Motion adaptation from static binocular images: A surprising prediction of efficient coding theory

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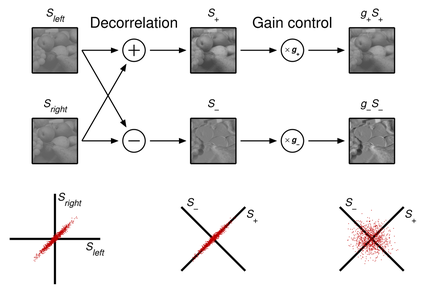
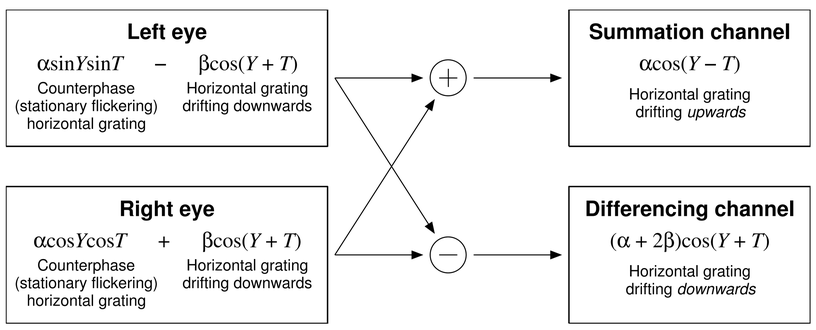
Introduction

- Li and Atick's theory of efficient stereo coding (Li & Atick, 1994, *Network*, **5**, 157–174)
- Summation (S_+) and differencing (S_-) channels decorrelate the ocular signals
- Gain control maximizes information capacity for a given energy budget and signal–to–noise ratio (SNR)
- Optimal channel gains depend on inter–ocular correlation and SNR, which both change over time during natural viewing



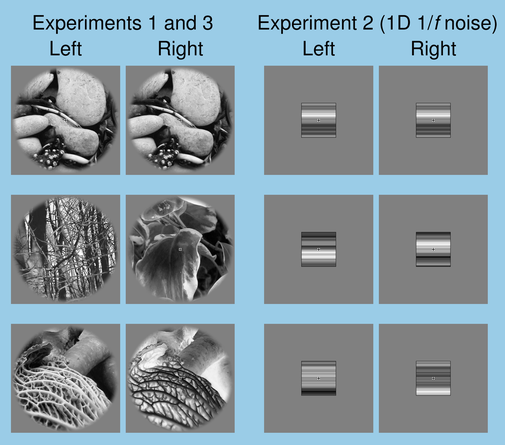
- So we'd expect sensitivities of S_+ and S_- channels to continually adapt to the prevailing binocular image statistics

Cyclopean motion



- Modification of Shadlen–Carney stimulus (Shadlen & Carney, 1986, *Science*, **232**, 95–97)
- S_+ and S_- channels see motion in opposite directions
- So perceived direction should depend on relative response strengths of S_+ and S_- channels
- By selectively adapting S_+ or S_- channel, we should be able to control perceived direction
- Details of test stimulus:
  - $Y = 2\pi fy$, where f = 0.25 c/deg, and y is vertical position
  - $T = 2\pi gt$, where g = 6 Hz, and t is time
  - Stimulus contrasts: α = 0.1; β = 0.02 in Expts 1 and 3, and 0.025 in Expt 2
- Shadlen and Carney always used β = 0. This gives equal signal strength in each channel, but motion is perceived in the summation (S_+) direction
- We added gratings of opposite contrast, $\pm\beta$, in each eye to boost the S_- signal so that performance was at chance in the *Uncorrelated Adaptation* confition

