Thalamus conveys diverse contextual information to layer 1 of visual cortex 148.26

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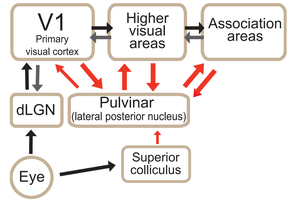
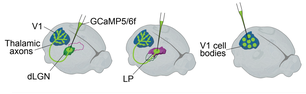
Sensory perception depends on context. Many models emphasise cortical feedback as the source of contextual modulation. However, **higher-order thalamic nuclei**, such as the pulvinar, interconnect with many cortical and subcortical areas, suggesting a role for the thalamus in providing sensory and behavioral context — yet the nature of the signals conveyed to cortex by higher-order thalamus remains poorly understood. We measured visual and behavioural information provided by the lateral posterior nucleus (**LP**; the **pulvinar** equivalent in the mouse) and **dLGN** axons **projecting to V1 in mice**.

We found that both LP and dLGN carry **locomotion signals**, but LP signals **discrepancies** between running and visual flow speeds.

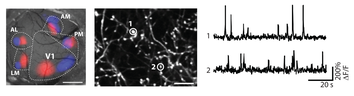
Methods

The lateral posterior nucleus (LP) in the mouse is the equivalent of the pulvinar in monkey. It receives a feed-forward input from the eye via the superior colliculus, and sends and receives inputs from primary visual cortex and most higher visual areas, as well as association areas.





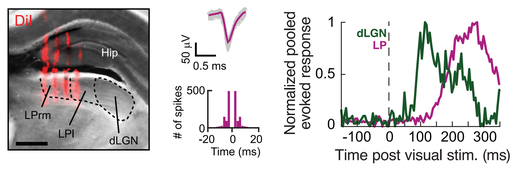
Injections of AAV1.Syn.GCaMP6f and AAV1.hSyn.GCaMP5G into dLGN or LP, or into V1



Intrinsic signal imaging to identify cortical areas, follwed by 2P calcium imaging of thalamic axons projecting to layer 1 of V1

Response latency in LP and dLGN

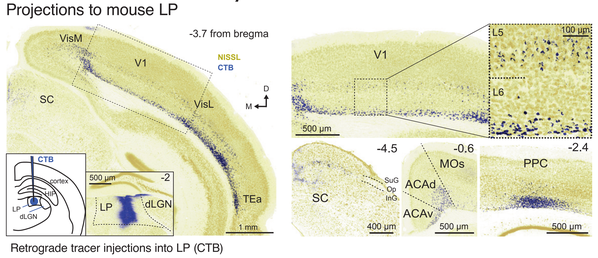
Electrophysiology in anesthetized mice



Visual response latency is longer in LP than in dLGN.

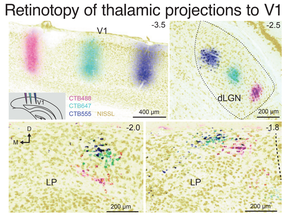
Thalamic connectivtiy

Projections to mouse LP



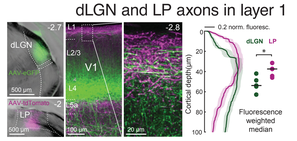
Retrograde tracer injections into LP (CTB)

Retinotopy of thalamic projections to V1



Multiple retrograde tracer injections into V1 (CTB)

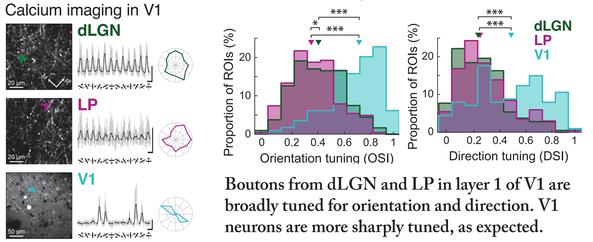
dLGN and LP axons in layer 1



Dual injections of anterograde tracers into LGN (AAV-GFP; green) and LP (AAV-tdTomato; red)

LP and dLGN boutons are broadly tuned

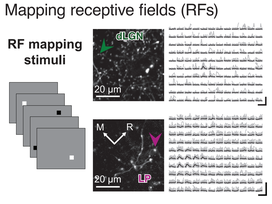
Calcium imaging in V1



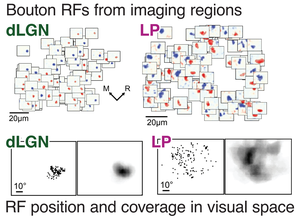
Boutons from dLGN and LP in layer 1 of V1 are broadly tuned for orientation and direction. V1 neurons are more sharply tuned, as expected.

