Experience dependent plasticity of orientation tuning of synaptic inputs onto V1 neurons

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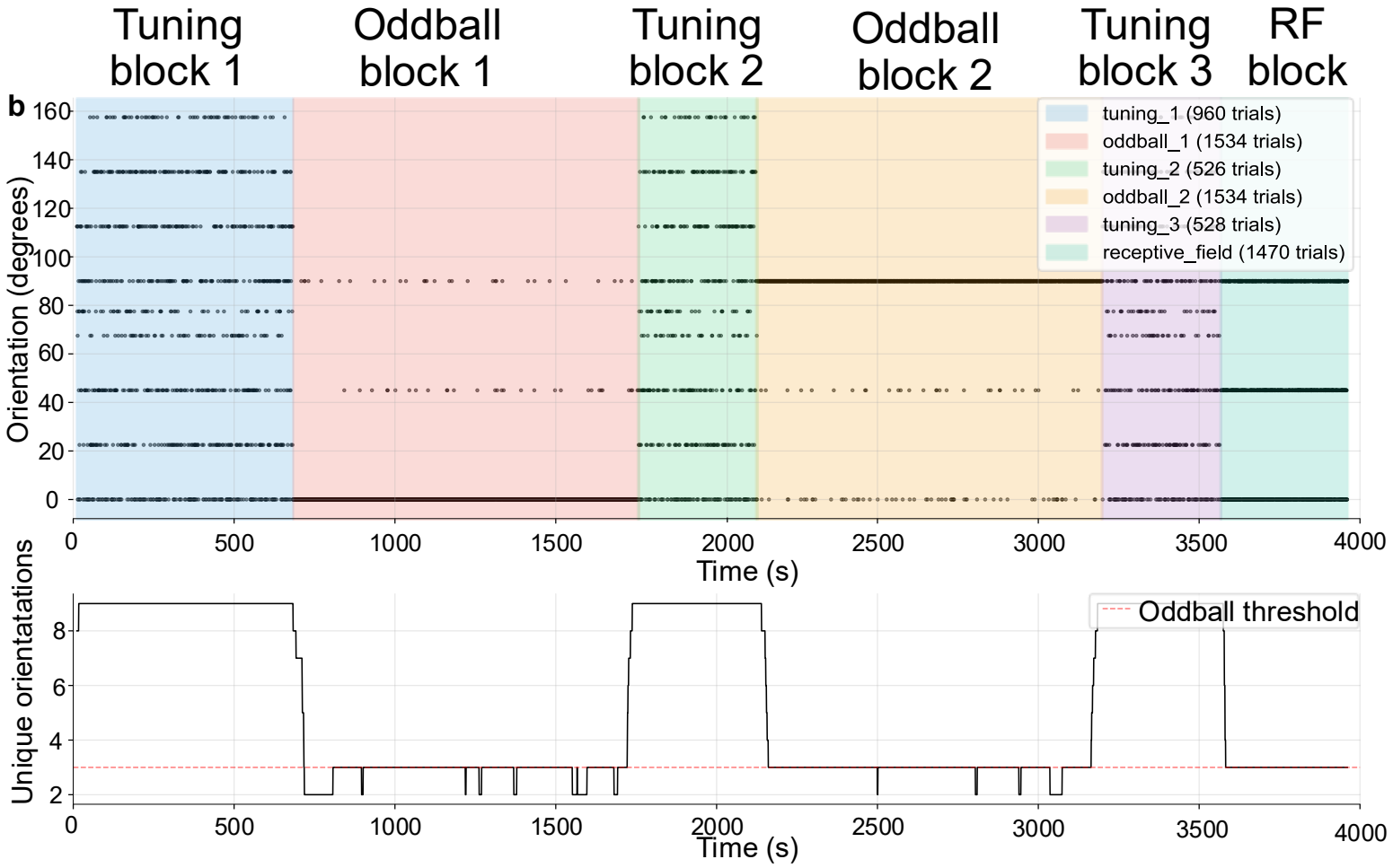
Do oddball blocks cause lasting changes in orientation selectivity?



- *Orientation-selective responses in V1 vary with stimulus context, shown by stimulus specific adaptation (SSA) and deviance detection (DD) in the oddball paradigm (Hamm et al., 2021)*

