Albert Einstein College of Medicine

Decoding visual stimulus orientation from adapted neural populations.

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How does adaptation affect population information?

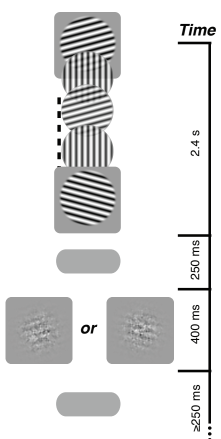
- Effects of visual adaptation on single V1 neurons have been extensively studied
- Less is known about how adaptation affects population codes
- How do the aggregate shifts in single neuron tuning and responsivity influence the quality and quality of information available in primary visual cortex?

We measured the effects of adaptation to dynamic sequences of drifting gratings with a range of orientations spanning from uniform distributions to single-orientations; others specifically chosen to influence neural populations most informative for fine orientation discrimination

(e.g. Price & Prescott, 2012)

Methods & Materials:

- Multielectrode array recordings of populations of neurons in primary visual cortex (V1) of anesthetized macaque
  (96-ch 'Utah' arrays, M. facicularis)
- Brief test stimulus presented after adaptation to a range of dynamic oriented adaptation distributions:



Adapt: Rapid sequence of oriented drifting gratings
- 80 ms/orientation • 30 ori/sequence • 2.4 s/trial
- Full contrast • 1.5 cyc/deg • 6.25 Hz
- Raised cosine profile, ~6° (wider than tails of test gabor)

Test: Drifting gabor masked in dynamic pixel noise
- 400 ms • 2.5° FWHM • 1.5 cyc/deg • 6.25 Hz
- Low contrast, 0.6 SNR (signal + noise contrast = full display range)
- Test orientations aligned to adaptation distribution
- 5-7 test orientations, ±18° mean adapt orientation

- Interleaved blocks of three conditions per session: 1 unadapted & 2 adapted; ~2.5hr/sessions i.e. [Unadapt, Uniform, Single] —or— [Unadapt, Narrow Flank, Wide Flank]
- 96 repeats per test orientation per condition
- Spike rates computed over a 300 ms time window, spanning 150–450 ms after test stimulus onset
- Orientation tuning and receptive field measurements were made before and/or after each experimental session

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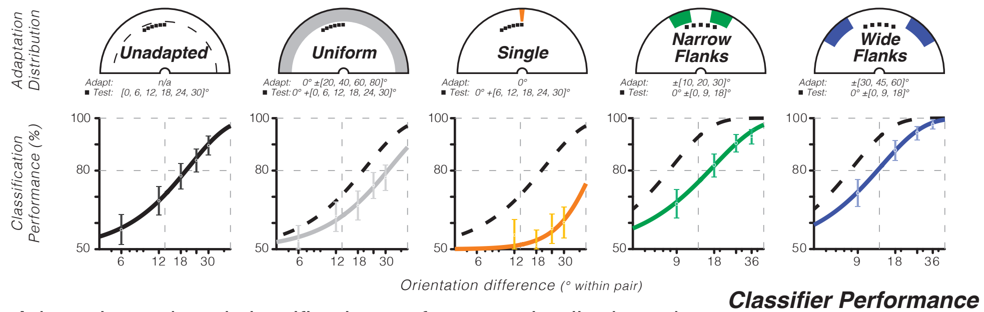
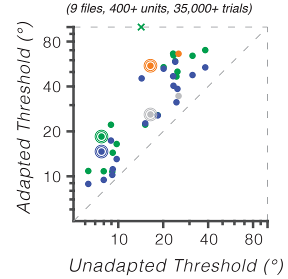
Adaptation reduces orientation information in V1 populations

- Linear SVM classifier trained on unadapted data, then tested after adaptation to various orientation distributions
  (LIBSVM software: Chang & Lin, 2011)
  - 48 simultaneously recorded units selected by rank ordering discrimination sensitivity (d') for each binary pairing
  - All classifications were performed as one-against-one binary comparisons, leave-one-out cross validation was used whenever train & test populations were the same
  - Neurometric functions fit to classification performance on all pairwise combinations of test orientations



