Decoding orientation distributions from noisy observations in V1

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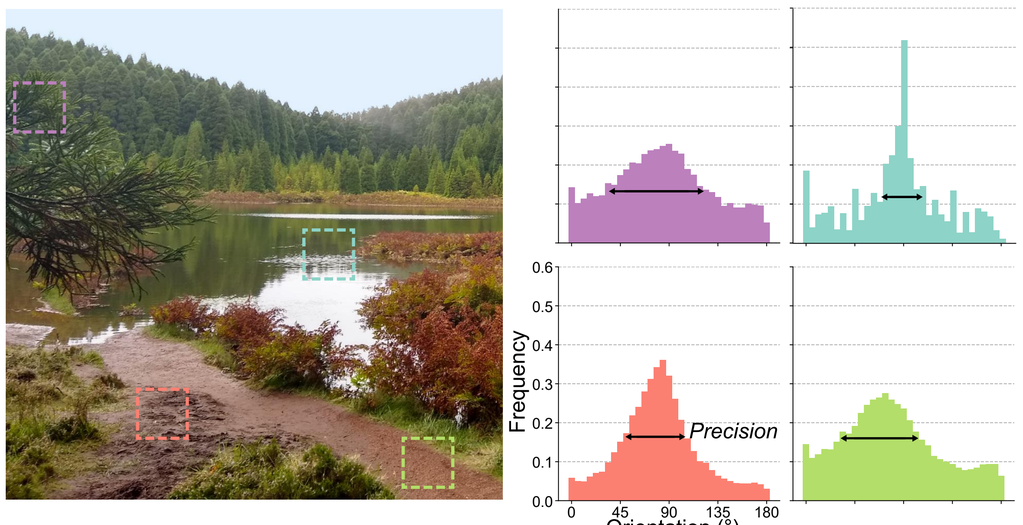
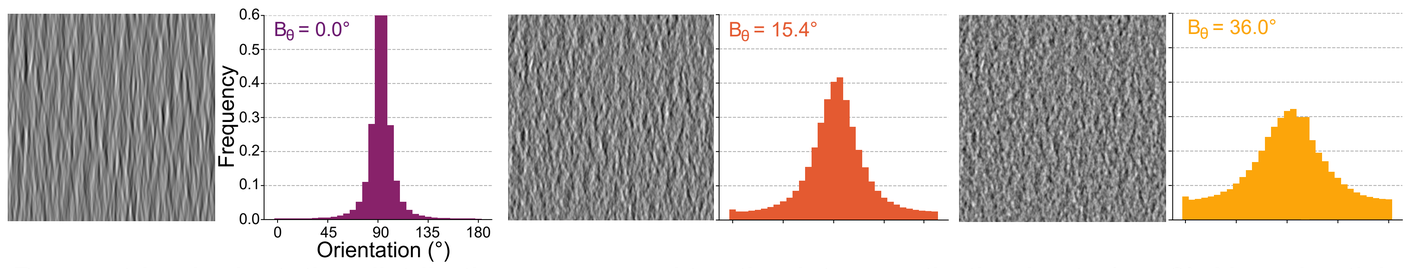
Introduction

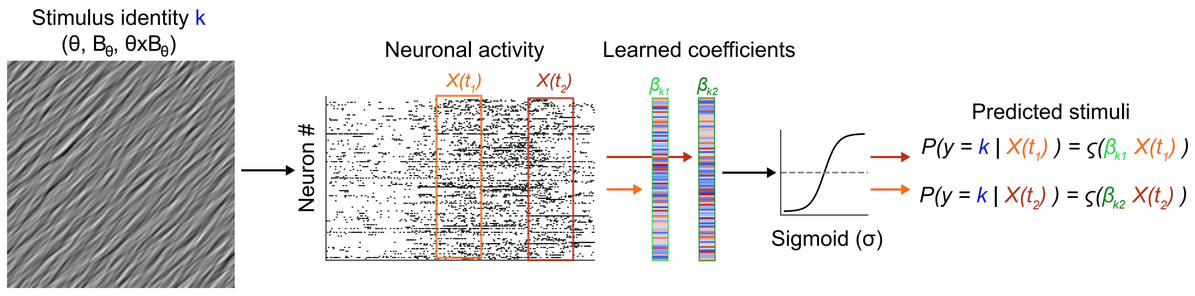


Our everyday visual environment is made of distributions of orientations. The bandwidth of these distributions represents the heterogeneity of the oriented input to V1. Broader bandwidths reduce the precision of the visual information. **How does V1 process the precision of the highly heterogeneous orientation distributions found in natural images ?**