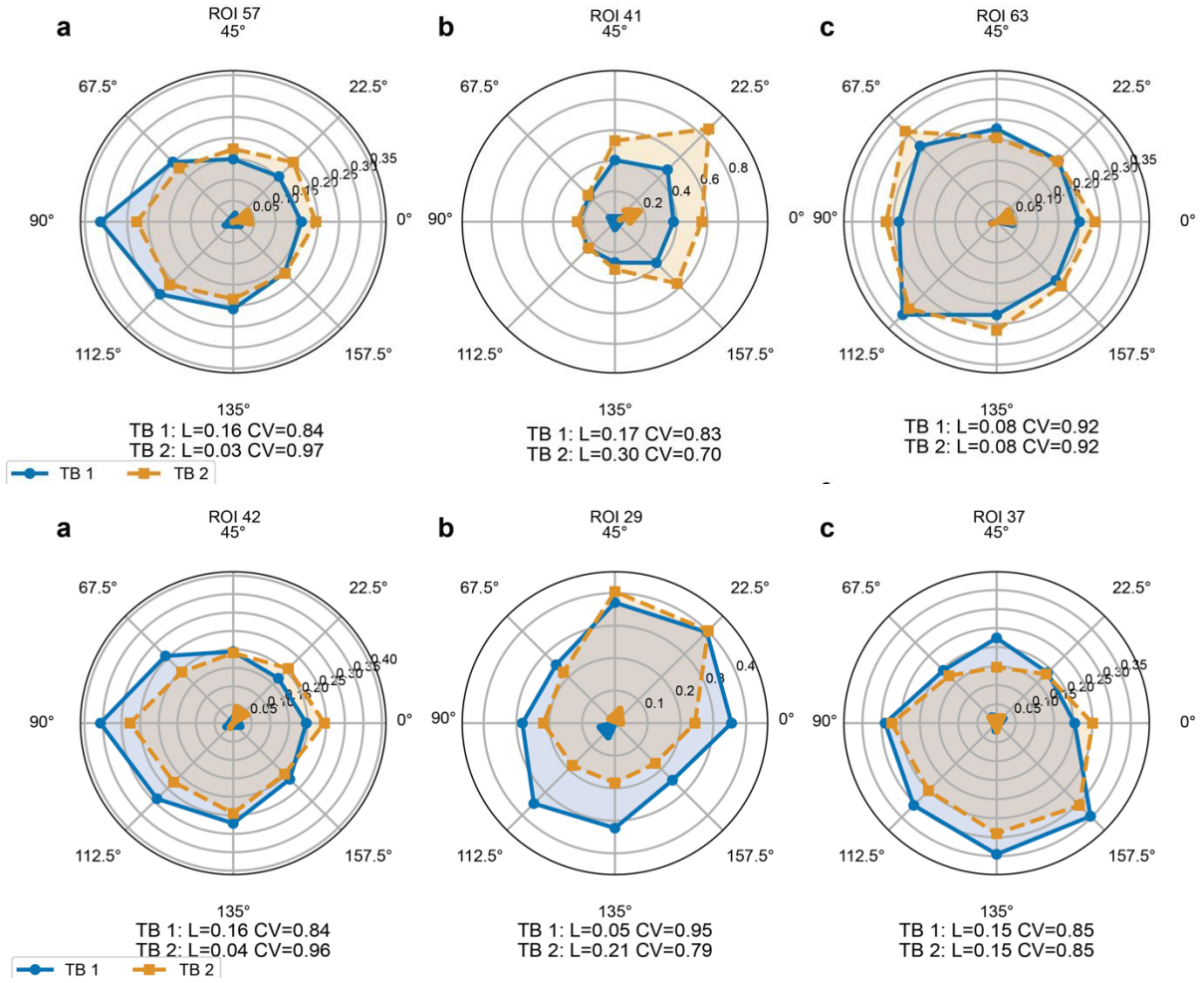
Disclaimer

Modalities (glutamate and calcium) and cell types (pyramidal and VIP) were pooled in the across-subject analysis due to small subject numbers

Levels of analysis:

1. Example ROIs (individual synaptic inputs)
2. ROIs in one dendrite (ROI population within a session)
3. Across neurons (subject level)

Does tuning strength and preferred orientation change across blocks?



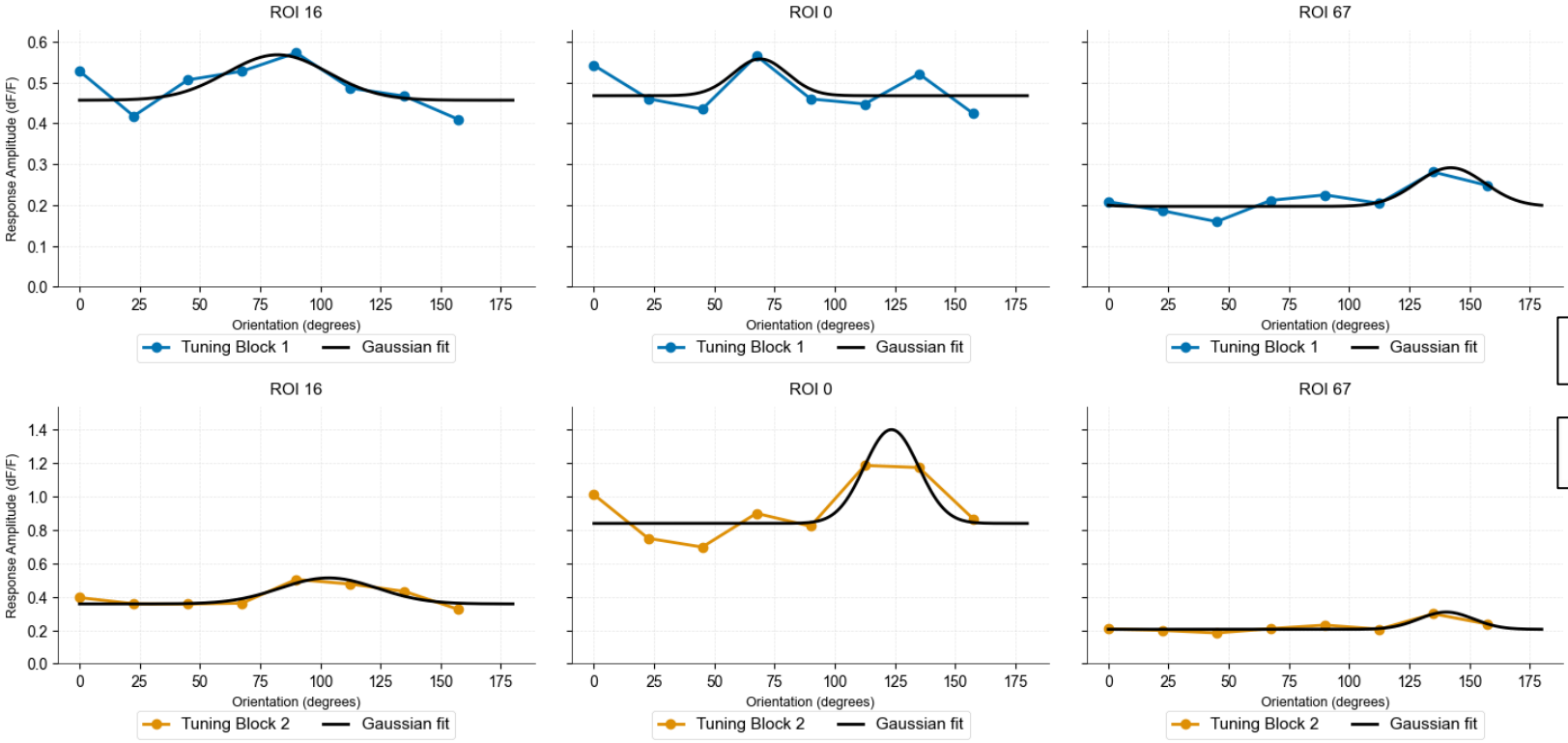
- *Vector sum method used to extract tuning strength (L_ori) and preferred orientation (θ_pref) (Mazurek et al., 2014)*

$$L\_ori = |\Sigma_k R(\theta_k) \exp(2i\theta_k)| / \Sigma_k R(\theta_k)$$

$$\theta\_pref = \tfrac{1}{2} \arg(\Sigma_k R(\theta_k) \exp(2i\theta_k))$$

- ROI-level changes in vector sum parameters were heterogeneous across TB1 versus TB2 in apical (top) and proximal (bottom) dendrites
- This heterogeneity led to a population-level analysis to identify overall trends

Does tuning sharpness (HWHH) change across blocks?



