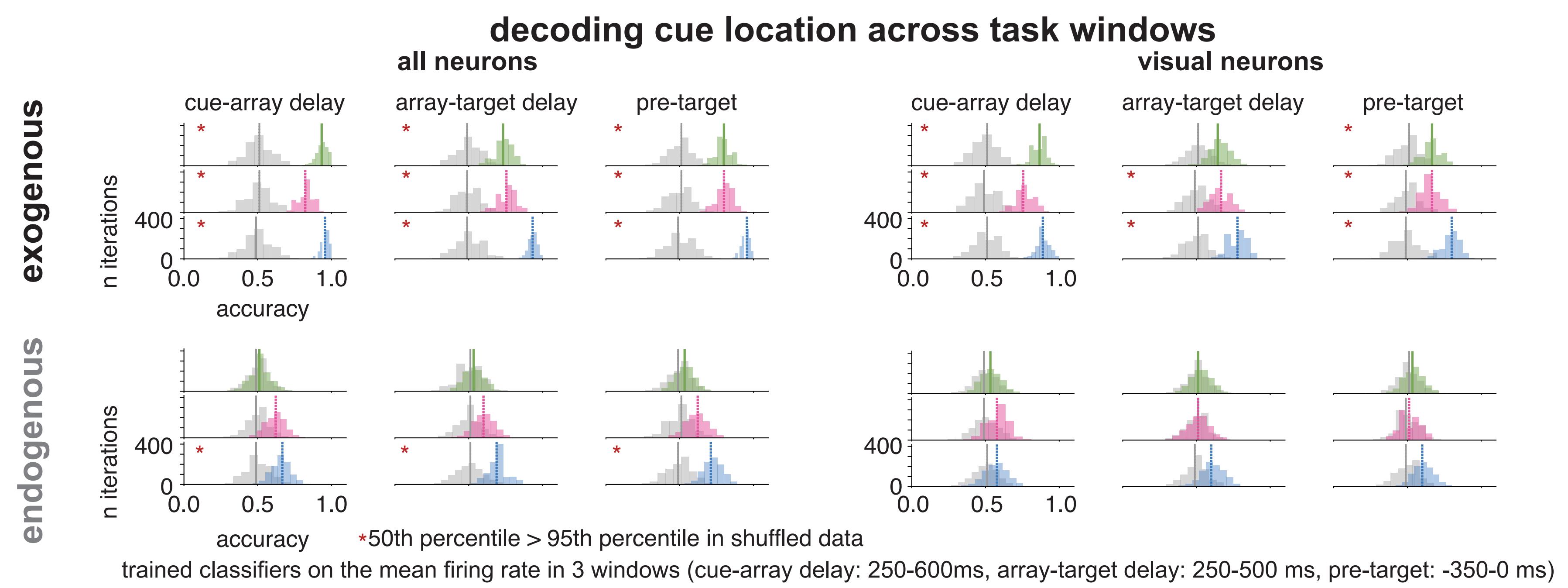
## Cue location information is different across mdPul, FEF, and LIP



Exo cue location info is most prominent and sustained throughout the full trial in FEF.

