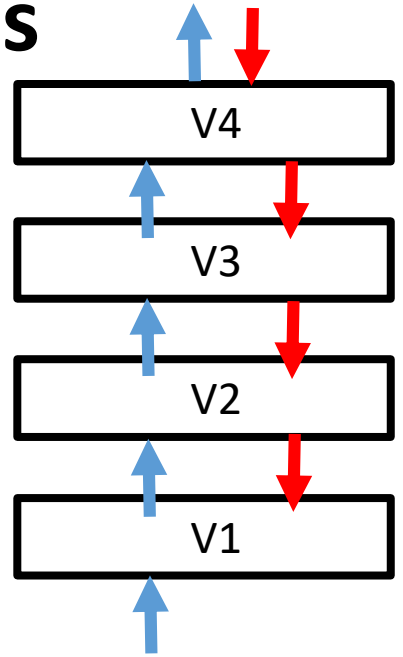
Feedforward and **feedback** processes for **visual detection and recognition in humans**

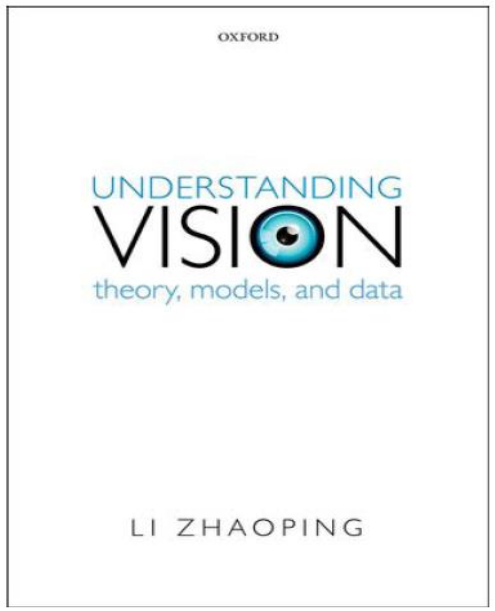
Background and old works

Zhaoping 2017, in press for Vision Research

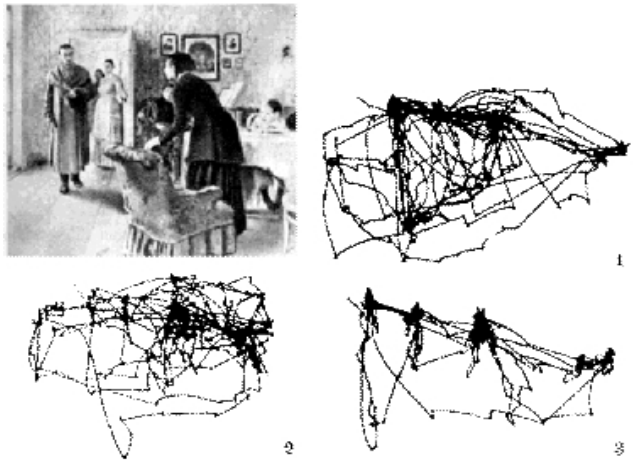


Li Zhaoping www.cs.ucl.ac.uk/staff/Zhaoping.Li/
University College London
For AI/Deepmind workshop, May 12, 2017

Vision seen through a three-stage framework



A textbook on computational vision



Yarbus 1967

For motor action or cognitive decisions

(e.g., face recognition)

Decoding

(Attentional selection)

Selection

(e.g., by retinal neural activities)

Encoding

visual input

Attentional bottleneck: 40 bits/second

Bottom-up selection

V4

V3

V2

V1

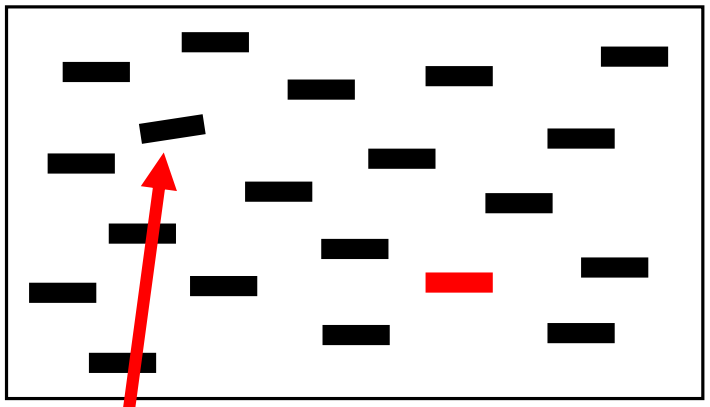
20 frames, or 20 megabytes, per second

A quick overview on bottom-up and top-down attentional selection

automatic

Goal directed

Task: find the non-horizontal bar



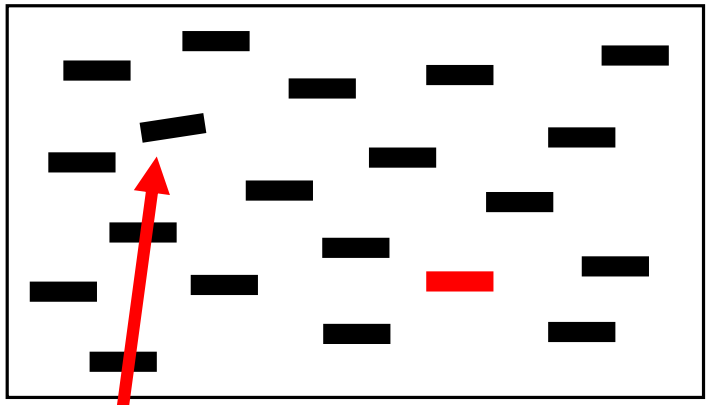
Top-down

A quick overview on bottom-up and top-down attentional selection

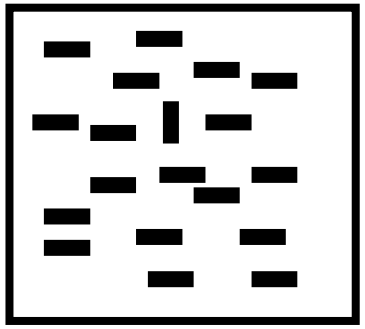
automatic

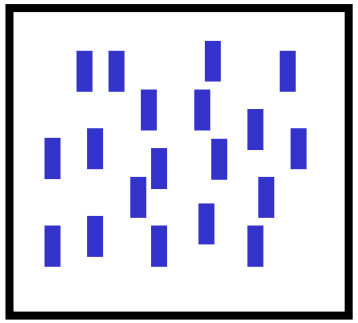
Goal directed

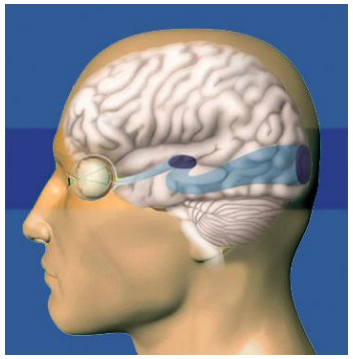
Task: find the non-horizontal bar



Top-down







Which brain area is responsible for guiding bottom-up attention?

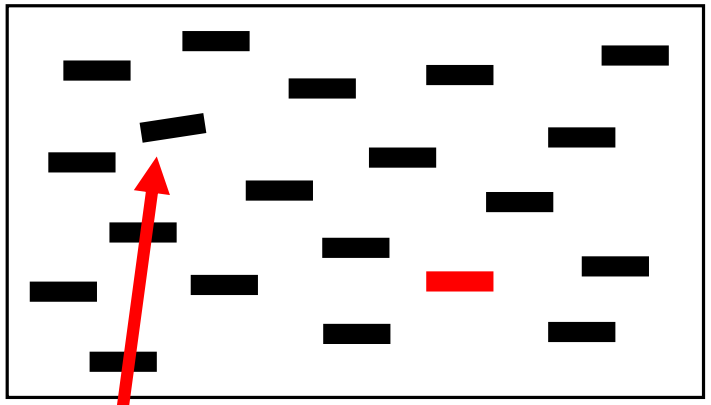
Answer: V1 ! (Li 1999, 2002, Zhaoping 2008)