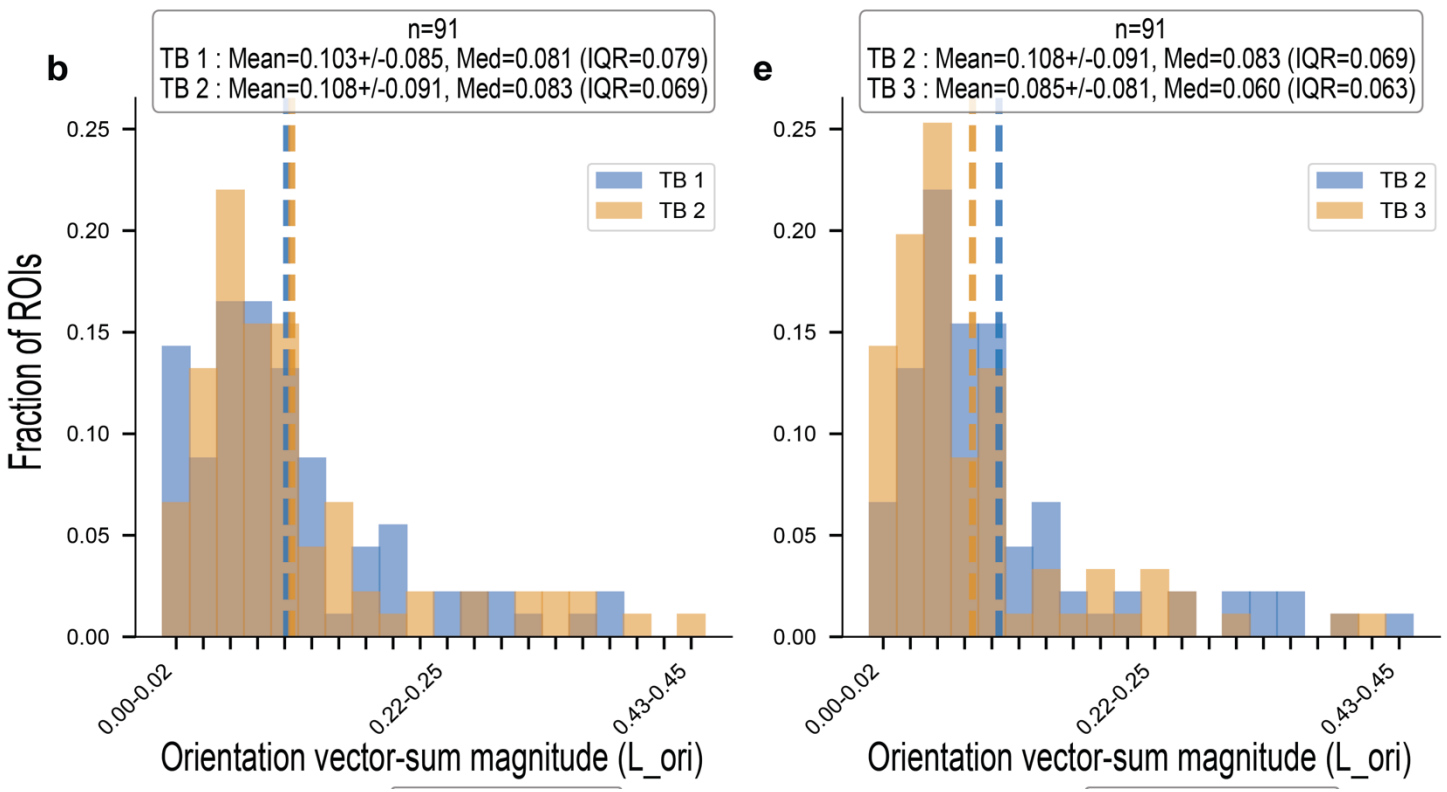
- *Constrained single Gaussian fit method used to extract tuning sharpness (HWHH) (Mazurek et al., 2014)*

$$(\theta) = C + R_p \cdot \exp(-\text{ang\_ori}(\theta - \theta\text{\_pref})^2 / 2\sigma^2)$$

$$\sigma\sqrt{(\ln 4)} = \text{HWHH}$$

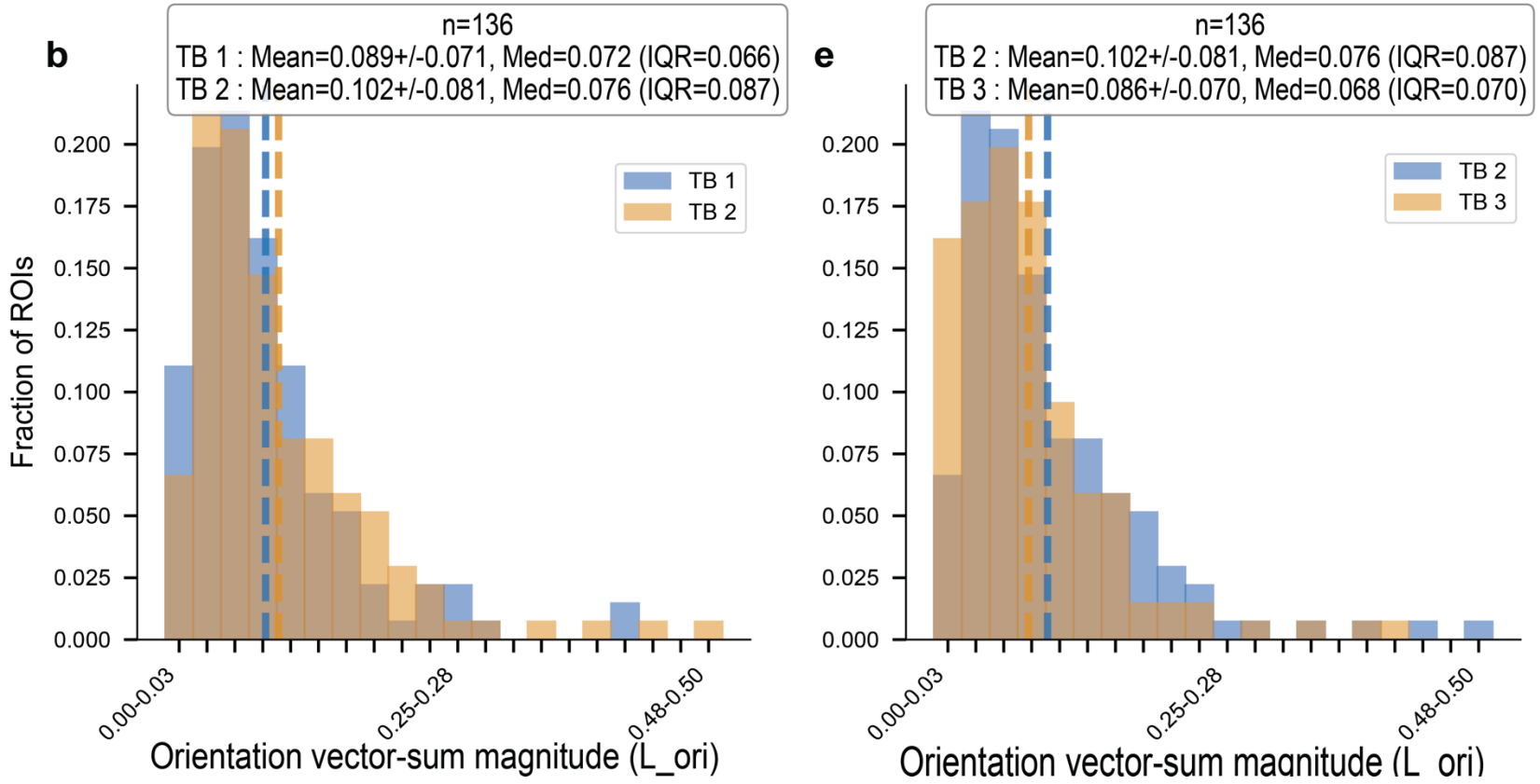
- ROI-level changes in HWHH were heterogeneous in TB1 and TB2 in the apical dendrite
- This heterogeneity led to a population-level analysis to identify overall trends

How does tuning strength vary in apical dendrites at the ROI population level within a session?