Materials and Methods

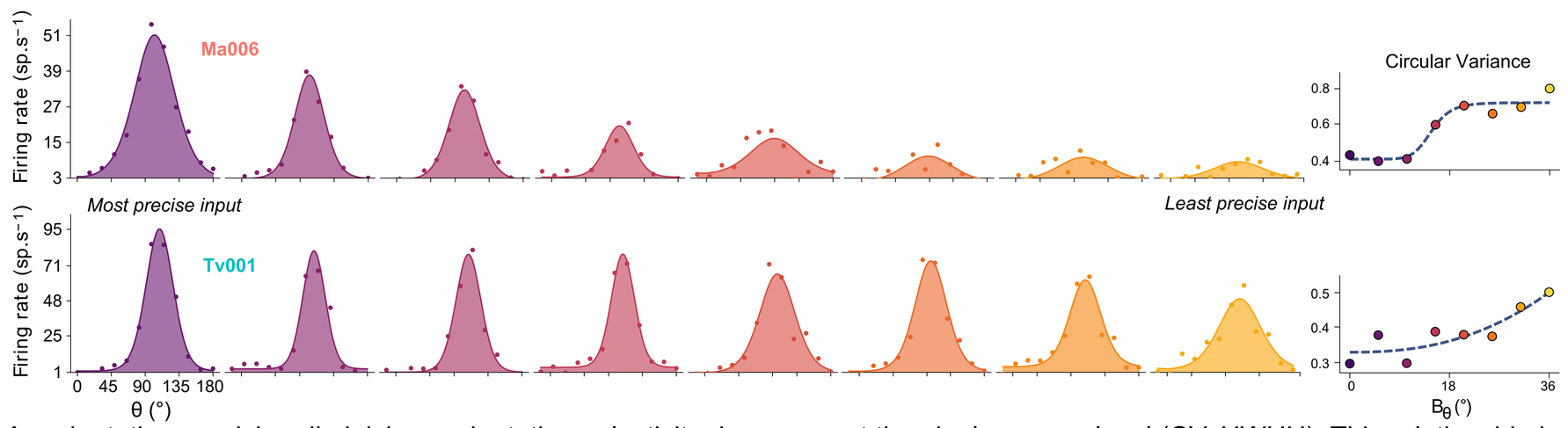


Parametrized orientation distributions were used to stimulate anesthetized cats (n = 3). Neural activity was recorded for 12 orientations θ and 8 precisions B_θ in 249 neurons with 32 channels electrodes.

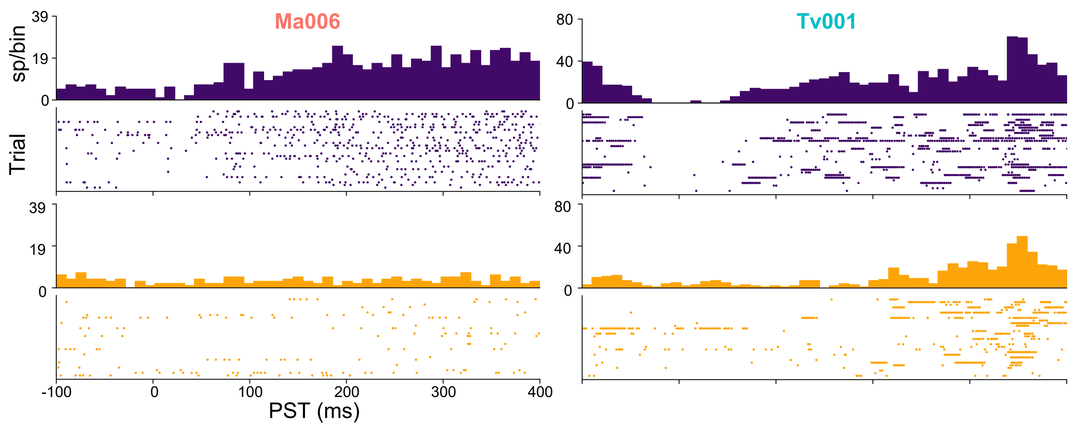


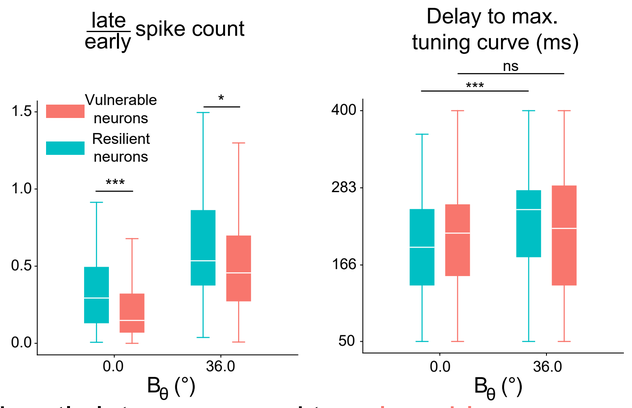
A multinomial logistic regression was used to decode the population activity and infer the identity of the stimulations. Coefficients β_k were learned from the activity of all neurons in a 100ms sliding window.

