Visual response adaption dynamics depend on luminance polarity and spatial frequency in primary visual cortex but not superior colliculus neurons

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Yue Yu, João B. Bittar, & Ziad M. Hafed [1,2]

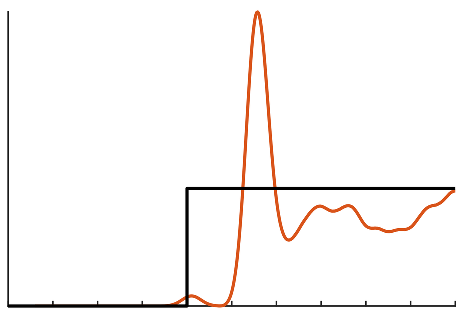
1. Werner Reichardt Centre for Integrative Neuroscience, Tuebingen, Germany
2. Hertie Institute for Clinical Brain Research, Tuebingen, Germany

Hertie-Institut für klinische Hirnforschung

CIN Werner Reichardt Centre for Integrative Neuroscience

Introduction

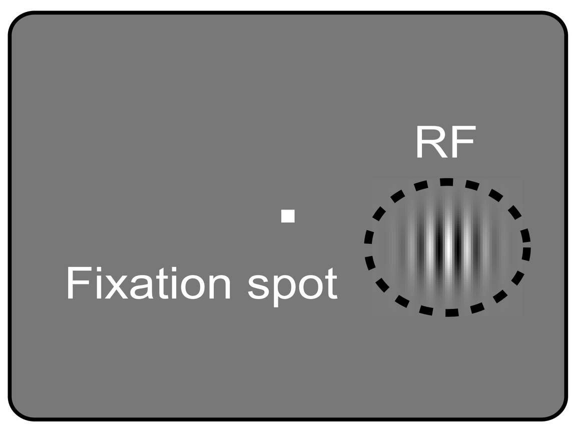
- Stimulus-driven neuronal responses are often characterized by an initial spike burst followed by a gradual reduction towards lower steady-state activity
- Such temporal adaptation is mathematically equivalent to a high-pass filter



- Spatial frequency and luminance polarity (darks or brights) may not be equally likely at all possible temporal frequencies in natural dynamic scenes
- Do primary visual cortex (V1) and superior colliculus (SC) neurons exhibit different adaptation time constants along these feature dimensions?

