Data-driven, model-optimized stimuli to probe visual projection neurons in *Drosophila*

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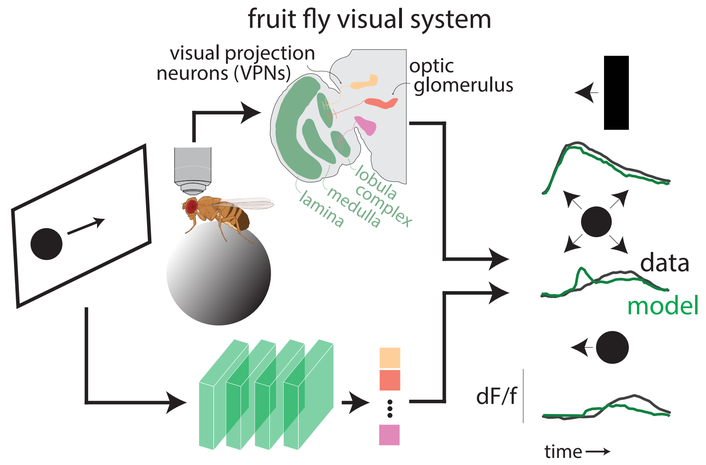
Motivation

• Visual projection neurons (VPNs) form a bottleneck between the optic lobe and central brain.

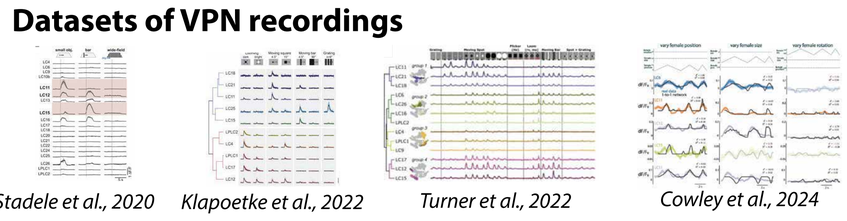
• Recent studies have recorded from VPNs to a battery of stimuli. We seek to determine to what extent computational models predict these responses

• We find deep neural network (DNN) models are predictive. However, current stimuli are too impoverished to tell models apart.

