Binocular integration in human vision adapts to maximize information coding efficiency

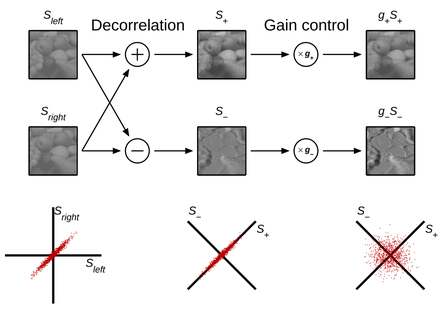
Keith May[1], Li Zhaoping[1] & Paul Hibbard[2]

[1]UCL Dept of Computer Science [2]School of Psychology, University of St Andrews

Static binocular adaptation affects perceived direction of *motion!*

Background

- Li and Atick's theory of efficient stereo coding (Li & Atick, 1994, *Network*, **5**, 157−174)
- Summation (S_+) and difference (S_-) channels decorrelate the ocular signals
- Gain control maximizes information capacity for a given energy budget and signal−to−noise ratio



Cyclopean motion

Left eye

$\alpha \sin Y \sin T \quad - \quad \beta \cos(Y + T)$

Counterphase (stationary flickering) horizontal grating — Horizontal grating drifting downwards

Right eye

$\alpha \cos Y \cos T \quad + \quad \beta \cos(Y + T)$

Counterphase (stationary flickering) horizontal grating — Horizontal grating drifting downwards

Summation channel

$\alpha \cos(Y - T)$

Horizontal grating drifting *upwards*

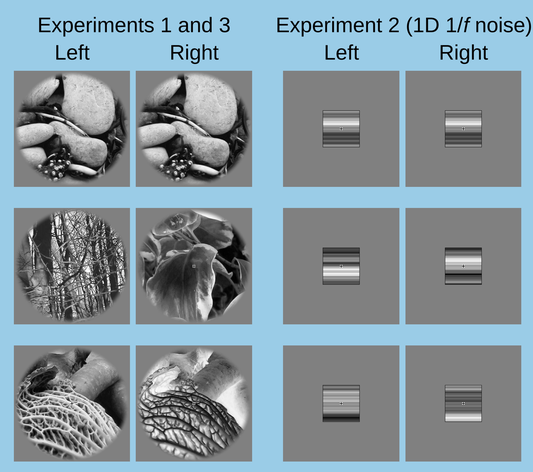
Difference channel

$(\alpha + 2\beta)\cos(Y + T)$

Horizontal grating drifting *downwards*

- $Y = 2\pi f y$, where f = 0.25 c/deg, and y is vertical position
- $T = 2\pi g t$, where g = 6 Hz, and t is time
- Michelson contrasts: α = 0.1; β = 0.02 in Expts 1 and 3, and 0.025 in Expt 2
- Shadlen and Carney invented this stimulus (Shadlen & Carney, 1986, *Science*, **232**, 95−97)
- Shadlen and Carney always used β = 0. This gives equal signal strength in each channel, but motion is perceived in the summation (S_+) direction
- Perceived direction should depend on which channel (S_+ or S_-) responds most strongly
- By selectively adapting S_+ or S_- channel, we should be able to control perceived direction

Adaptation of binocular channels



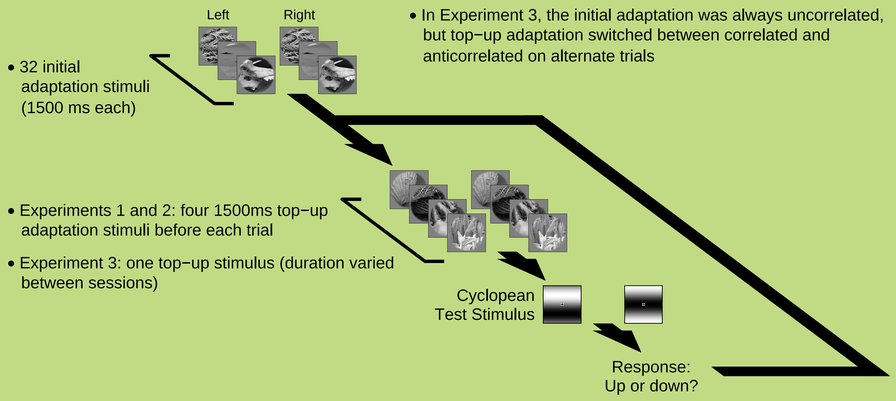
Correlated Adaptation
- both eyes see the same image
- S_+ channel stimulated
- S_- channel silent

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

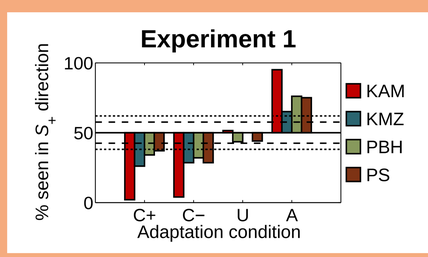
Anticorrelated Adaptation
- each eye sees the photonegative of the other eye's image
- S_+ channel silent
- S_- channel stimulated

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

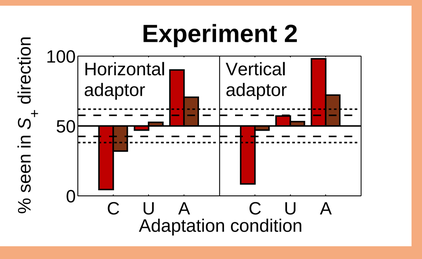


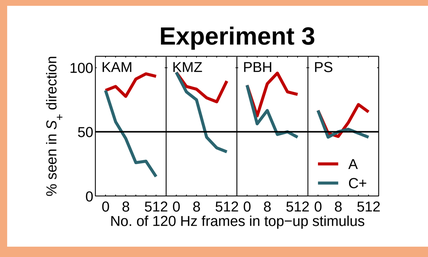
Results and discussion



- C = Correlated adaptation (C+ and C− refer to positive and negative natural images, respectively)
- U = Uncorrelated adaptation
- A = Anticorrelated adaptation
- Dashed lines indicate significant bias from 50%
  - Long dashes: $p < 0.05$ (two−tailed)
  - Short dashes: $p < 0.001$ (two−tailed)
- Adaptation to *static* binocular stimuli affects perceived direction of *motion*

- Adaptation of summation and difference channels not very orientation selective
- Suggests adaptation occurs very early in cortex, before orientation selectivity has built up
- This fits with the idea that the adaptation achieves efficient coding: efficiency savings are maximized if efficient coding is implemented as early as possible





- Switching between correlated (C+) and anticorrelated (A) adaptation on alternate trials shows that adaptation to a single static binocular stimulus for one second can be sufficient to determine perceived direction of motion
- S_+ bias with short or zero adaptation duration suggests S_- channel adapts more quickly
- Explains Shadlen and Carney's finding of S_+ bias when S_+ and S_- signals balanced (β = 0): brief test stimulus activates both channels, but S_- adapts more, causing stronger response in S_+ channel

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