nature neuroscience

The development of cortical circuits for motion discrimination

Gordon B Smith[1,8], Audrey Sederberg[2,7,8], Yishai M Elyada[1], Stephen D Van Hooser[3], Matthias Kaschube[4–6,9] & David Fitzpatrick[1,9]

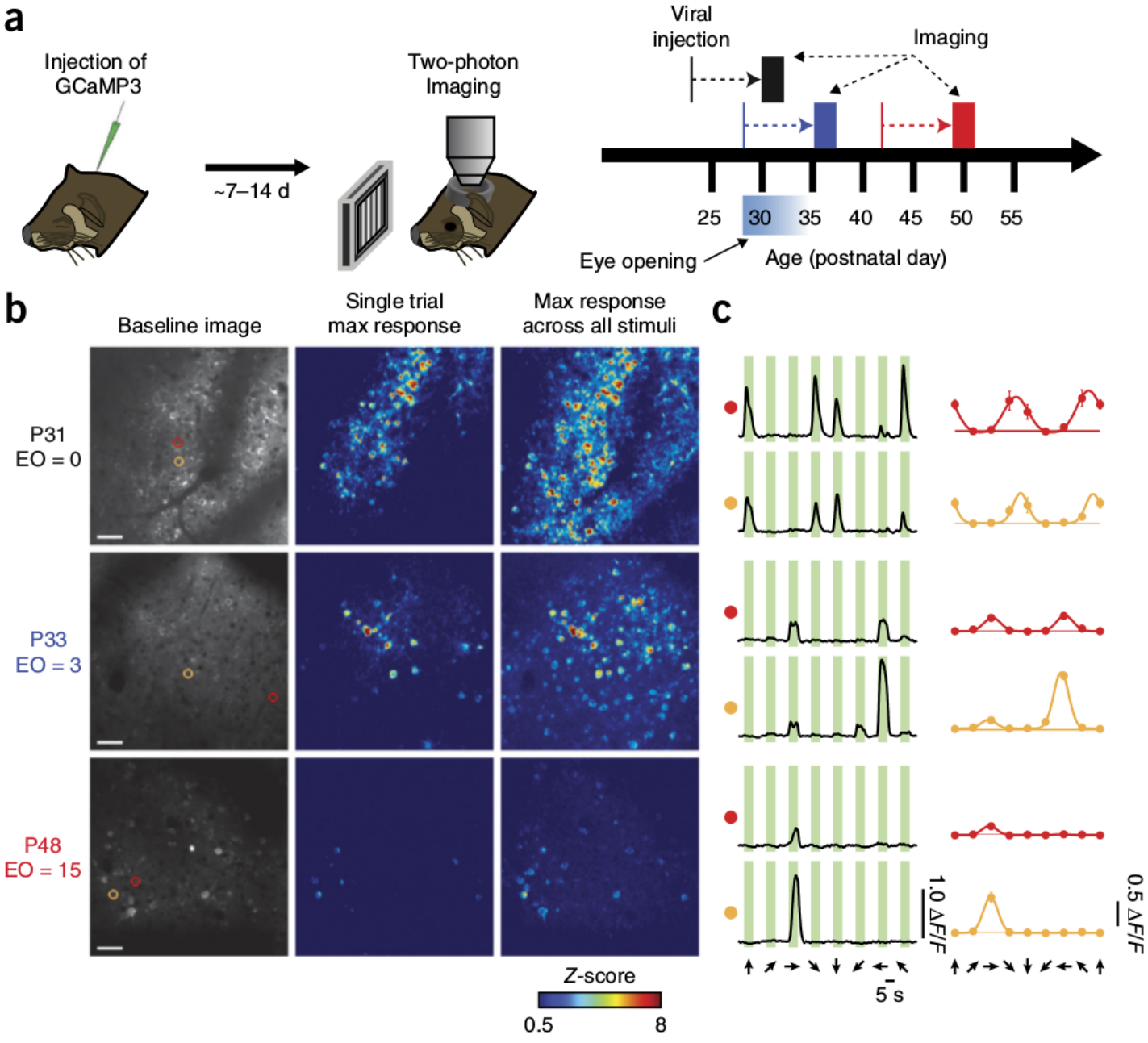
[1]Department of Functional Architecture and Development of Cerebral Cortex, Max Planck Florida Institute for Neuroscience, Jupiter, Florida, USA. [2]Department of Physics, Princeton University, Princeton, New Jersey, USA. [3]Department of Biology, Brandeis University, Waltham, Massachusetts, USA. [4]Frankfurt Institute for Advanced Studies, Frankfurt, Germany. [5]Faculty of Computer Science and Mathematics, Goethe University, Frankfurt, Germany. [6]Bernstein Focus: Neurotechnology Frankfurt, Frankfurt, Germany. [7]Present address: Department of Organismal Biology and Anatomy and Department of Neurobiology, University of Chicago, Chicago, Illinois, USA. [8]These authors contributed equally to this work. [9]These authors jointly directed this work. Correspondence should be addressed to D.F. (david.fitzpatrick@mpfi.org) or M.K. (kaschube@fias.uni-frankfurt.de).