A quick overview on bottom-up and top-down attentional selection

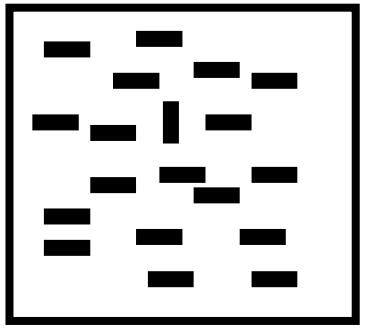
automatic

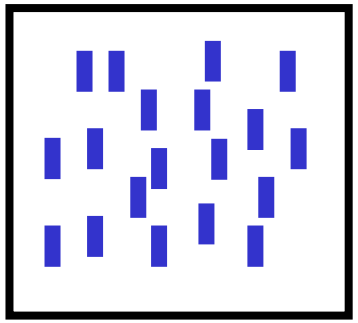
Goal directed

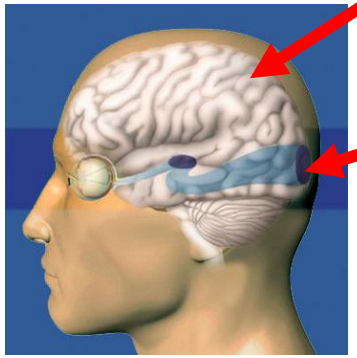
Task: find the non-horizontal bar



Top-down





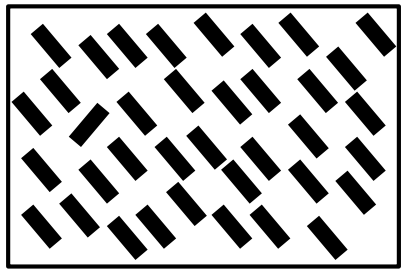


V2 and above are blind to eye of origin

V1 can see eye of origin of visual inputs

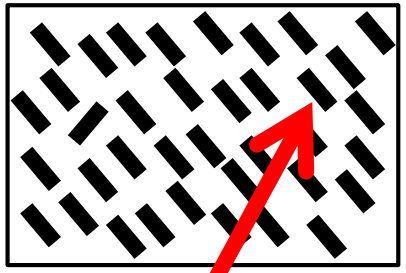
Answer: V1 ! (Li 1999, 2002, Zhaoping 2008)

Left eye image



Right eye image

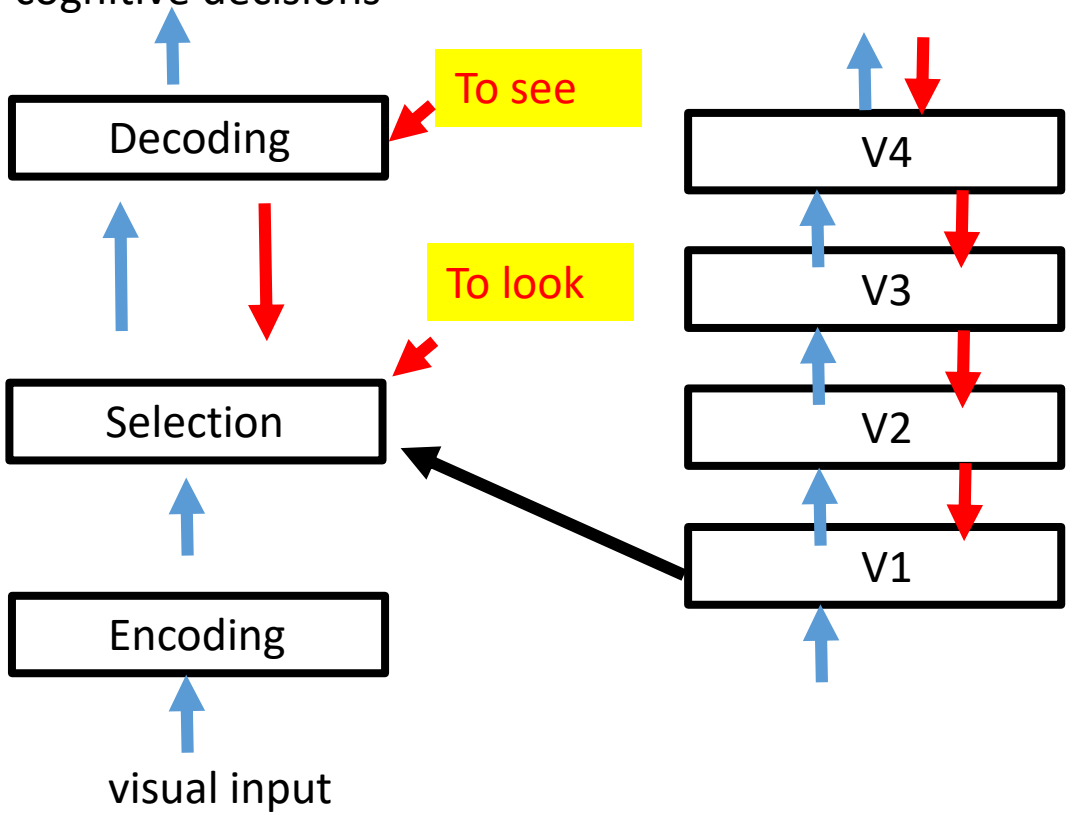
Fused perception

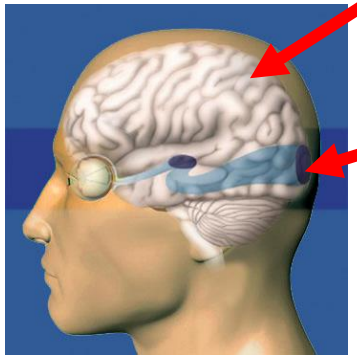


Task: find the orientation singleton ASAP!

Initial gaze shift is directed to ocular singleton 75% of the trials

Zhaoping 2008, 2012





V2 and above are blind to eye of origin

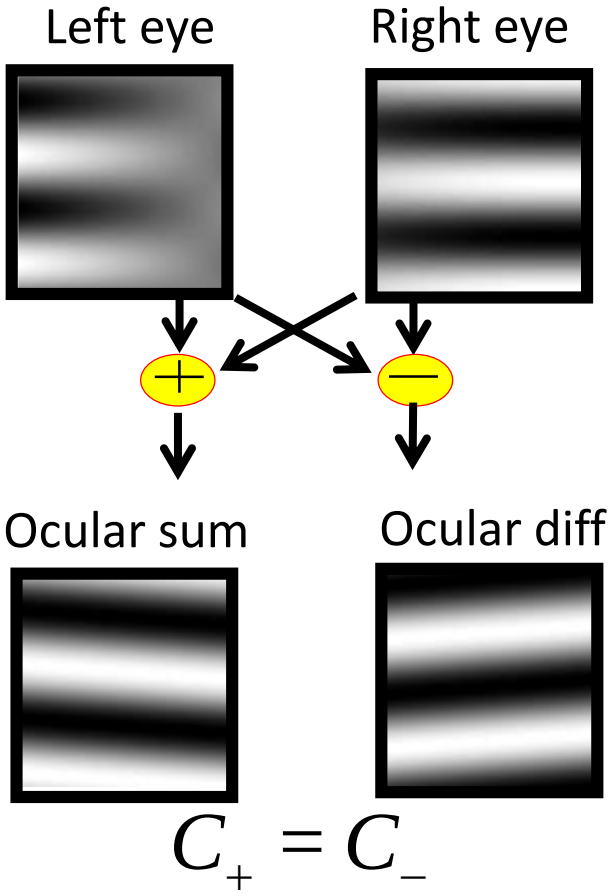
V1 can see eye of origin of visual inputs

Neurophysiologically or Anatomically, much less is known about the feedback than feedforward processes

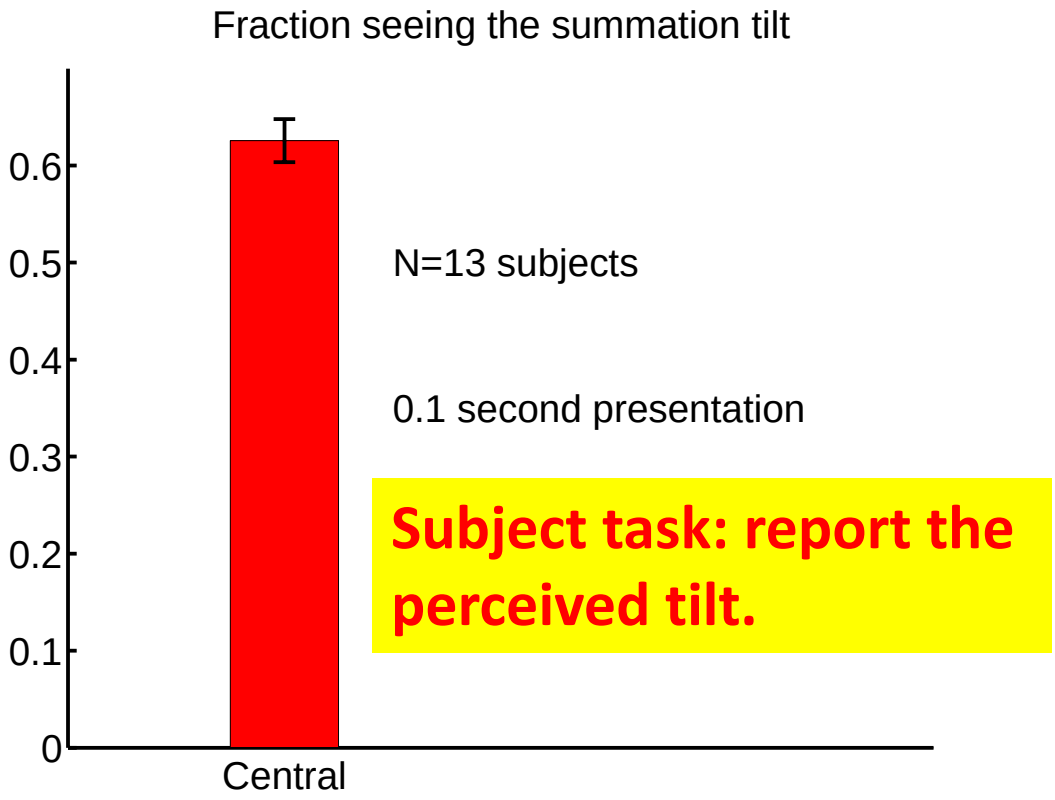
Use behavioral methods:

(1) Probe **ambiguous perceptions, when feedback is more likely needed.**

(2) Probe visual **perception that depends on eye-of-origin information**, so that higher visual areas has to use feedback to V1 to verify that information



Summation percept dominant



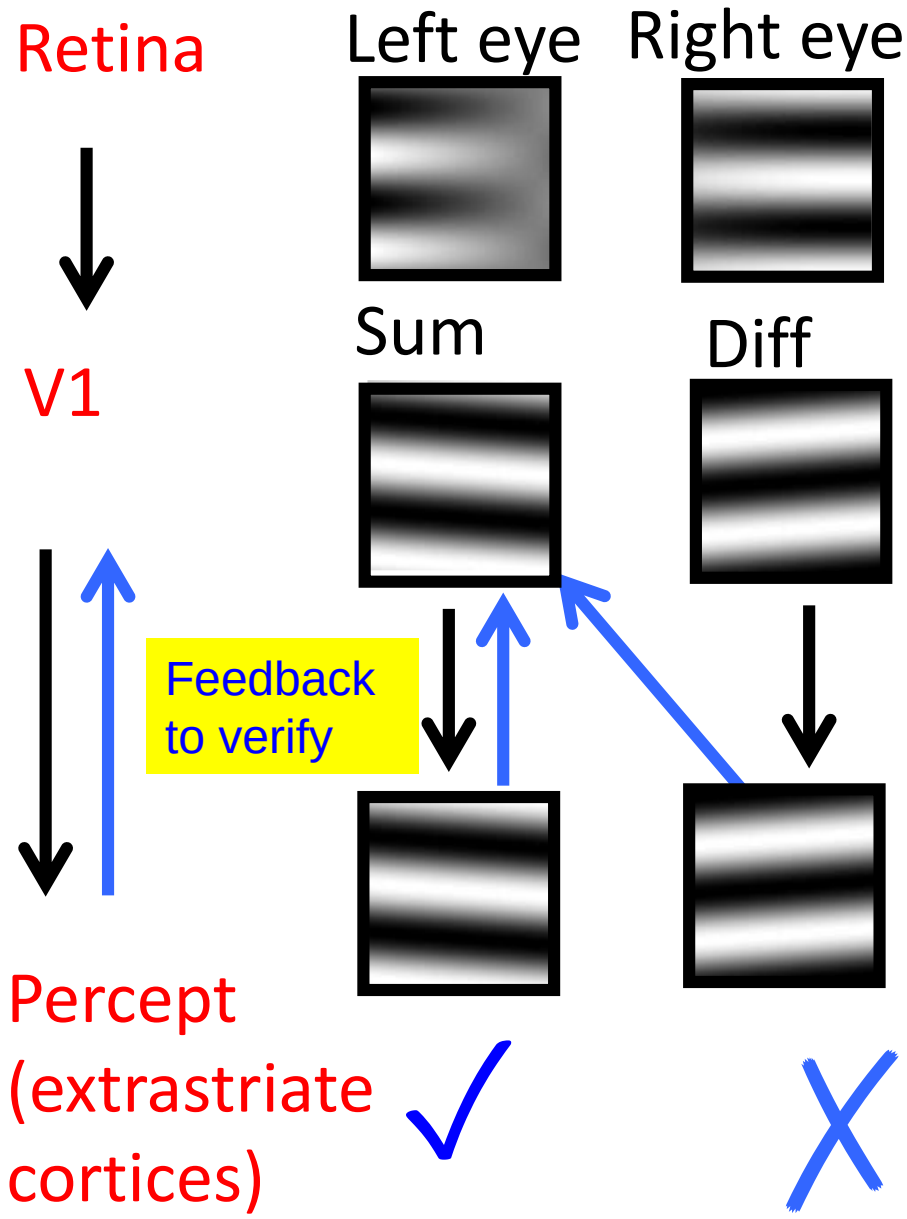
Subject task: report the perceived tilt.

In V1, signals are efficiently encoded by these two de-correlated channels
(Li & Atick 1994)

Perception = ?

Zhaoping APCV 2013

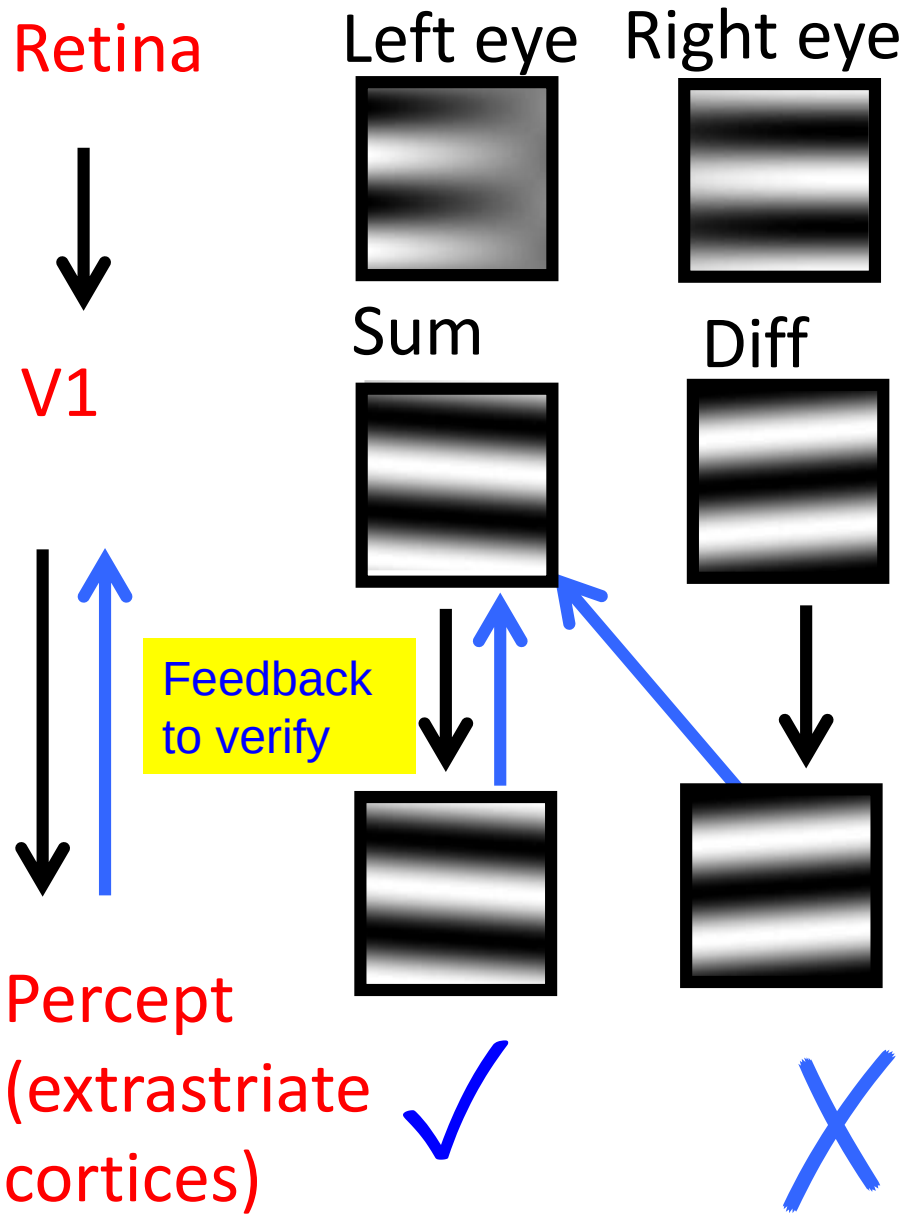
Why does perception prefer ocular summation?



If I perceive it, it is likely (prior) shown to both my left and my right eyes, so it should resemble the input in the sum channel!!!

The Bayesian(?) monster

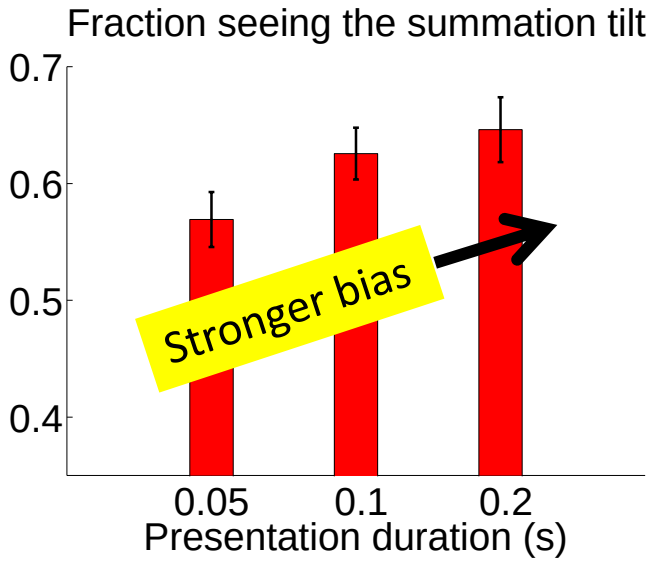
Why does perception prefer ocular summation?