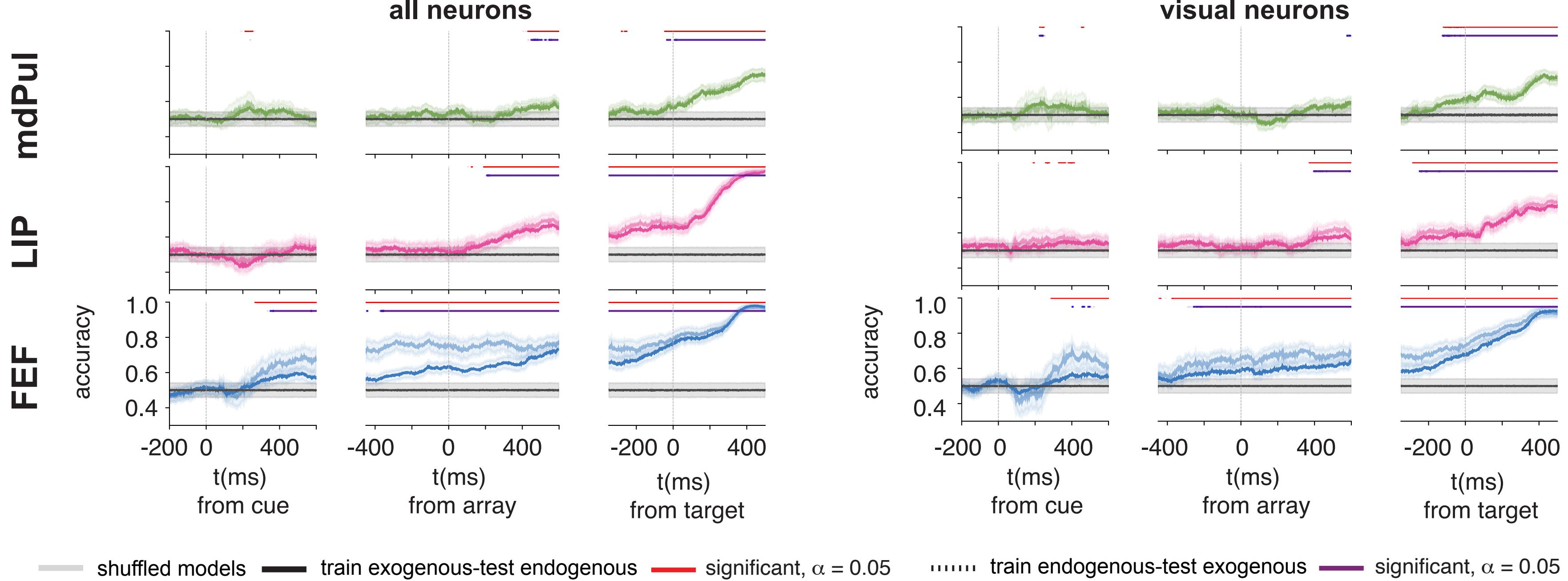


Endo cue location info is present during selection in LIP and FEF, and is sustained during the delay in FEF.



FEF carries cue location information for both exogenously and endogenously cued trials.  
All neurons carry cue location information for exogenously cued trials.

## Generalization of exogenously cued and endogenously cued attention



Exogenous and endogenous cue information is shared throughout the trial in FEF.

There is some evidence for shared information during the array-target delay in LIP and mdPul as well.

## Results

### Attention modulation of visual neurons



## Summary

Neuron populations in mdPul, LIP, and FEF carried information about cue location when the cue was presented exogenously. This information was present following the onset of the cue and was sustained during the cue-array delay (no salient stimulation following cue offset) and during the array-target delay (salient display prior to target onset).

Neuron populations in FEF carried information about cue location when the cue was presented endogenously. The onset of this information was ~300 ms following cue onset, in line with estimates of how long it takes for endogenous attention to be deployed [1].

Classifiers trained to decode the location of endogenous cues from FEF neuron populations generalized to decode the location of exogenous cues and vice versa following cue onset (> 300 ms). This generalization was also present prior to target onset for LIP populations.

The finding that FEF neuron populations represent the location of both exogenously and endogenously presented cues aligns well with the work in Astrand et al. (2016).

## References and Acknowledgments

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2. Fiebelkorn, I.C., Pinsk, M.A., and Kastner, S. (2018). The mediiodorsal pulvinar coordinates the macaque fronto-parietal network during rhythmic spatial attention. *Nature Communications*
3. Astrand, E., Wardak, C., Baraduc, P., and Ben Hamed, S.(2016). Direct two-dimensional access to the location of covert attention in macaque prefrontal cortex. *Current Biology*

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