# Rapid adaptation to parametric and natural stimuli along the visual pathway

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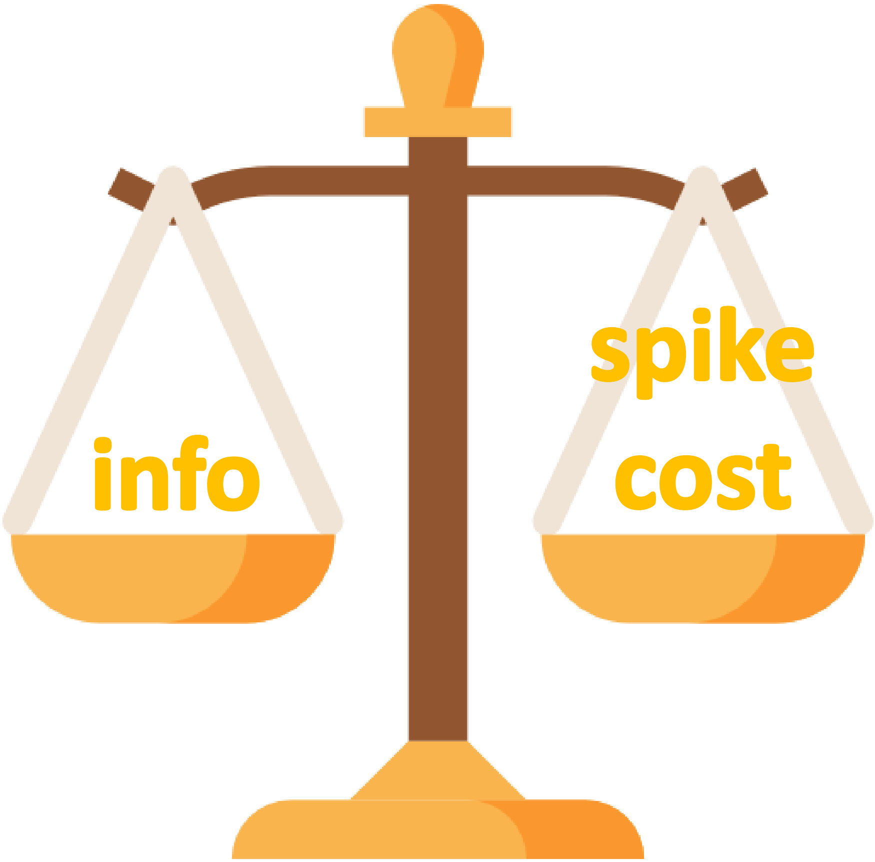
2022.04


SWEET COCKTAIL
TOMATO
Solanum lycopersicum
CONTINUOUSLY FRUITS IN SPRING, SUMMER + FALL
SELF-POLLINATING
INDOOR + OUTDOOR USE
SINCE
1963
Dewar

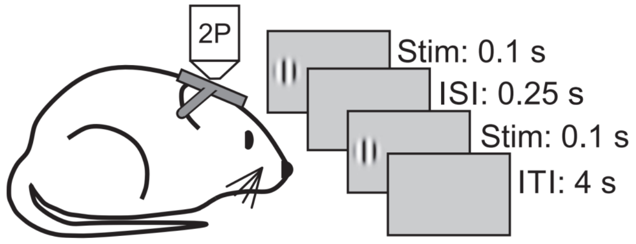
# Trade-off between information transmission and metabolic cost

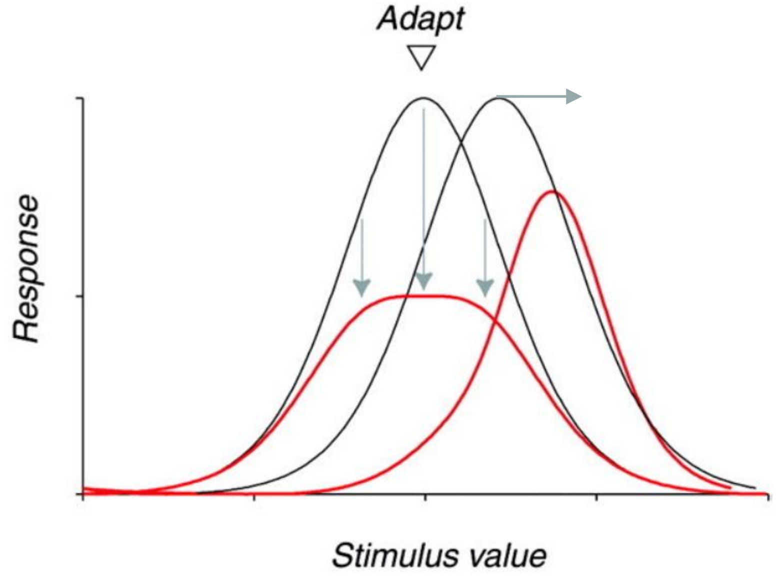



>> Efficient coding hypothesis

maximizing mutual information between input and neuronal response using minimal number of spikes (Barlow, 1961)