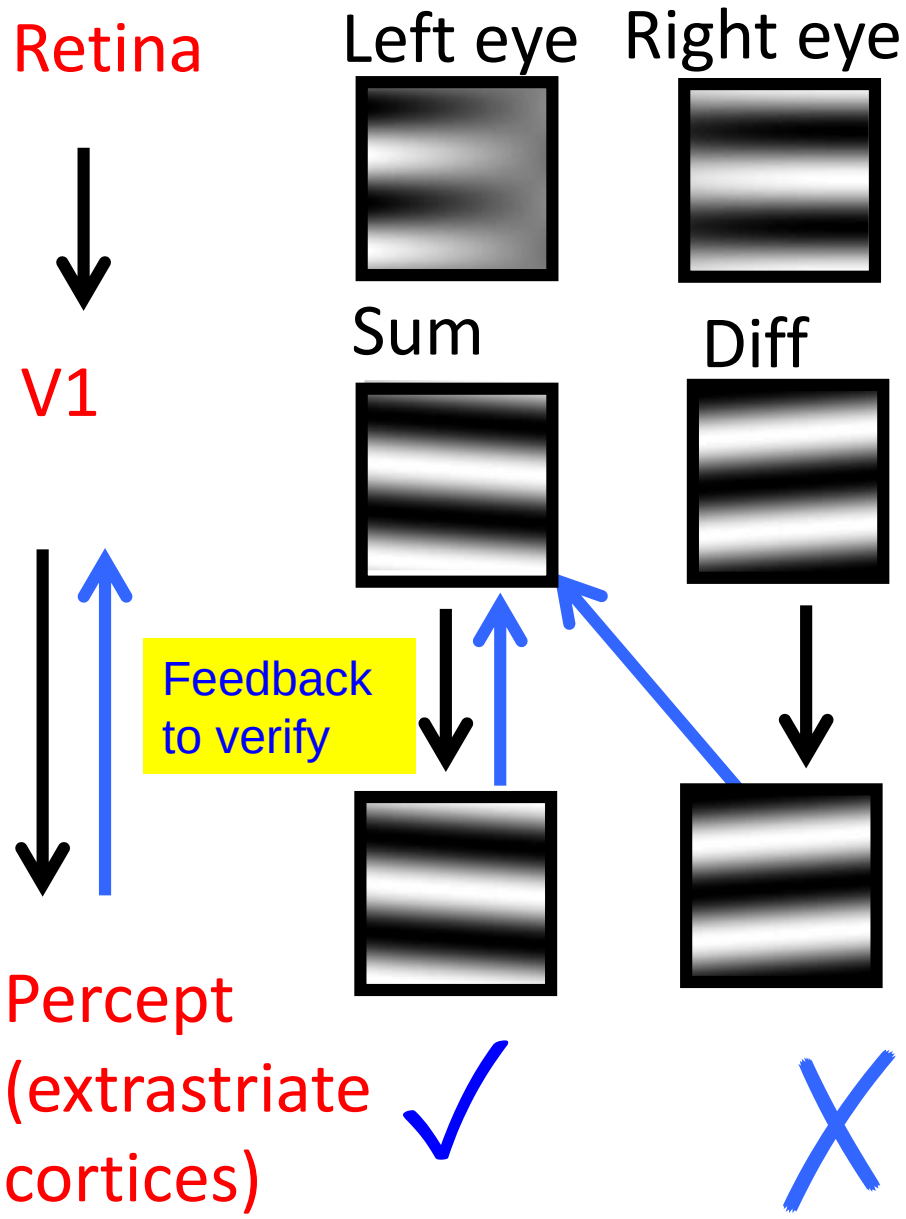
A **feedforward-feedback-verify-weight** process

for analysis-by-synthesis

Prediction: feedback should mainly target V1 neurons coding the ocular summation (e.g., binocular cells tuned to zero disparity), at least for feedback in the ventral stream.



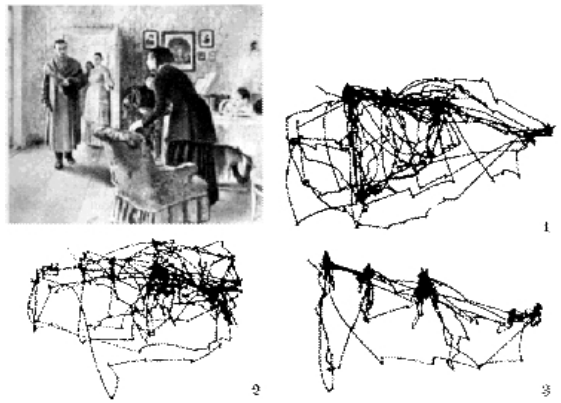
Why does perception prefer ocular summation?



A **feedforward-feedback-verify-weight** process

for analysis-by-synthesis

Prediction: feedback should mainly target V1 neurons coding the ocular summation (e.g., binocular cells tuned to zero disparity), at least for feedback in the ventral stream.

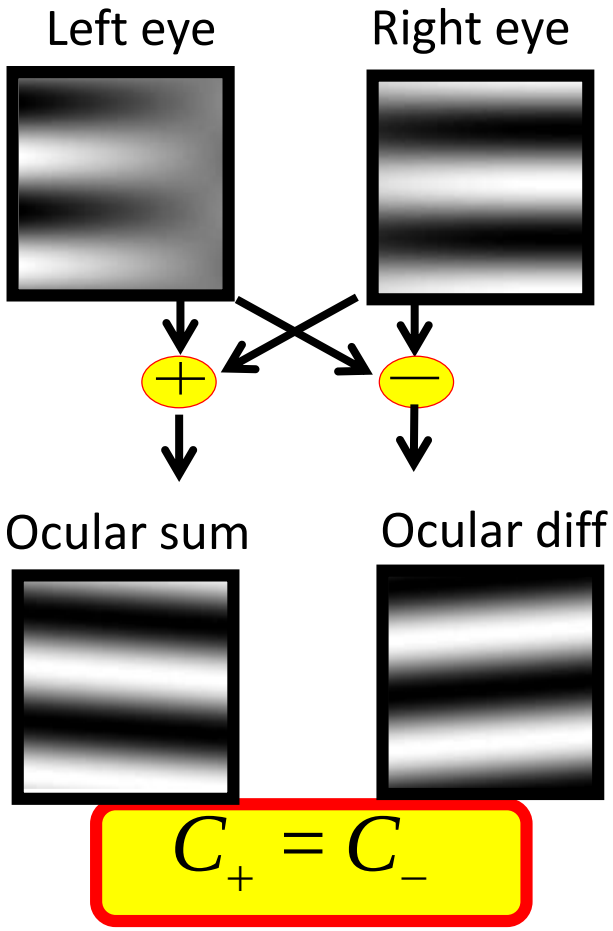


Yarbus 1967

In natural vision, gaze mandatorily follows the location of visual attention !

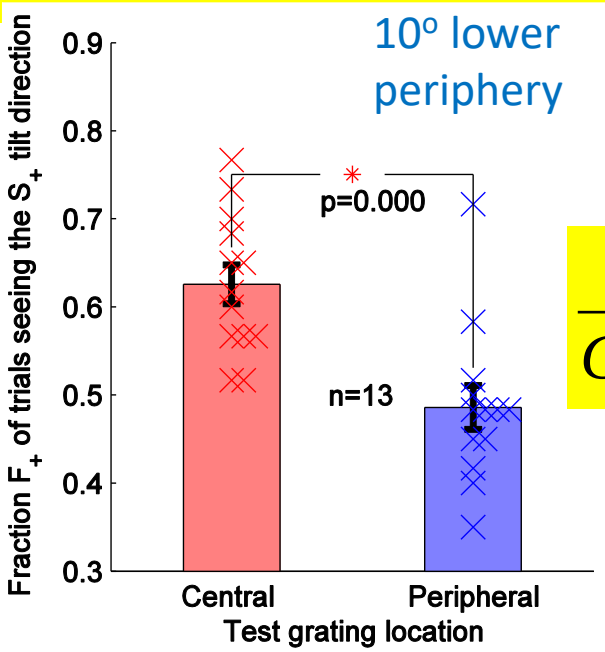
Central vision: --- to see
Peripheral vision: --- to look

Feedback in central and peripheral vision may be different!

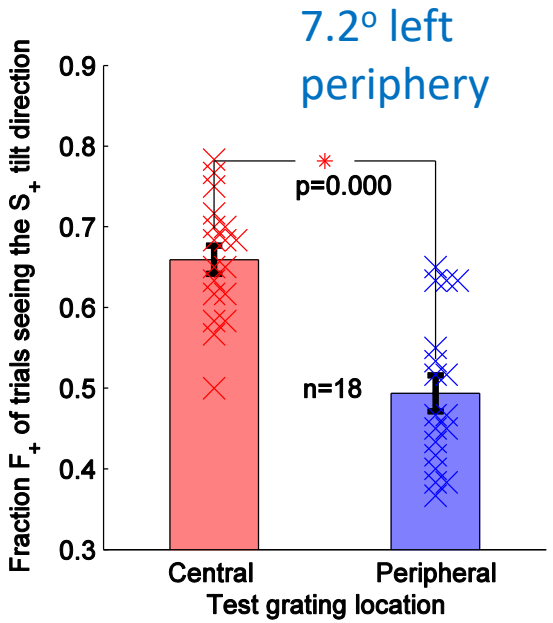


Is this because we cannot see as clearly or confidently in the peripheral?

