Visual adaptation and medical image perception: How images can shape what you see

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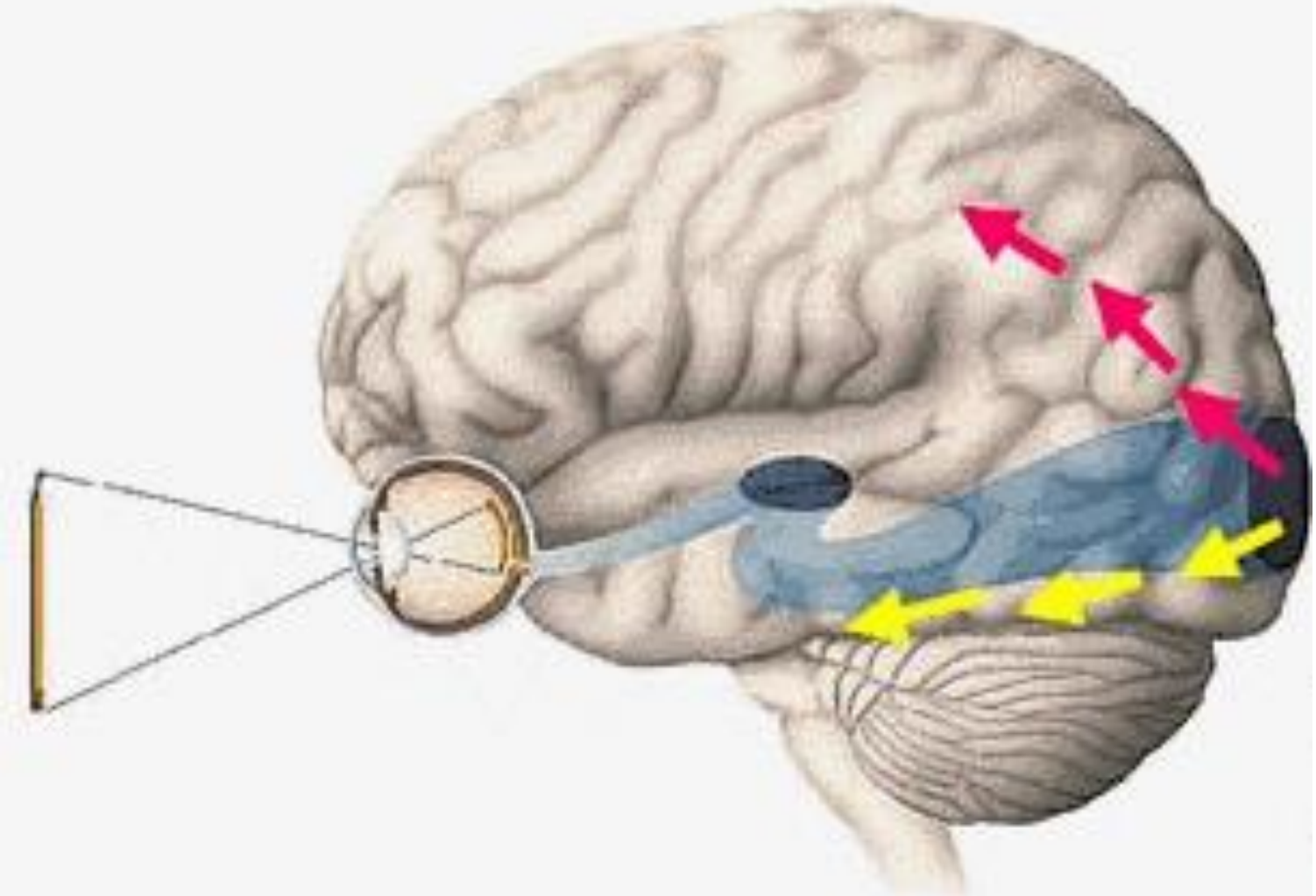
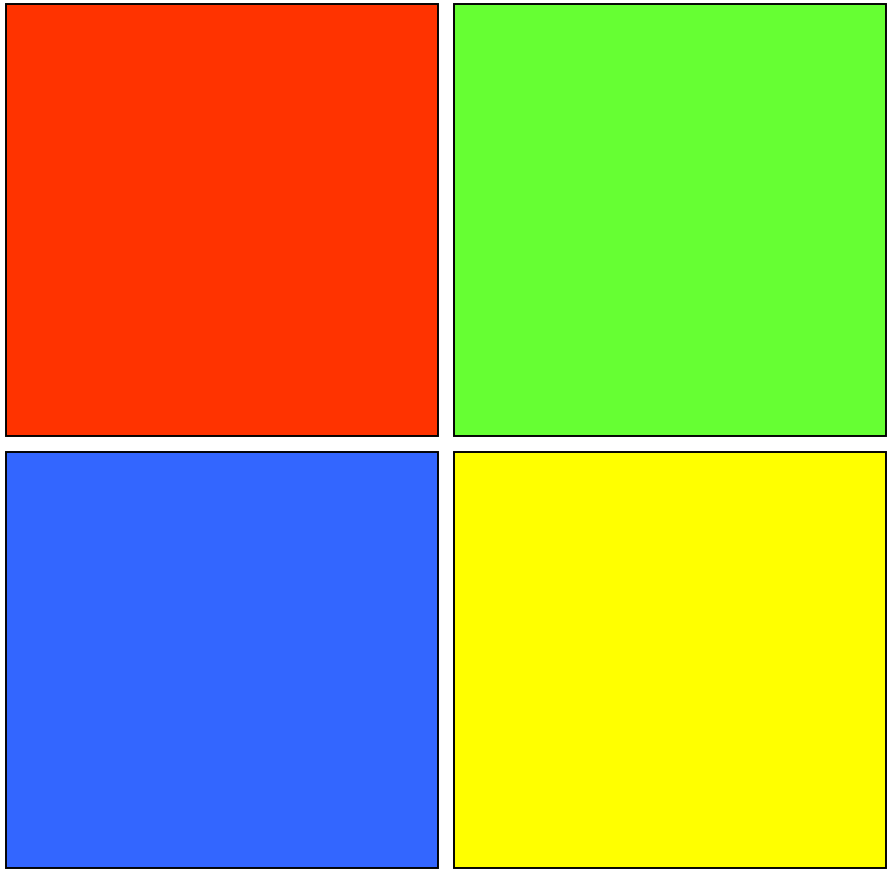
The human visual system



The visual system is highly adaptable

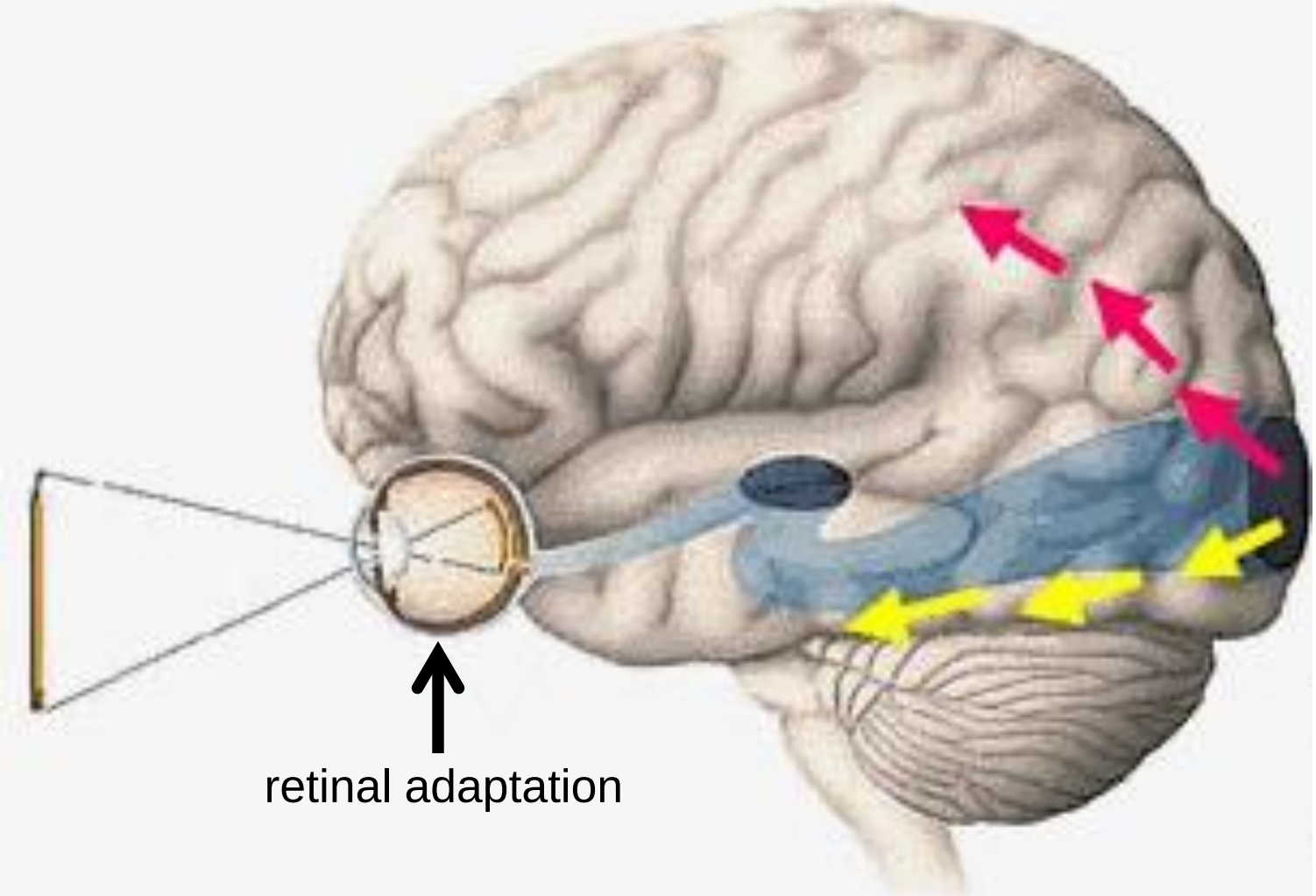


Adaptation across the visual hierarchy

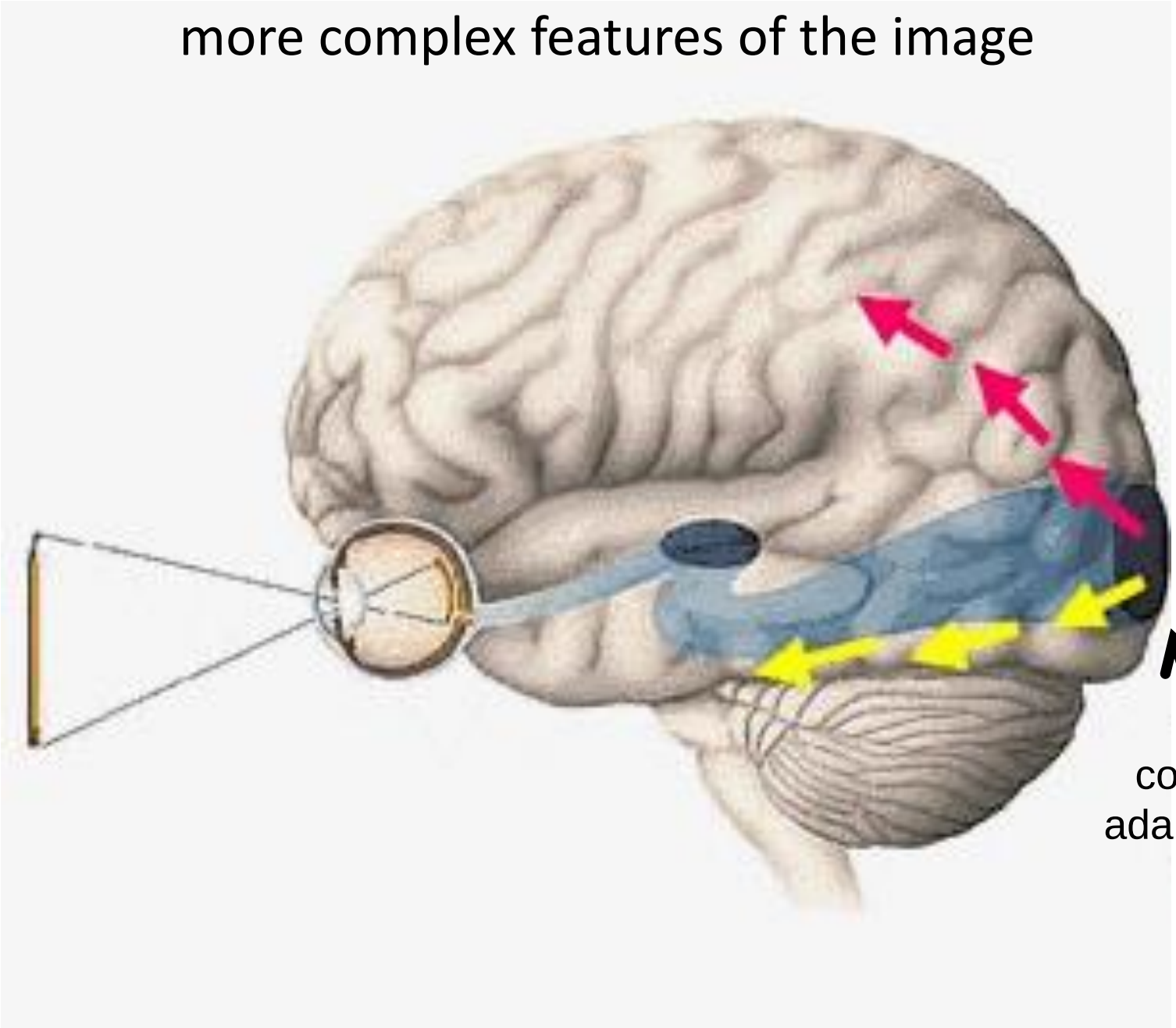
Adaptation operates in functionally similar ways at all levels of visual coding.