Received 5 November 2014; accepted 10 December 2014; published online 19 January 2015; doi:10.1038/nn.3921

Introduction

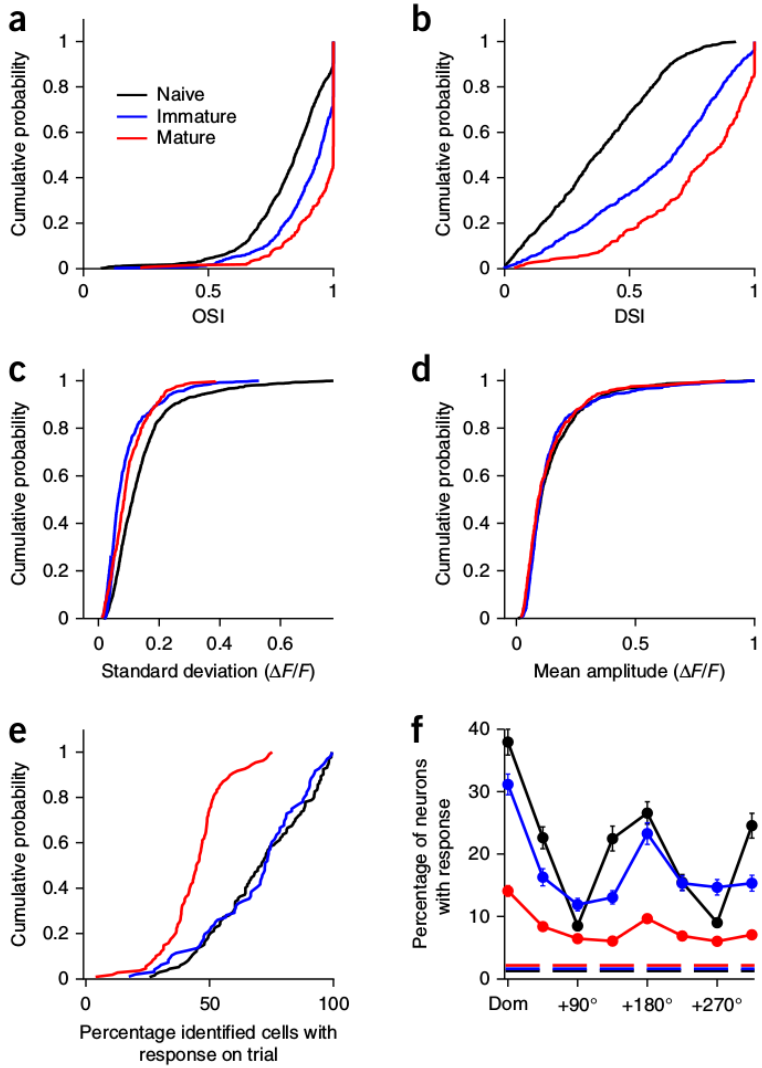
- orientation selectivity present and organized in a columnar fashion around eye opening
- direction selectivity requires visual experience
- much less is known about the development of the temporal properties of the response
- WHAT THEY SEE: traveling waves with strong noise correlations $\Rightarrow$ sparse responses and waves disappeared
- they quantify these changes... but don't offer concrete mechanisms

Experimental setup (orientation->direction selectivity)