- I pooled ROIs per dendrite into a single population for each neuron within a session
- Tuning strength (L_ori) was mostly unchanged across tuning blocks in both apical and proximal dendrites
  - A small decrease from TB2 to TB3 may reflect cumulative SSA
  - Individual ROI changes were variable and largely cancelled out at the mean

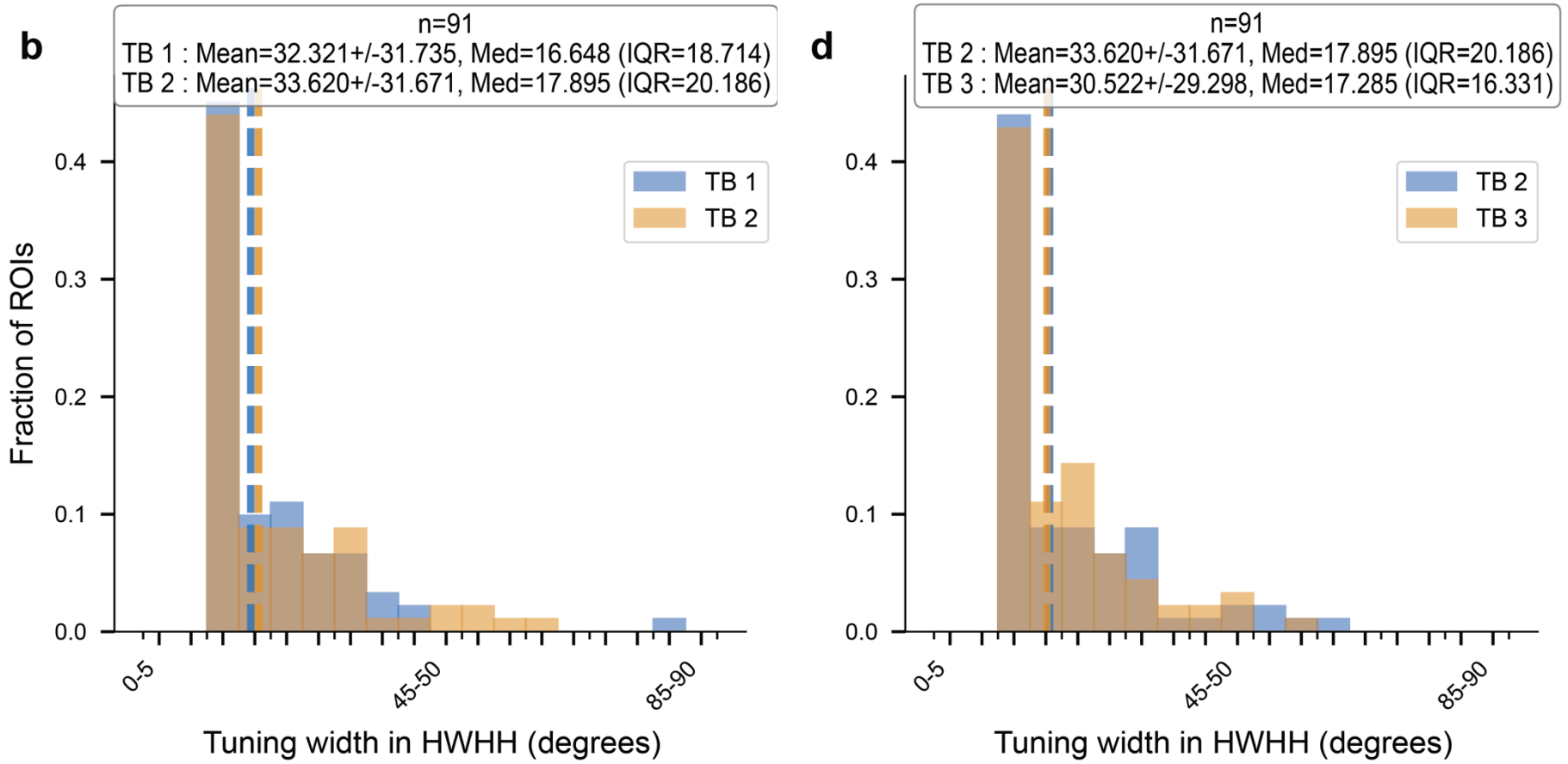
How does tuning strength vary in proximal dendrites at the ROI population level within a session?



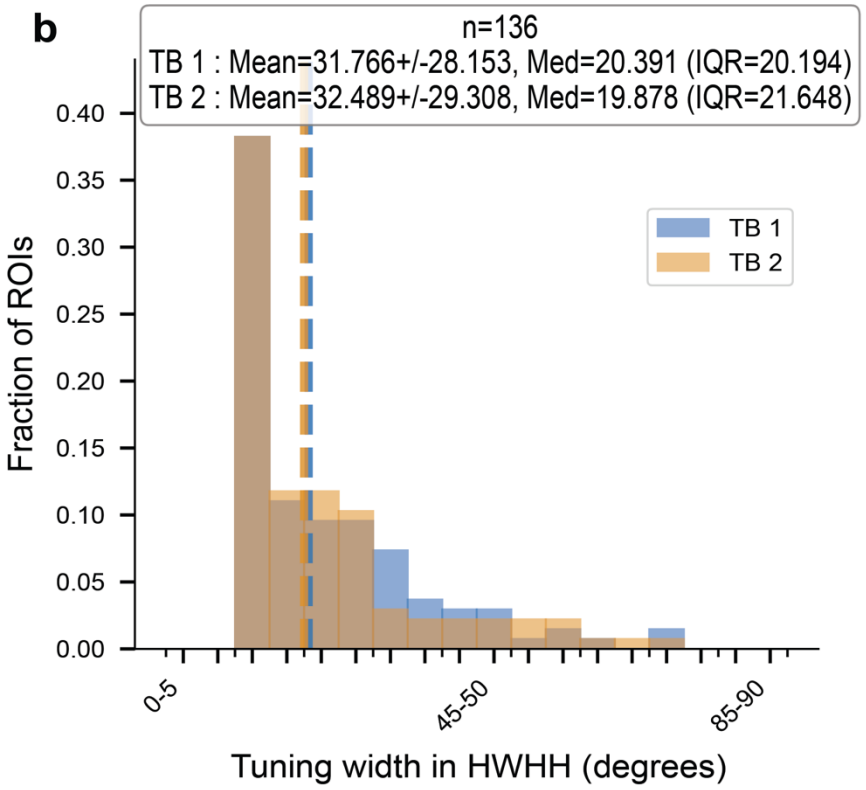
- A small decrease in tuning strength from TB2 to TB3 was also seen in proximal dendrite
- Individual ROI changes were variable and largely cancelled out at the mean