# Adaptation alters visual processing according to recent history

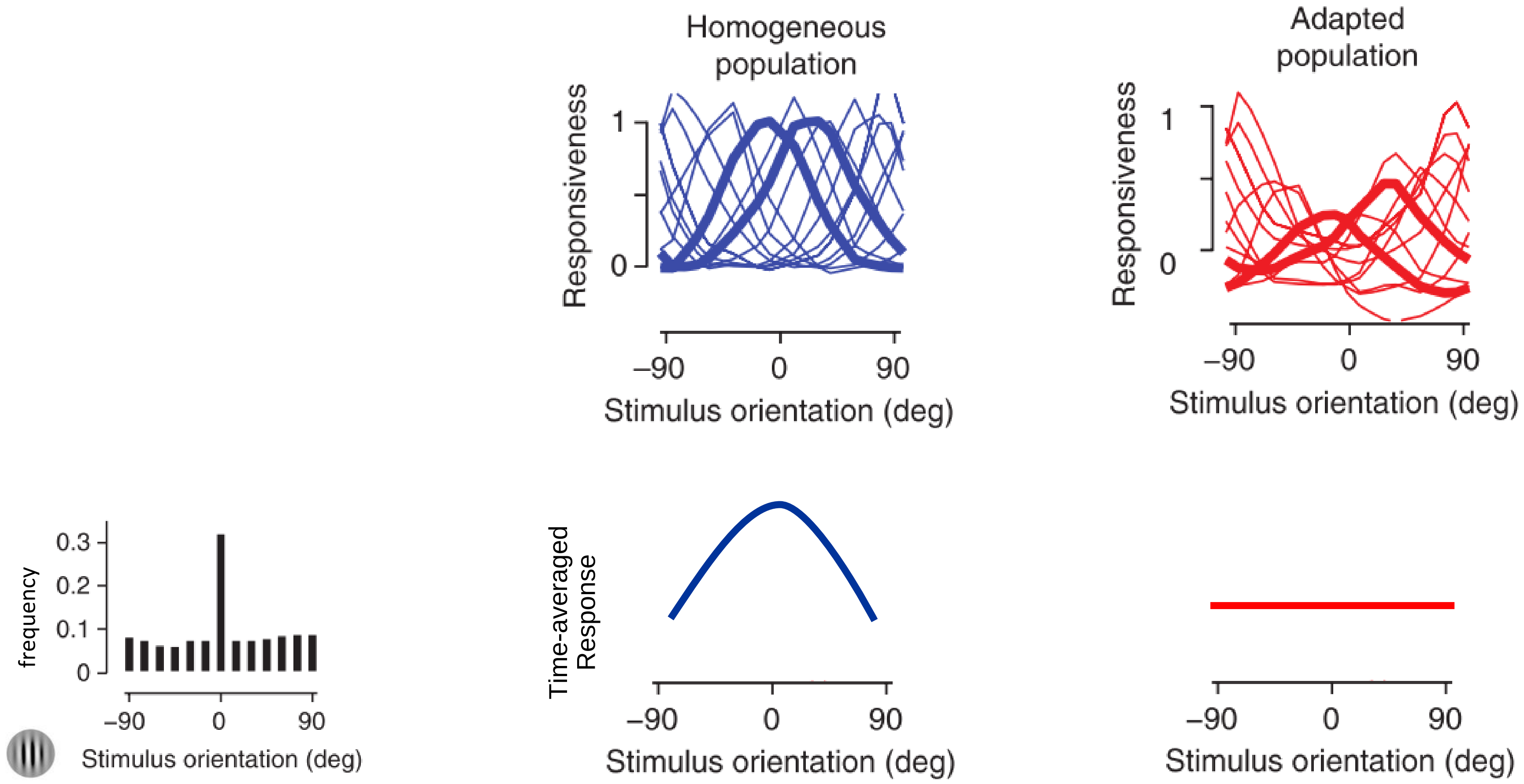

*e.g. grating orientation*

Characteristics of adaptation:

- Firing rate reduction
- Neuronal preference tuning bias

Kohn, 2007

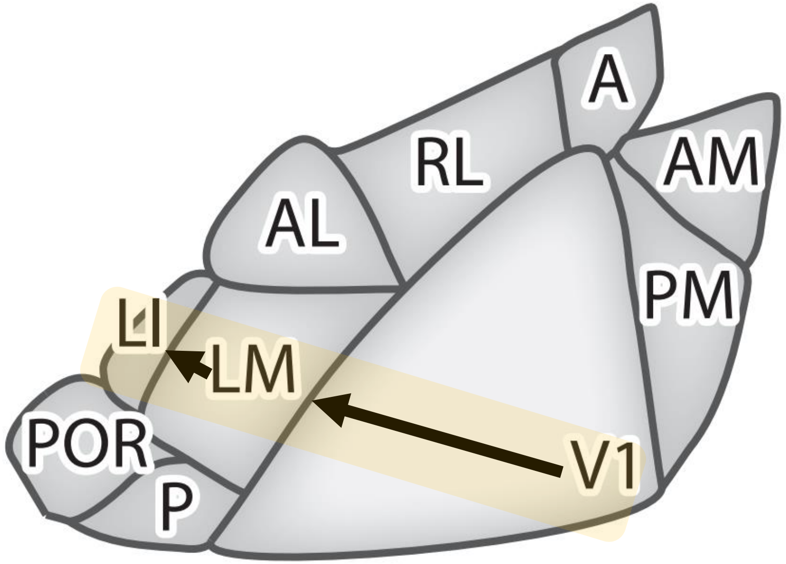
# Adaptation in V1 reduces redundancy of frequent stimulus & benefits coding efficiency




Benucci et al, 2013
Figure adapted by Jennifer Li

# Increasingly sparse representations along the visual hierarchy

- V1 project to higher visual areas
- Sparse firing and sparse population coding in higher visual areas (Young & Yamane, 1992, Zhuang et al, 2017, Vinken et al, 2017)
- Hypothesis: increasing sparseness in higher visual area could be accompanied by increasing adaptation



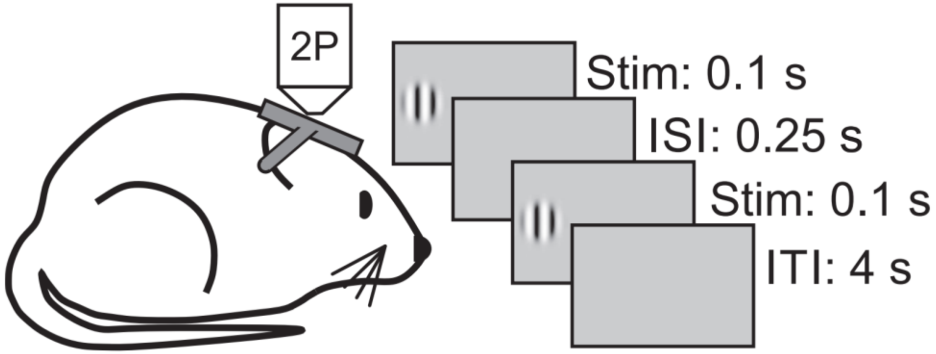

Ventral visual pathway

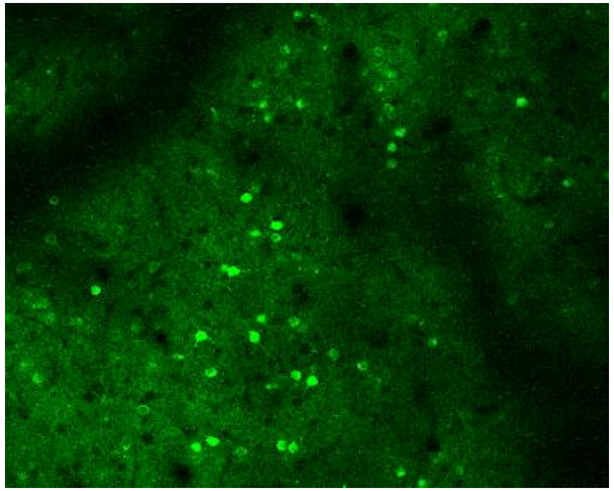
Glickfeld & Olsen, 2017

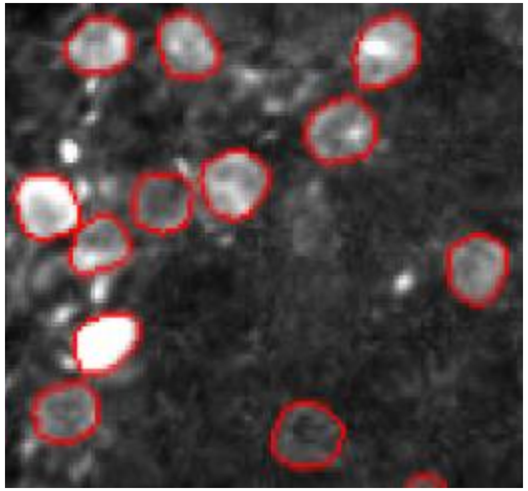
# Expectation

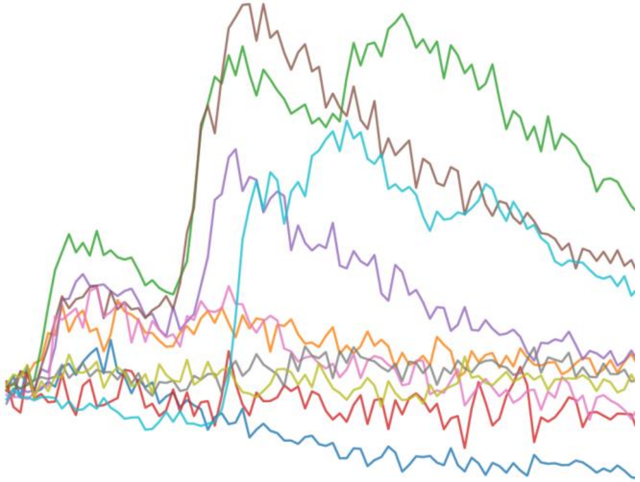
Adaptation increases from V1 to LM to LI