And thus points to common processes of sensitivity regulation at all processing stages

e.g. receptors in the eye adjust to the average light level and color



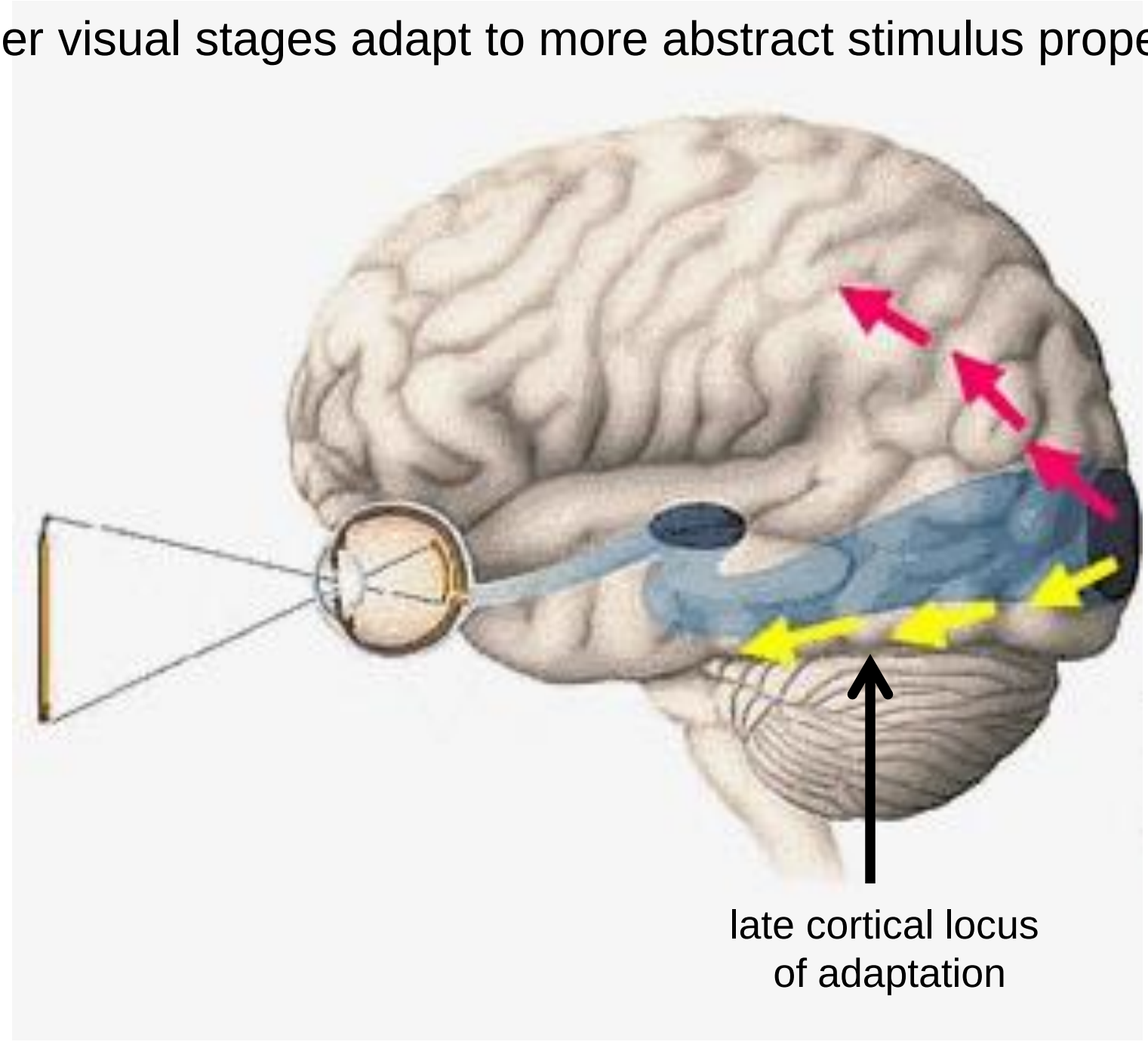
Adaptation in the cortex adjusts to more complex features of the image