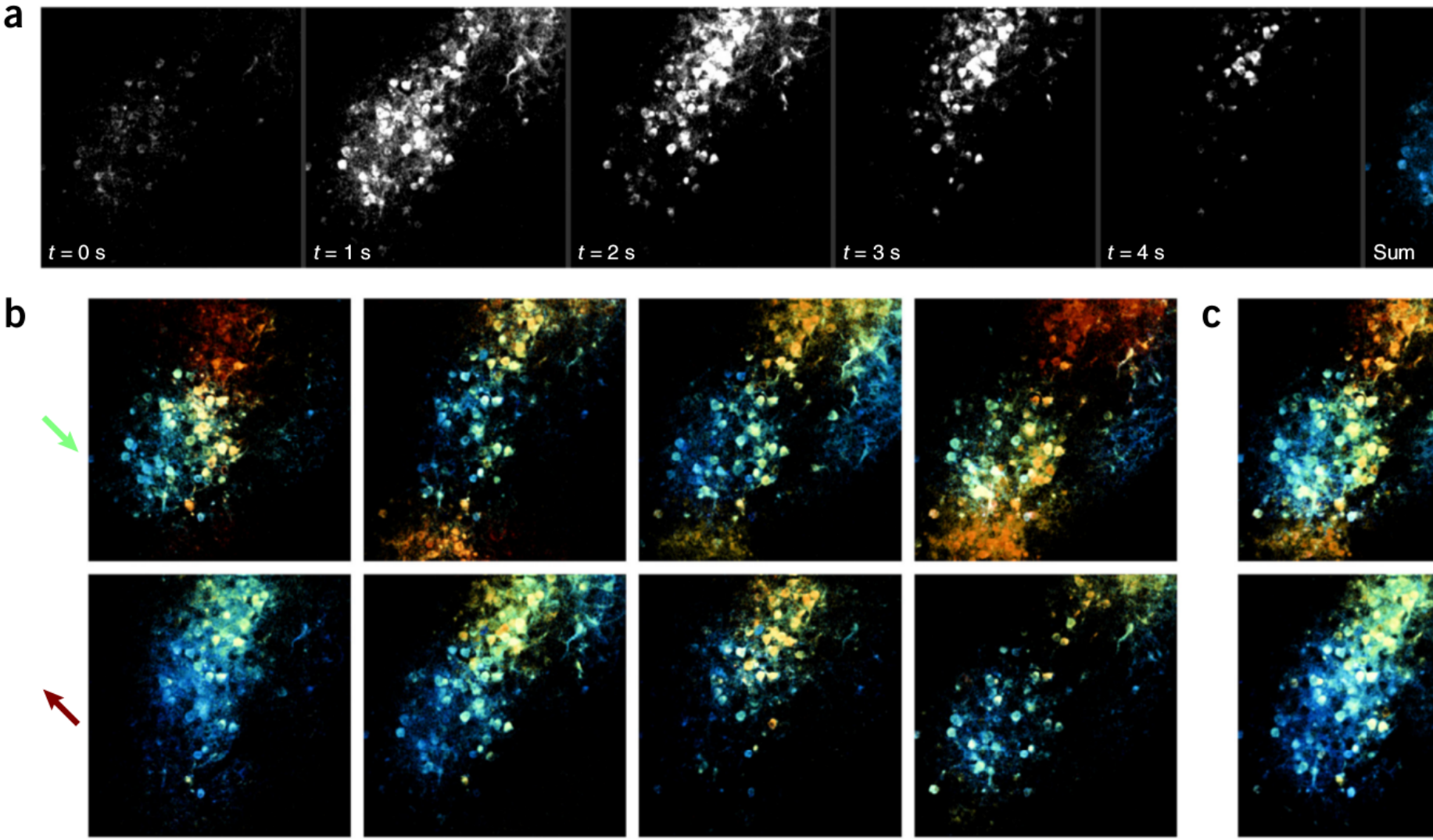


ketamine

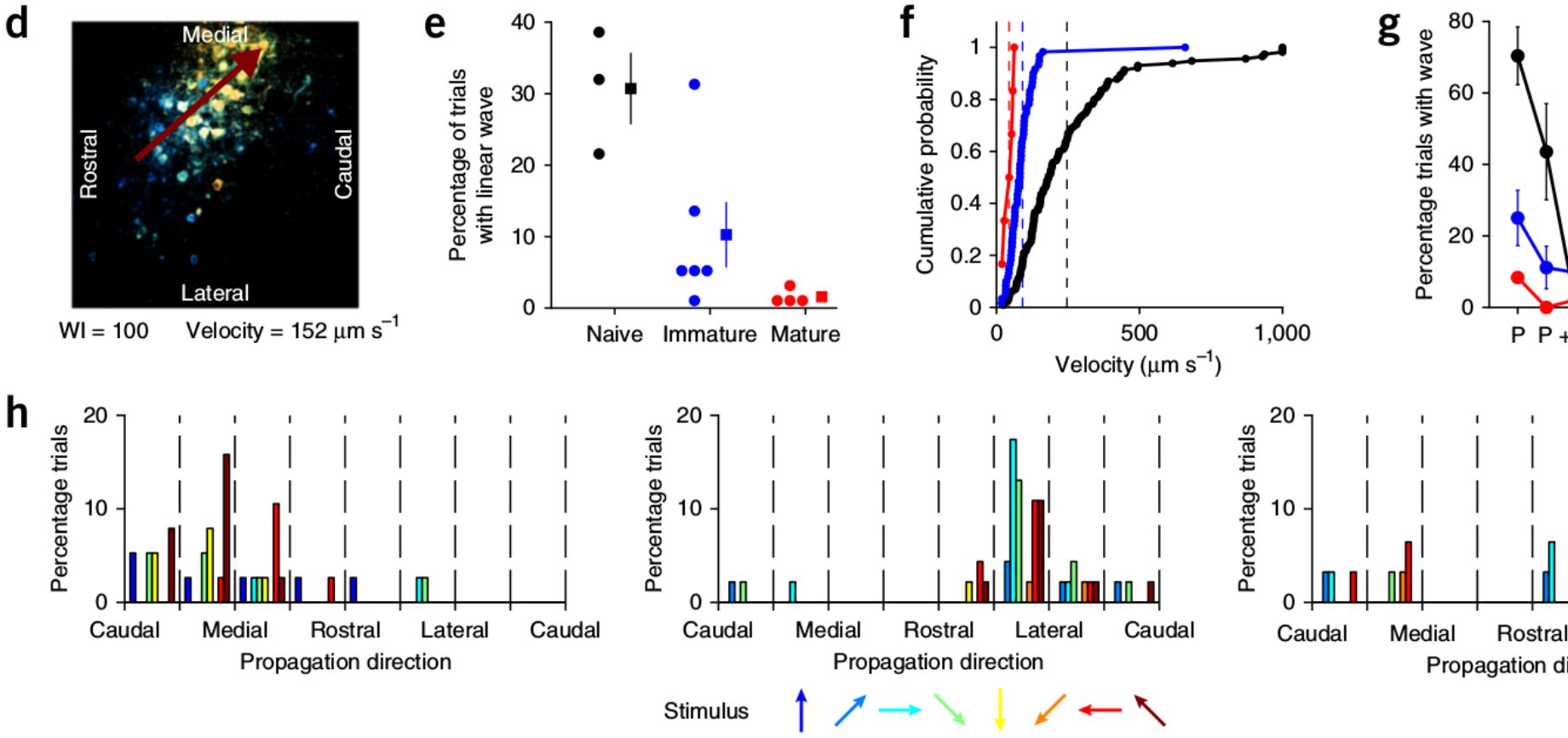
Stimulus selectivity increases and population response density decreases (evidence for ?)



Traveling waves in young animals (+video)



