Albert Einstein College of Medicine

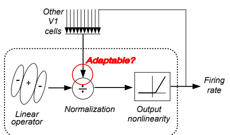
Developing a normalization framework of adaptation

Amir Aschner[1], Sam Solomon[2], Michael Landy[3], David Heeger[3], Adam Kohn[1]

[1] Dept. of Neuroscience, Albert Einstein College of Medicine, Bronx NY; [2] Dept. of Experimental Psychology, UCL; [3] Dept. of Psychology & Center for Neural Science, NYU

1 Background

- Adaptation phenomena may arise in part from altered normalization.[1,2,3]
- Normalization is a neuronal computation whereby a neuron's responses are modulated (typically reduced) by the activity of other neurons (normalization pool).

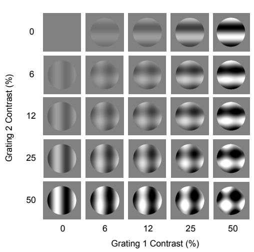


- Normalization signals from the receptive field surround can be weakened by adaptation. The impact of adaptation on normalization signals within the receptive field is less clear.[4,5,6]
- To explain the suppressive effects of adaptation — those that cannot be explained by simple fatigue mechanisms — normalization must also be strengthened by some adapters.
- **Theoretical work suggests that contingent adaptation — consistently pairing a target and mask grating — should produce strengthened normalization (stronger masking). Presenting a target and mask asynchronously should weaken normalization signals.**[2]

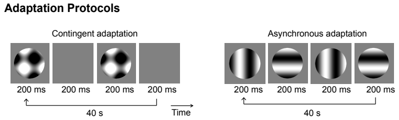
2 Methods and experimental design

- Single- and multi-unit recordings from V1 of anesthetized macaques
- Adapt neurons for 40 s with different patterns of drifting, sinusoidal gratings within their receptive fields (1.5 deg, 1 cycle/deg, 3 HZ drift)
- Measure strength of normalization in each unit before and after adaptation

Test Stimuli



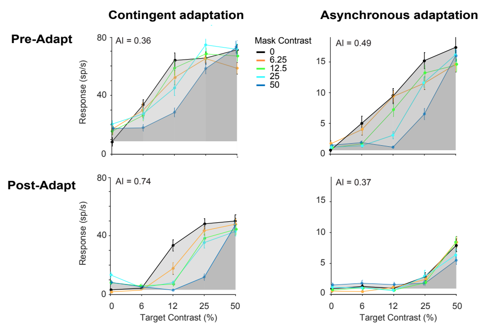
Adaptation Protocols



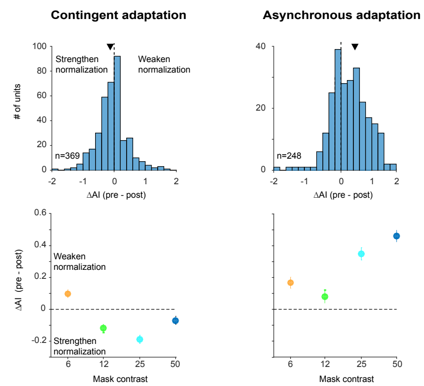
3 Example cells

- Normalization strength was measured using an Area Index (AI), calculated separately for each mask contrast:

$$AI = \frac{AUC_T - AUC_{T+M}}{AUC_T + AUC_{T+M}}$$



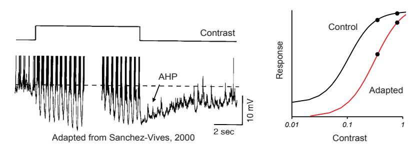
4 Population summary



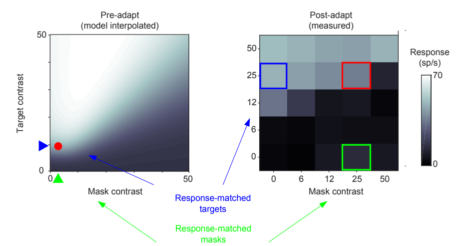
- Contingent adaptation strengthens normalization. Asynchronous adaptation weakens normalization.

5 Does summation change after adaptation?

- Apparent adaptation-induced changes in normalization could be due to altered intrinsic excitability:

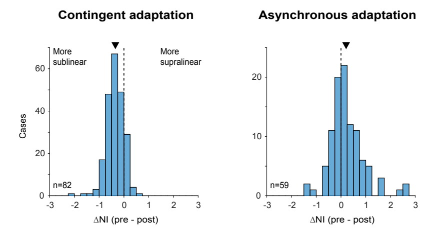


- We calculated a rate-matched normalization index (NI) to measure summation, while controlling for changes in responsivity.



$$NI = 1 - \frac{Resp(T+M)}{Resp(T) + Resp(M)}$$

- We computed a post-adaptation NI by comparing the measured responses to plaids (red square; right) and their component gratings (blue, green).
- We then fit the pre-adaptation data with a standard descriptive function, and found pre-adaptation component gratings (blue, green arrowheads) that evoked the same response as those measured post-adaptation. We computed a pre-adaptation NI by comparing these component responses to the plaid formed by their combination (red dot).



- Contingent adaptation causes a shift toward sublinear summation.
- Asynchronous adaptation does not strongly alter summation.
- Weakening of normalization by asynchronous adaptation can thus be largely — but not entirely — explained by changes in responsivity. Strengthening of normalization by contingent adaptation cannot be explained by changes in responsivity.

6 Conclusions

- Normalization signals within the receptive field can be altered by adaptation.
- Normalization signals change in qualitatively different ways when a neuron and normalization pool are consistently co-activated or driven asynchronously.
- Contingent adaptation strengthens normalization signals, even after controlling for changes in responsivity.
- Asynchronous adaptation weakens normalization signals; however, much of this effect can be explained by altered neuronal responsivity.
- The effects of contingent adaptation may provide a neural basis for contingent perceptual aftereffects.
- **These results support a normalization framework of adaptation, suggesting some suppressive effects of adaptation may be due to strengthened normalization.**

References

1. Heeger, 1992, *Visual Neuroscience*
2. Solomon & Kohn, 2014, *Current Biology*
3. Westrick et al., 2016, *Journal of Neuroscience*
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5. Patterson et al., 2013, *Journal of Neuroscience*
6. Wissig & Kohn, 2012, *Journal of Neurophysiology*

CONTACT: AASCHNER@MAIL.EINSTEIN.YU.EDU