Data-driven and task-driven DNN models to predict visual projection neurons

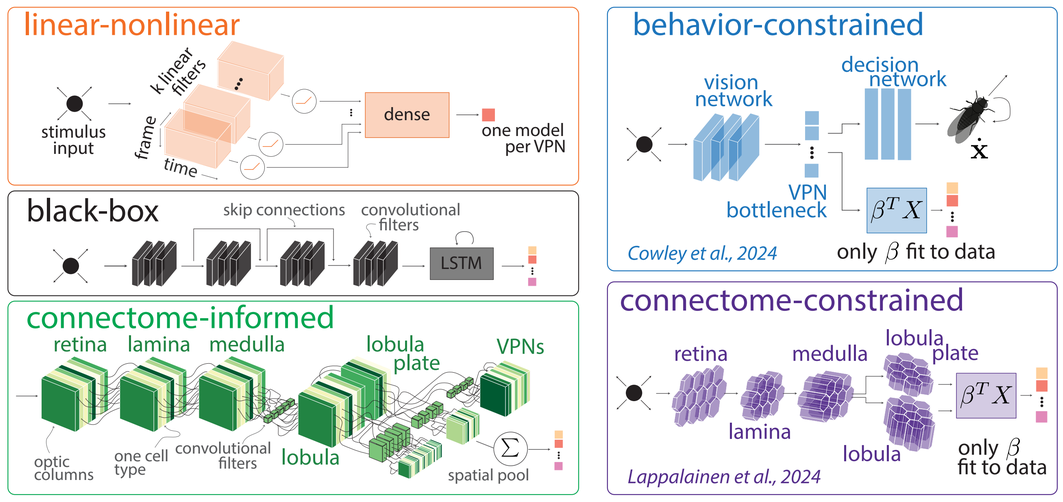


Datasets of VPN recordings

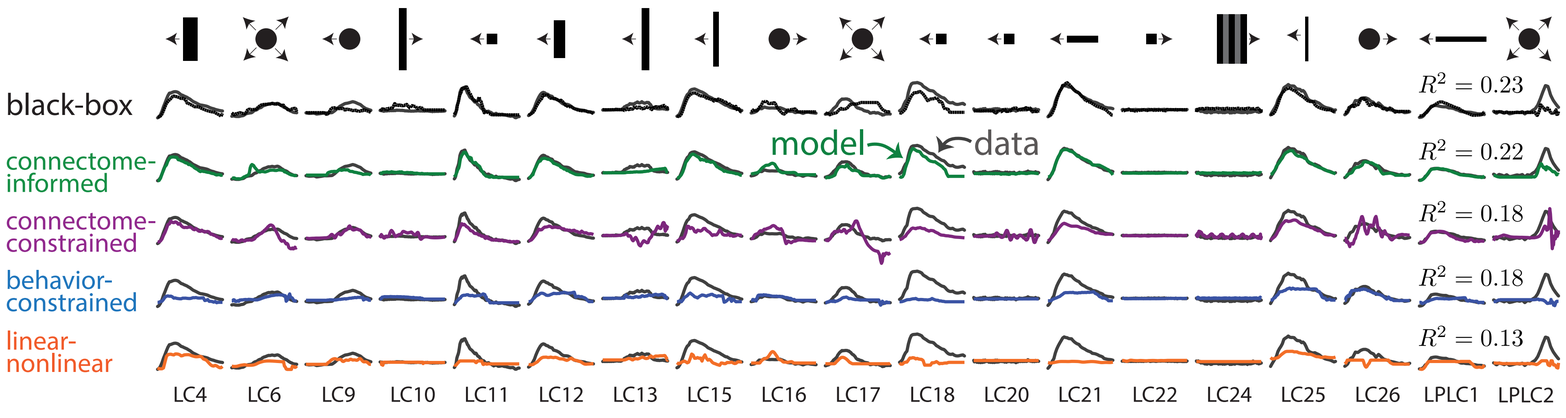


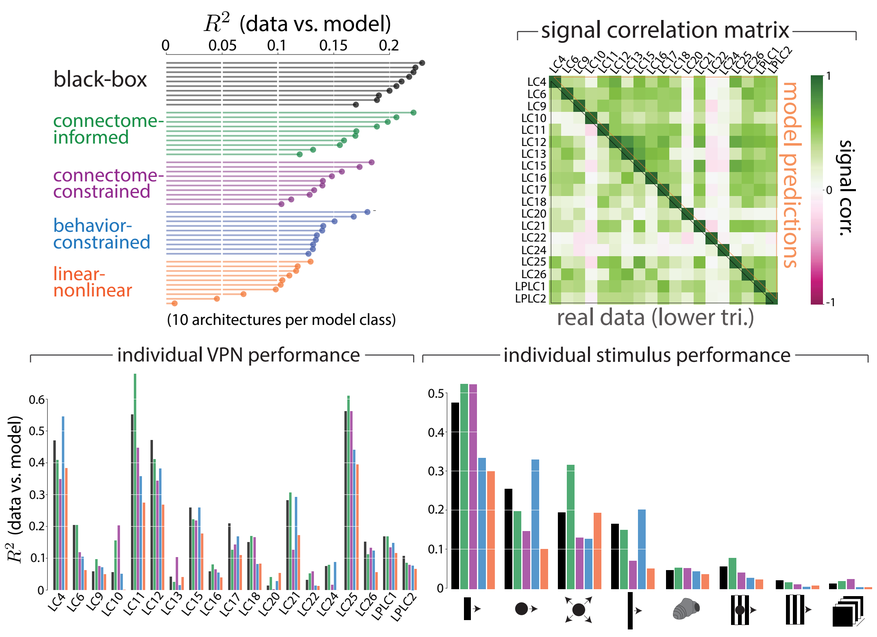
Stadele et al., 2020 *Klapoetke et al., 2022* *Turner et al., 2022* *Cowley et al., 2024*

classes of models



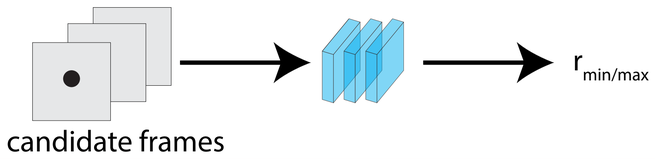
Prediction performance across model classes, VPN cell types, and stimuli





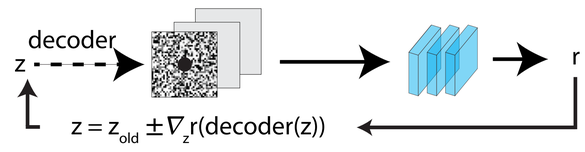
Model-optimized stimuli to probe stimulus preferences of VPNs

