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Orientation preference in V1 shows experience dependent drift

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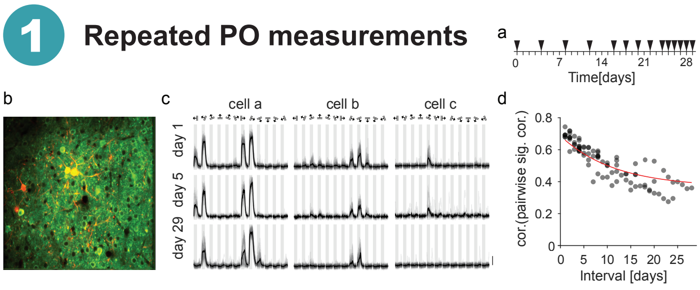
INTRODUCTION

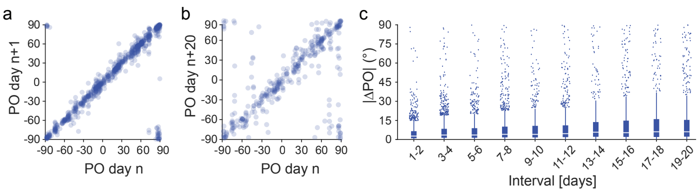
Recent studies have shown that responses to sensory stimuli in mouse visual cortex are not as stable over time as previously thought. Chronic recordings of neuronal responses to complex stimuli such as natural movies, and – to a lesser extent – drifting gratings, have revealed slow correlation decay on a population scale (1-3). However, it remains unclear, which changes in single cell response properties contribute to this so-called representational drift. Drift has also been observed in olfactory cortex, where frequent exposure to an odor was shown to slow the drift of its neuronal representation (4). Here, we use repeated 2-photon calcium imaging to first test if the preferred orientation (PO) of neurons in layer 2/3 of mouse V1 drifts under normal conditions. We then manipulate the statistics of the visual environment using cylinder lens goggles to examine if stable visual experience anchors orientation preference.

1 Repeated PO measurements



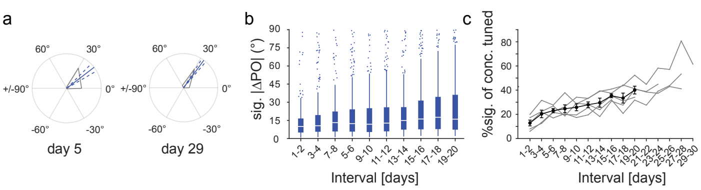
Example data from one of five mouse: **a)** Imaging timeline. **b)** Average GCaMP6s (green) and mRuby2 (red) fluorescence. **c)** Responses of three cells on three days (single responses: gray, average: black). Gray bars: stimulus window, grating directions indicated above. Scale bar: ΔF/F of 200. **d)** Correlation of pairwise signal correlation compared across all days. Red: exponential decay fit (half-life: 11.5 days).

2 Preferred orientation drifts over time



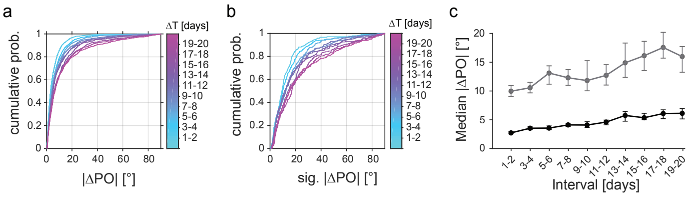
a) POs 1 day apart. Circular-circular Pearson's correlation r=0.968 (p<0.005), n=781 comparisons from 169 neurons. **b)** As in **a** but 20 days apart. r=0.800 (p<0.005), n=360 comparisons from 170 neurons. **c)** Absolute changes in PO vs. interval length. n=11891 comparisons from 320 neurons. N = 5 mice.

3 Number of PO changes increase over time



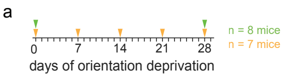
a) PO of a neruon on two days with bootstrapped 95% confidence intervals (dashed lines). **b)** Magnitude of absolute significant changes vs. interval length (n = 2895 intervals from 221 neurons). **c)** Percentage of concurrently tuned cells that significantly change their PO vs. interval length.