Methods

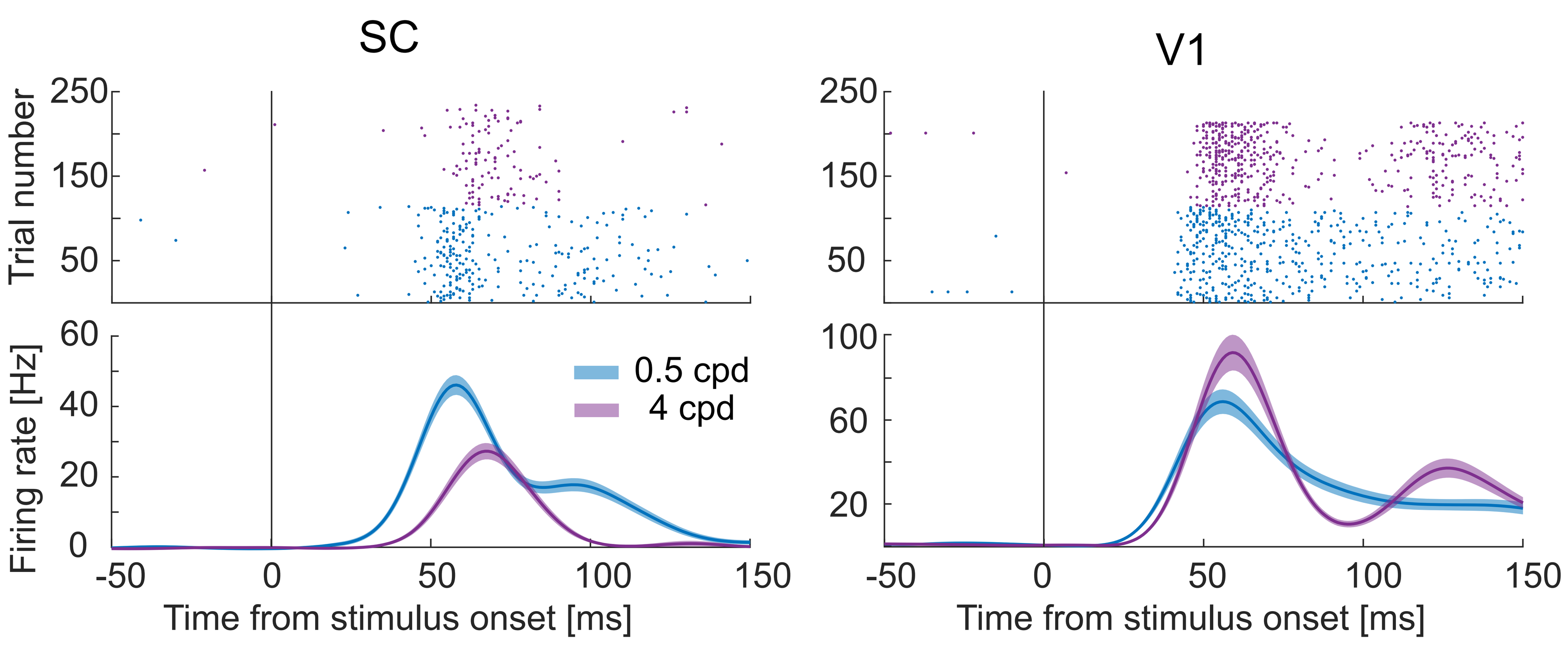
Task 1:
- 80% contrast Gabor grating.
- 4 spatial frequencies: 0.5, 1, 2, 4 cpd
- 251 and 108 V1 and SC neurons, respectively from 2 rehsus macaque monkeys



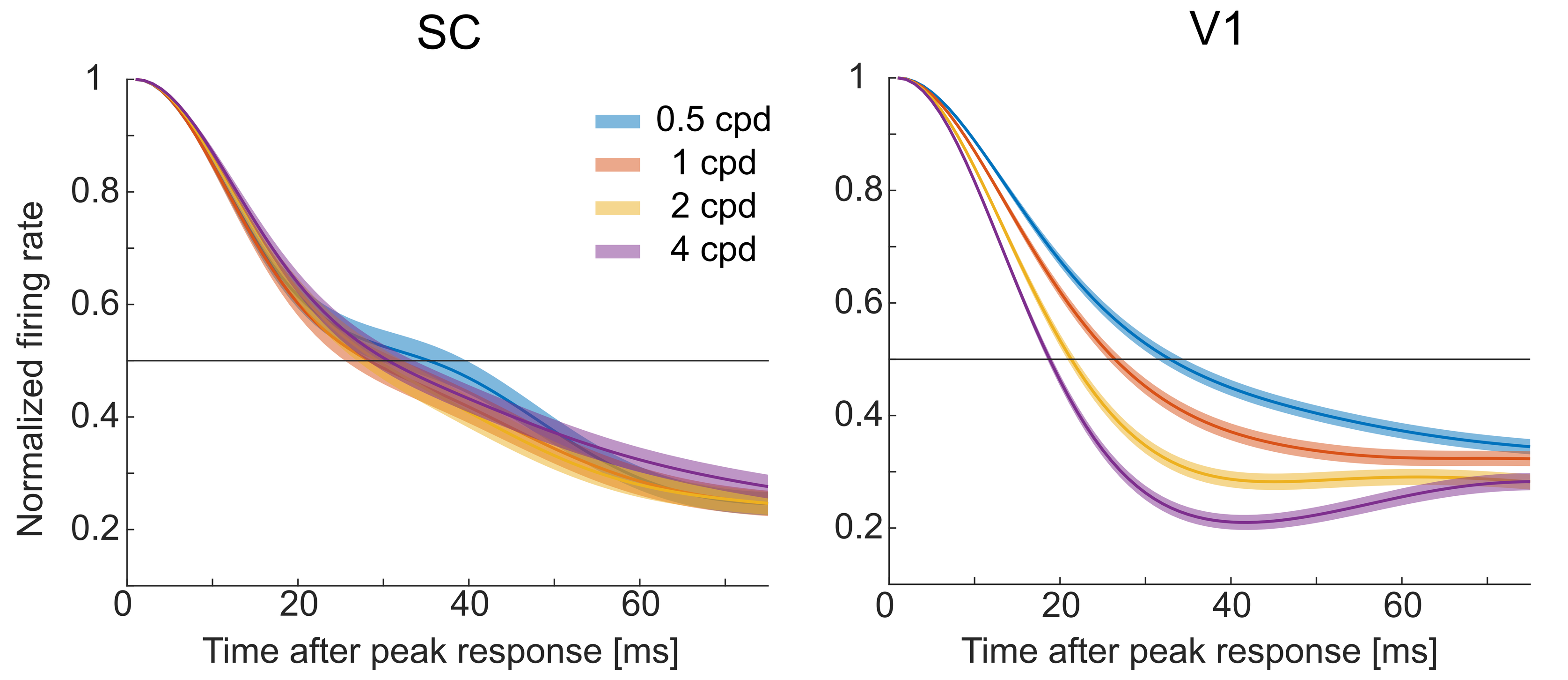
Task 2:
- 0.51 deg radius disc
- 8 dark or bright Weber contrasts: 10%, 20%, 50%, 100%
- 408 V1 (two monkeys) and 238 SC (three monkeys) neurons