# Adaptation to gratings increases along ventral visual pathway

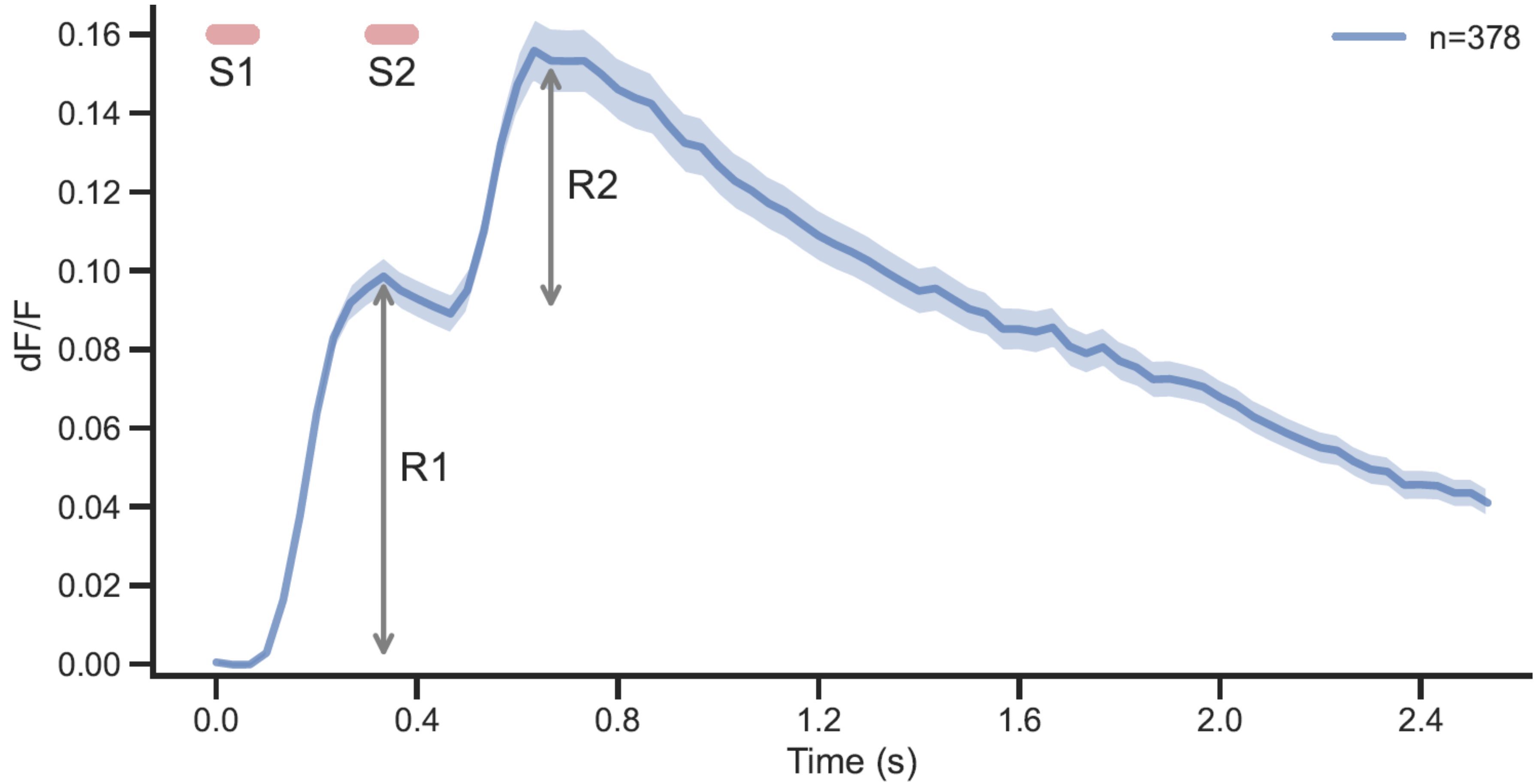




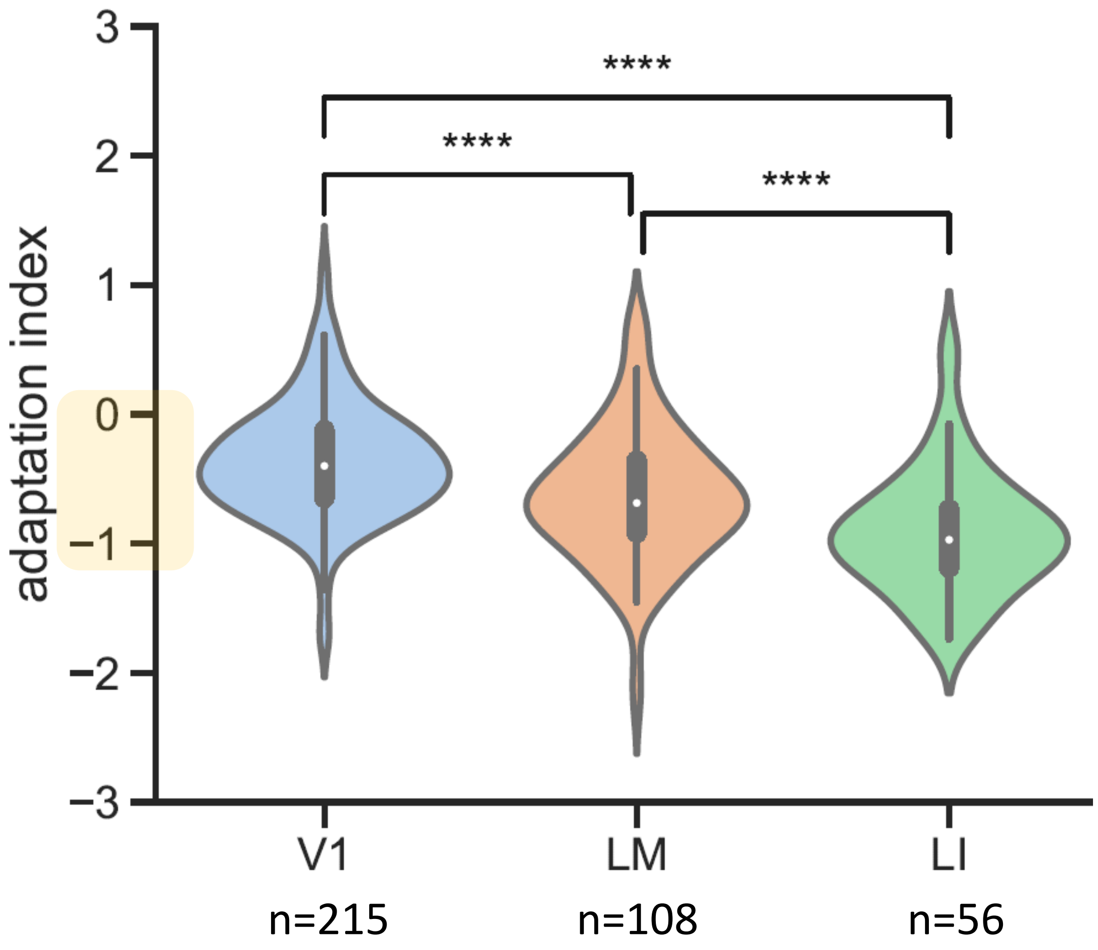


# V1 response to gratings: trace of grand trial average



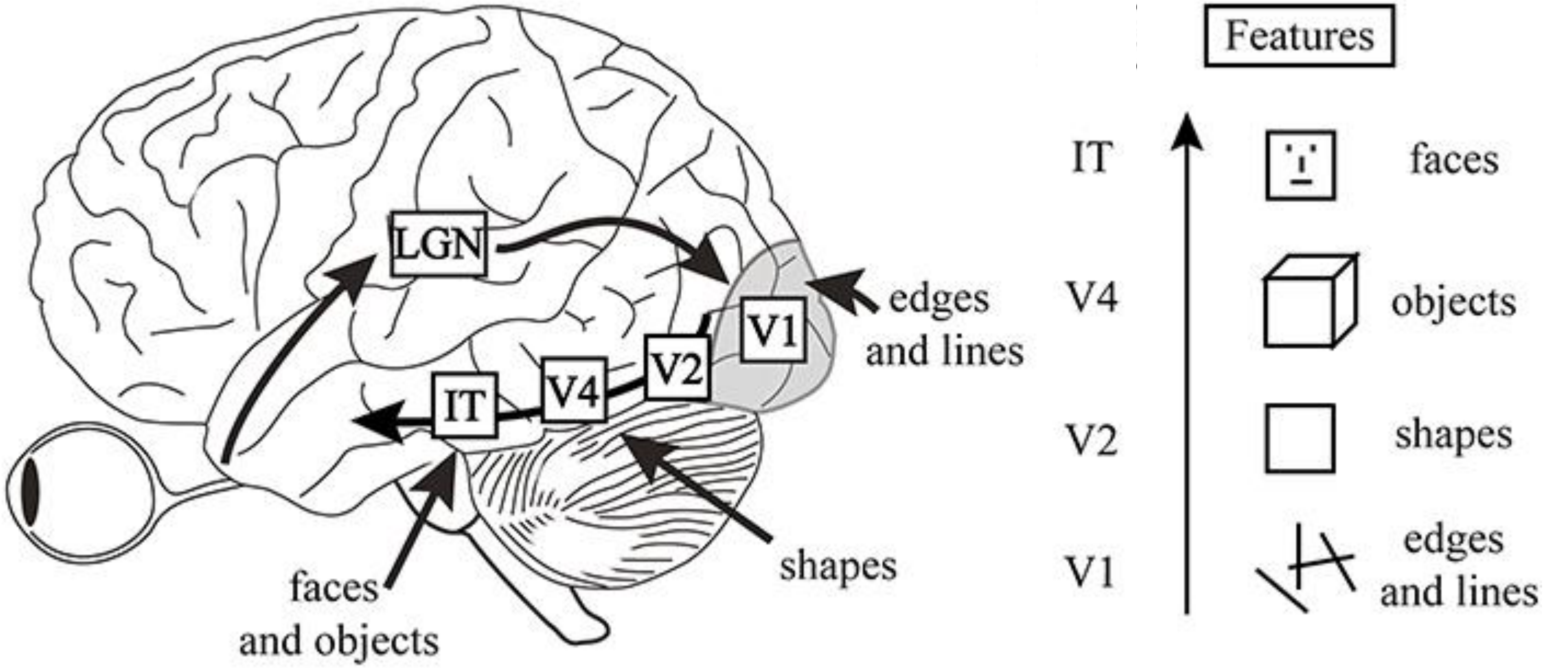
# Adaptation magnitude increases along ventral stream

$$Adaptation\ index = \frac{R_2 - R_1}{R_1 + epsilon}$$



# But… shouldn't only use gratings

- Higher visual areas better encode natural images

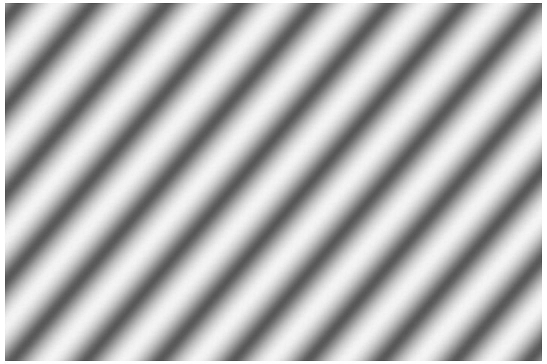


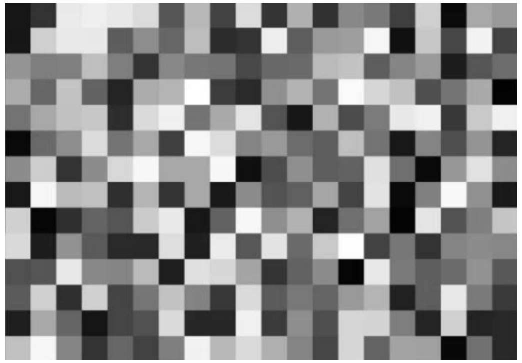

Herzog & Clarke, 2014
Freeman et al, 2013
Nayebi et al, 2018

# Spatial redundancy might open door for more adaptation

- Neural systems performing efficient coding should try to squeeze out all predictable information in the input (Atick & Redlich 1990, 1992)

  >> reduce not only temporal, but also spatial correlational structure in the stimulus? (Weber et al. 2019)