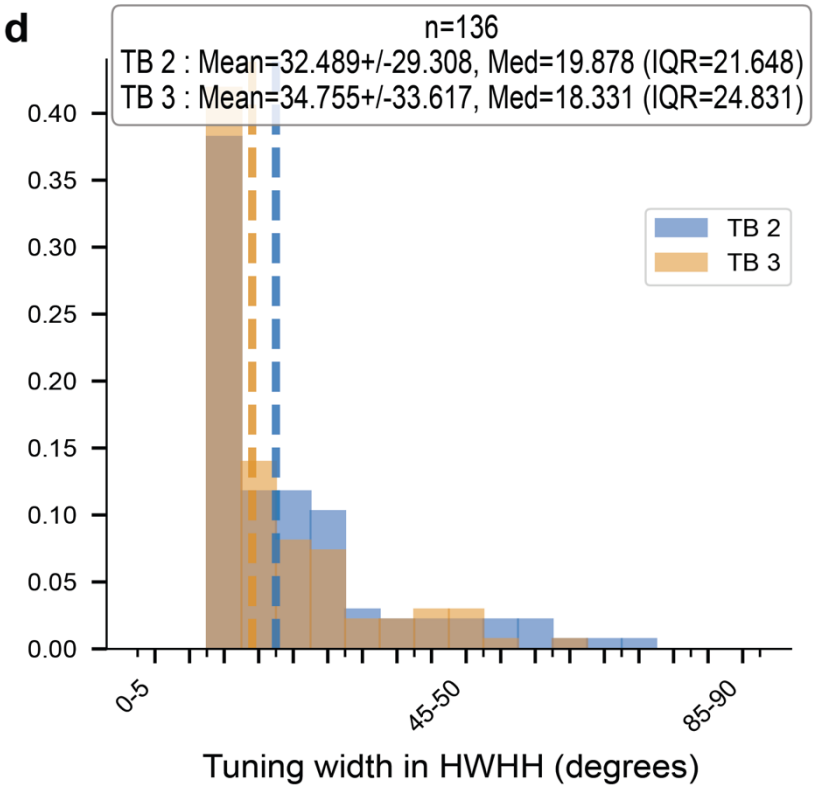
How does tuning sharpness vary in apical dendrites at the ROI population level within a session?

- HWHH distributions were positively skewed and remained unchanged across tuning blocks



How does tuning sharpness vary in proximal dendrites at the ROI population level within a session?

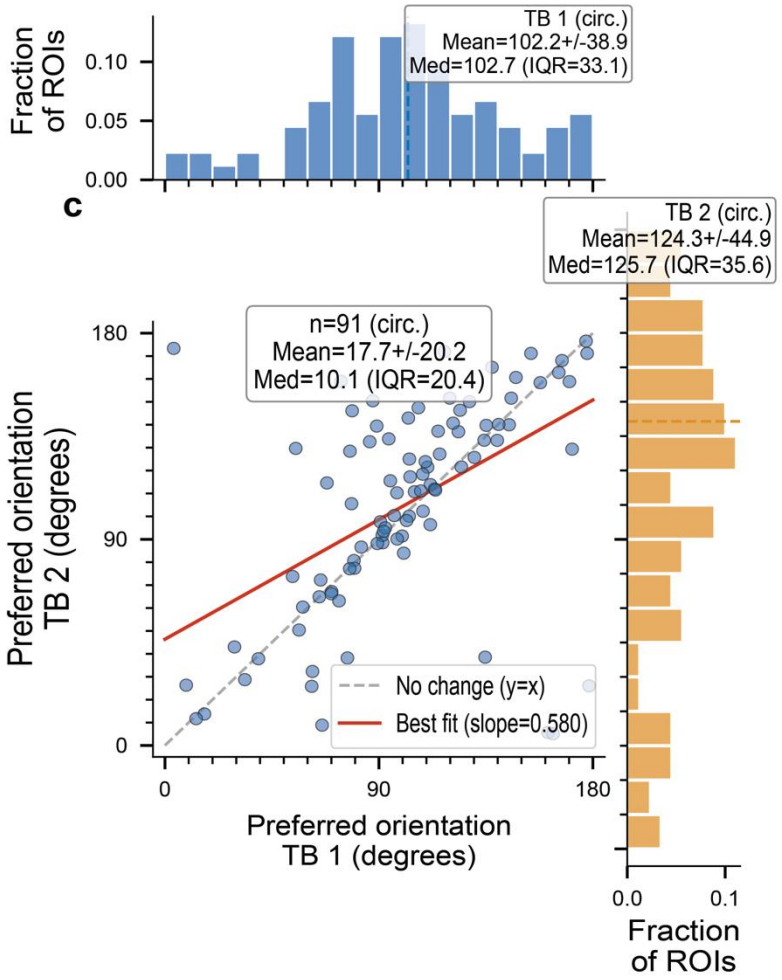


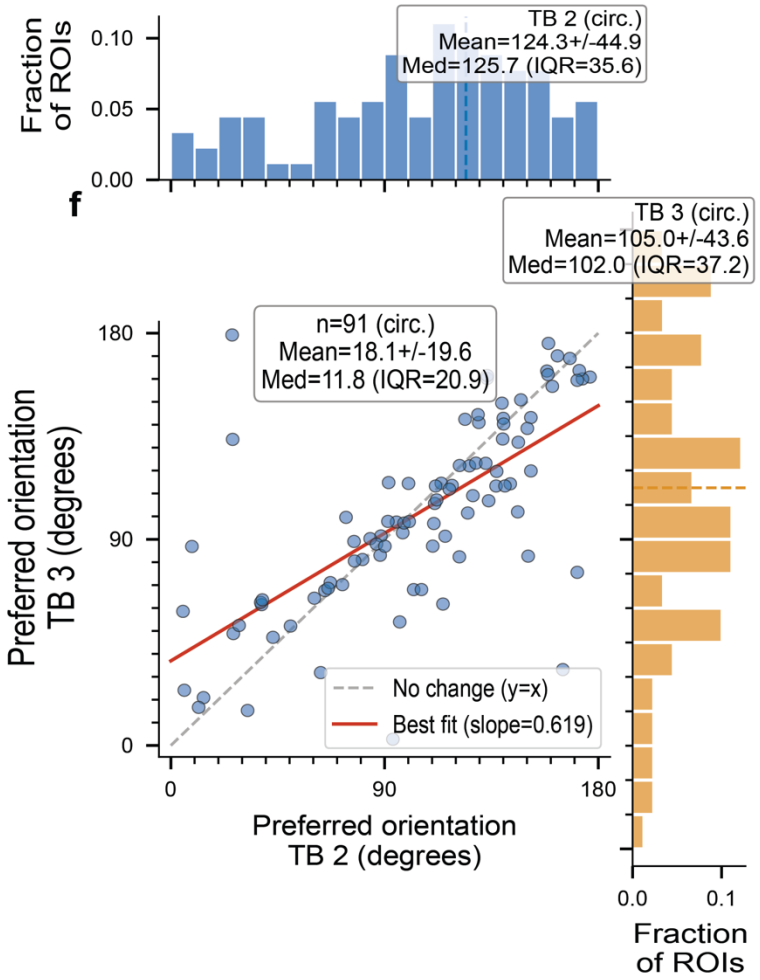


- Same pattern as the ROIs on the apical dendrites

- The stability may reflect tuning sharpness being a fixed property of synaptic inputs
- The positive skew likely arises from the constrained single Gaussian fit modelling double-peaked tuning curves as single peaks, inflating width estimates

