Thalamocortical interactions shape hierarchical neural variability during stimulus perception

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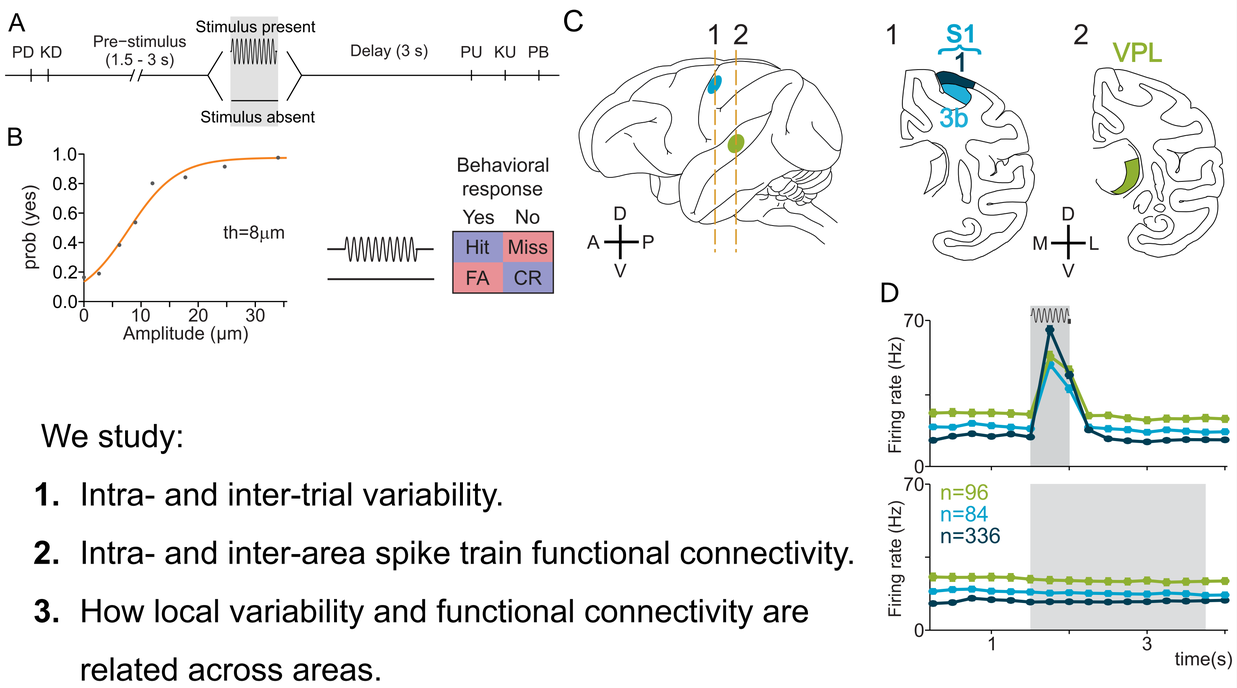
Introduction

Brain circuits require functional hierarchical diversification to efficiently process sensory signals. But, to what extent do **functional connections** within and across areas shape this **hierarchical order**? In order to ask this question, we analyze **simultaneously recorded neurons** with overlapping cutaneous receptive fields in the **somatosensory thalamus** (**VPL**) and **areas 3b** and **1** of the somatosensory **cortex**.

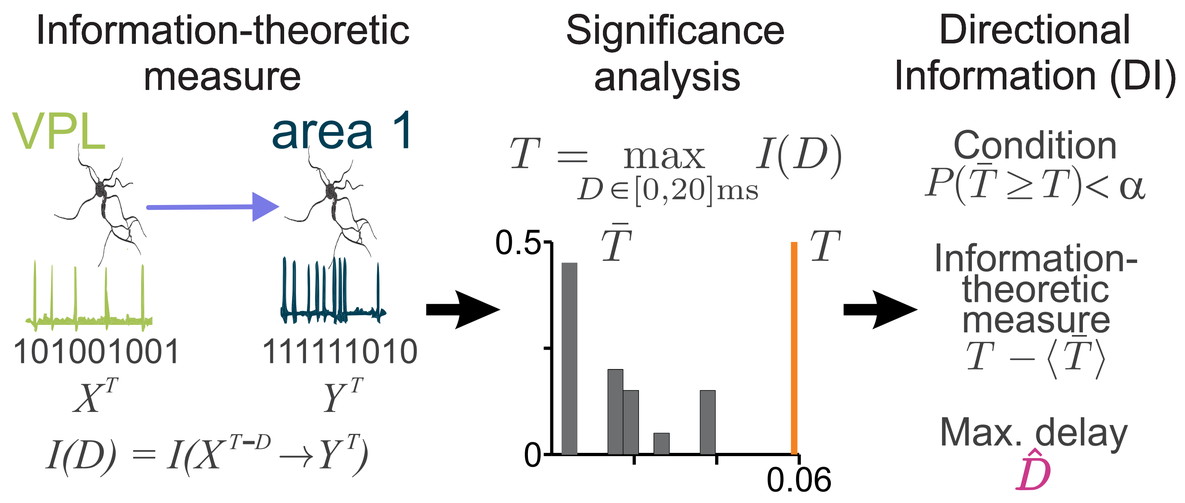


We study:

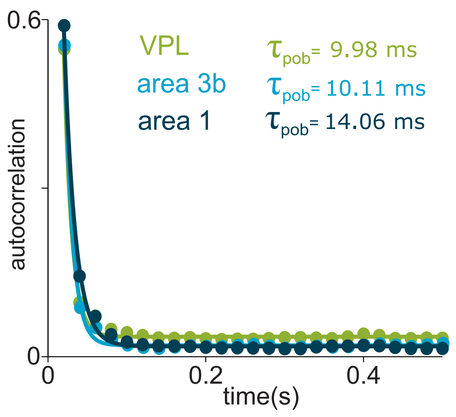
1. Intra- and inter-trial variability.
2. Intra- and inter-area spike train functional connectivity.
3. How local variability and functional connectivity are related across areas.

Methods

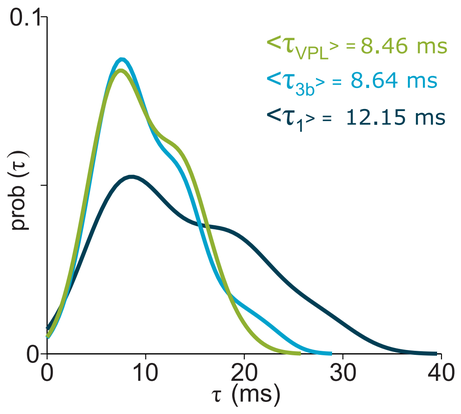
- 1ms resolution microarray spiking data from **4** trained **monkeys** (500+ neurons, 60,000+ trials).
- Within-trial temporal variability: **Intrinsic Timescale**
- Inter-trial variability: **Fano Factor**
- Estimation of **Directional Interactions**
  - nonlinear nonparametric method.
  - yields a significance assessment (0/1), statistic value, and maximizing delay.
  - accumulated significance across trials and across neurons for each area pair.



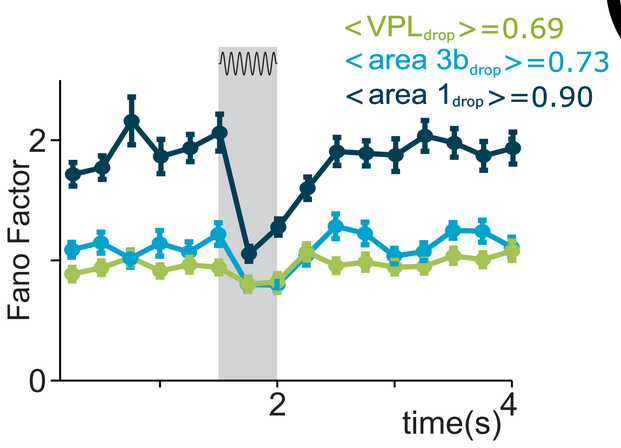
Intrinsic timescale: input integration pinpoints specific neural dynamics



- Distinct neural dynamics detected across regions within S1.



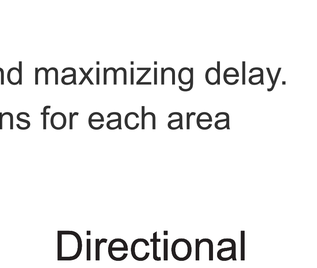
Fano Factor: coding efficiency correlates with hierarchy



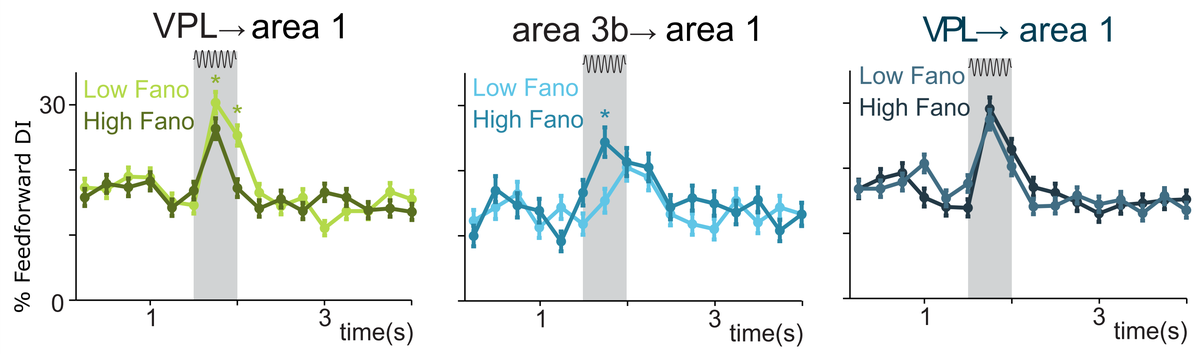
- Area 3b resembles VPL in terms of local integration and coding.
- Area 1 is characterized by a higher intrinsic variability.