LP boutons carry wide-field visual signals

Mapping receptive fields (RFs)

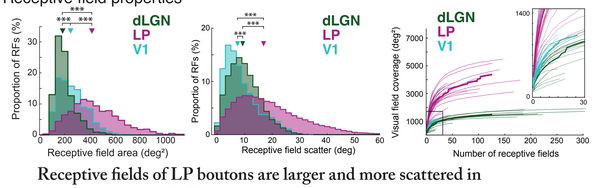


Bouton RFs from imaging regions



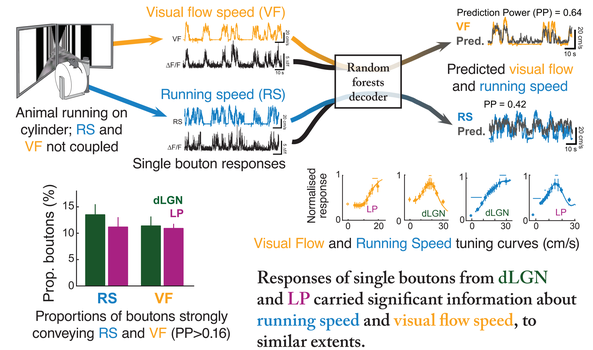
RF position and coverage in visual space

Receptive field properties



Receptive fields of LP boutons are larger and more scattered in visual space than dLGN boutons.

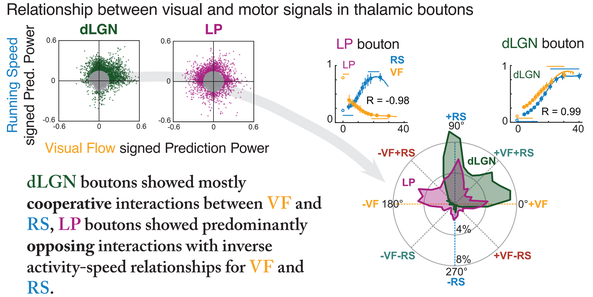
Both visual and motor signals found in dLGN and LP



Responses of single boutons from dLGN and LP carried significant information about running speed and visual flow speed, to similar extents.

Visuo-motor integration in dLGN and LP

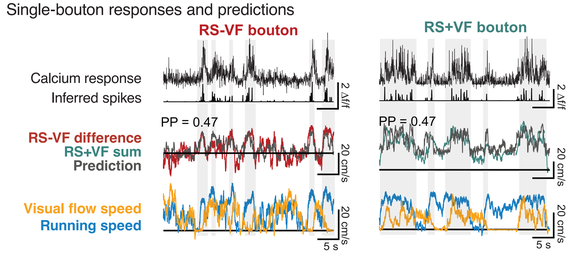
Relationship between visual and motor signals in thalamic boutons



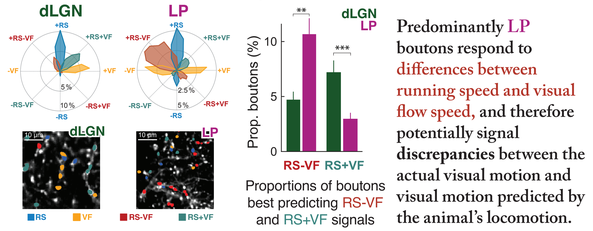
dLGN boutons showed mostly **cooperative** interactions between VF and RS, LP boutons showed predominantly **opposing** interactions with inverse activity-speed relationships for VF and RS.

Discrepancy signals are prevalent in LP

Single-bouton responses and predictions



Distribution of RS-VF and RS+VF signals between dLGN and LP

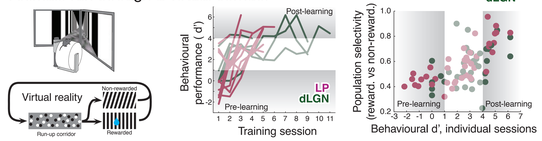


Proportions of boutons best predicting RS-VF and RS+VF signals

Predominantly LP boutons respond to differences between running speed and visual flow speed, and therefore potentially signal **discrepancies** between the actual visual motion and visual motion predicted by the animal's locomotion.

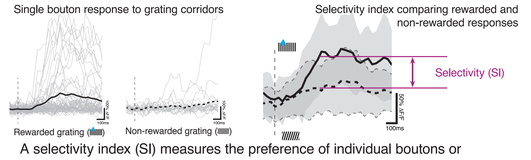
Acquisition of task-related signals

Animals run through a virtual corridor



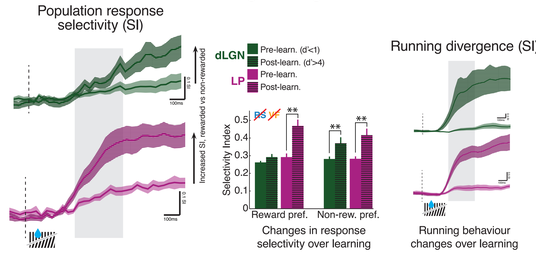
Animals learn to perform an orientation discrimination task over several training sessions. Decoding results allow us to **exclude** boutons modulated by running speed or visual flow from analysis.

Some boutons are selective for rewarded or non-rewarded stimuli



A selectivity index (SI) measures the preference of individual boutons or populations, for rewarded over non-rewarded stimuli.

Increase in selectivity over learning is stronger in LP than dLGN



Stimulus-selective responses **evolve faster** in LP than dLGN, in spite of longer latency in LP. Representations in LP increase in selectivity over learning, and selectivity is stronger than in dLGN.

Conclusions

- Inputs and targets of LP are comparable to pulvinar
- LP boutons are visually responsive, with large and broadly tuned receptive fields
- dLGN inputs to L1 are spatially precise
- Both dLGN and LP convey significant information about the animal's motor behaviour to V1
- Integrated visual and motor information is present in the thalamus
- LP signals discrepancies between visual and motor information
- Task-related contextual signals develop in the thalamus during learning

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