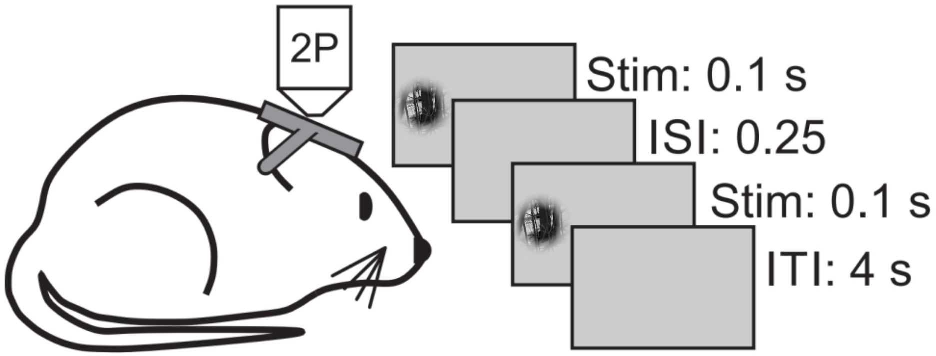
overall redundancy level decreases

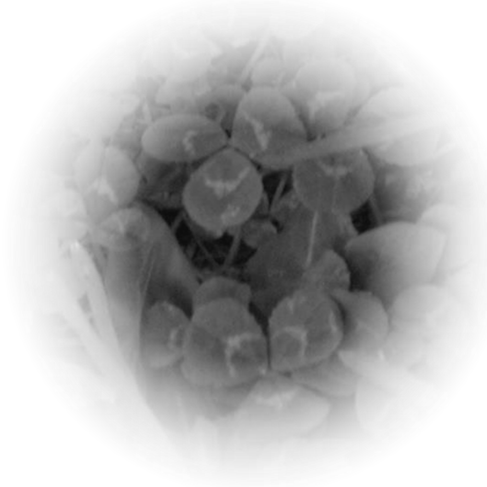
Thomson 1999

# Expectation

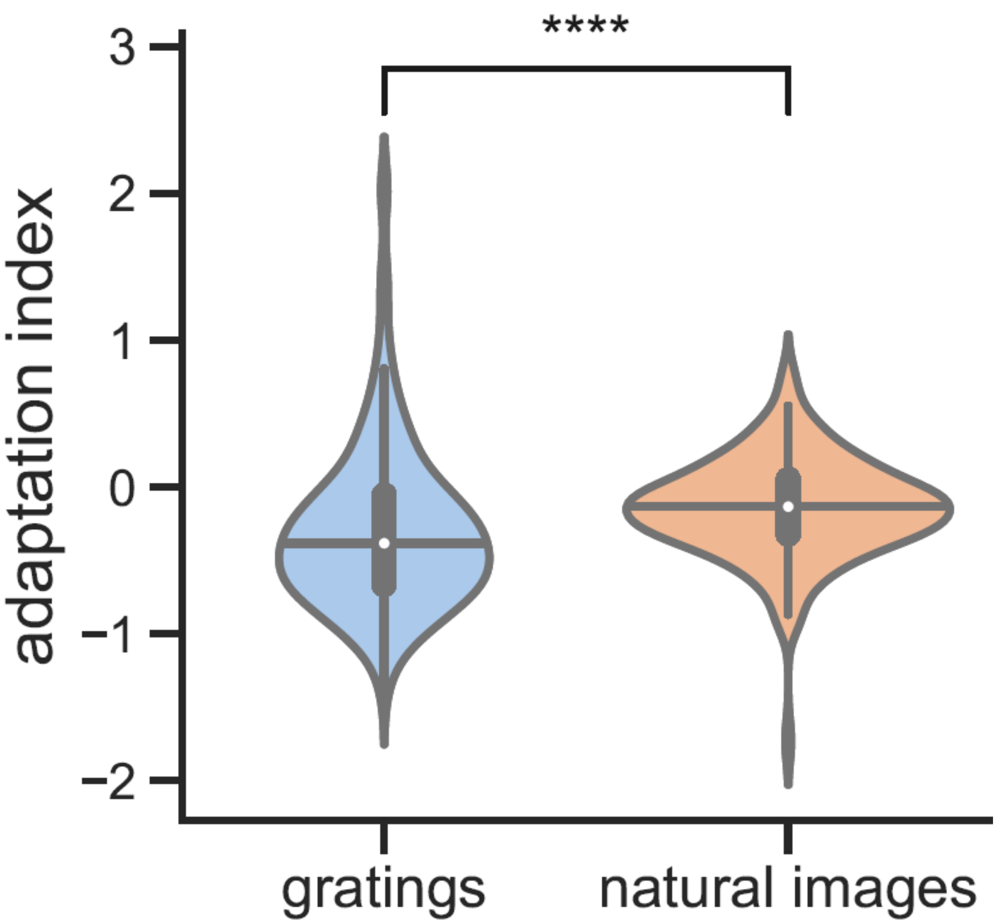
Adaptation increases from low redundancy to high redundancy stimulus, e.g. from natural images to gratings