V1 neurons adapt faster than SC neurons at high spatial frequencies

- Example neurons for low (0.5 cpd) and high (4 cpd) spatial frequency stimuli



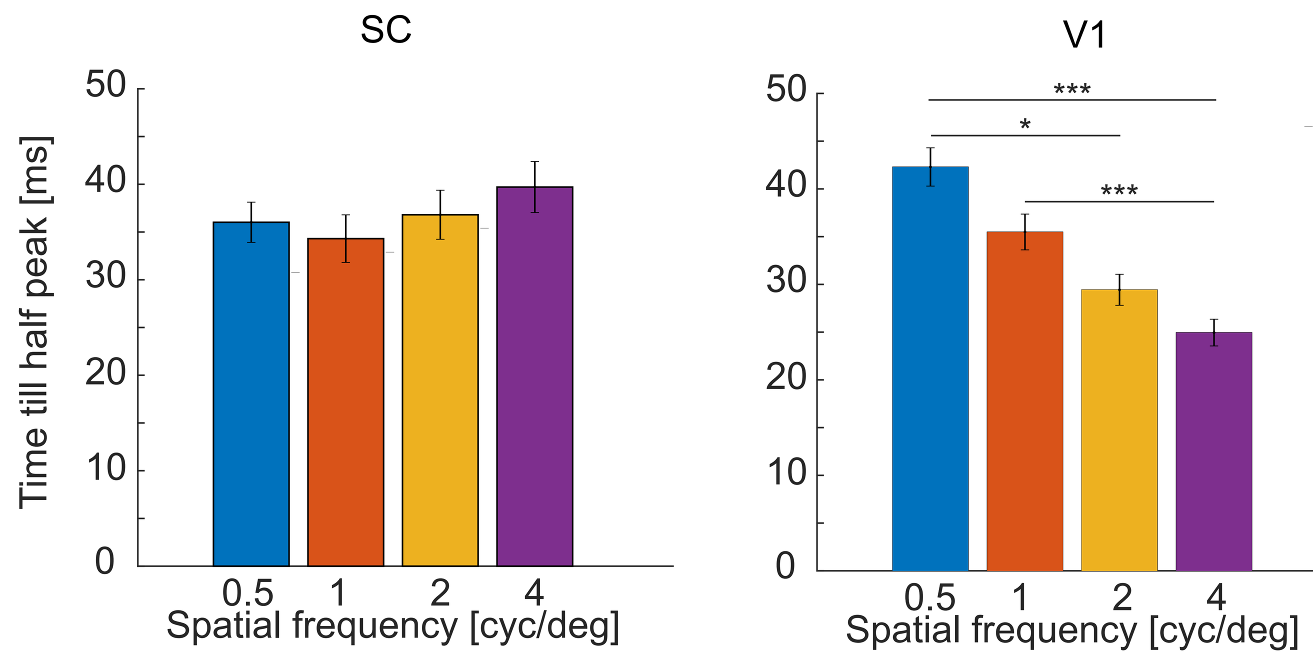
- The V1 neuron showed slower adaptation at 0.5 cpd but faster adaptation at 4 cpd
- To compare the adaptation rates between conditions, we normalized the average firing rates, and then aligned them to the peak response time