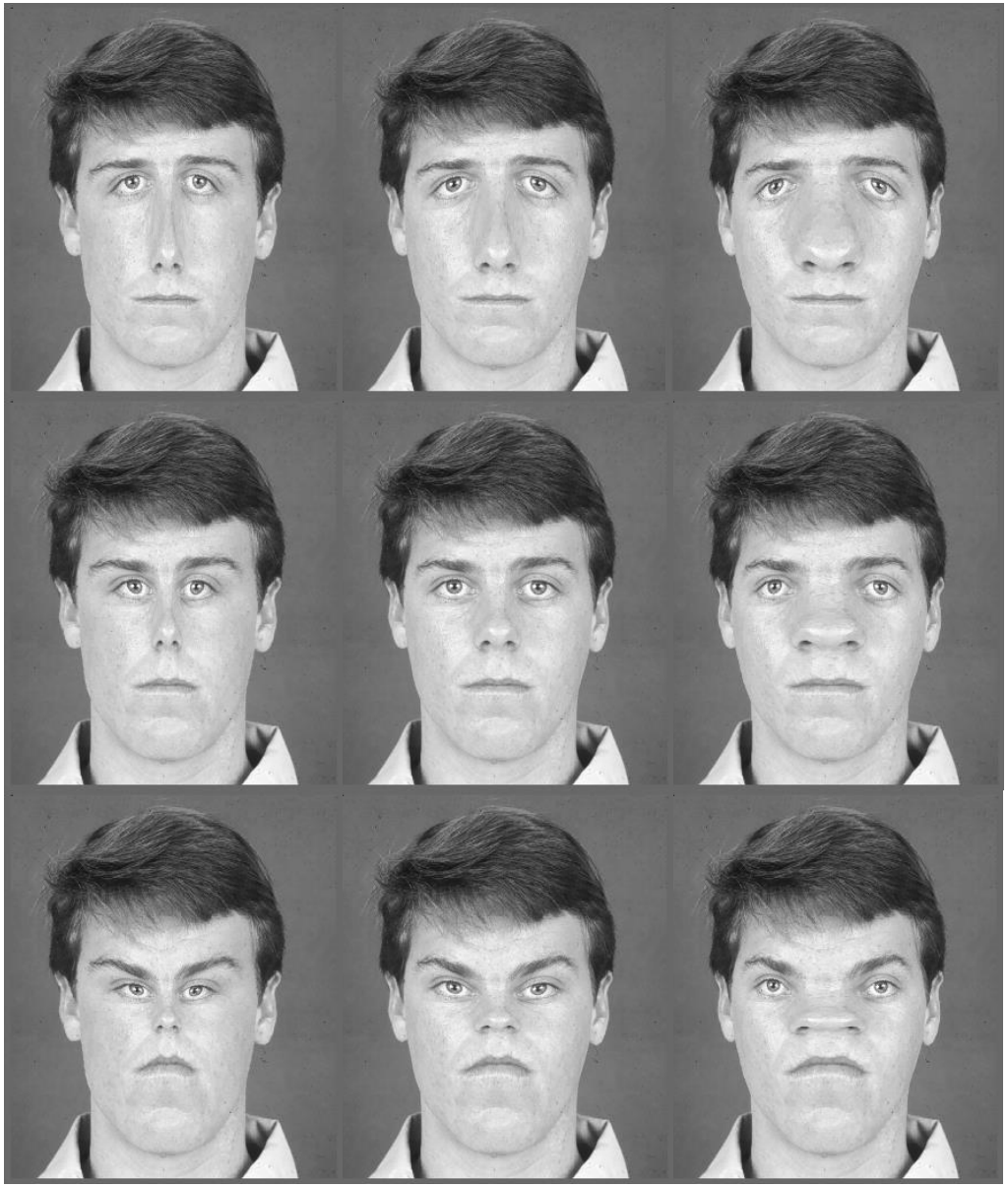
e.g. adaptation to image blur

Webster at al. Nature Neuroscience 2002

Higher visual stages adapt to more abstract stimulus properties

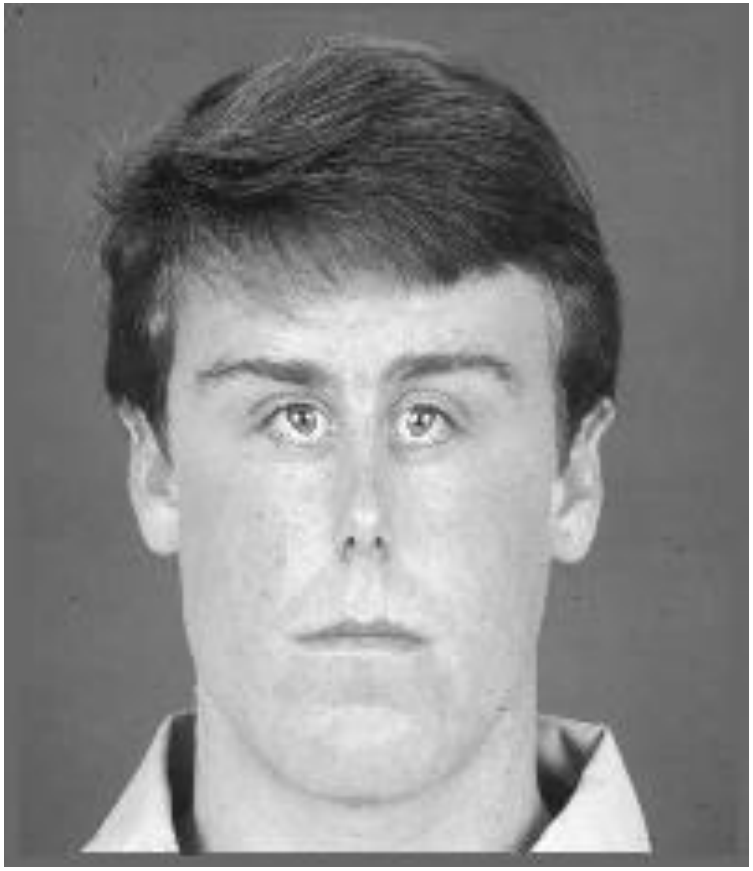


e.g. adaptation to faces

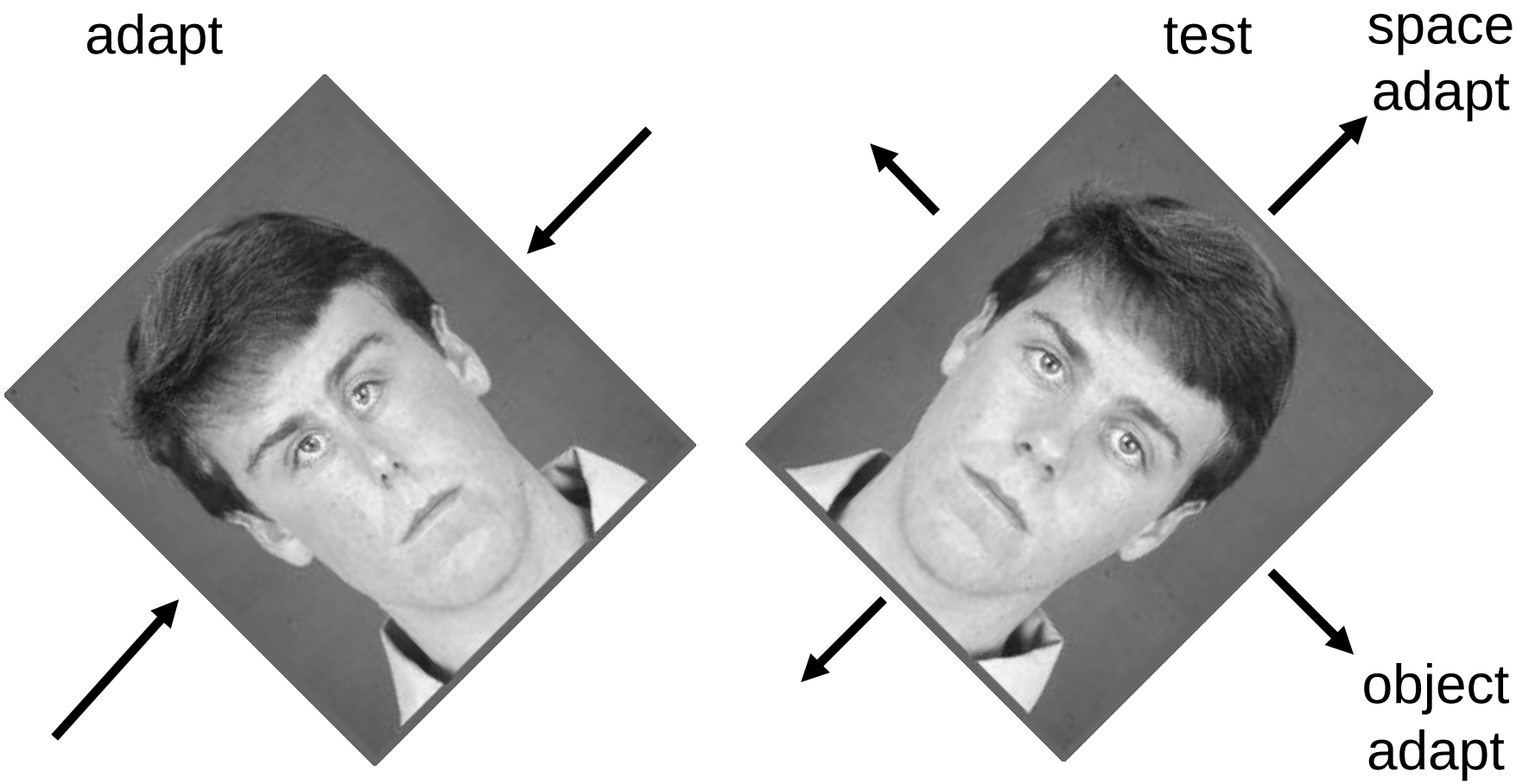


Webster and MacLeod Phil Trans Royal Soc 2011

A demonstration of face adaptation



The adaptation partly occurs at object- and possibly face-specific loci



Watson and Clifford 2003

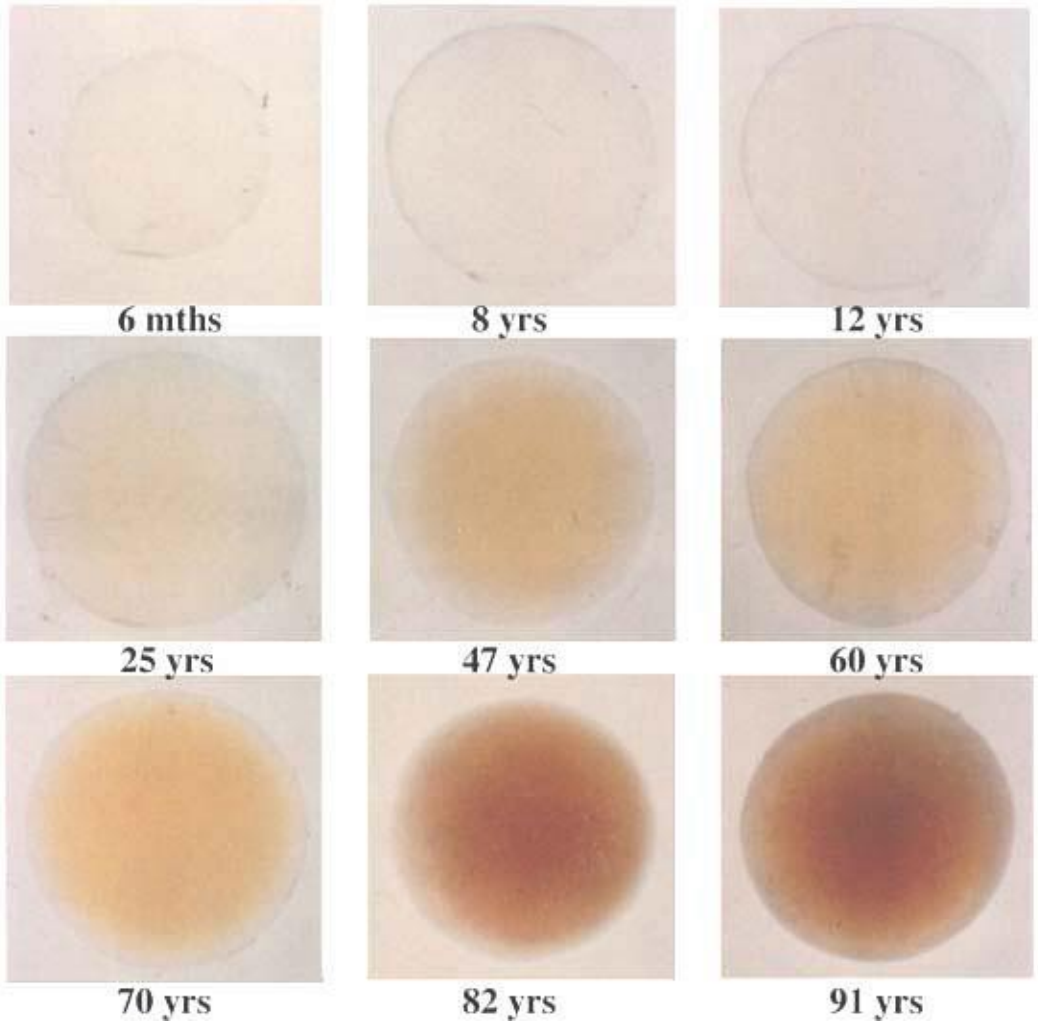
Adaptation is strong and persistent in natural viewing

Natural images and natural visual tasks provide very potent stimuli for adaptation

Thus vision is constantly under adaptation to the properties of the visual world

This optimizes perception not only for changes in the world but also variations in the observer

e.g. we are strongly adapted to the spectral filtering by our lens



Lerman *Radiant energy and the eye* 1980

Color changes predicted by lens density changes

as seen by
young observer

image filtered through
lens of older eye

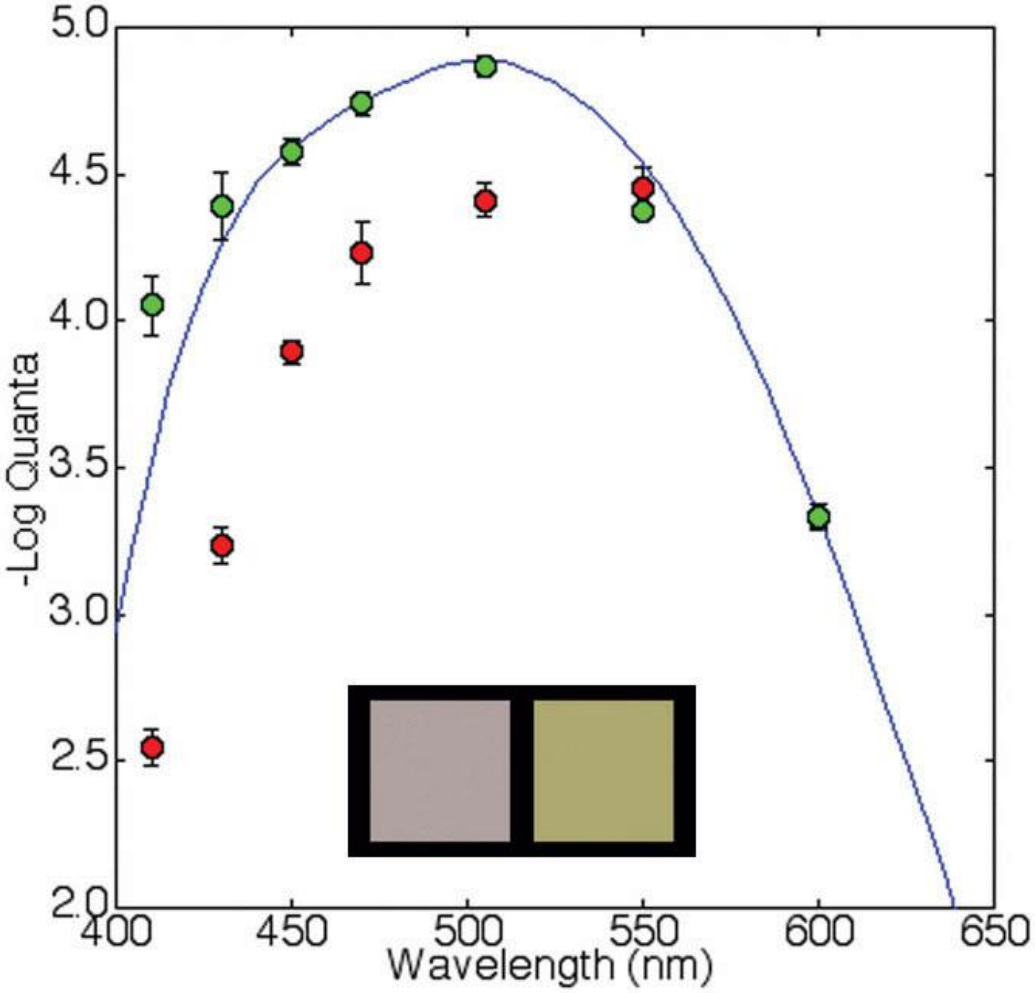
Adapting different observers to the same environment

as seen by
young observer

image filtered through
lens of older eye

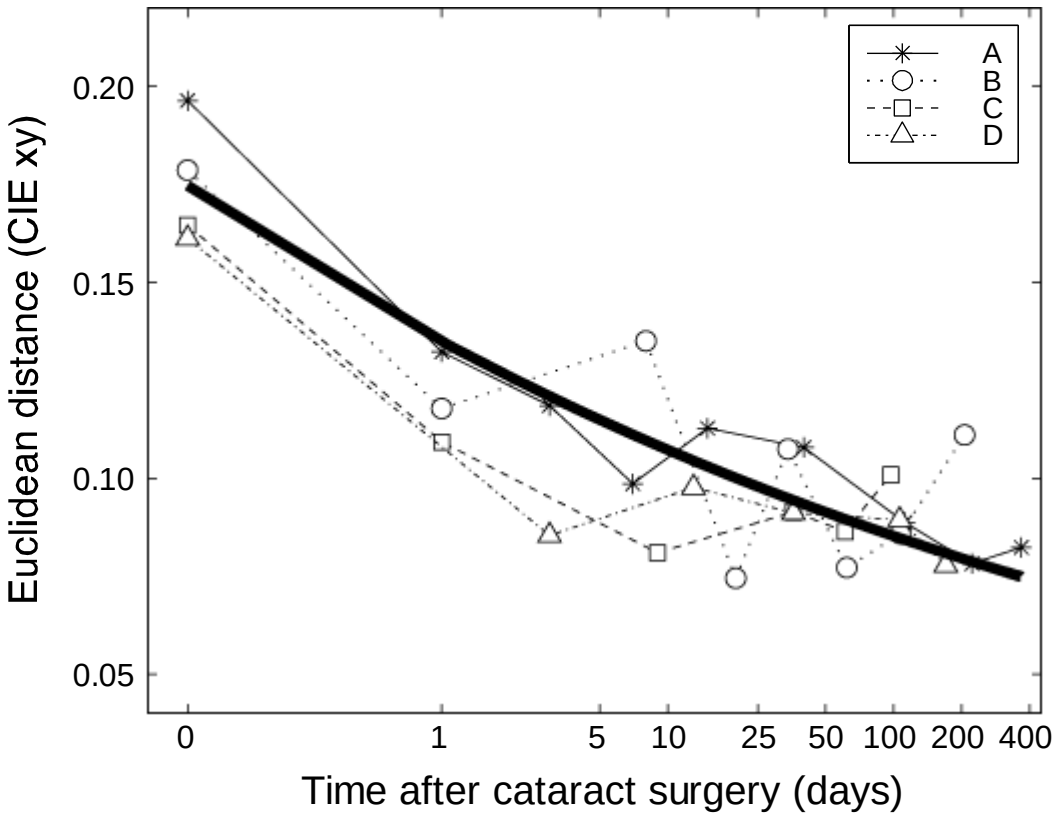
as seen by older observer
adapted to their lens