# Adaptation to natural image in V1



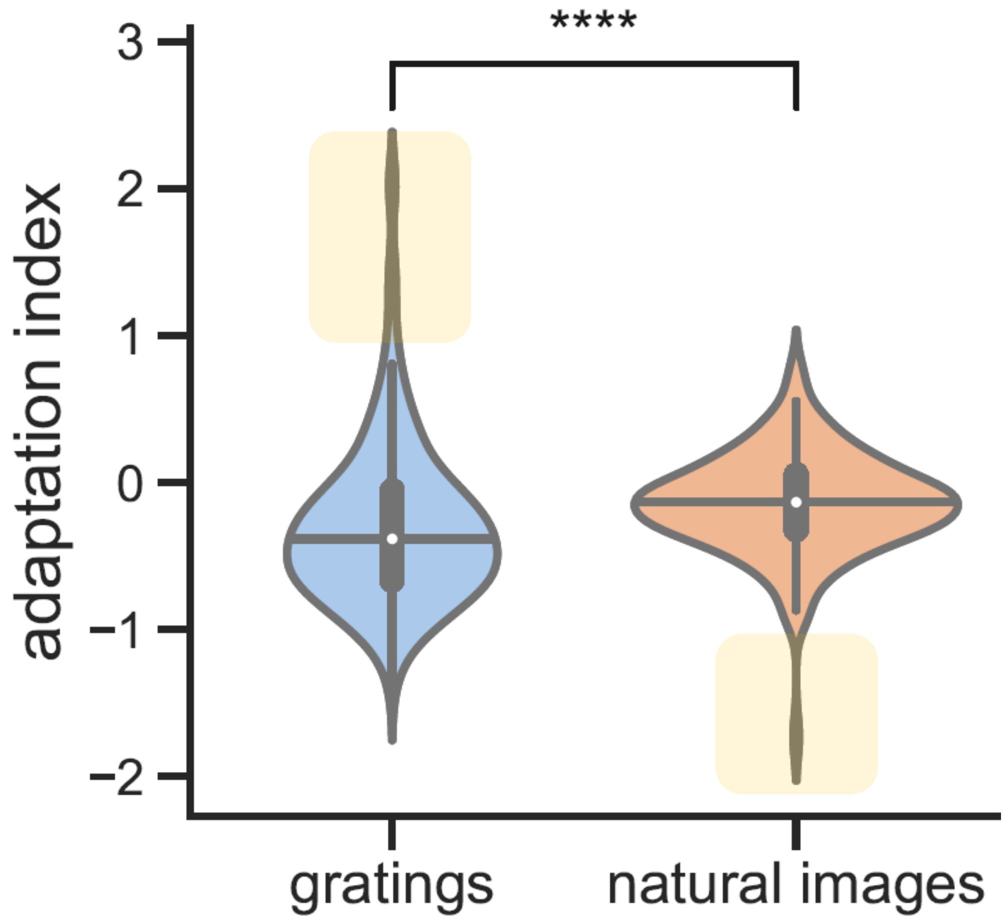



# Adaptation to grating is larger than natural images in V1



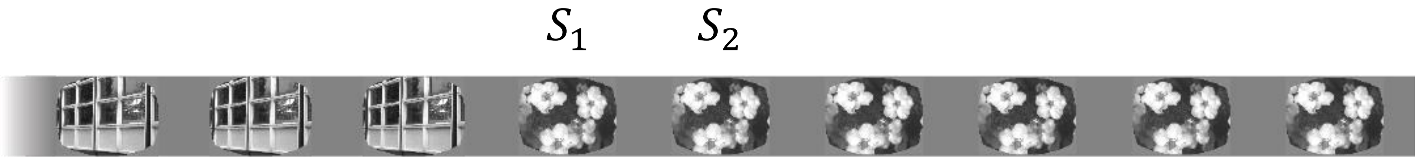

n=363 n=248

# Why is adaptation heterogenous in neuronal population?

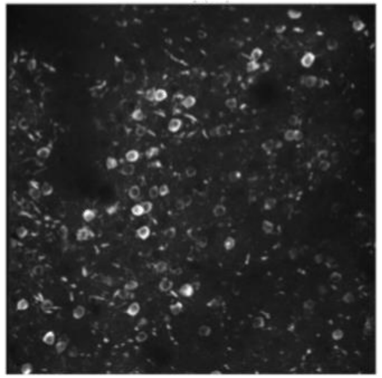


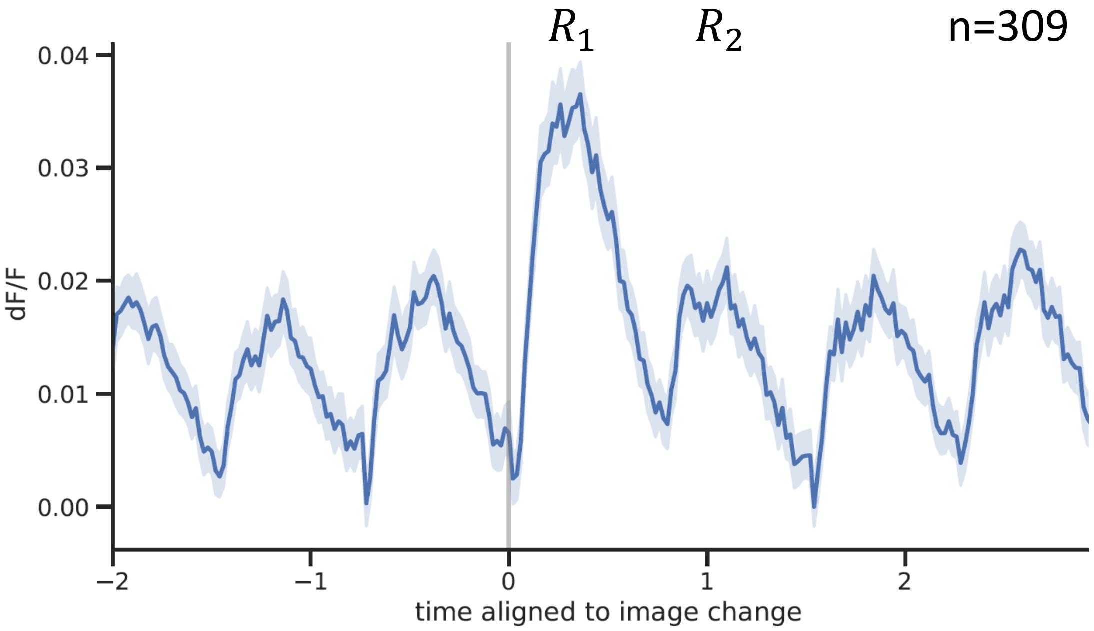