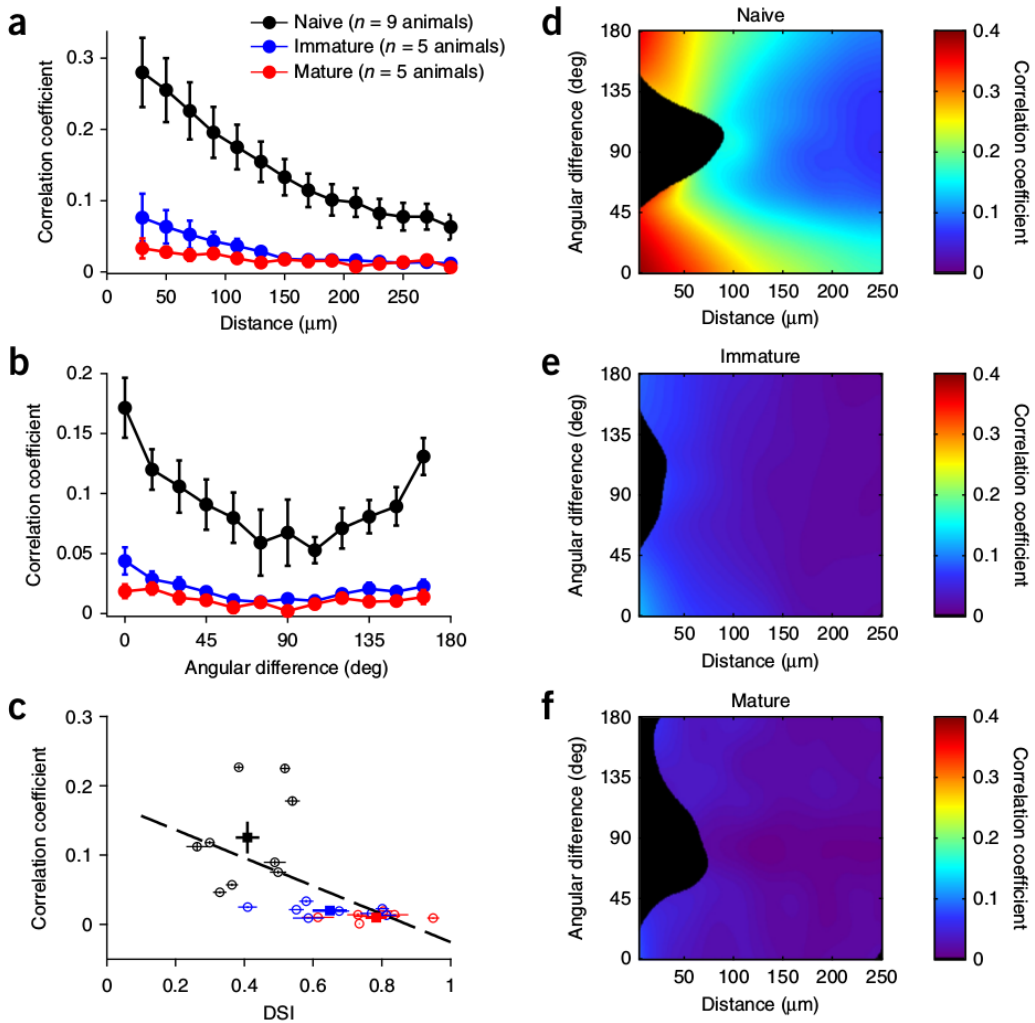
Traveling wave likelihood depends on direction of stimulus; traveling waves decrease as animals mature