Spectral sensitivity before (red) and after (green) cataract surgery

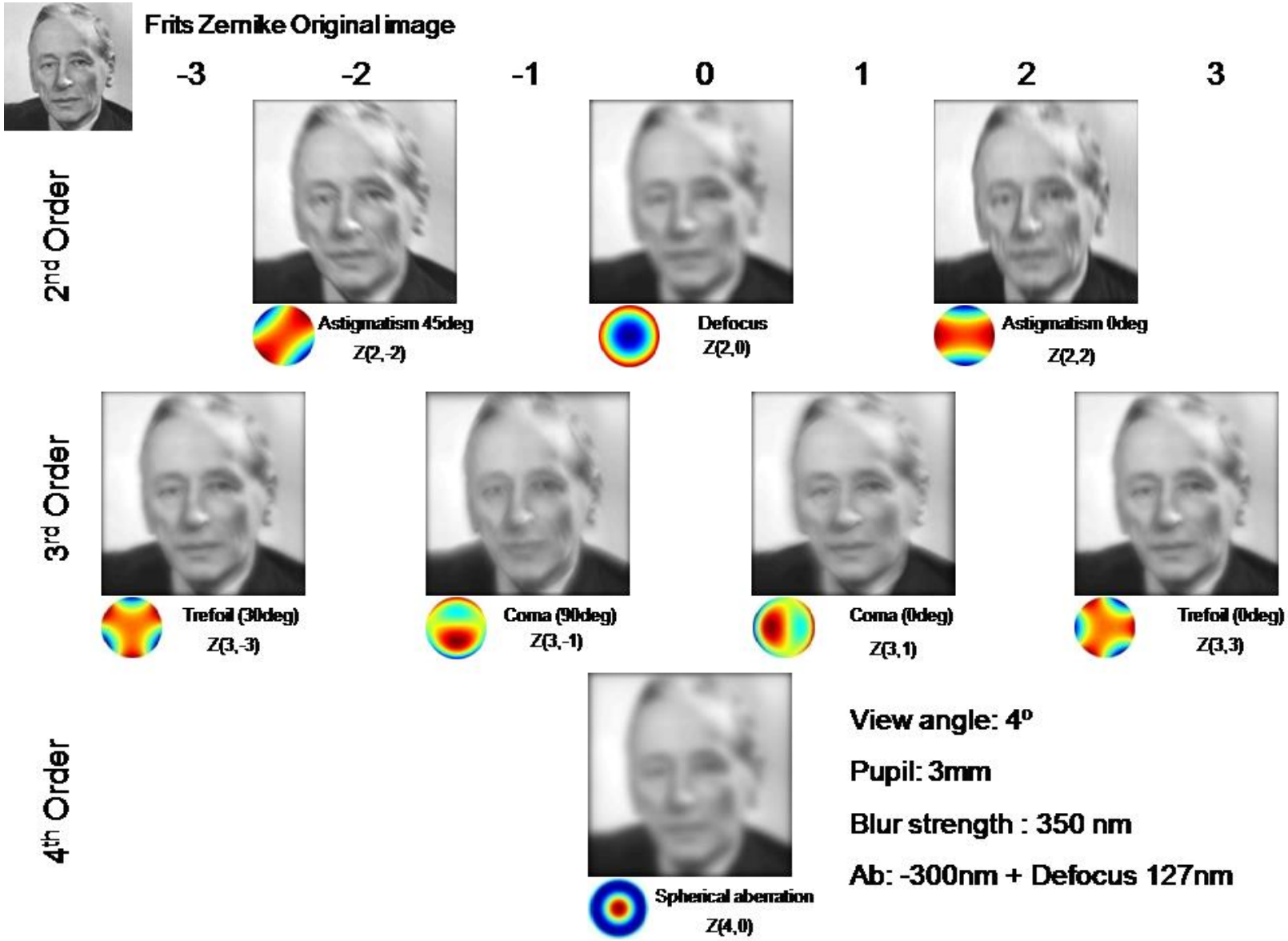


Delahunt et al. Visual Neuroscience 2004

Changes in the perception of “white” following surgery reveal a very slow re-adaptation to the world.