optimization 1: greedy frame-by-frame



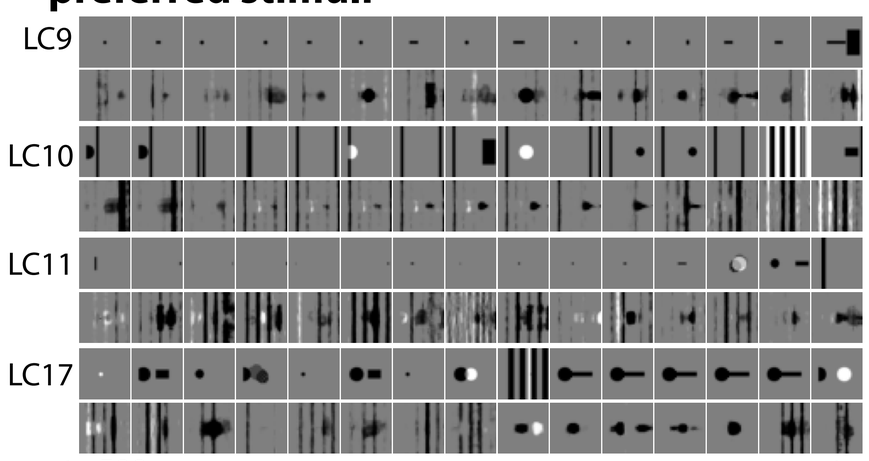
Greedily choose each frame from 100k candidate stimulus frames.

optimization 2: synthesize all frames at once via latent embedding

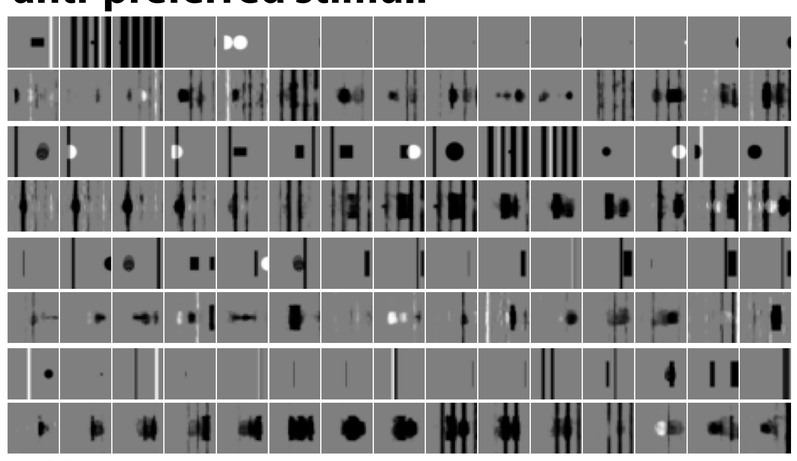


Update stimulus by sending gradient to latent stimulus embedding (obtained via a VAE).