Results 1 : Single neuron dynamics



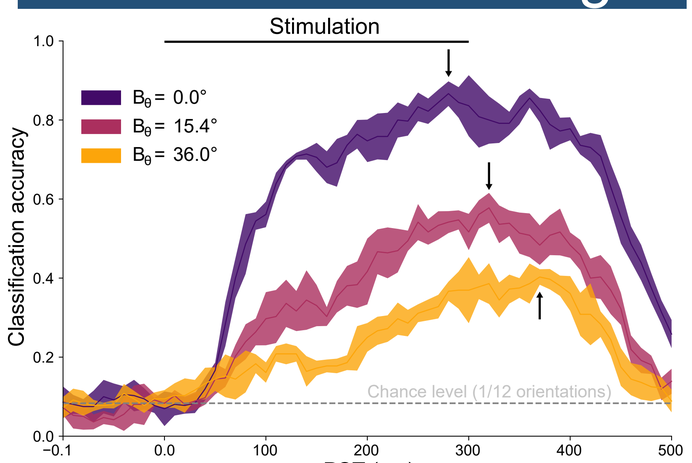
As orientation precision diminishes, orientation selectivity decreases at the single neuron level (CV, HWHH). This relationship is captured by a Naka-Rushton function, revealing heterogeneous modulations between neurons at the population level. Neurons still significantly tuned (Hotelling T^2) when B_θ=36.0° were described as resilient, as opposed to vulnerable, untuned neurons.



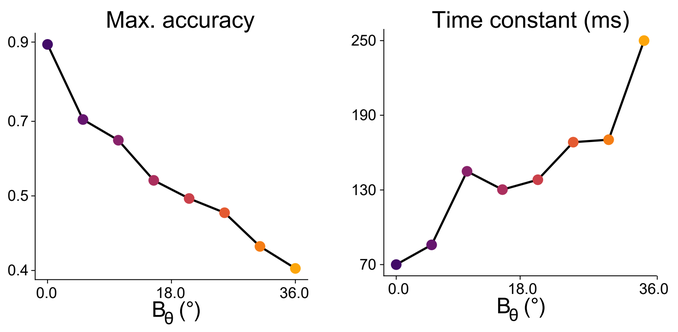


Resilient neurons have a sharper tuning when B_θ=0.0°. Furthermore, they fire significantly later compared to vulnerable neurons. Accordingly, their orientation tuning displays a slow dynamic, which can take up to a few hundred miliseconds to peak.

Results 2 : Decoding θ

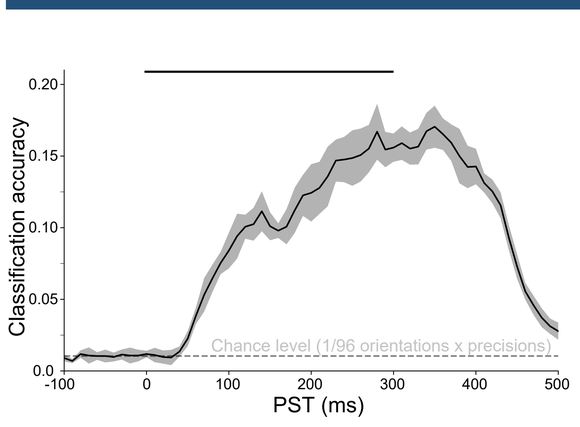


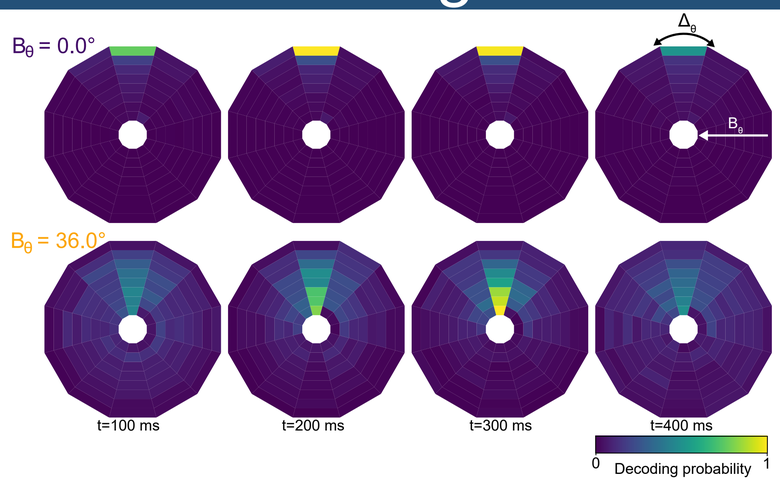
θ can be read-out from the population with great accuracy at all B_θ. The 26% of neurons that are resilient allow a 5x chance level decoding when B_θ=36.0°. At this precision, maximum accuracy is reached in more than 300ms, in stark contrast with the usual very fast dynamics of V1.