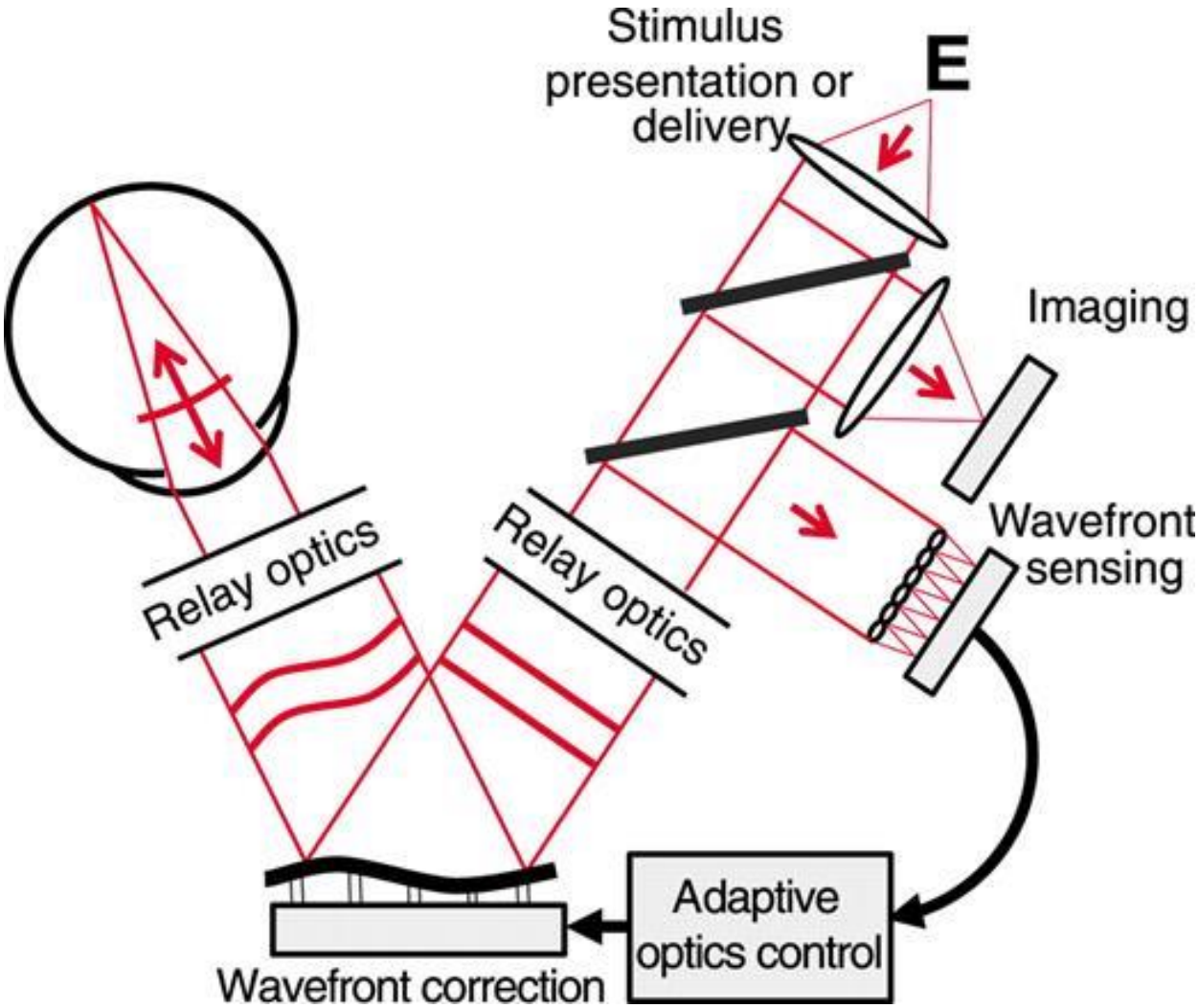


e.g. we are also adapted to the optical blur of our own eyes

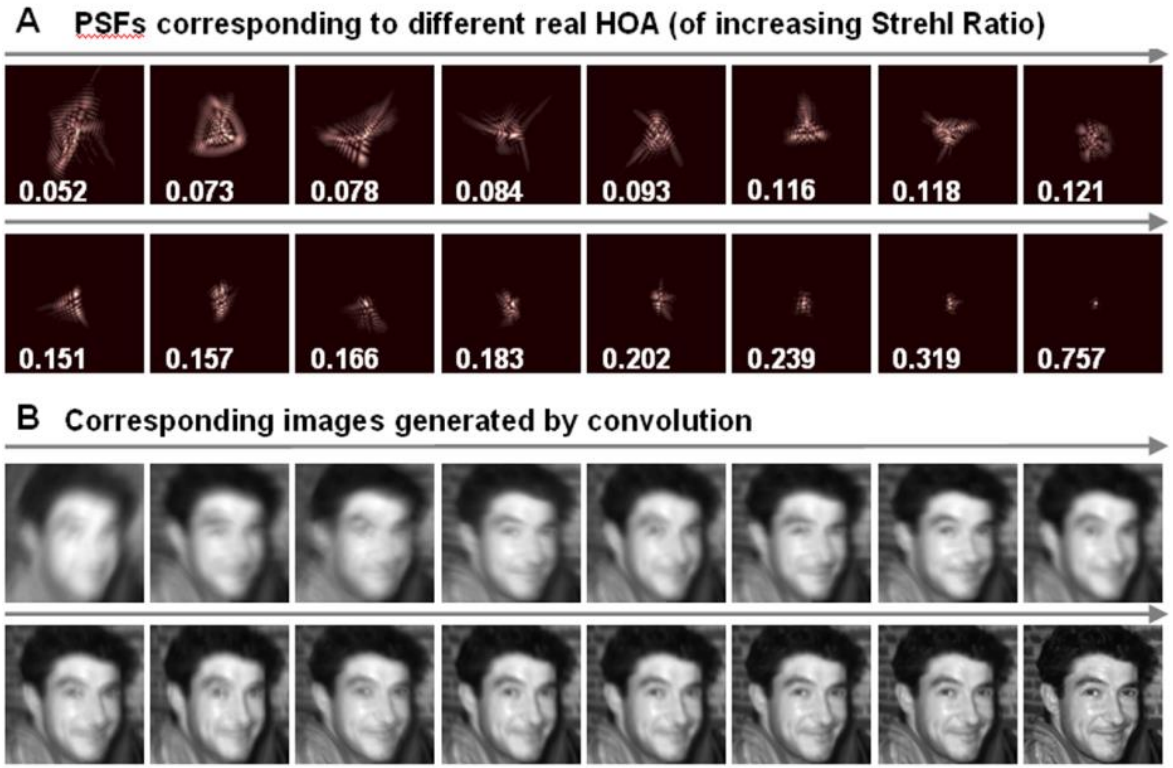


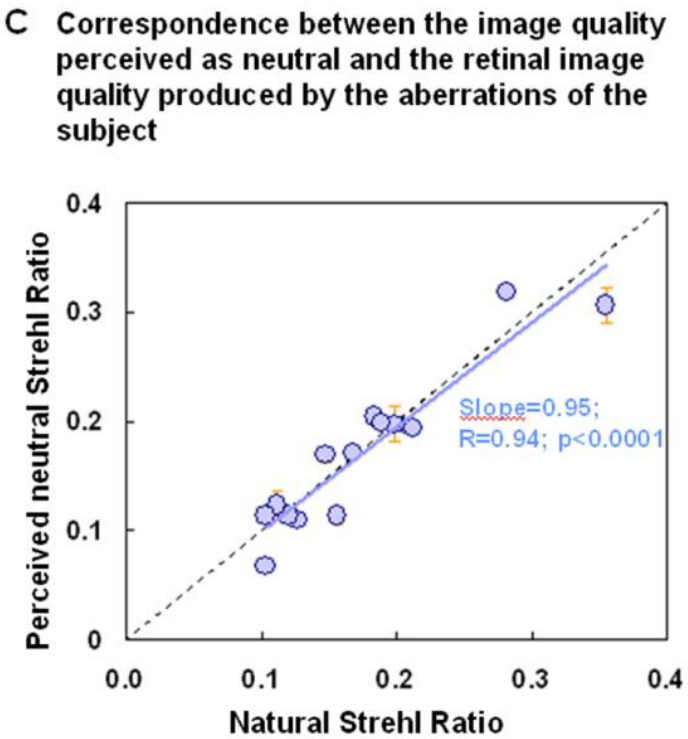
Adaptation to high-order aberrations

Adaptive Optics



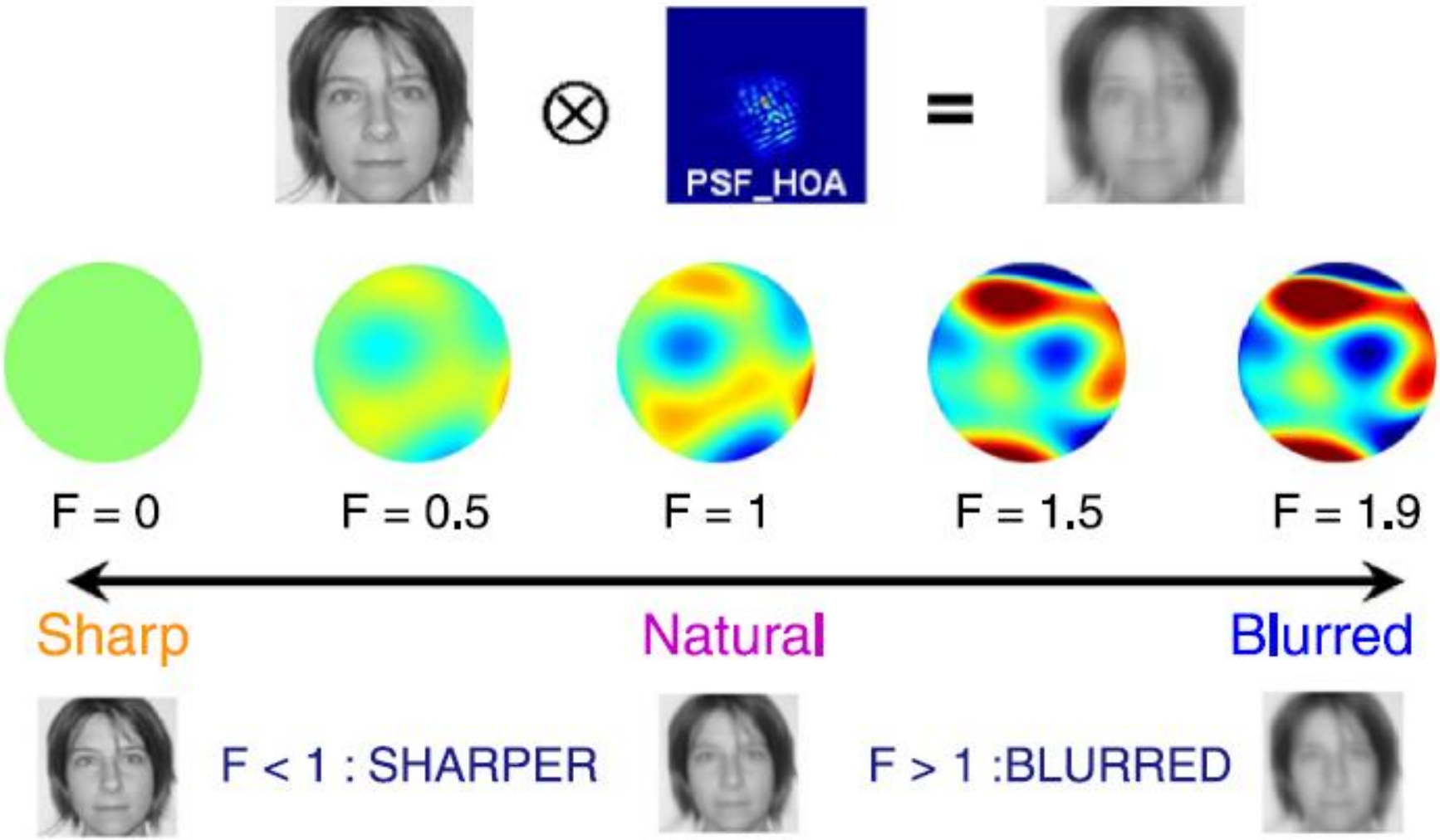
Observers perceive images filtered by their own magnitude of wave aberrations as “best-focused”



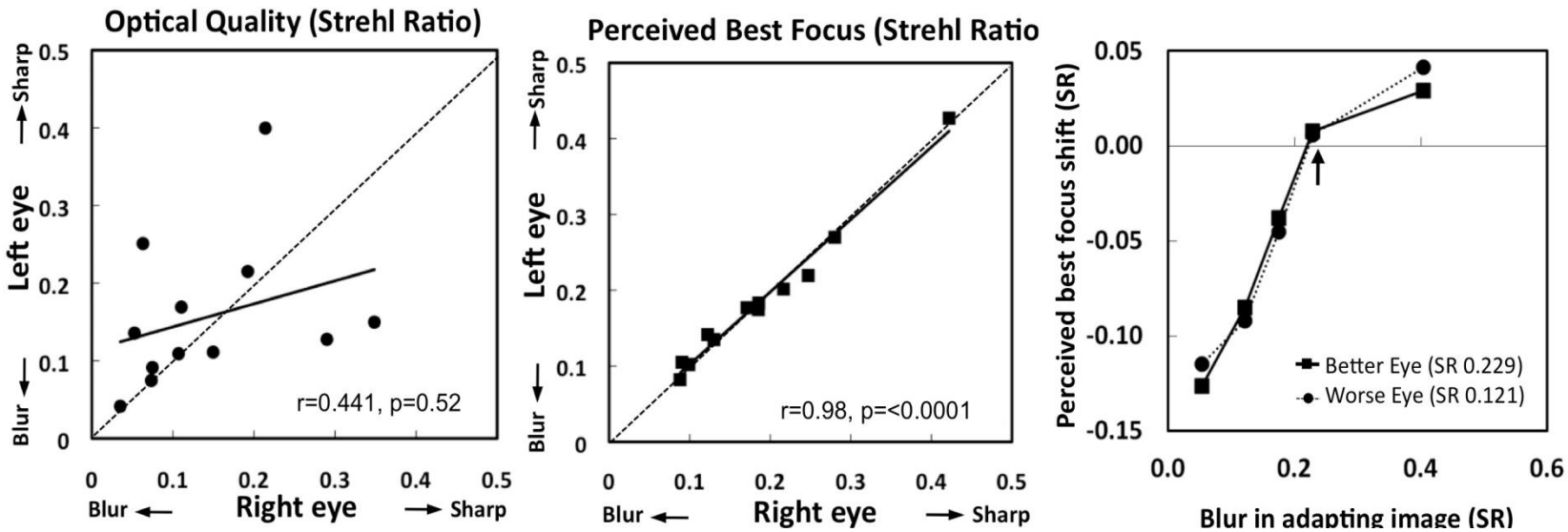


Sawides et al. PLoS ONE 2011

Observers also adapt to changes in the magnitude of their own HOA's

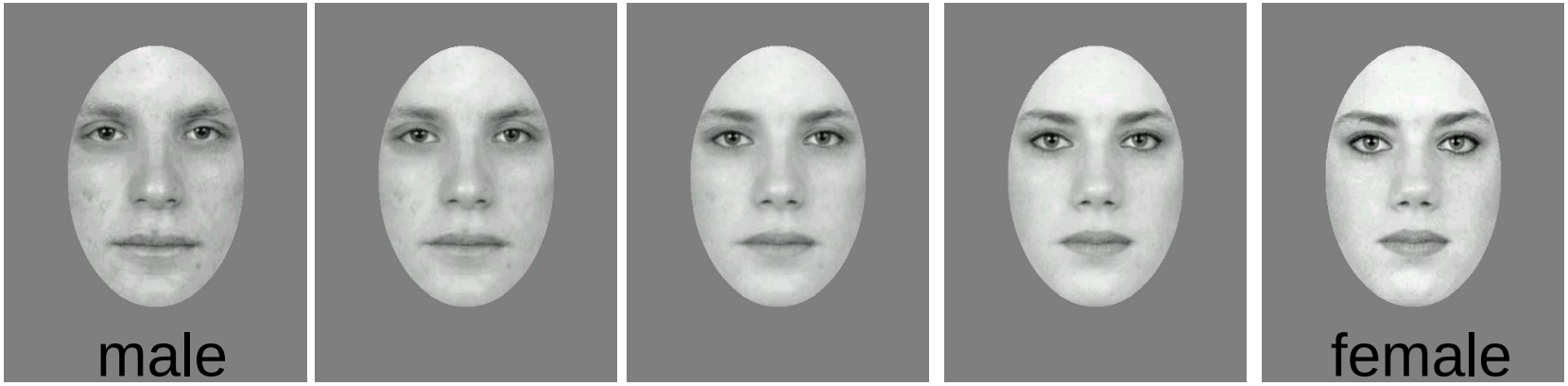


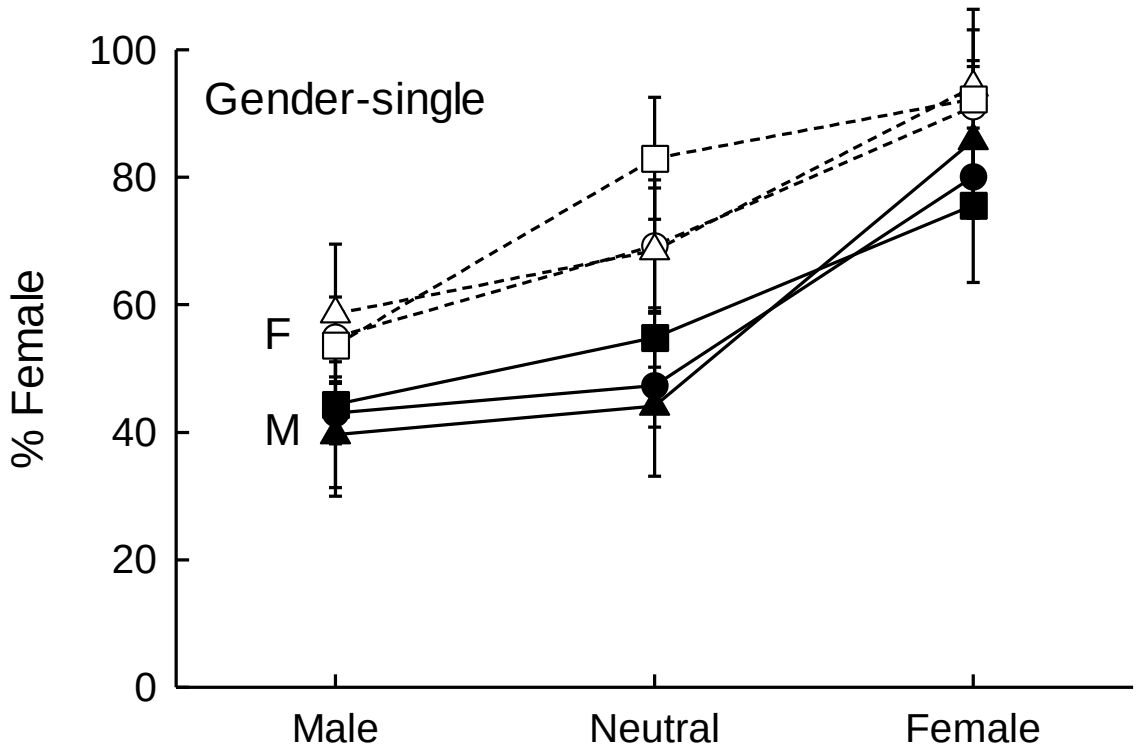
Perceived focus and blur adaptation are set by the eye with better image quality