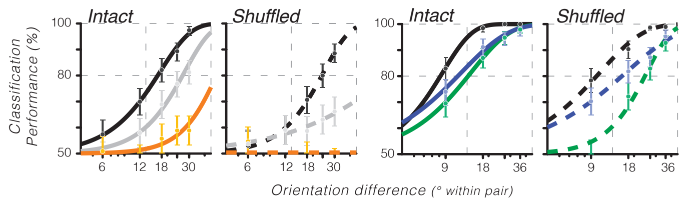
- Adaptation reduced classification performance in all adapted populations
- Stronger effect for narrower ranges of adaptation orientations

Classifier Performance
(9 files, 400+ units, 35,000+ trials)



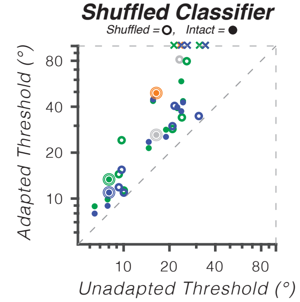
What drives reductions in classification performance after adaptation?

Classifiers trained & tested on shuffled response matrix to remove spike count correlations in training & testing populations



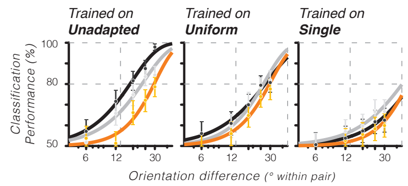
- Shuffling broadly reduced classification performance in unadapted & adapted populations
- Shared rate fluctuations may be beneficial for small populations, but did not appear to be a primary source of adaptation effects

Shuffled Classifier



Effects of adaptation were not mitigated by an 'adaptation aware' decoder

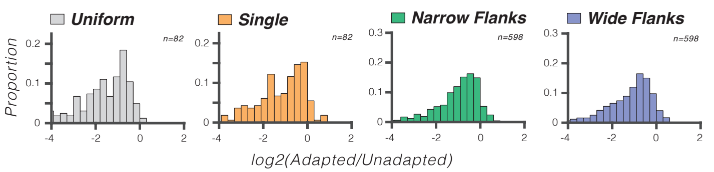
- Classifiers retrained on each adapted population, then tested with leave-one-out cross validation
- When trained on adapted populations decoders also unable to recover information from unadapted population responses.
  - Suggesting the performance deficit is not only a matter of information content, but also an inability to identify relevant elements within the population.



Adaptation influences on responsivity and variability

Adaptation reduced responsivity by approx. 50%

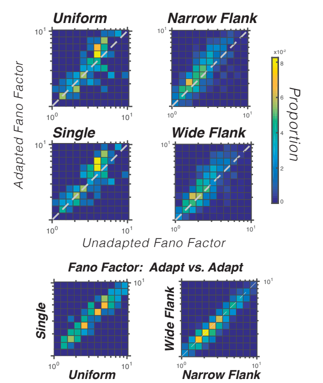
- Effect of adaptation on responsivity assessed by adaptation index (AI) as the mean ratio of post- / pre-adaptation spike rates across test orientations



- Responsivity was greatly reduced after adaptation
- Overall distribution of adaptation indices were similar across conditions

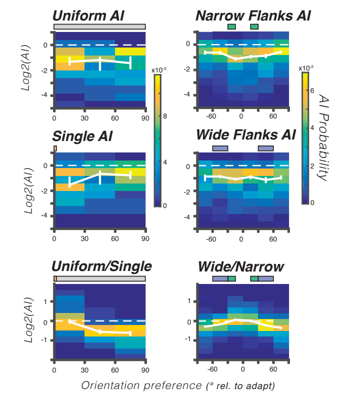
Variability of adapted populations increased 10–15%

- Comparison of fano factor before and after adaptation revealed modest increases in variability
- Fano factors between adaptation conditions showed variability of adapted populations to be impressively well matched



Tuned adaptation evident between adapted populations

- Distribution of AI relative to orientation preference revealed broad tuning of the population effects
- Greater reduction in responsivity for units tuned near center of narrow adaptation distributions
- Responsivity index computed between narrow and broadly spaced distributions exposed finer tuning within adapted populations



Brief adaptation is potent, reducing responsivity & modestly increasing variability

- Adaptation reduces V1 population information about stimulus orientation, for a wide range of adaptation distributions
- Change in population information is not driven by changes in correlations
- Detrimental effects of adaptation can not be overcome by an 'adaptation aware' decoder
- Complimentary experiments with awake-behaving animals will help integrate understanding of how neuronal population effects influence behavioral decisions