(h) wave direction consistent within animals but different across animals

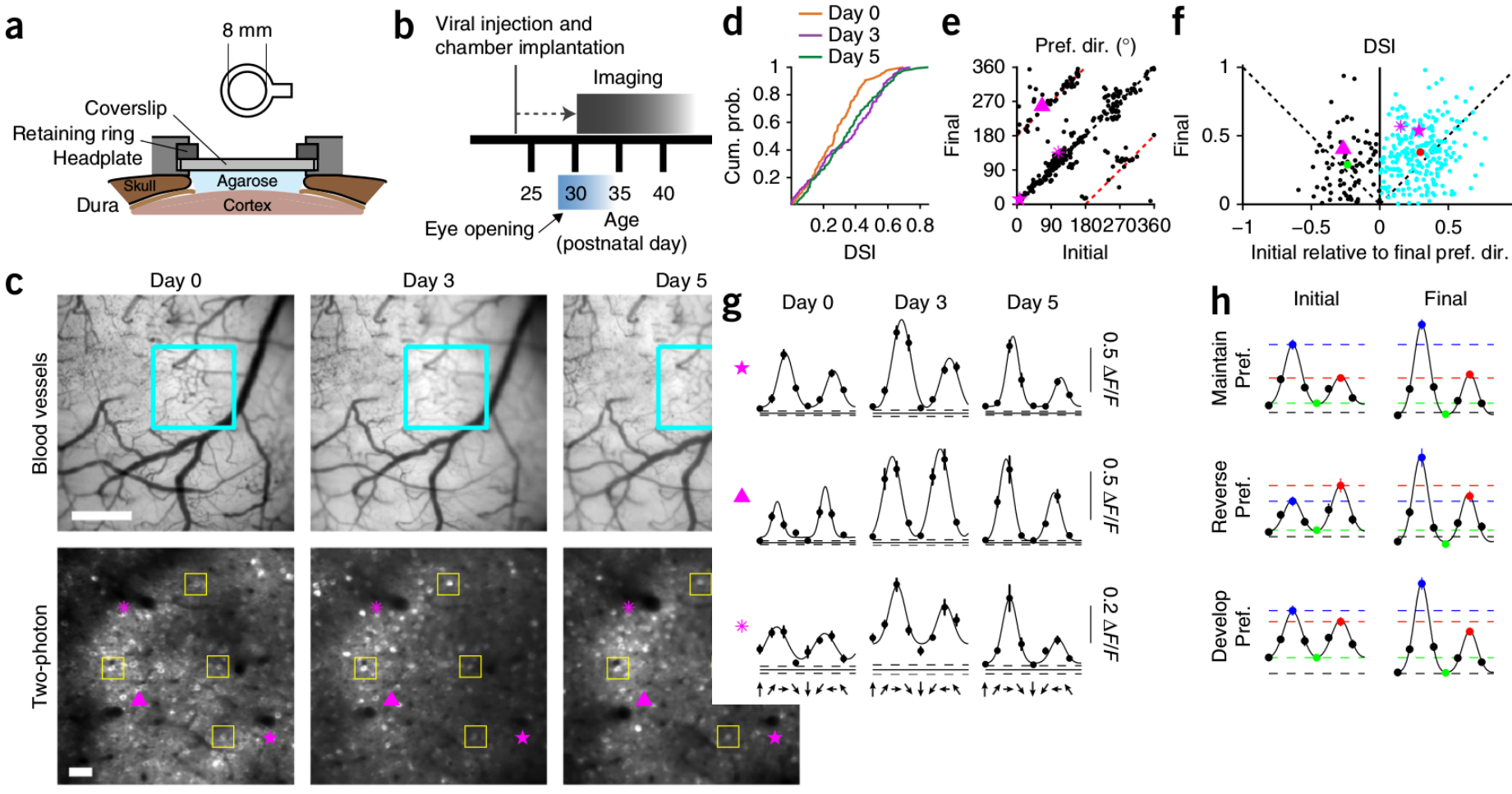
Noise correlations decrease with age

also trials with traveling waves have higher noise correlations



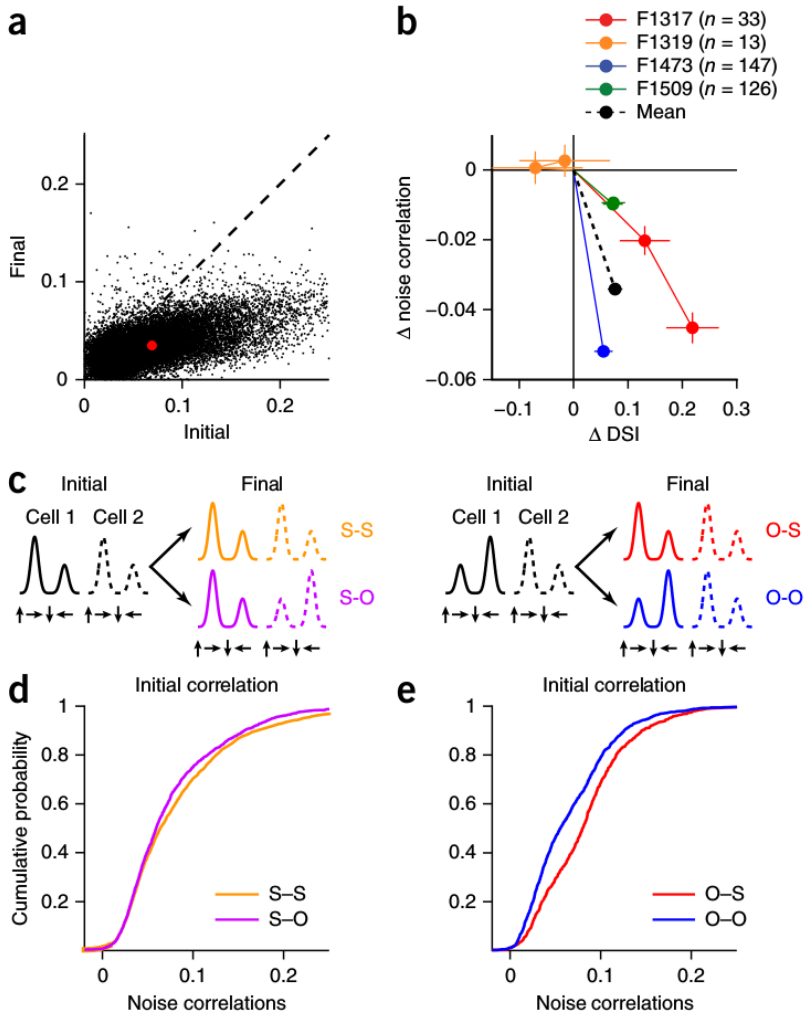
Emergence of direction selectivity