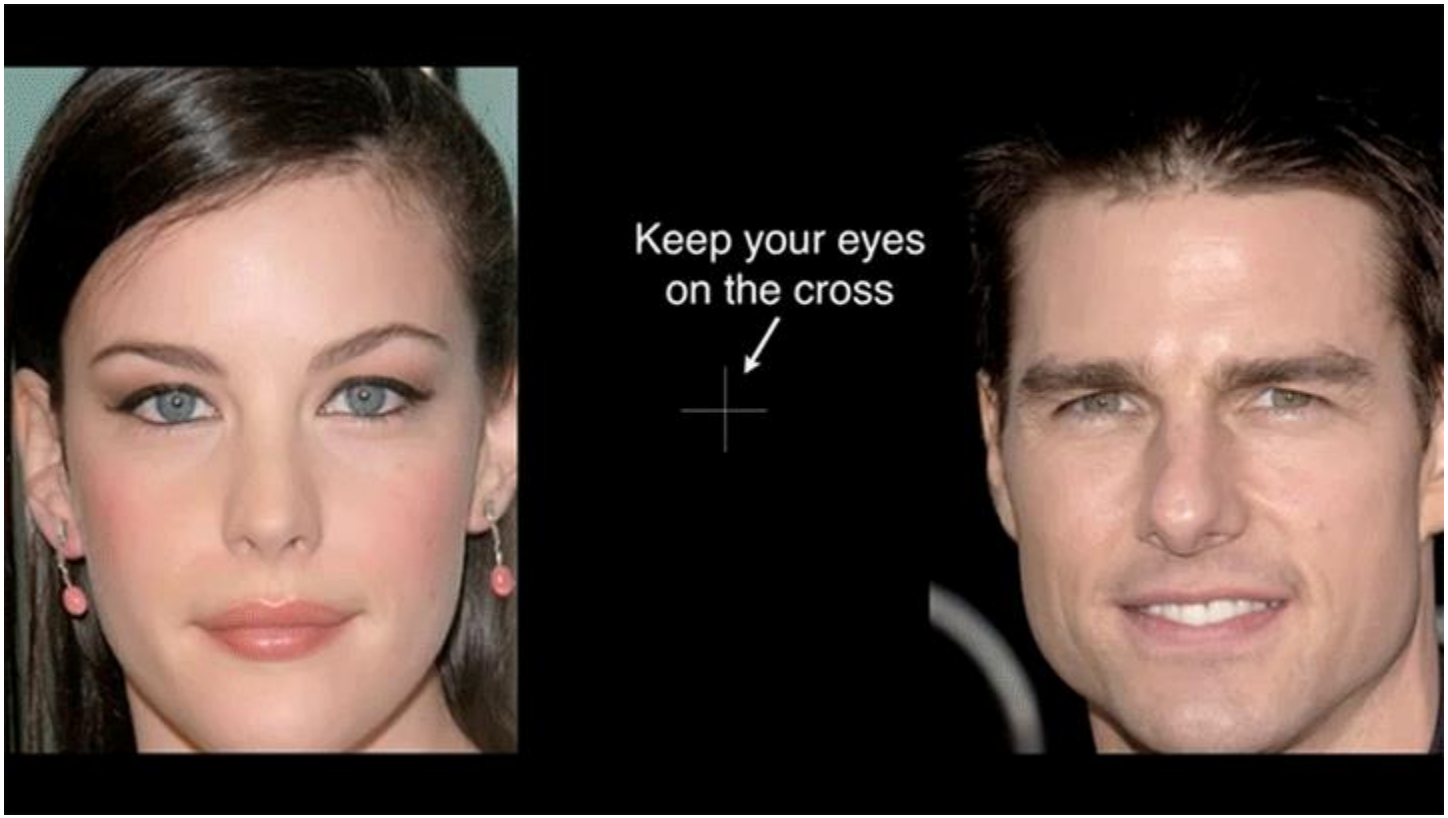
Radhakrishnan et al. Current Biology 2015

eg: adaptation to natural variations in faces





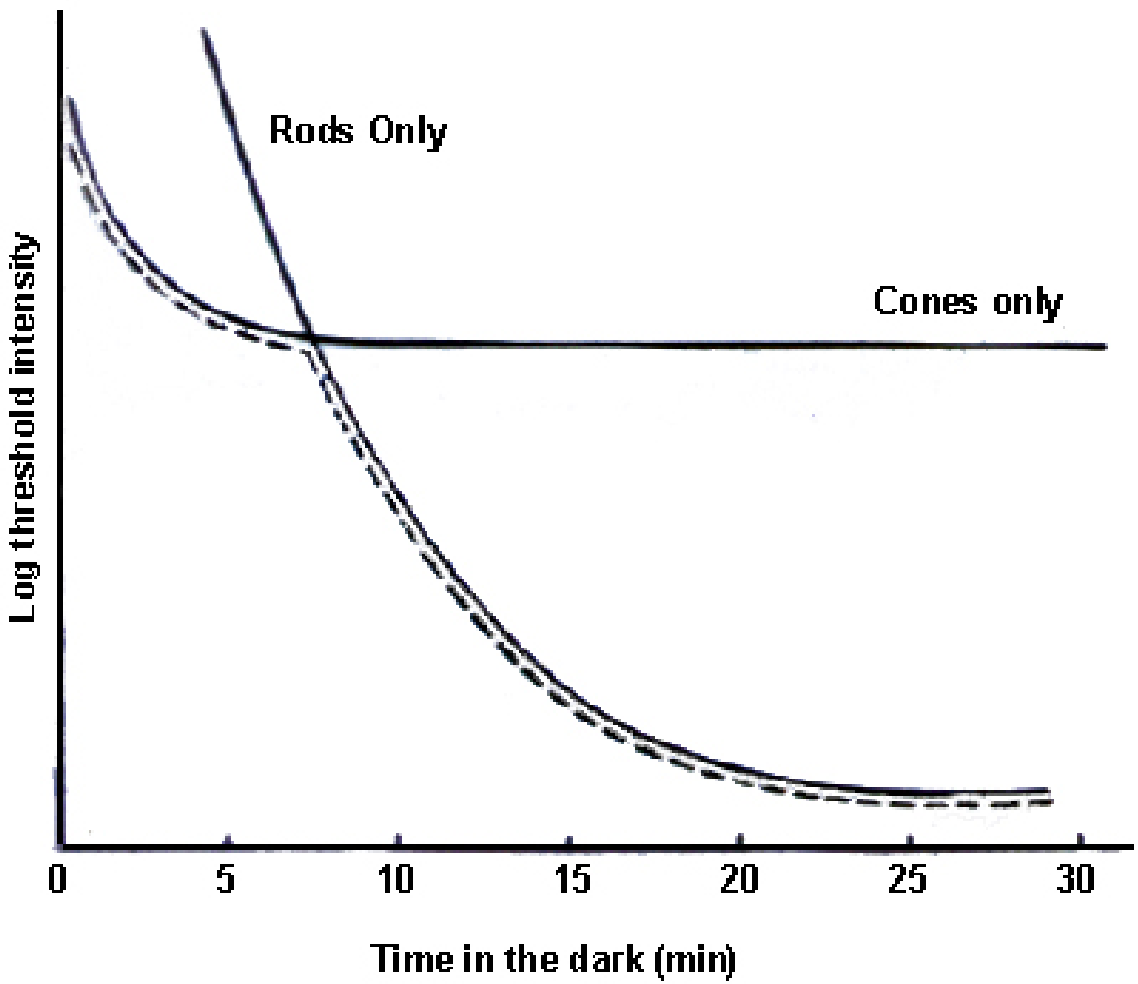
Webster et al. Nature 2004



Tangen et al. Perception 2011

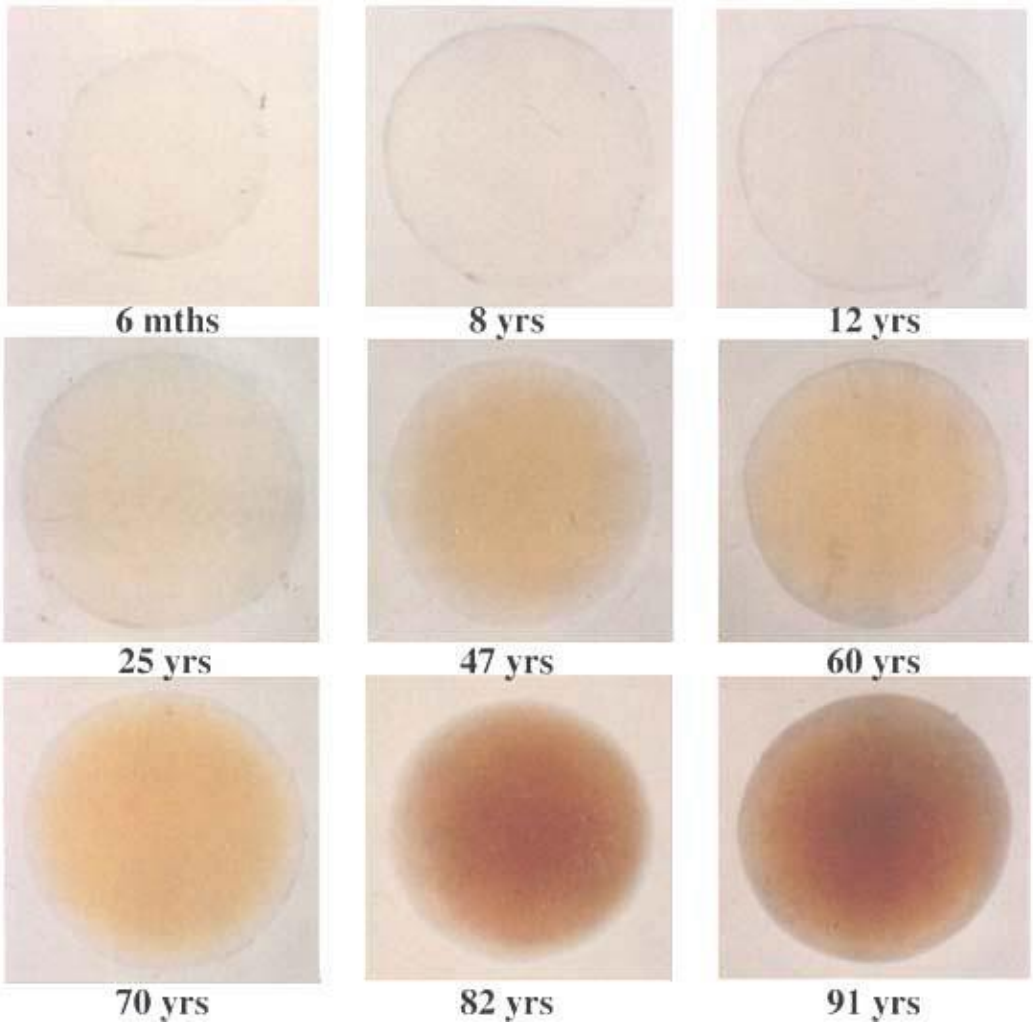
Why adapt?

1. Coding efficiency: adaptation optimizes neural resources for the ambient range of stimuli

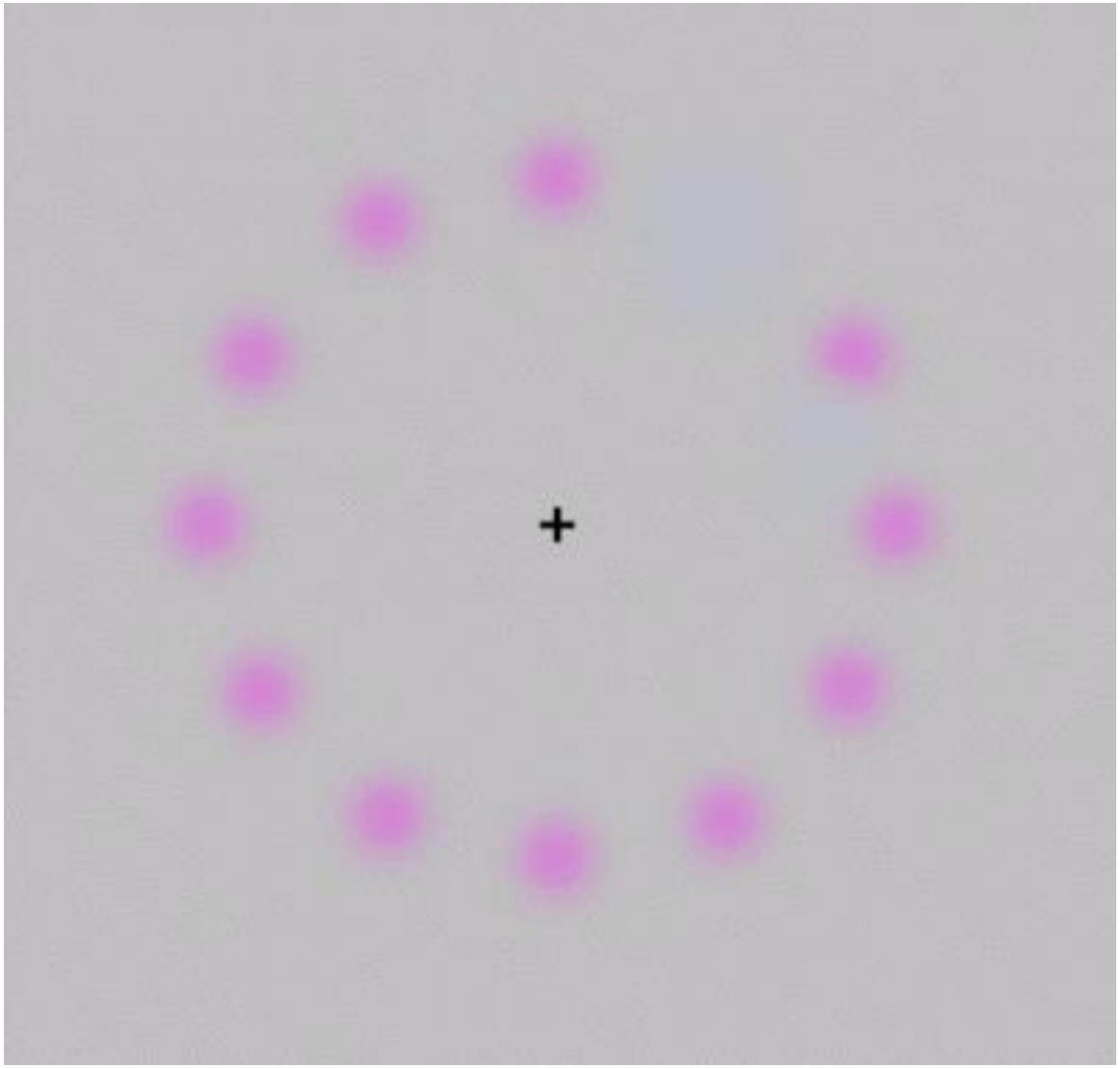


Why adapt?