- Errorbar indicates the SEM

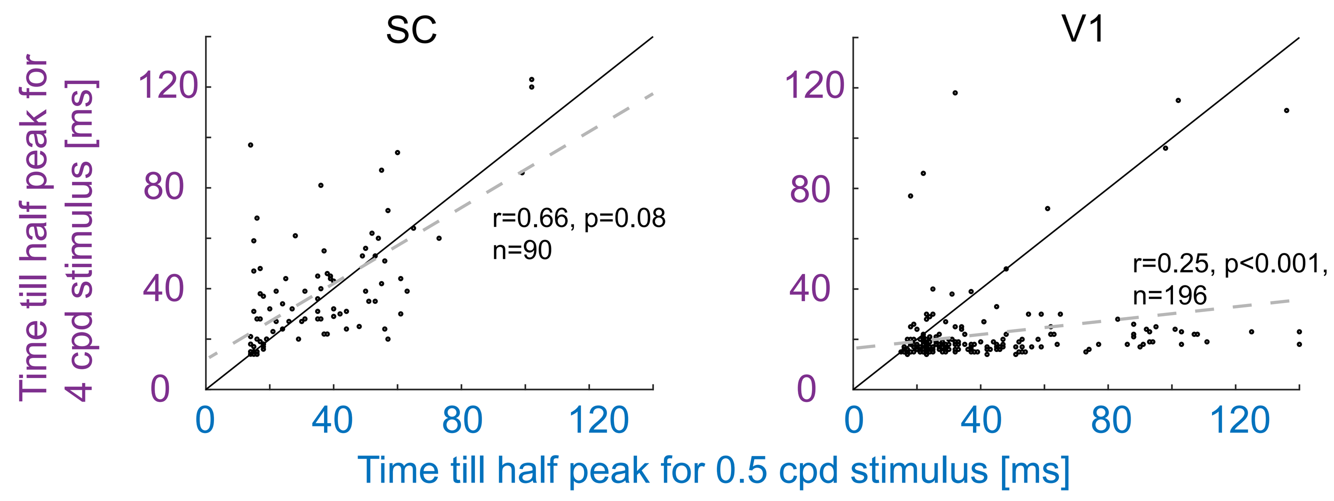
- SC neurons did not show clear differences in adaptation rates for different spatial frequency stimuli
- V1 neurons exhibited faster adaptation for higher spatial frequency stimuli
- We used the time till the response decreased to half the peak response as a measure to quantify this effect