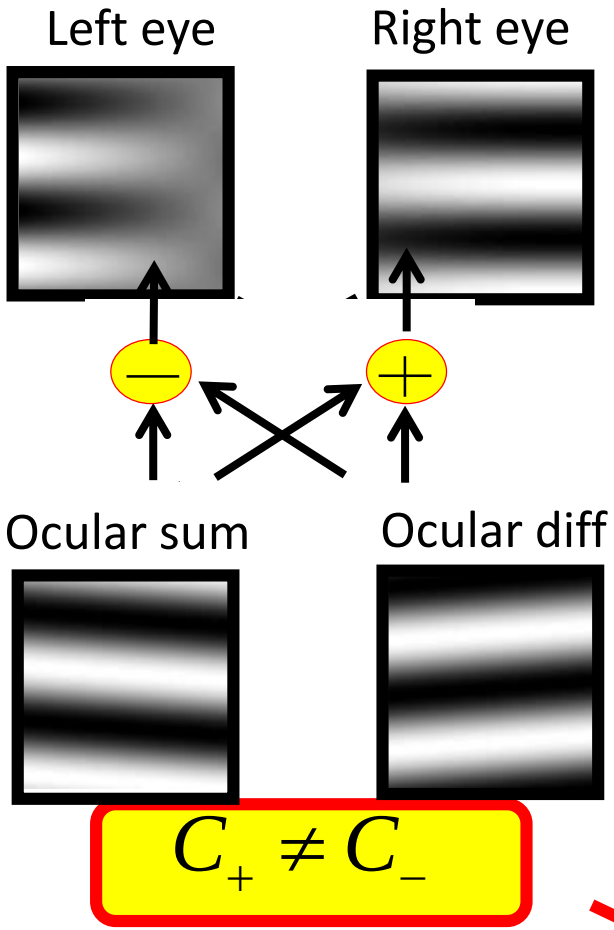
The summation bias weaker at periphery:



$$\frac{C_+}{C_+ + C_-} = 0.5$$

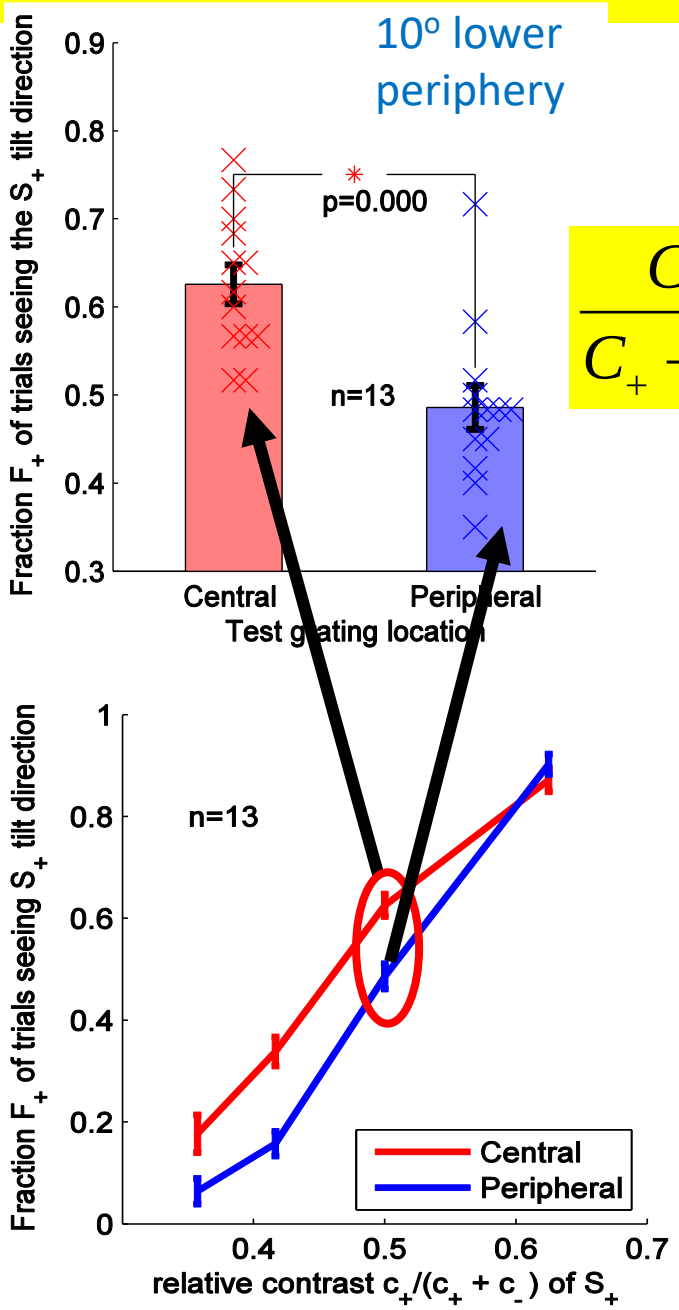


Stimulus size scaled up in periphery to compensate for acuity change

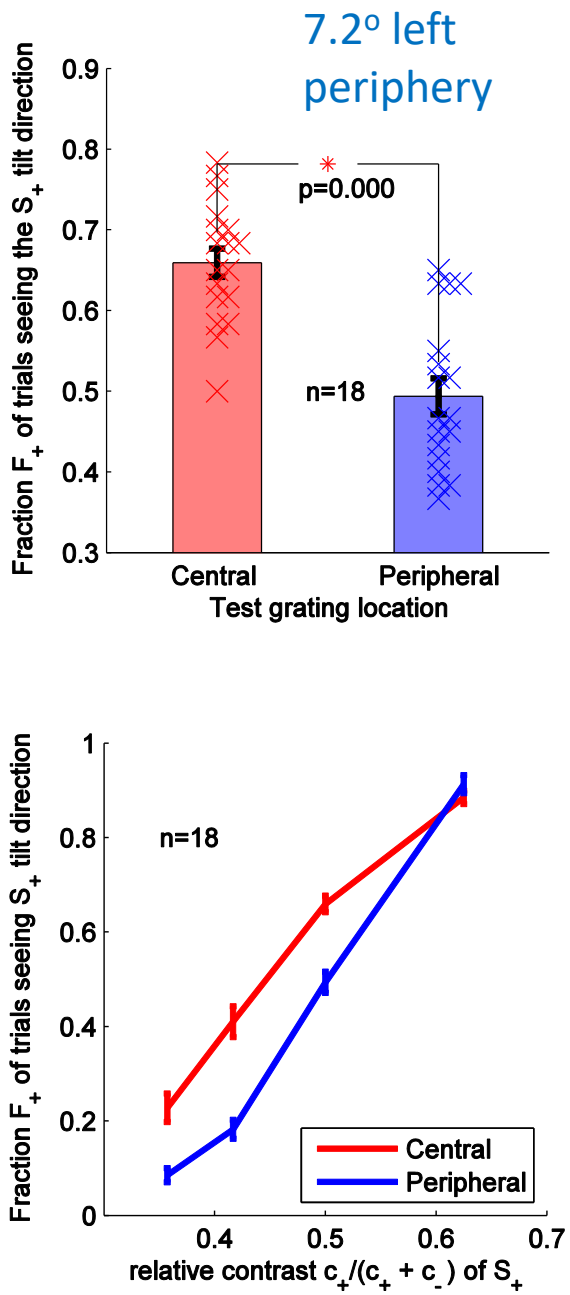


Peripheral percept has similar input sensitivity as central vision,
but is less biased to ocular summation