2. Error correction / constancy: adaptation discounts variance in the observer or stimulus to maintain stable percepts



Why adapt?
3. Predictive coding: adaptation nulls responses for expected stimuli to enhance the salience of novel stimuli



Lilac Chaser, by Jeremy Hinton

e.g. finding a fruit among foliage

Adaptation and the natural environment

Adaptation effects are pronounced in natural viewing

The adjustments strongly impact most if not all percepts

Adapting allows us to see better within the environments we are currently adapted to

Adaptation to unnatural environments

Modern technology is increasingly immersing us in novel and idiosyncratic visual environments

How will visual coding adjust to these worlds?

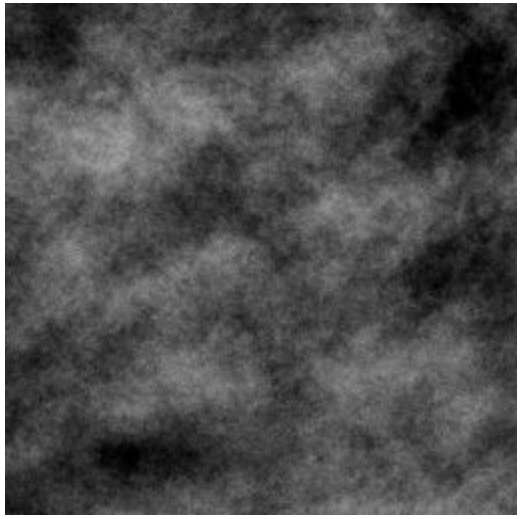
e.g. adaptation to medical images

Radiologists spend hours inspecting images
that have unnatural properties (e.g. texture and blur)

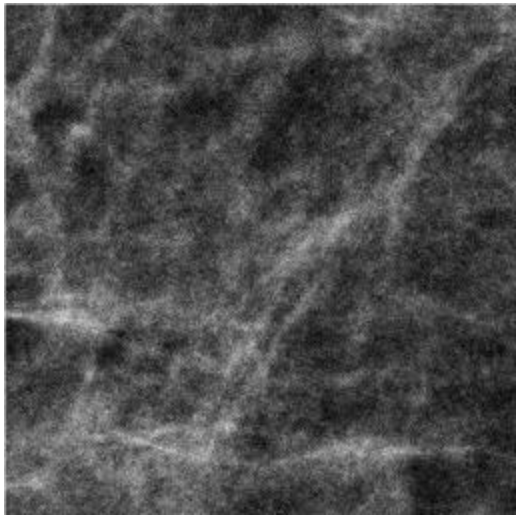
They might therefore adapt to the unique statistics of their
“environment”

e.g. tissue in mammograms typically classified from dense to fatty

Could these classifications be affected by the distribution of images seen previously?



dense

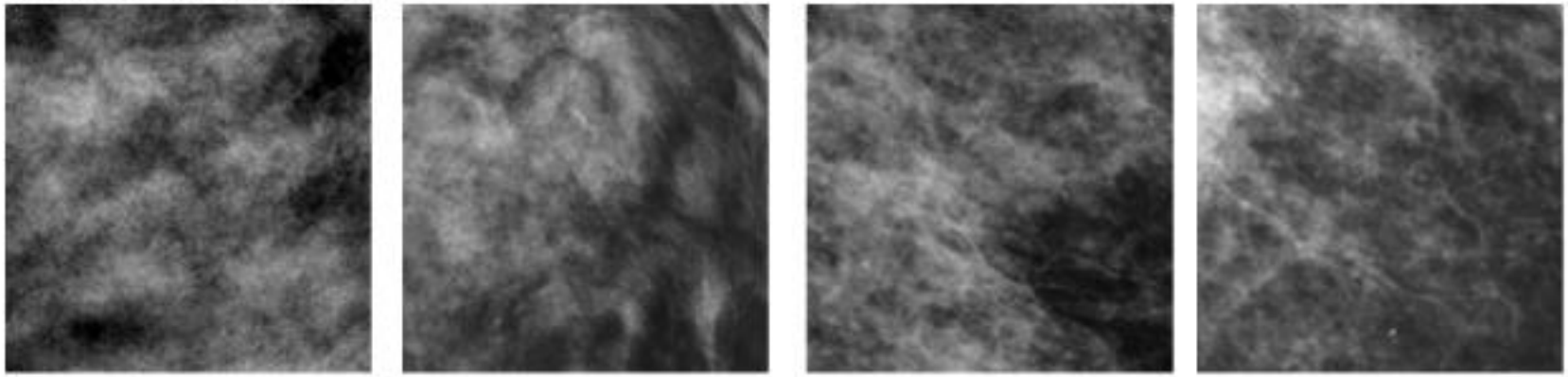


fatty

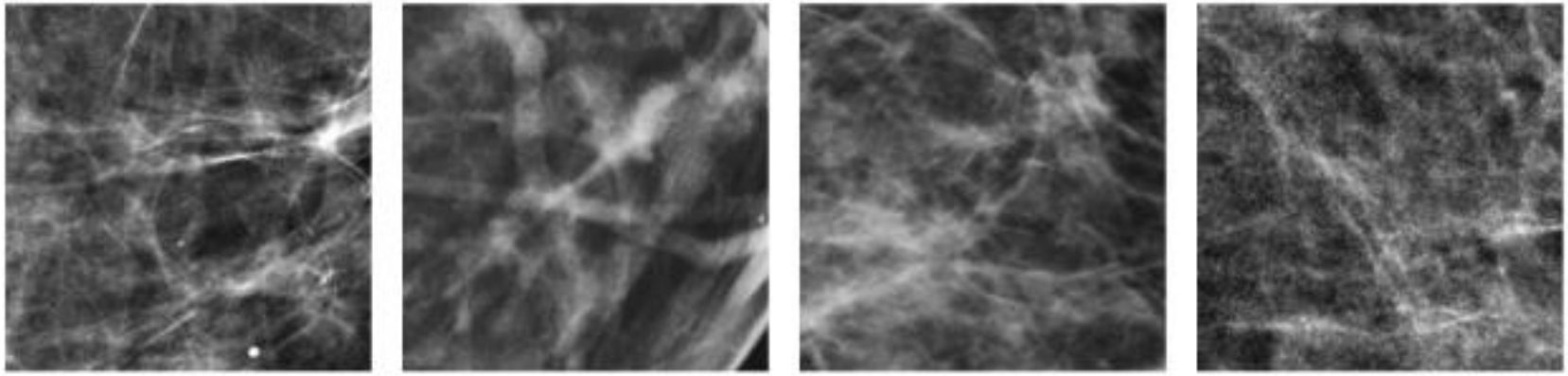
Kompaniez, Abbey, Boone, and Webster PLOS One, 2013

BIRADS classification of mammograms as dense or fatty tissue

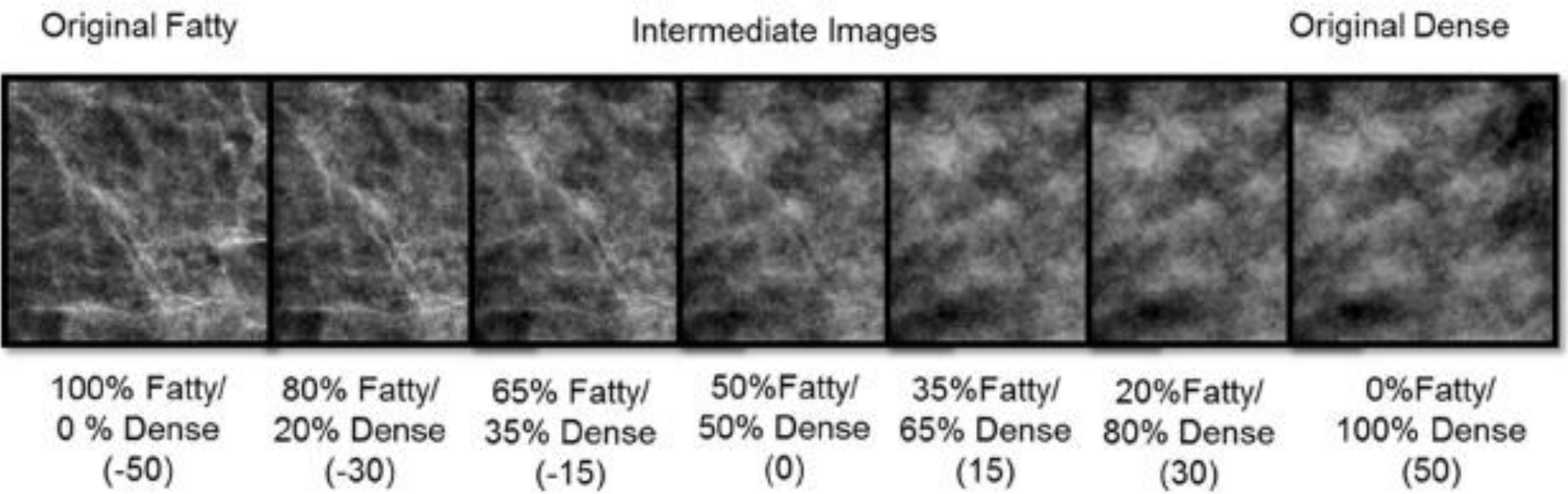
Dense - (BIRADS 4)



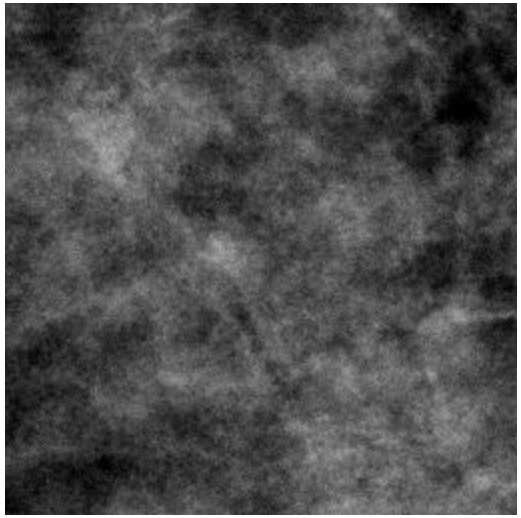
Fatty - (BIRADS 1)