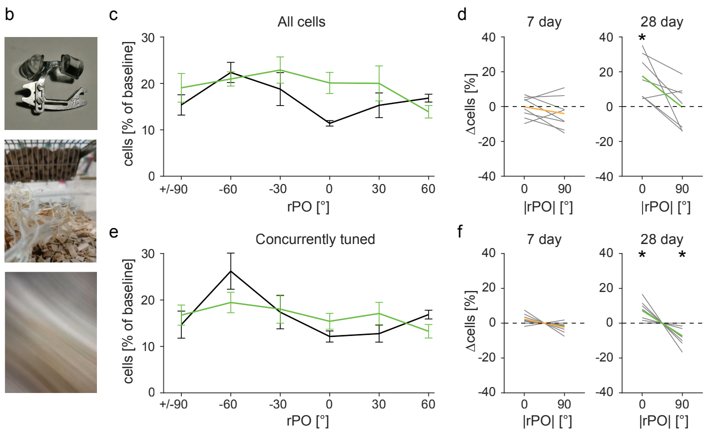
4 Size of PO changes increase over time



a) Cumulative probability distribution of the absolute size of PO changes for different intervals. **b)** Same as **d**, but only including significant PO changes. **c)** Median absolute PO changes from distributions in **a** (black: all PO changes) and **b** (gray: sig. PO changes). Error bars are bootstrapped 95% CIs.

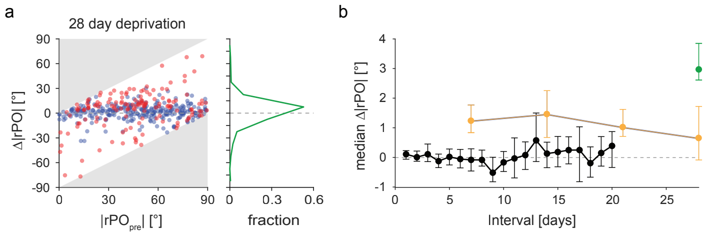
5 Orientation deprivation





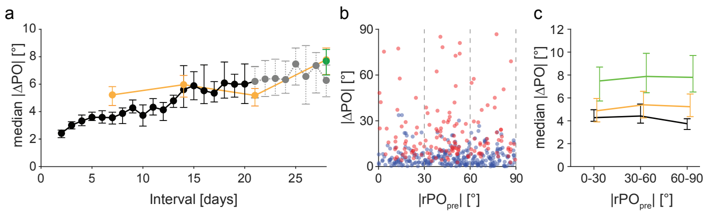
a) Imaging timelines. **b)** Top: Headbar with cylinder lens goggles; Middle/Bottom: Image without/with the lens. **c)** Distribution of POs relative to the permitted orientation (rPO). **d)** Change in the number of neurons tuned close (rPO = 0 to +/-45°) or far (rPO = 90 +/-45°) from the permitted orientation. **e - f)** As **c** and **d** but only concurrently tuned cells. Here, changes can only be caused by neurons shifting their PO. Black: Baseline, Green: 28 day deprivation, Orange: 7 day deprivation, Gray: single animals, Color: Mean across animals. Error bars: S.E.M. across mice. One-sample two-tailed t-test. * p < .05

6 Drift towards permitted orientation



a) Left: Absolute rPO before 28 day deprivation vs. the absolute change in rPO (Δ|rPO|). Positive Δ|rPO| indicate changes towards the permitted orientation. Right: histogram of Δ|rPO| distribution (n = 414 cells). **b)** Median Δ|rPO| vs. time interval. Error bars: bootstrapped 95% CIs.

7 Effect of deprivation on drift magnitude



a) Median absolute PO change across intervals. Gray: n < 5 mice. **b)** Absolute change in PO after 28 day deprivation vs. initial absolute relative PO. Red: significant changes; lines: bins for **c**. **c)** Median absolute PO change vs. distance from permitted orientation. Error bars: bootstrapped 95% CIs.

CONCLUSION

In this study, we identify a specific tuning feature of neurons in mouse V1, preferred orientation (PO), that undergoes representational drift. We used cylinder lens goggles to remove the experience of specific visual features to assess whether the continuous experience of these features reduces their representational drift. Our data show that orientation deprivation results in experience dependent drift towards the permitted orientation. However, neurons with POs further away from the permitted orientation did not increase their drift magnitude more than others. Taken together stripe rearing does not affect PO drift magnitude in an experience dependent manner, but alters the drift direction. This results in an overall redistribution of POs in favor of the experienced orientation.

Literature:
1. Montijn, J. S., Meijer, G. T., Lansink, C. S., & Pennartz, C. M. (2016). Population-Level Neural Codes Are Robust to Single-Neuron Variability from a Multidimensional Coding Perspective. Cell reports, 16(9), 2486–2498.
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3. Marks, T. D., & Goard, M. J. (2021). Author Correction: Stimulus-dependent representational drift in primary visual cortex. Nature communications, 12(1), 5486.
4. Schoonover, C. E., Ohashi, S. N., Axel, R., & Fink, A. (2021). Representational drift in primary olfactory cortex. Nature, 594(7864), 541–546.