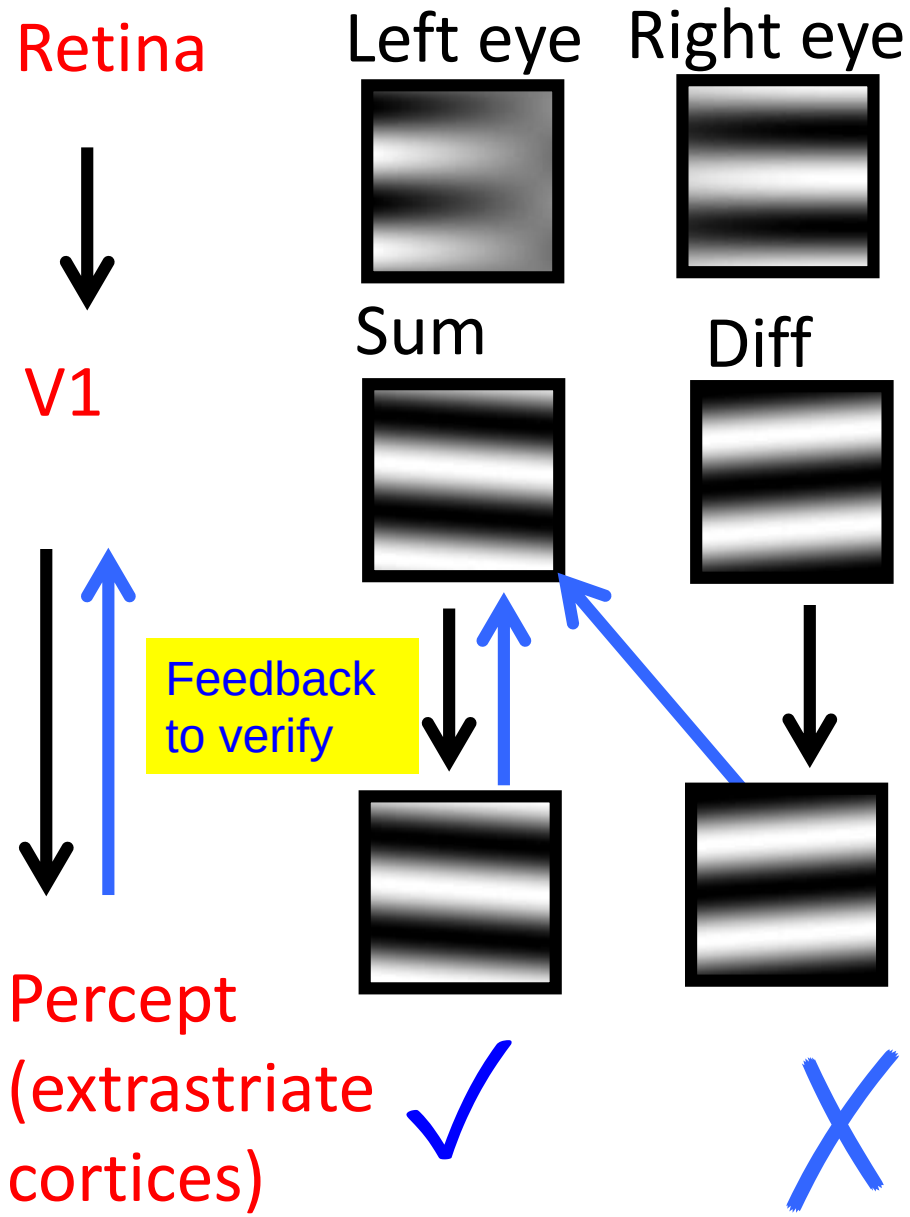
The summation bias weaker at periphery:



$$\frac{C_+}{C_+ + C_-} = 0.5$$



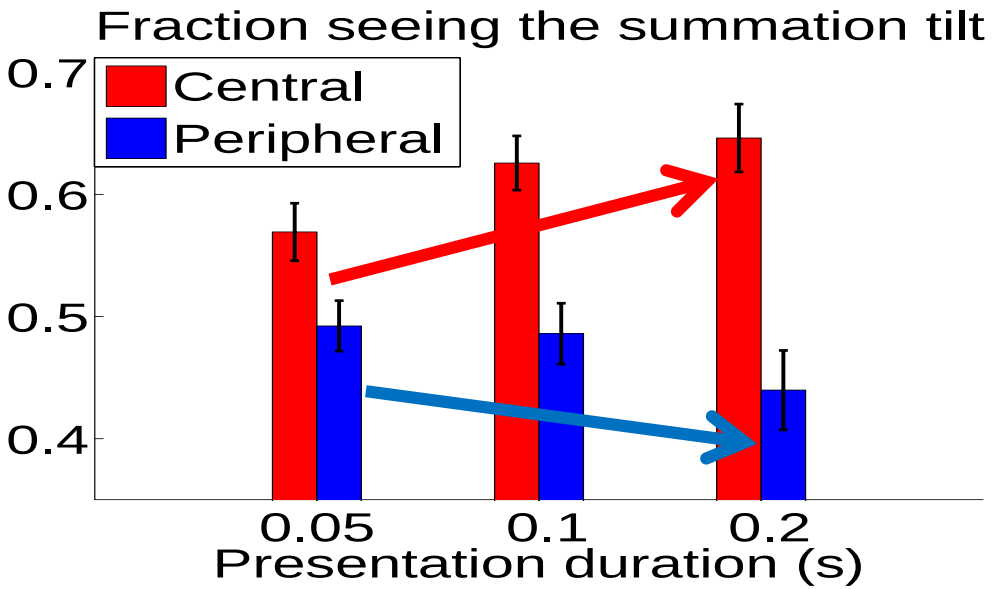
Why is the summation bias weaker in the periphery?



A **feedforward-feedback-verify-weight** process

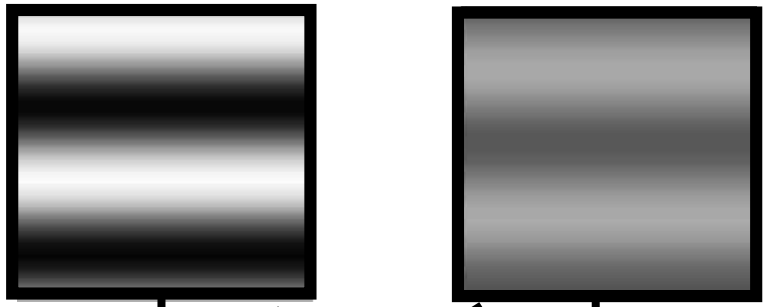
If the summation bias requires feedback from higher visual areas

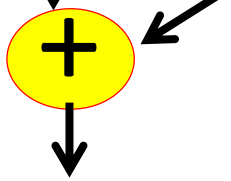
I propose that feedback is absent or weaker in peripheral vision
(Zhaoping, ECVP2013, SFN2014)



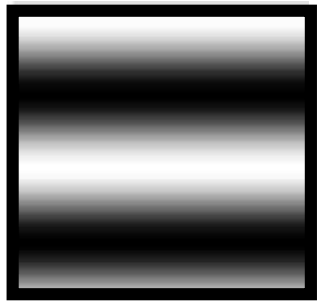
Left eye S_L
$= \cos(x)\cos(t)$

Right eye S_R
$= \sin(x)\sin(t)$





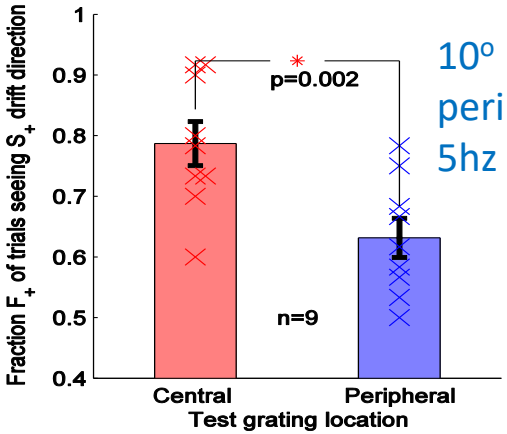
Summation S_+
$= \cos(x-t)$



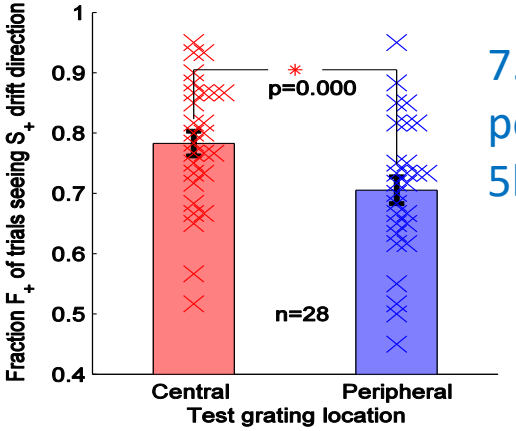
Difference S_-
$= \cos(x+t)$

$$C_+ = C_-$$

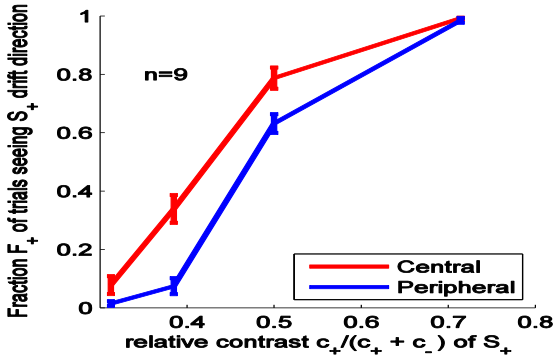
Similarly for ambiguous motion direction perception