Network information dynamics

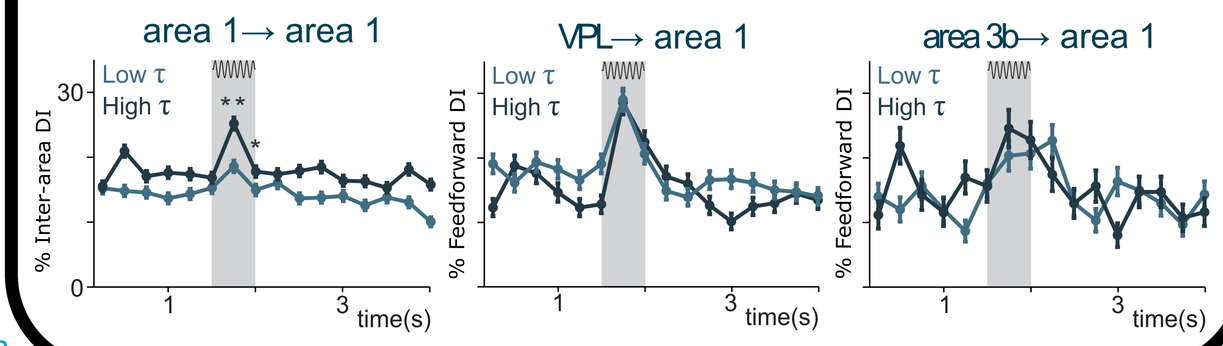
- Parallel feedforward pathways VPL- 3b and VPL- 1.
- Stimulus-driven intra-area interactions in area 1.
- Delay results contradict relay role hypothesis for area 3b to area 1.

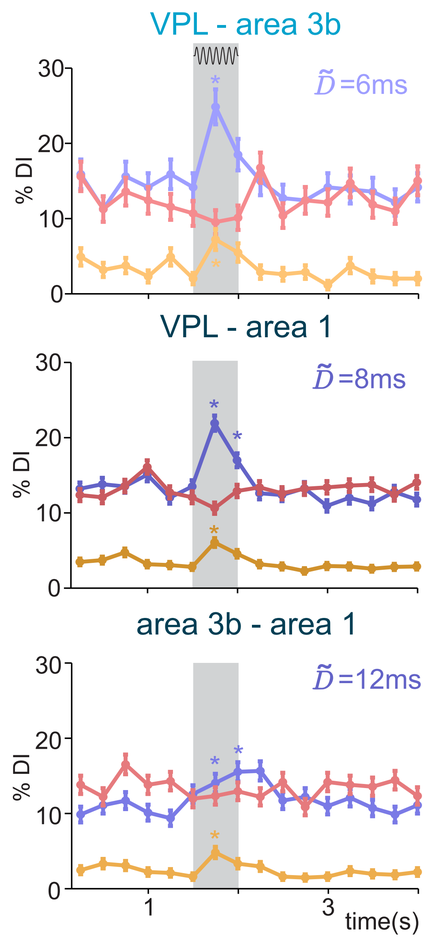


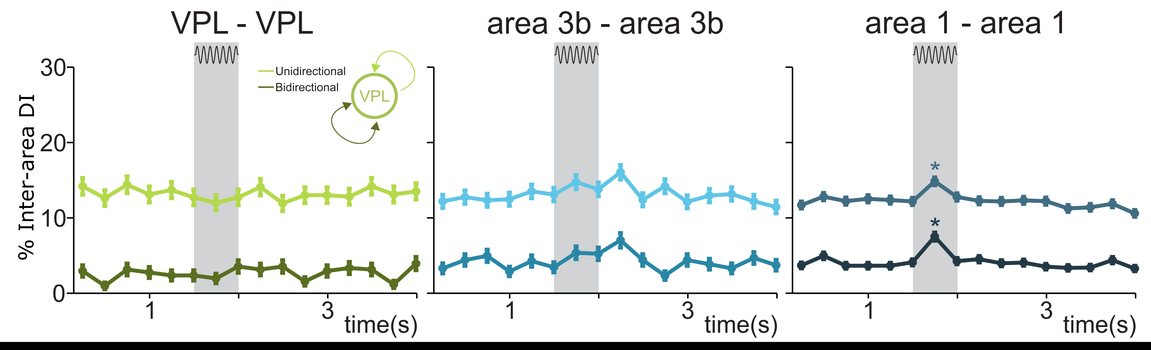
Feedforward interactions are related to the Fano Factor in VPL and area 3b



Timescales capture recurrent interactions in area 1







Conclusions

- Contrasting variability and functional connectivity measures unveils a **hierarchical order in the somatosensory network** and the **role of local variability** in neural interactions.
- We hypothesis that **local variability** of **VPL** and **area 3b** facilitates **feedforward** thalamocortical communication.
- **Higher variability** of **area 1** supports **intra-cortical** interactions during sensory processing.

References

DI inference code

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4. A. Tauste Campo, et al., Feed-forward information and zero-lag synchronization in the sensory thalamocortical circuit are modulated during stimulus perception. Proc. Natl. Acad. Sci. 116, 7513–7522 (2019).

Acknowledgements

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