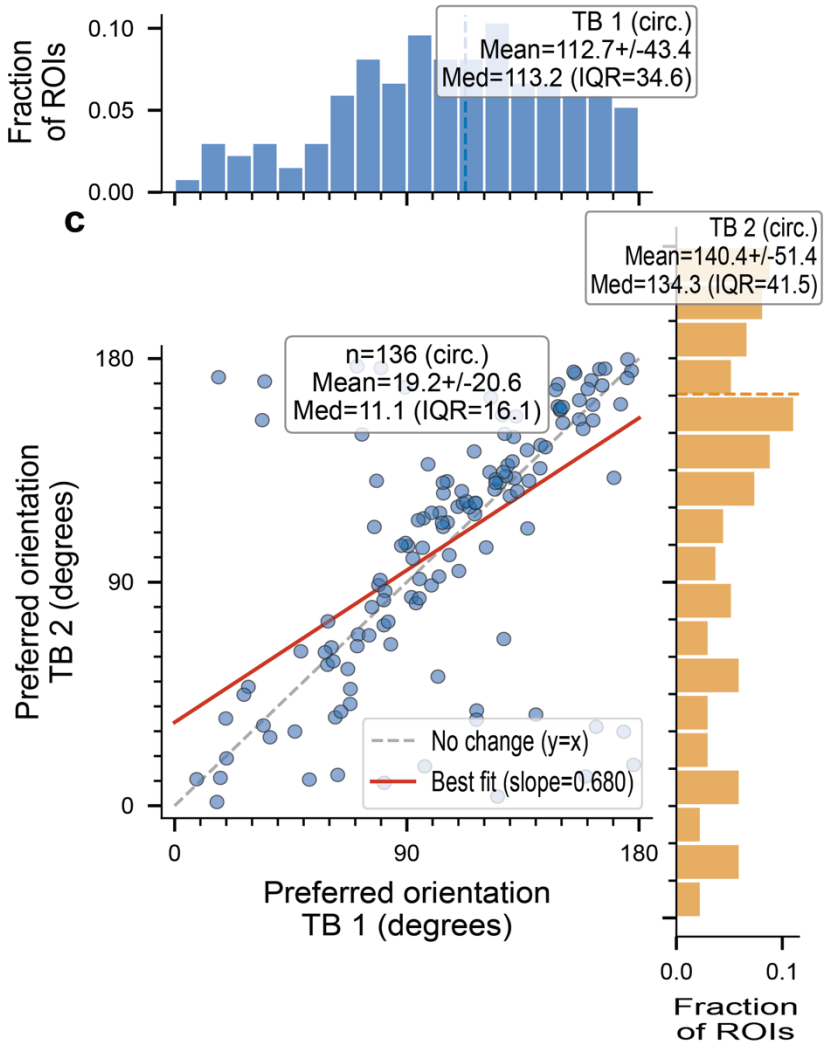
How does the preferred orientation vary in an apical dendrite at the ROI population level within a session?

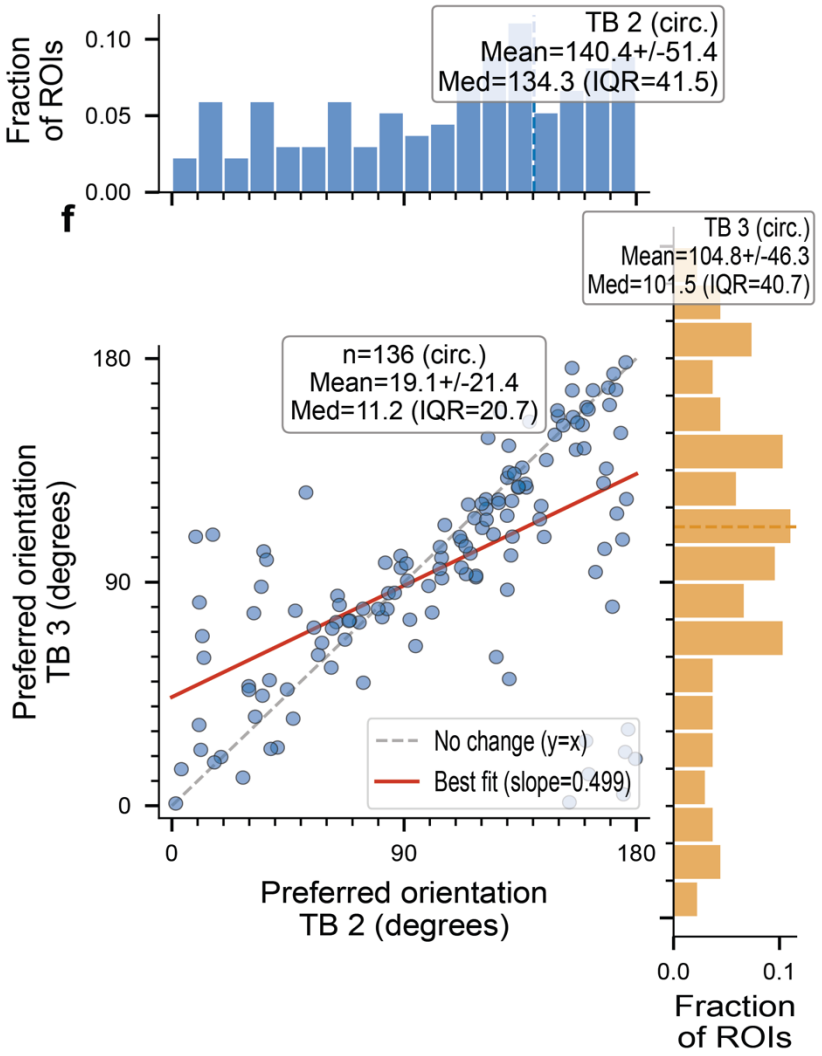




- Preferred orientation changed in 100% of ROIs across all comparisons
  - Expected consequence of the vector sum method
  - Circular distances were small (15 to 19°)