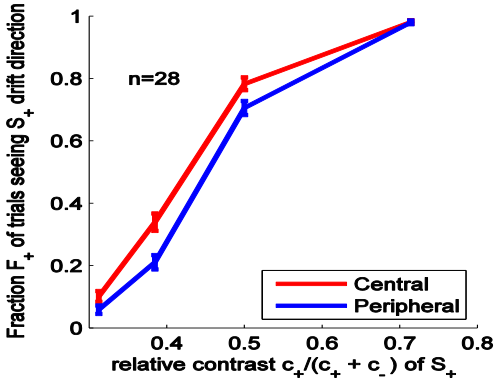


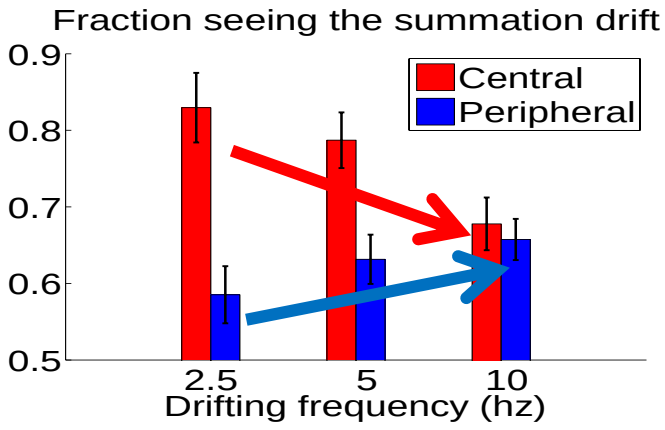
10° lower periphery 5hz



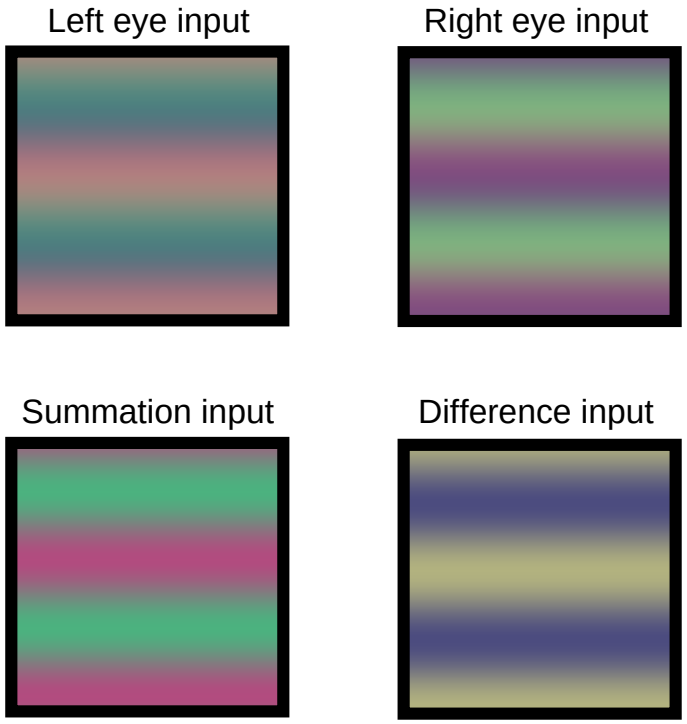
7.2° left periphery 5hz



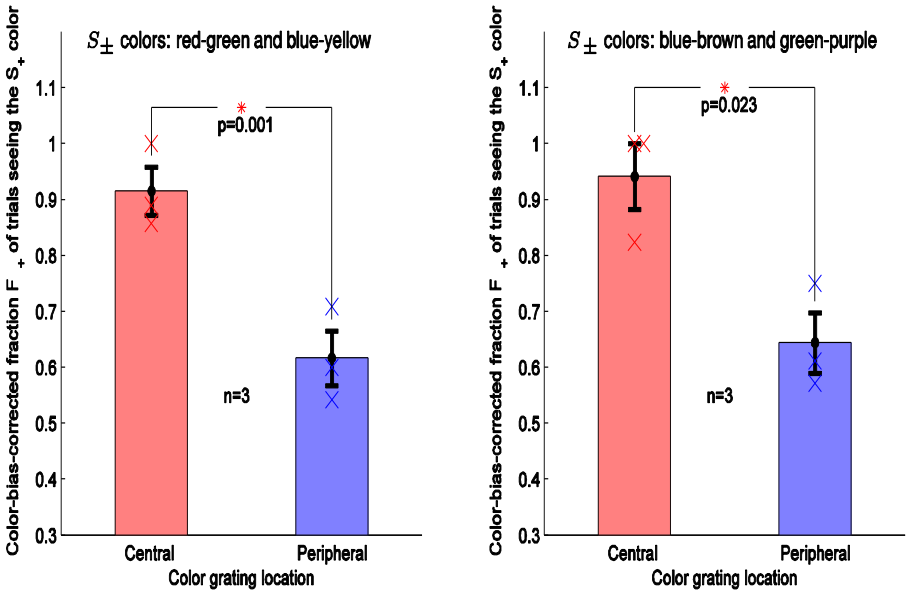




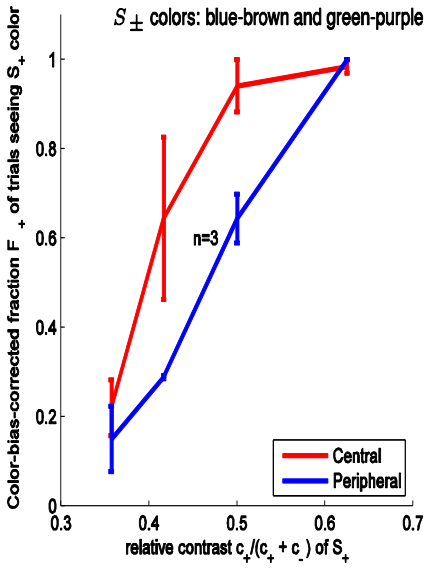
Also in the domain of color perception



A: Response-bias-corrected fraction F_+ of seeing the S_+ color when $c_+ = c_-$



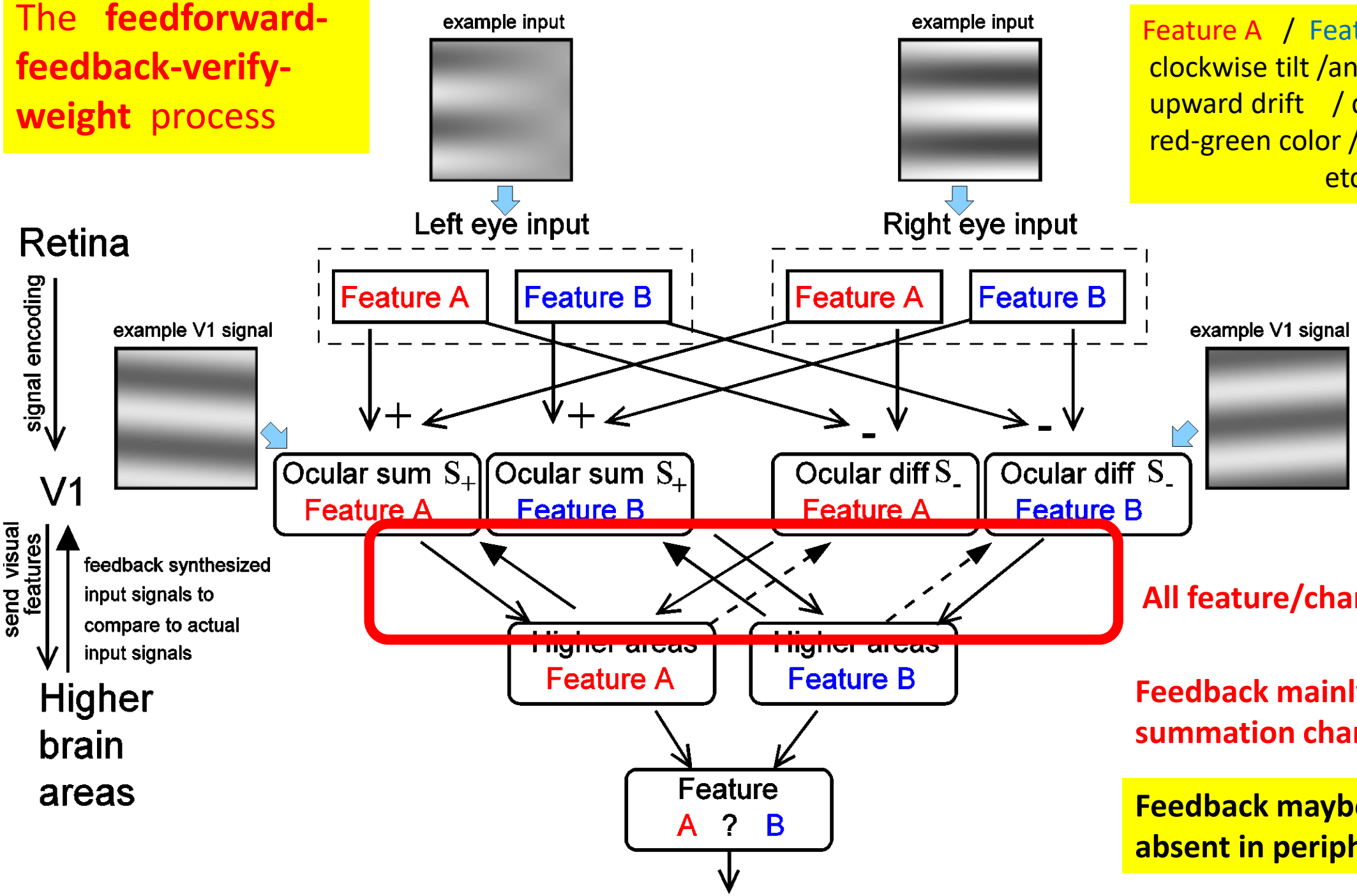
B: F_+ variation with relative contrast $c_+/(c_+ + c_-)$



Left periphery 7.2 deg.