Adaptation of binocular channels



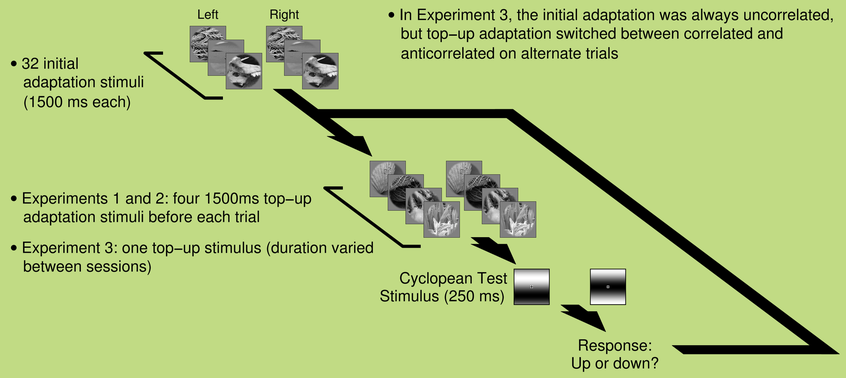
Correlated Adaptation
- both eyes see the same image
- S_+ channel stimulated
- S_- channel silent

Uncorrelated Adaptation
- each eye sees a completely different image
- S_+ and S_- channels stimulated

Anticorrelated Adaptation
- each eye sees the photographic negative of the other eye's image
- S_+ channel silent
- S_- channel stimulated

Procedure

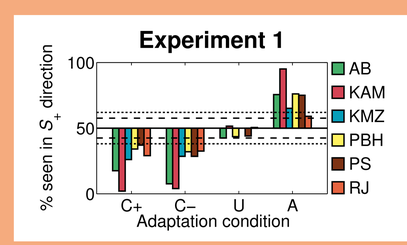
- Experiments 1 and 2 had the same type of adaptation throughout a session
- Experiment 2 differed from Experiment 1 only in that it used 1D noise adaptors instead of natural images
- These 1D noise adaptors could be vertical or horizontal
- The cyclopean test stimulus was horizontal in all experiments
- In Experiment 3, the initial adaptation was always uncorrelated, but top–up adaptation switched between correlated and anticorrelated on alternate trials



Results and discussion

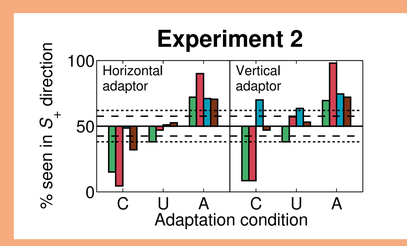
Experiment 1

- Four types of adaptation: C+ (correlated positive natural images), C– (correlated negative natural images), U (uncorrelated), A (anticorrelated)
- Dashed lines indicate significant bias from 50% (long dashes: $p < 0.05$; short dashes: $p < 0.001$)
- Result: Adaptation to *static* binocular stimuli affects perceived direction of cyclopean *motion*



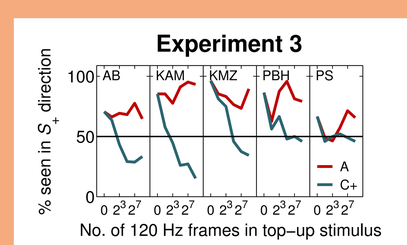
Experiment 2

- For some subjects, adaptation of summation and differencing channels not very orientation selective, suggesting adaptation for these subjects depended mainly on non–orientation–selective neurons in visual cortex
  - Summation channel implemented by cells with identical isotropic receptive fields in the two eyes
  - Differencing channel implemented by cells with isotropic receptive fields in which the polarity in one eye was opposite to that in the other – a few cells like this have been reported (Livingstone & Hubel, 1984, *J Neurosci*, **4**, 309–356; Snodderly & Gur, 1995, *J Neurophysiol*, **74**, 2100–2125)



Experiment 3

- Switching between correlated (C+) and anti–correlated (A) adaptation on alternate trials shows that adaptation to a single static binocular stimulus for less than one second can be sufficient to determine perceived direction of cyclopean motion



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