some cells had 180° shifts in orientation selectivity
increase in direction selectivity... ($p<0.001$?)



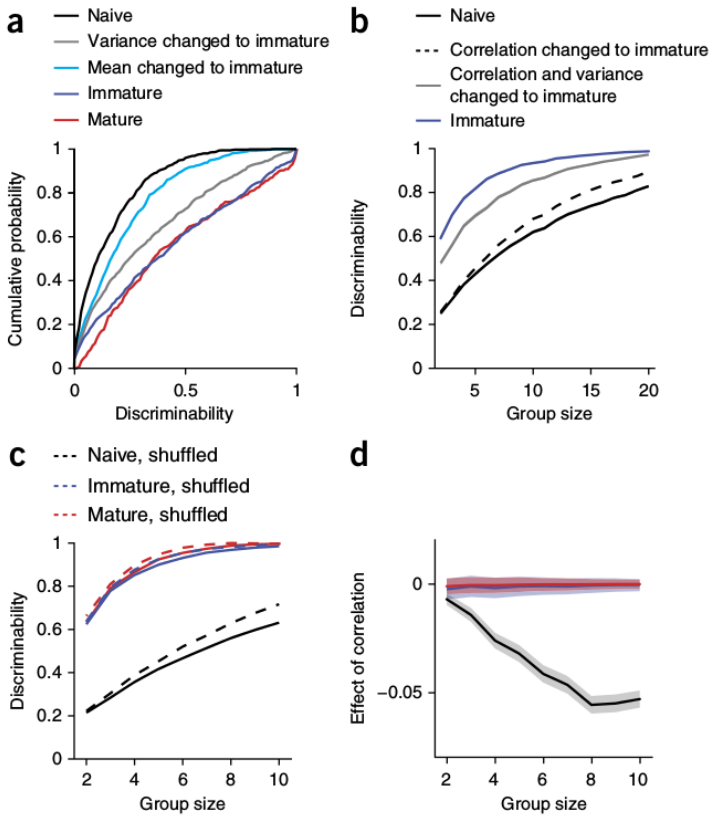
Increases in DSI and decreases in noise correlations

if noise correlations are initially higher between two cells, they are more likely to adopt the same direction preference