# Allen Institute open source data

Multi-plane imaging
(2 areas, 4 depths)

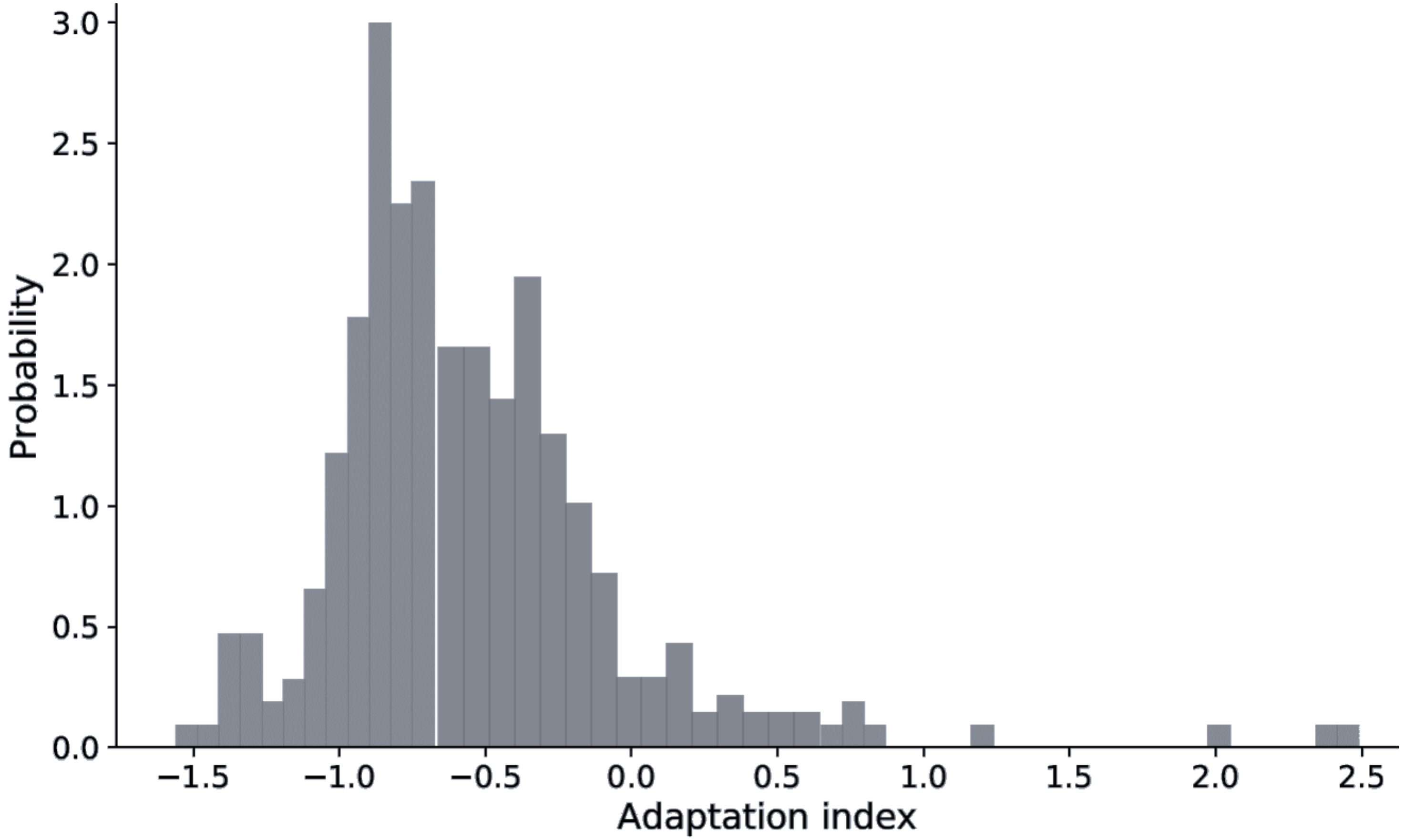



**Excitatory**
Slc17a7-IRES2-Cre;CaMk2-tTA;
Ai93(GCaMP6f)





# Similarly wide distribution of adaptation index in Allen Institute data




n=309

# Representation in subpopulations with different adaptation

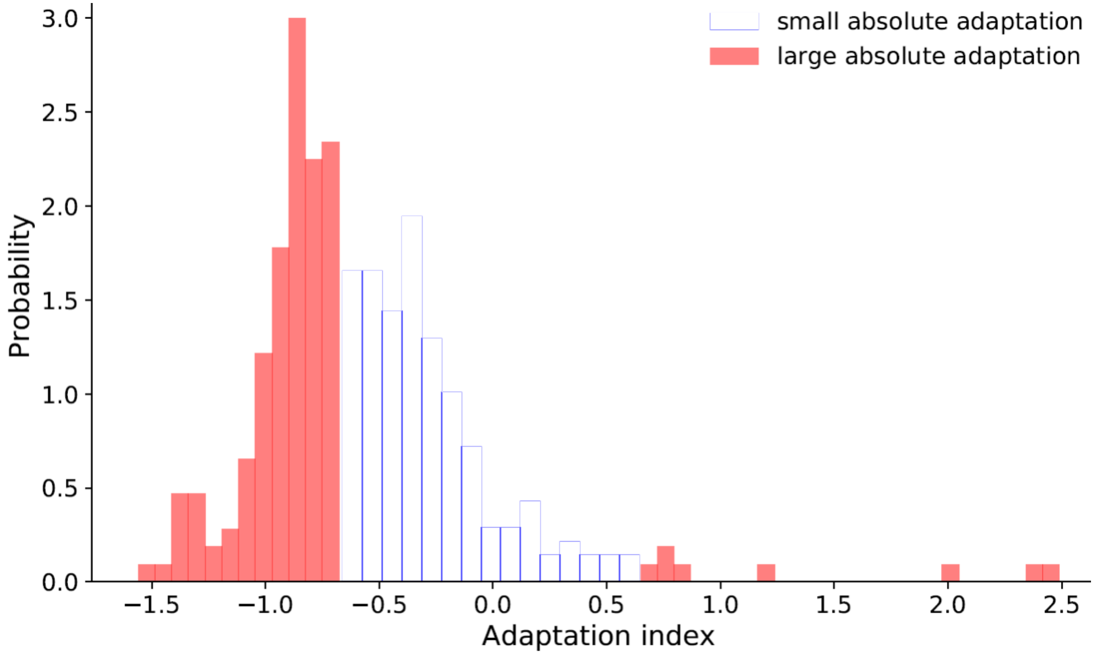
Expectation:

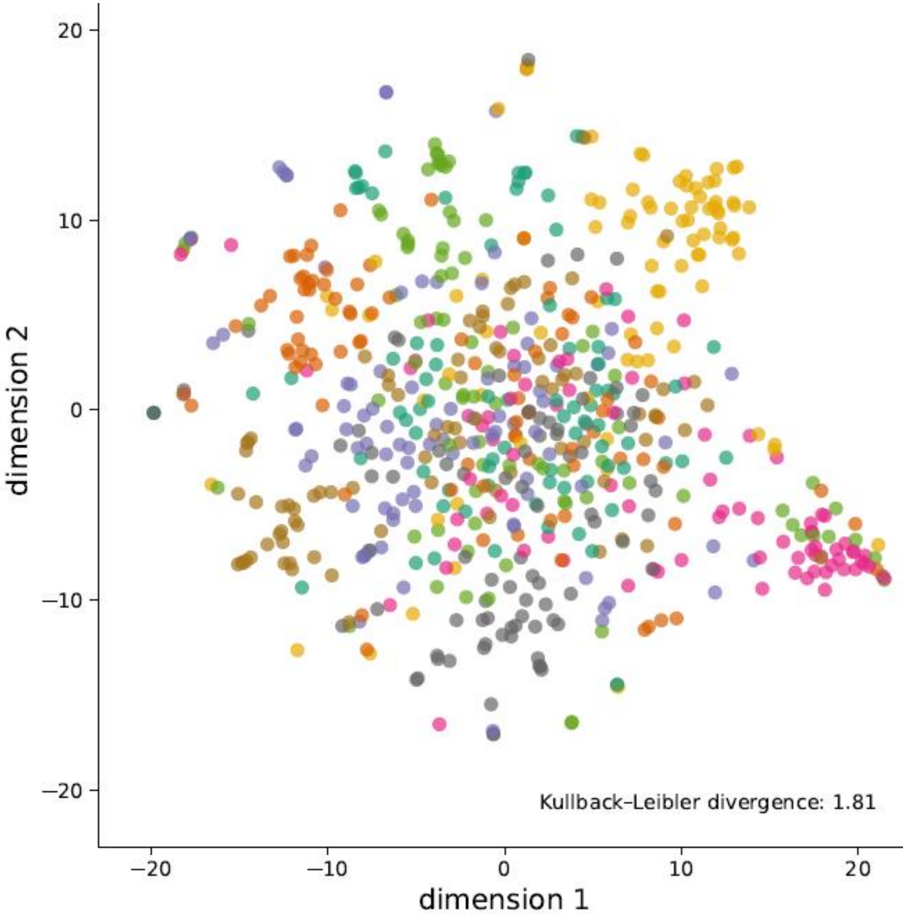
- tradeoff: neuronal population wants to retain information (e.g. about image identity) and simultaneously minimize spike number
- division of labor?
    - one subpopulation reduces activity after adaptation
    - the other encodes image identity

Analysis:

- data: response of each neuron in each trial
- split neurons into 2 groups by median of absolute adaptation index
- dimensionality reduction

# Lower dimensional representation in less-adapting cells



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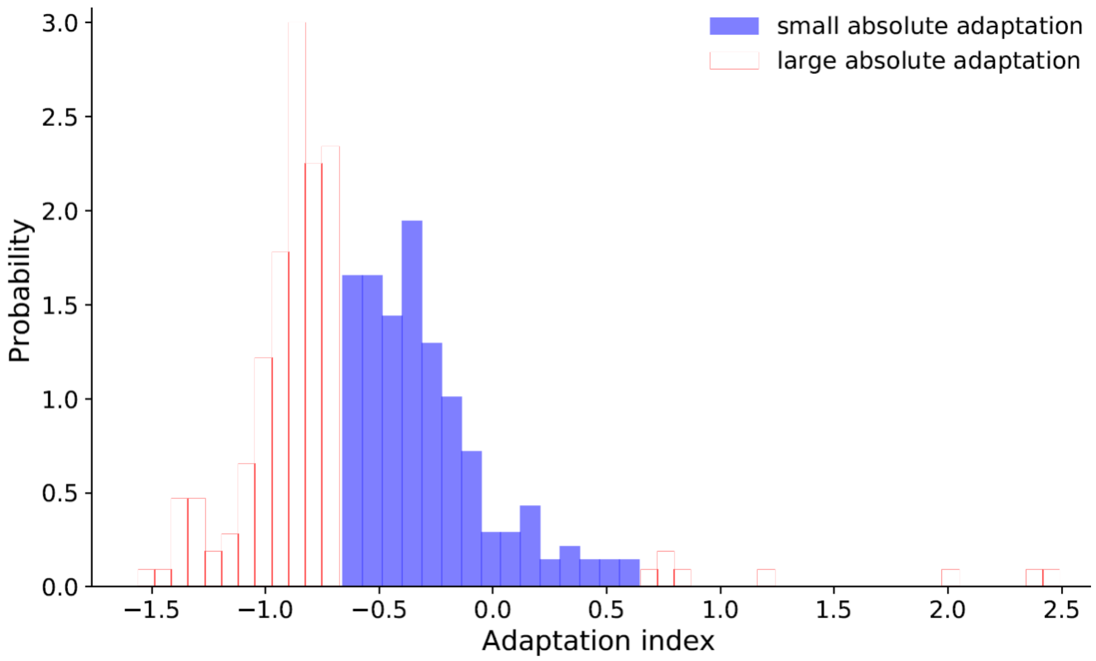