Dependence of V1 adaptation rates on spatial frequency



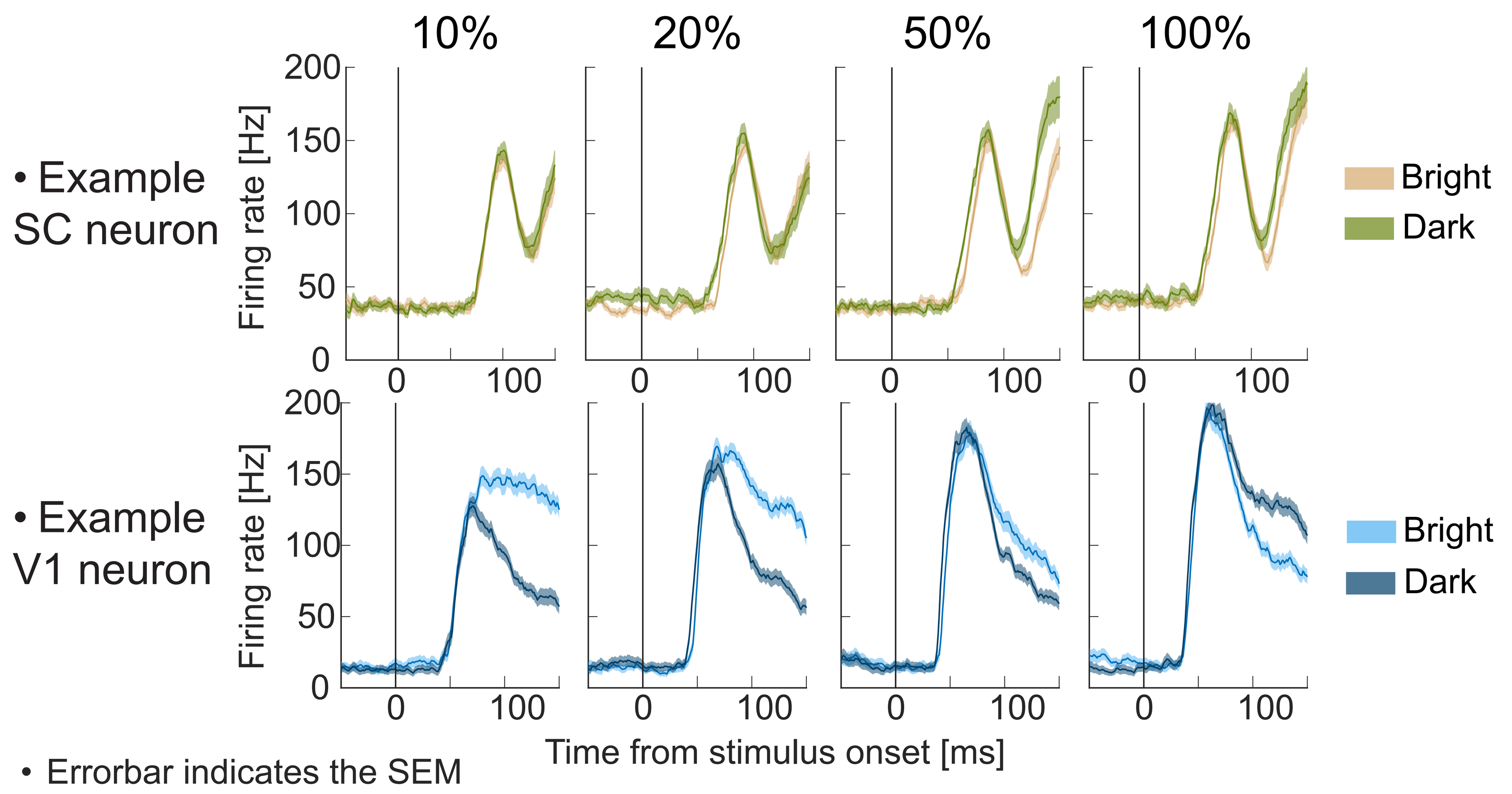
- Errorbar indicates the SEM

- For SC neurons, there was no significant difference in adaptation rate across different spatial frequencies (1-way ANOVA, n=108)
- For V1 neurons, there were clear dependencies (ANOVA, n = 251, p<0.001); post-hoc pairwise comparisons revealed significant differences between 0.5 cpd and 2 cpd, 1 cpd and 4 cpd, and 0.5 cpd and 4 cpd



- The effects in V1 were highly systematic across the great majority of neurons

Image-dependent adaptation for luminance polarities in V1 but not SC



- Errorbar indicates the SEM

- SC showed faster adaptation than V1 across stimuli
- V1 adapted more slowly for 100% dark than 100% bright, and more slowly for 10% bright than 10% dark

Conclusions

There was no dependence on stimulus spatial frequency for SC neurons.

V1 neurons exhibited clear dependence on stimulus spatial frequency in their adaptation. They showed faster adaptation for higher spatial frequencies.

Additional image dependencies also emerged with luminance polarity, but again only in V1.

We hypothesize that this allow V1 neuron to better track scene dynamics.

For example, clouds are low contrast bright stimuli that have slow temporal dynamics, not necessitating fast neural adaptation.

Conversely, fixational eye movements enhance the temporal retinal image modulations of intermediate spatial frequencies, requiring faster V1 dynamics to represent them.