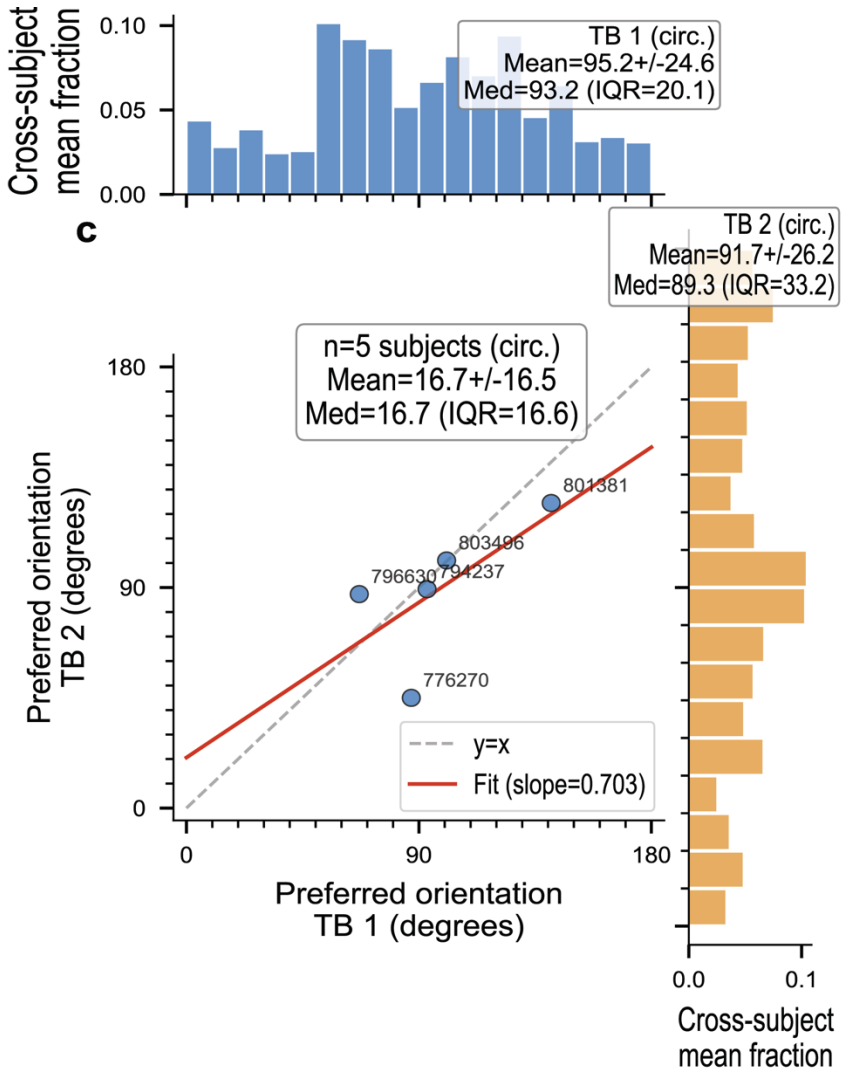
How does the preferred orientation vary in a proximal dendrite at the ROI population level within a session?

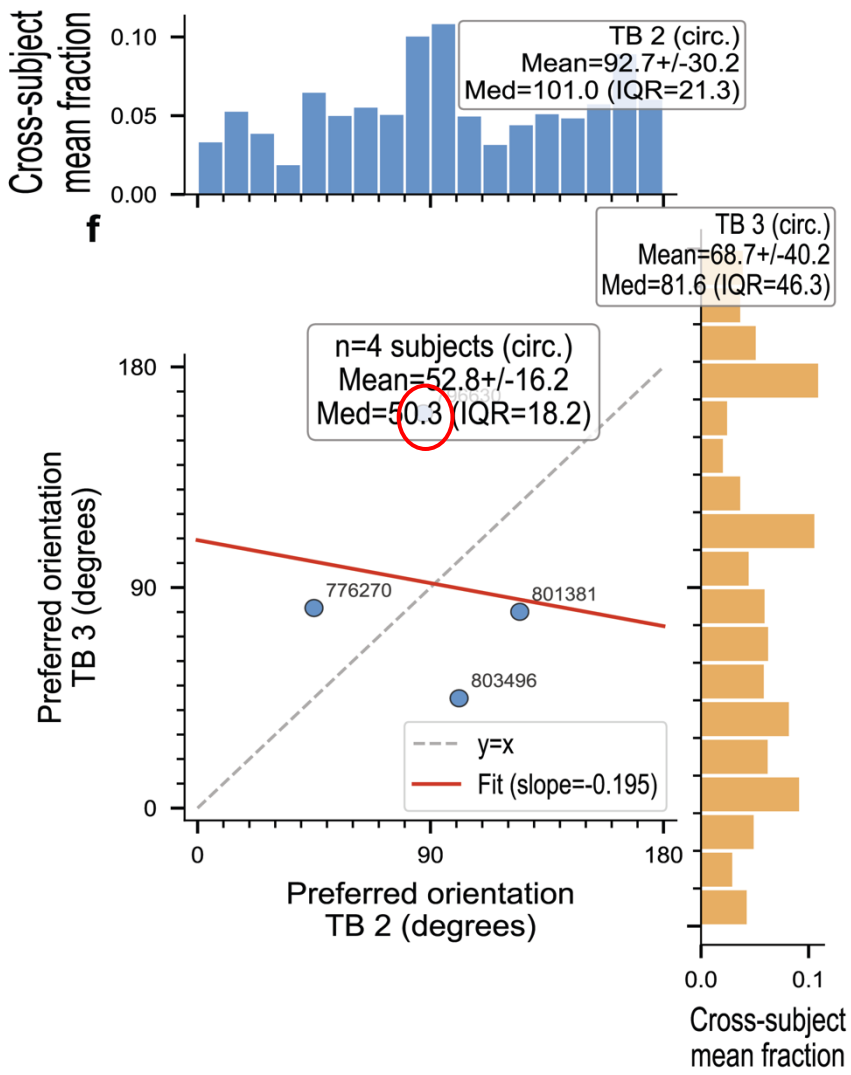




- Similar trends were observed in the proximal dendrite as the apical dendrite

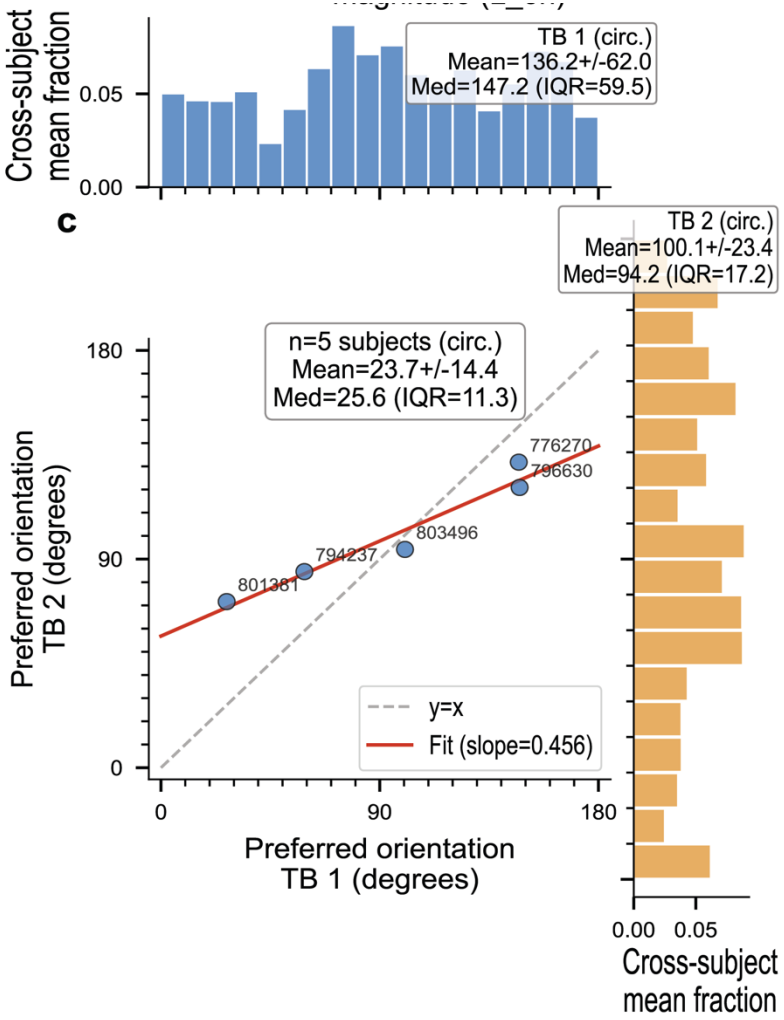
How does preferred orientation vary in apical dendrites across mice?