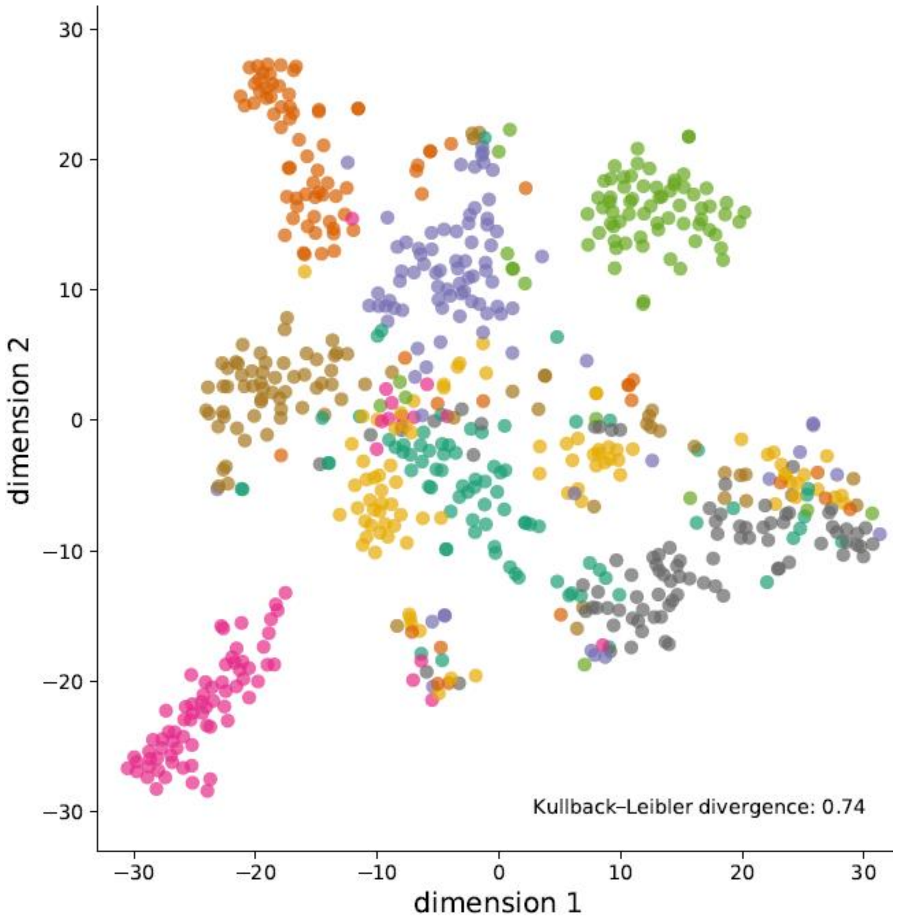

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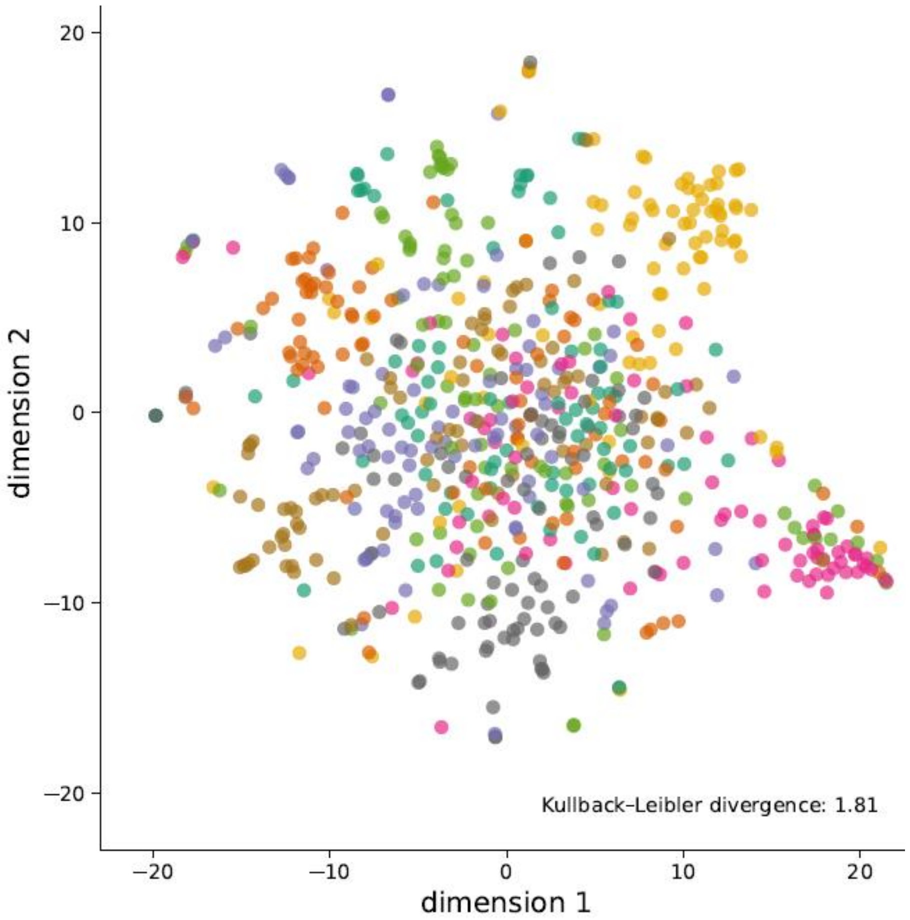


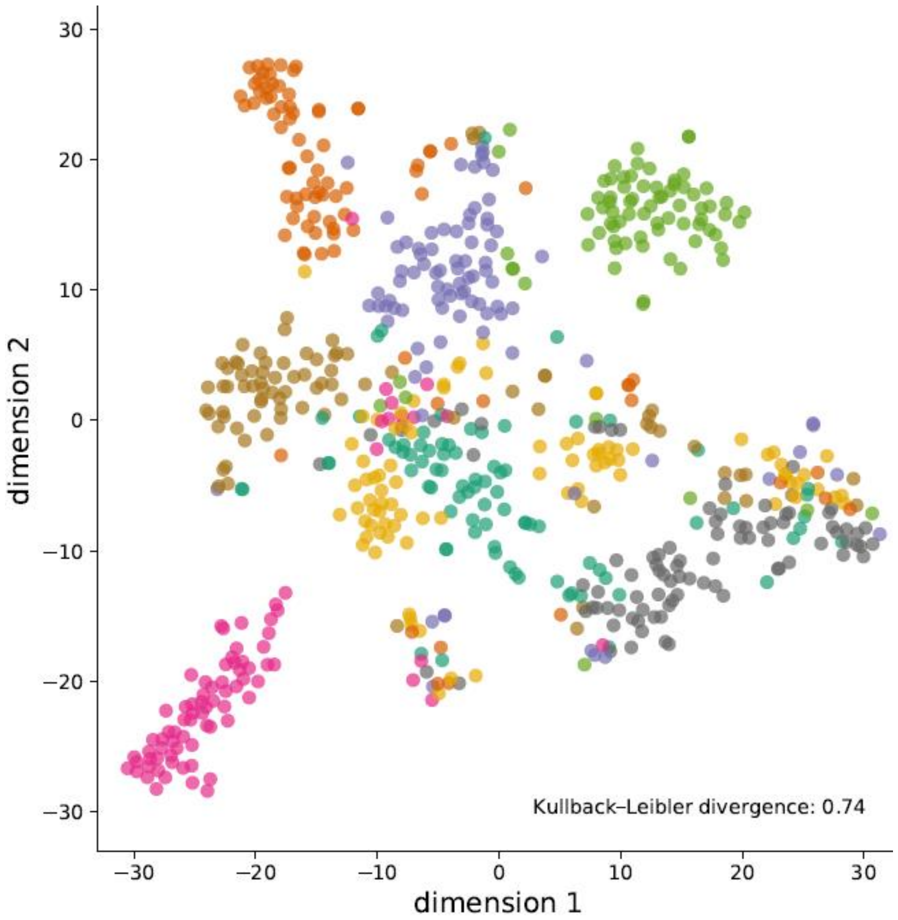

# Conclusion

1. Adaptation increases along the ventral visual pathway: from V1 to LM to LI

- as expected by increasingly sparse coding along visual hierarchy

2. Adaptation to natural images is smaller than adaptation to gratings in V1

- in accordance to more redundancy (to be squeezed out) in grating stimuli than natural images

3. Less adapting neurons might be encoding natural image identity in a lower dimensional space

- perhaps stable neuron subpopulation is responsible for encoding image identity, while adapting subpopulation is responsible for further sparsifying representation

# Future direction

- Direct measure of efficiency of neural coding
- Investigate adaptation to natural images in higher visual area
- Explore what image features modulate adaptation magnitude

# Acknowledgement

Lab members:

Lindsey Glickfeld

Celine Cammarata

Jennifer Li

Camaron Mangham

Tammy Hawley

Wenjuan Kong

Thomas (TJ) Wagner

Devesh Shah

Megan Stone

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