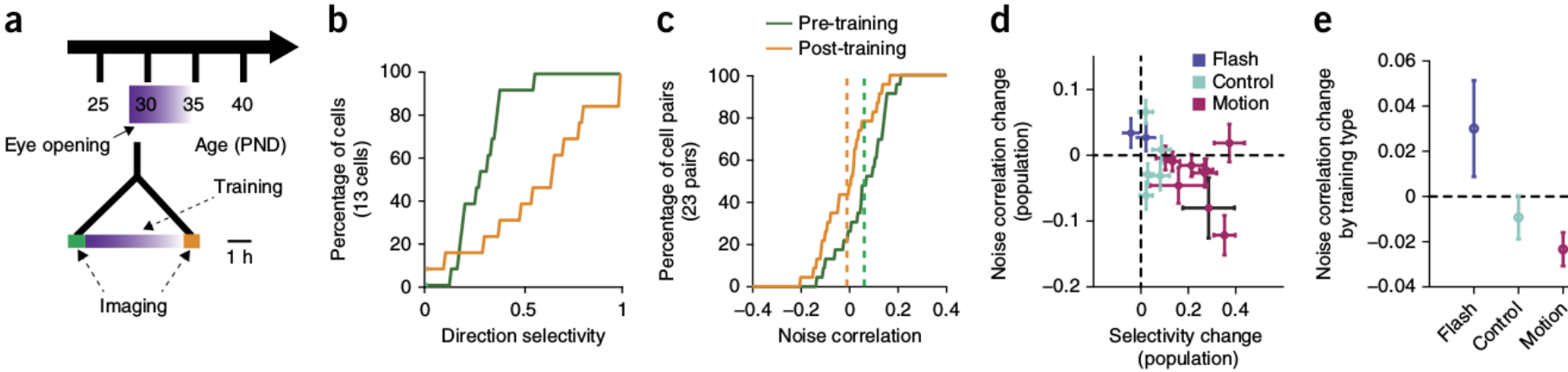
Maturity decreases trial-to-trial variability

- capable of driving increased discriminability even in the absence of improved selectivity
- how much of this enhancement is due to noise correlation (rather than a decrease in single cell varaince)? dashed black line
- as group size increases, noise correlations have a higher effect

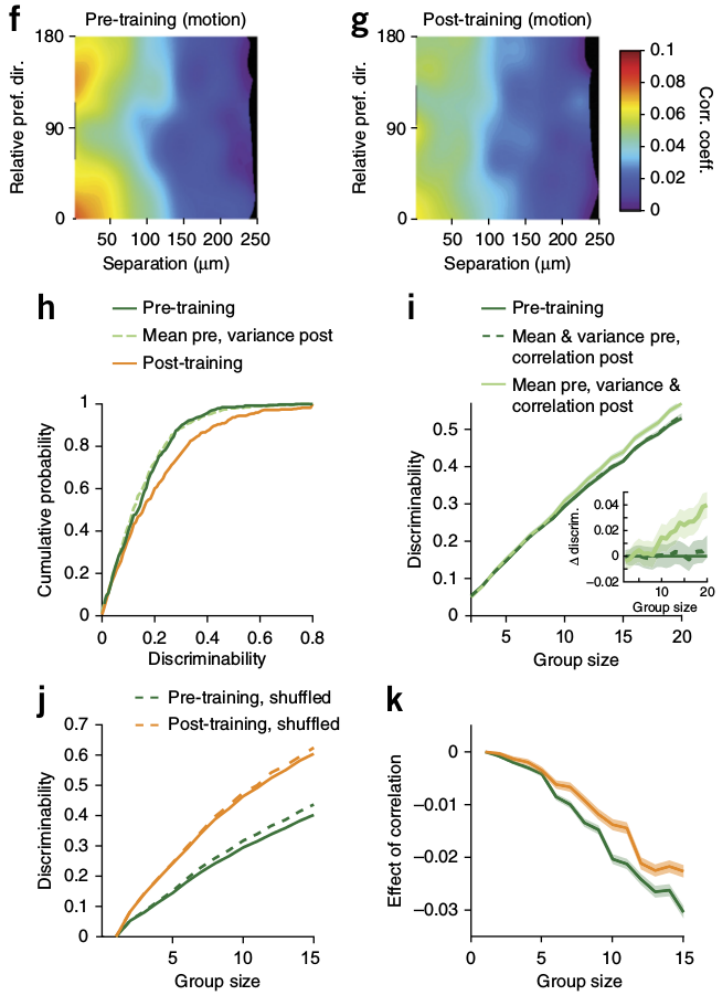


Motion training alone decreases noise correlations

- 4-6h of training is sufficient to increase selectivity and decrease noise correlations



And discriminability



Conclusions

- wave-like responses dominate at eye opening and are thought to establish maps of retinotopy and ocular dominance
- in developing cortex correlated noise limits performance
- could be a refinement of excitatory connections or a maturation of inhibition