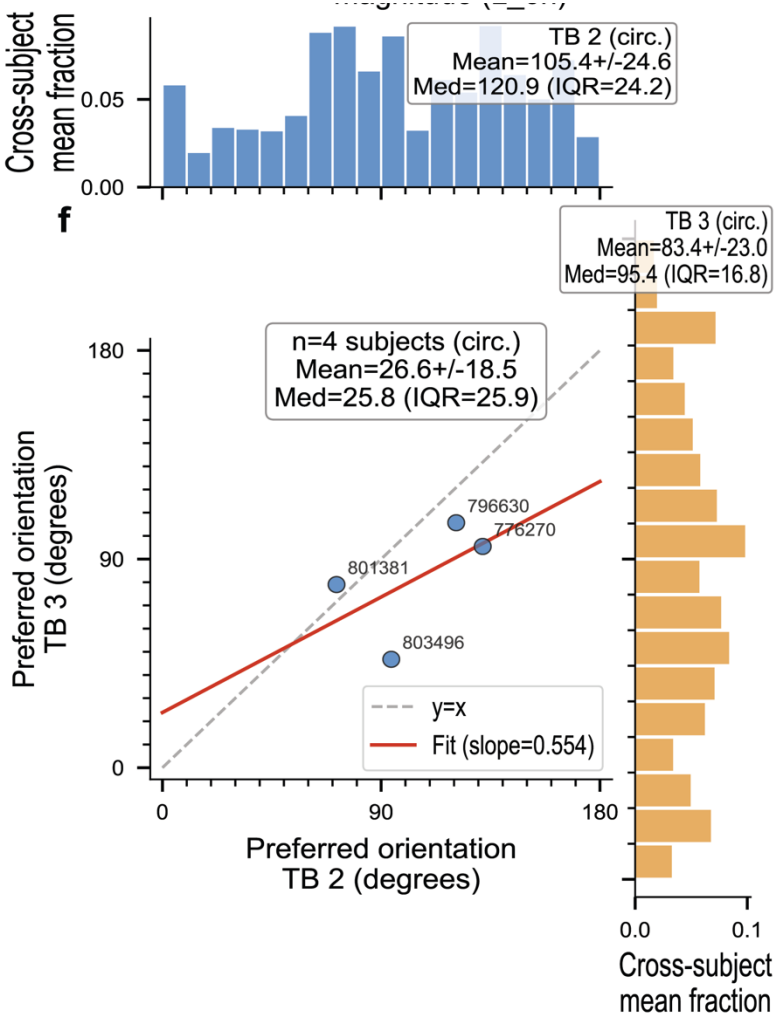




- Apical TB2 versus TB3 showed much larger circular distances than TB1 versus TB2 at the subject level (52.8° versus 16.7°)
- The same pattern was seen at the session level in an individual mouse (41.4° versus 17.0°, not shown)

How does preferred orientation vary in proximal dendrites across mice?





- Trends in apical dendrites were not seen in proximal dendrites, which showed comparable values across both tuning block comparisons
- **No statistical significance** in both dendrites due to small sample size (one sample Wilcoxon on circular distances, circular circular correlation and Watson U2)

Conclusion

At the ROI population level:

- only preferred orientation changes were detectable
- Tuning strength and sharpness changes were heterogeneous (and cancelled out at the mean)

Consistent with Jia et al. (2010), who showed that afferent inputs with the same orientation preference are widely dispersed across the dendritic tree

At the neuronal level:

- Preferred orientation showed the largest changes in pyramidal apical dendrites and superficial VIP somas, particularly between TB2 and TB3, and was absent in proximal dendrites and deep VIP somas

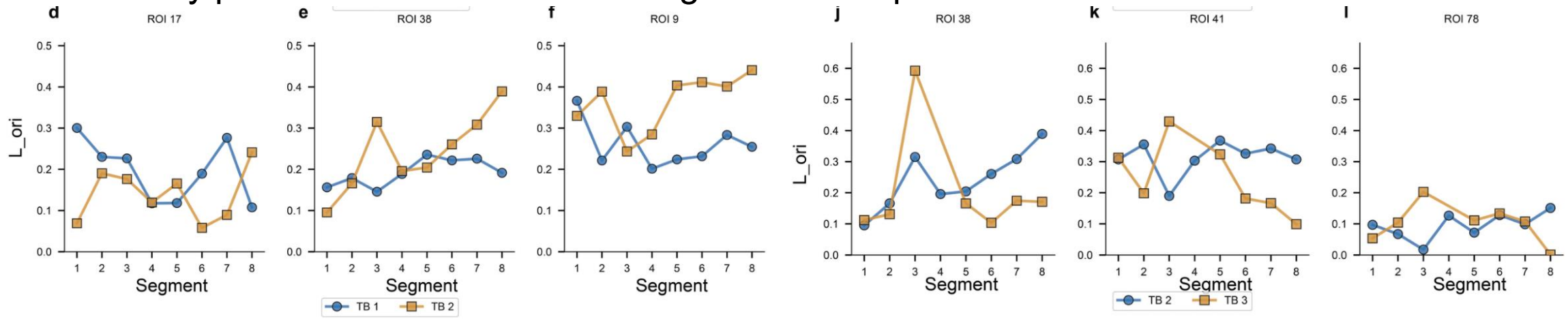
This may reflect compartment-specific input sources, with apical and superficial compartments receiving top-down feedback and proximal and deep compartments receiving feedforward input

Limitations and future directions

Limitations of the study are that:

- Small sample size (n = 4 to 5 subjects) meant no Wilcoxon test could reach significance regardless of effect size
- Modalities (glutamate and calcium) and cell types (pyramidal and VIP) were pooled due to subject numbers

Additional finding: L_ori values varied even within individual tuning blocks across all ROIs in both apical (shown) and proximal dendrites. Future analysis could test whether this within-block activity predicts the direction of change in ROI responses



Acknowledgements

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