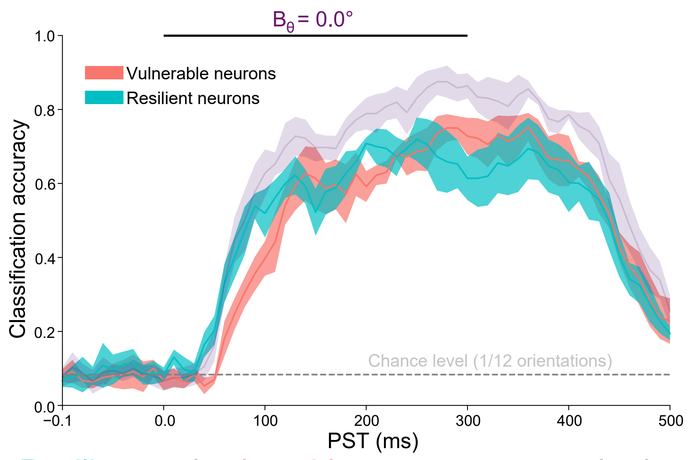
Decreasing precision causes a linear decrease of maximum accuracy and a quasi-linear increase in computation time required to reach it.

Results 3 : Decoding θ and Bθ

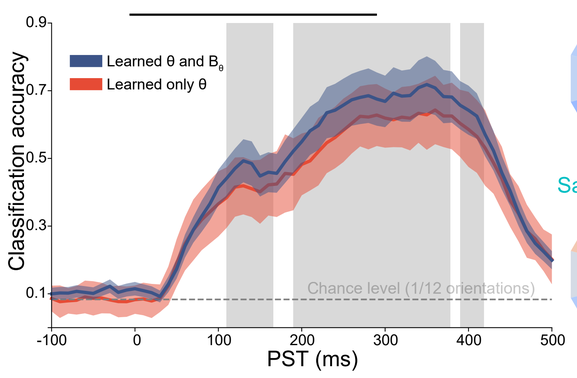




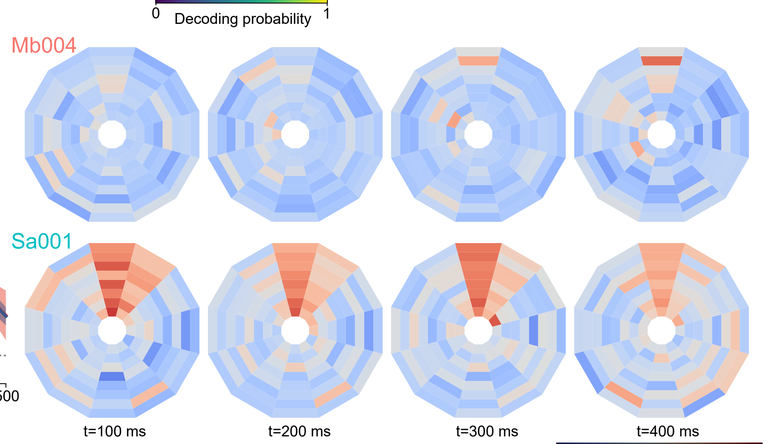
Simultaneous decoding of orientation and precision reaches 18x chance level. However, for high B_θ, the angular error of the decoder Δ_θ increases, as well as the ambiguitiy on the B_θ identity of the sensory input. Thus, what might be the advantage for V1 to encode precision ?



Resilient and vulnerable neurons are required to reach the maximum accuracy at B_θ=0.0°. Conversely, resilient neurons are performing the majority of the decoding when B_θ=36.0°.



Co-encoding both θ and B_θ increases significantly the orientation encoding performances of V1.



The ambiguity on precision is observed in the individual neurons weights.

Vulnerable neurons encode only θ, while resilient neurons perform a multiplexing of θ and B_θ.

Preprint & references

https://www.biorxiv.org/content/10.1101/2021.03.30.437692v3

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