The **feedforward-feedback-verify-weight** process

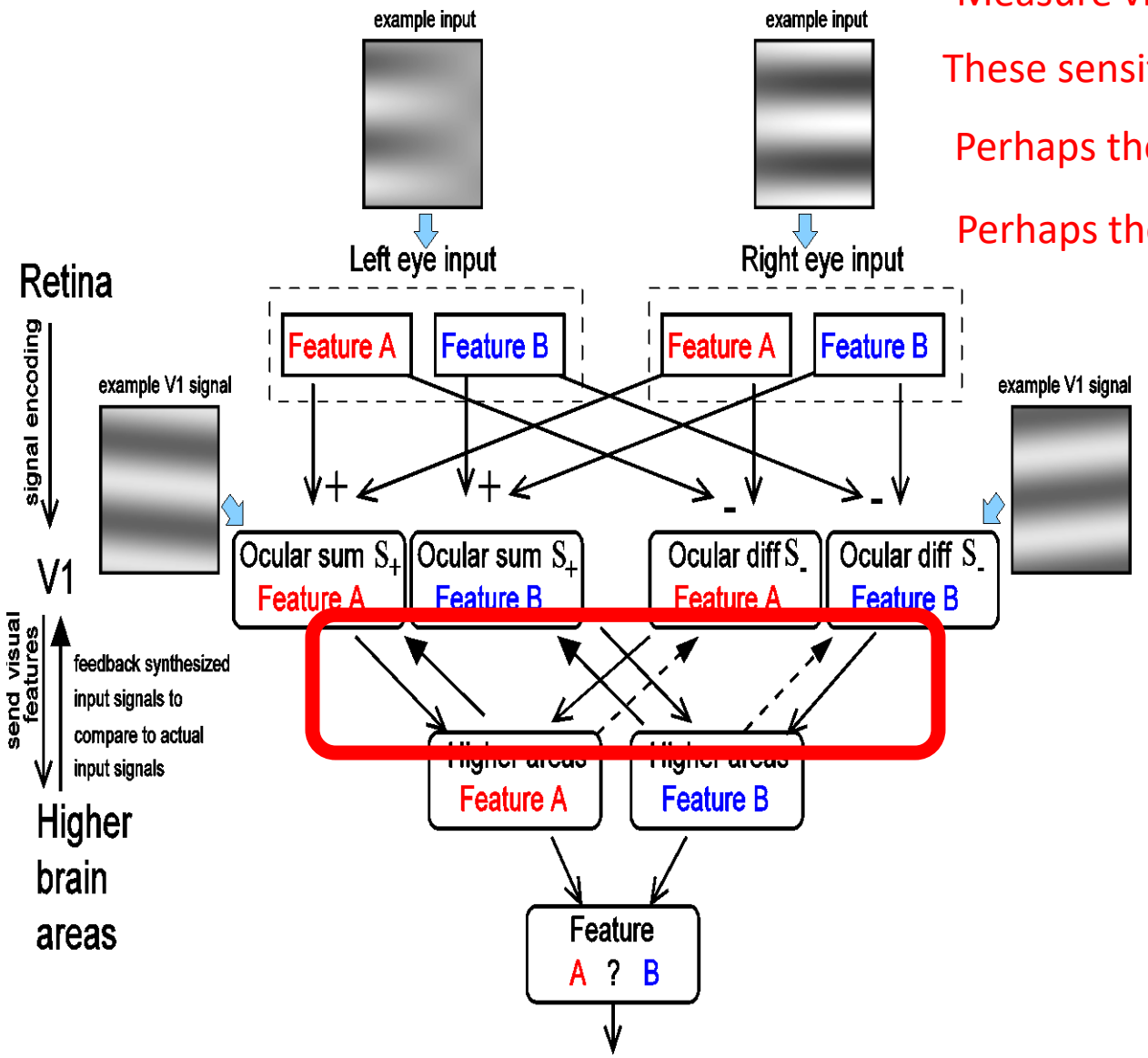
Feature A / Feature B
clockwise tilt /anticlockwise tilt
upward drift / downward drift
red-green color /blue-yellow color
etc



All feature/channels feedforward

Feedback mainly to the ocular summation channel

Feedback maybe weaker or absent in periphery



Measure visual sensitivities to ocular sum and ocular diff

These sensitivities reflect the feedforward processes

Perhaps the sensitivity to ocular sum is stronger? --- sometimes

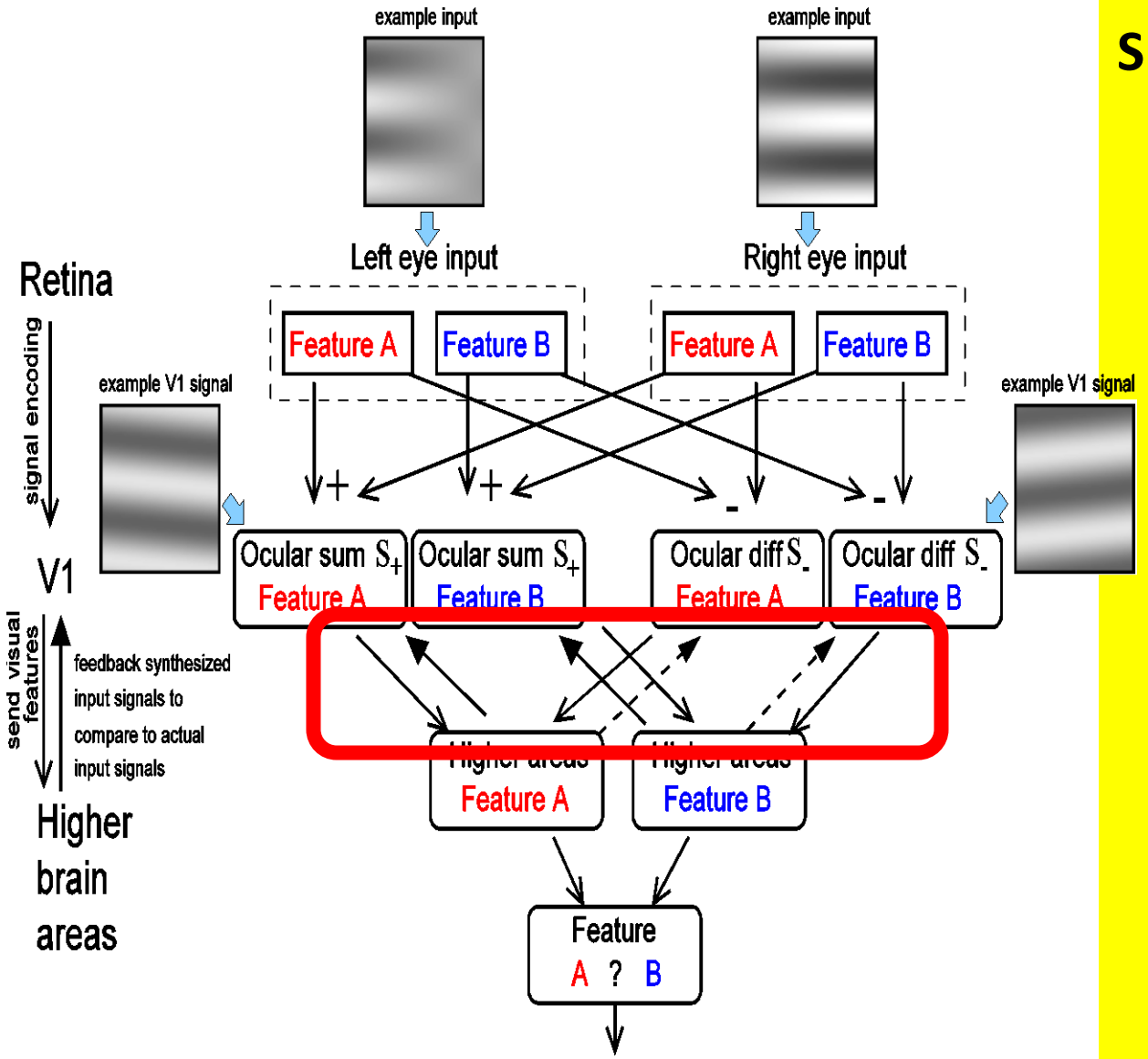
Perhaps their relative difference depends on central or periphery? – No!

} Could Central-peripheral difference in their biases towards binocular summation be caused by processes arising in the feedforward stage instead?

All feature/channels feedforward

Feedback mainly to the ocular summation channel

Feedback maybe weaker or absent in periphery



Summary:

Probe feedback to V1 by behavioral studies motivated by computational questions.

Central and peripheral difference motivated by the role of visual attention by gaze shifts.

Prediction 1: feedbacks target mainly the ocular summation channel in V1

Prediction 2: feedback is more for central vision

Can be tested by neural/anatomical studies.

Implications for artificial neural nets