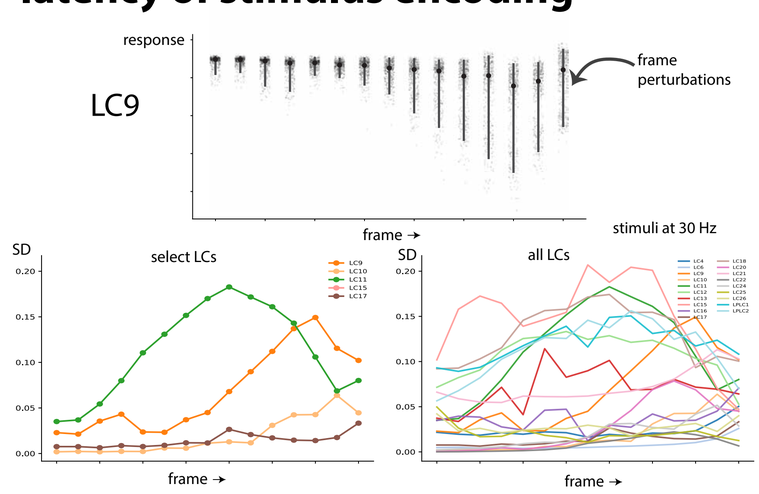
preferred stimuli



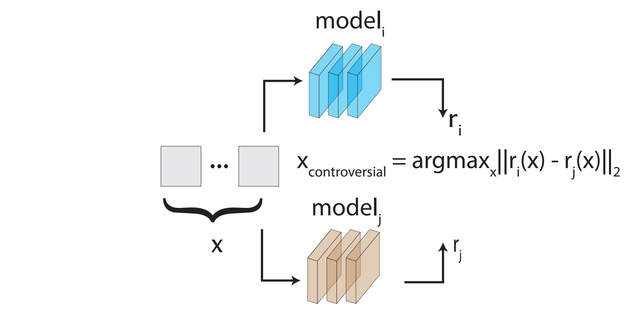
anti-preferred stimuli

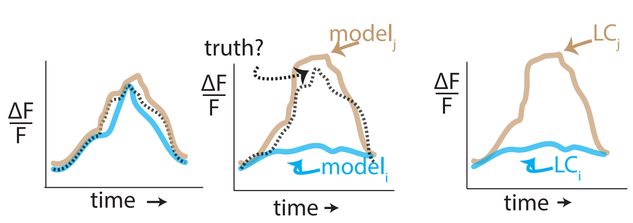


latency of stimulus encoding

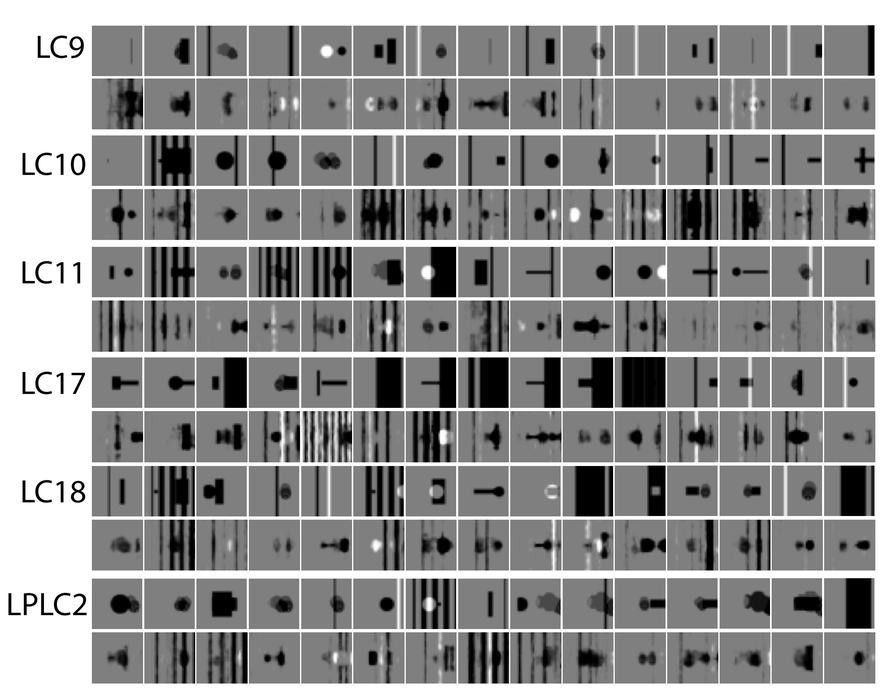


controversial stimuli

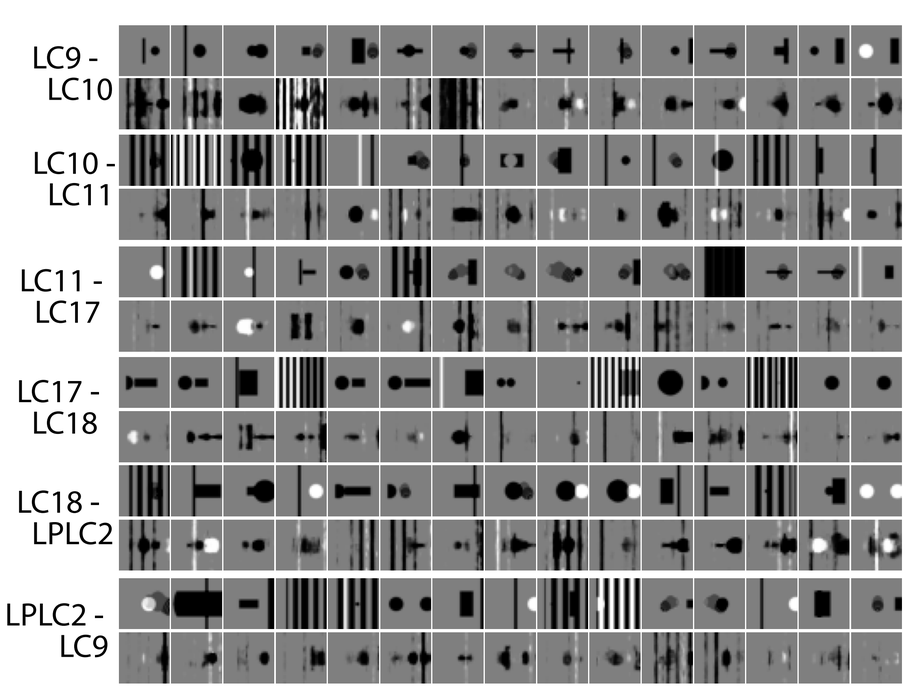




controversial stimuli between models



controversial stimuli between VPN types



Takeaways

• DNNs can accurately predict VPN responses to many standard artificial stimuli.
• Different model classes perform similarly on simplistic stimuli.
• Standard stimuli are insufficient to distinguish competing models/LCs.
• We generate stimuli to maximize LC preferences/anti-preferences, model/LC disagreement.
• Testing these stimuli enables principled model comparison and falsification.
• Controversial stimuli differentiate feature selectivity across LC types.
• Model-driven stimulus design could uncover new insights into visual feature encoding.

References

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