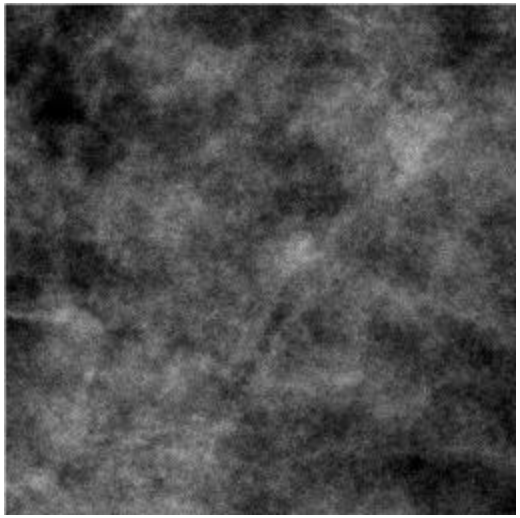


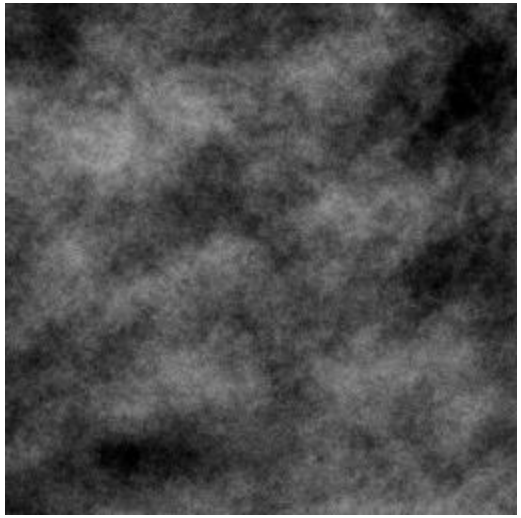
Graded blends of fatty and dense images

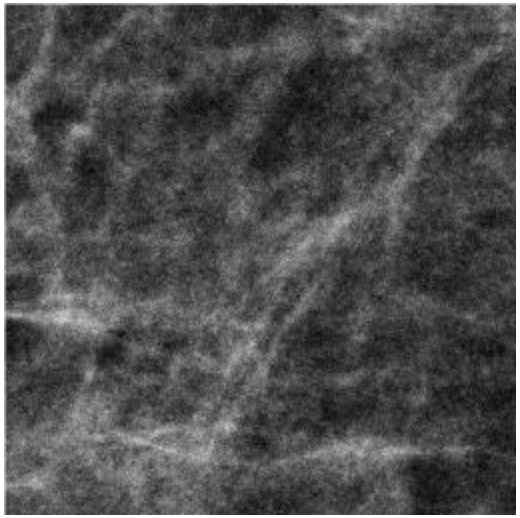


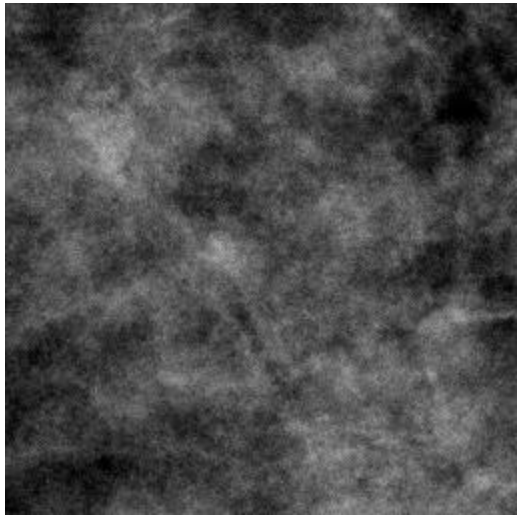
Adaptation to medical images

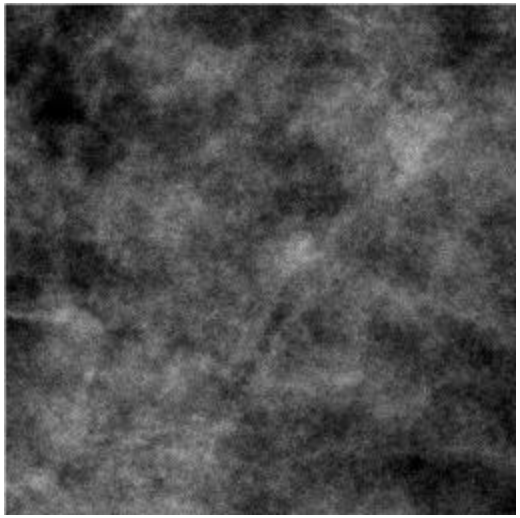




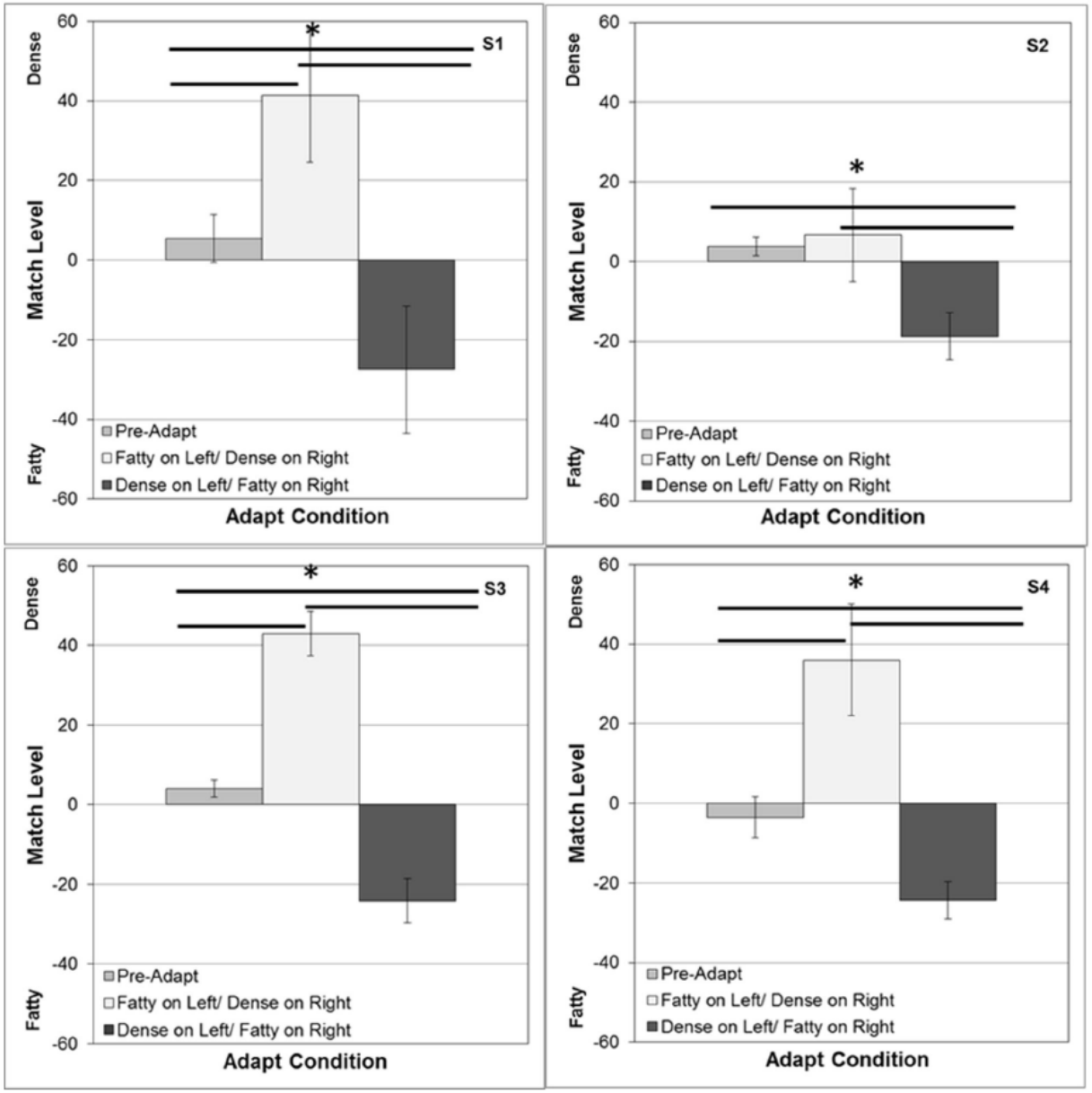




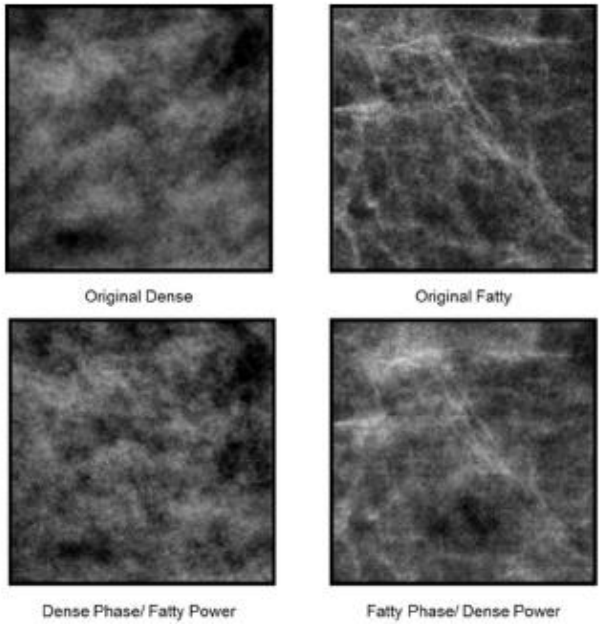


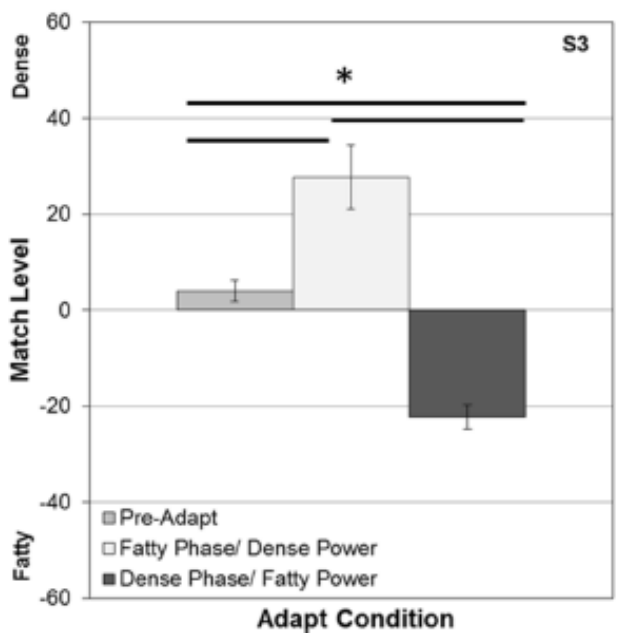


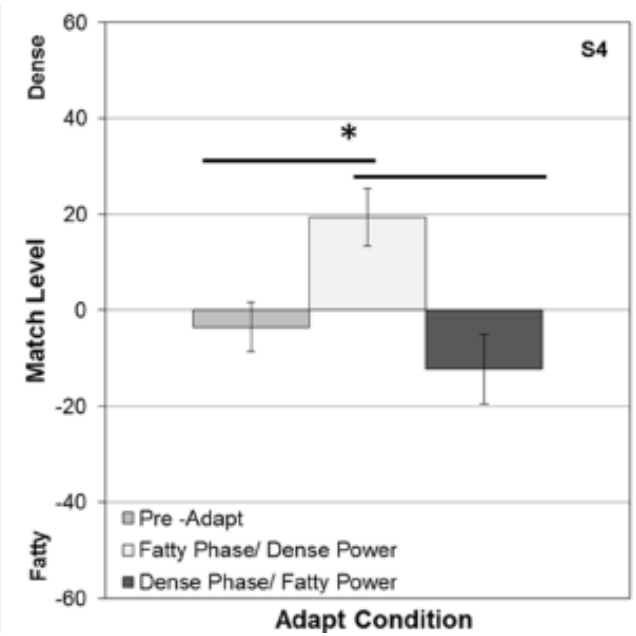
Adaptation biases the perceived texture in the images



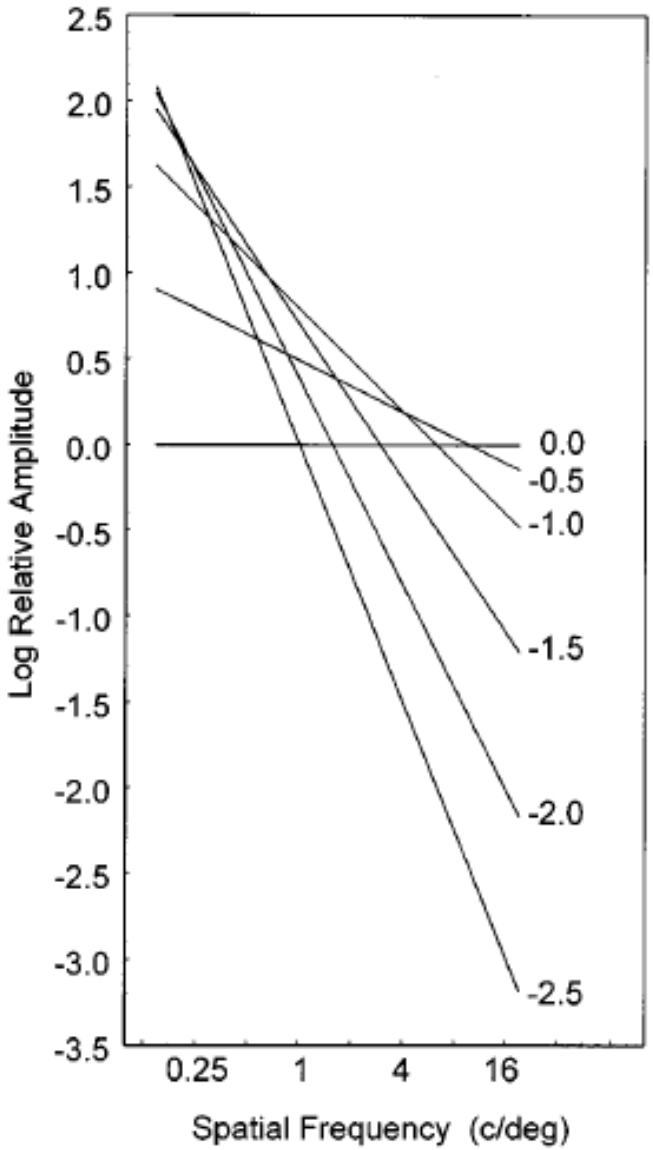
Aftereffects are driven by the phase spectrum and not the amplitude spectrum



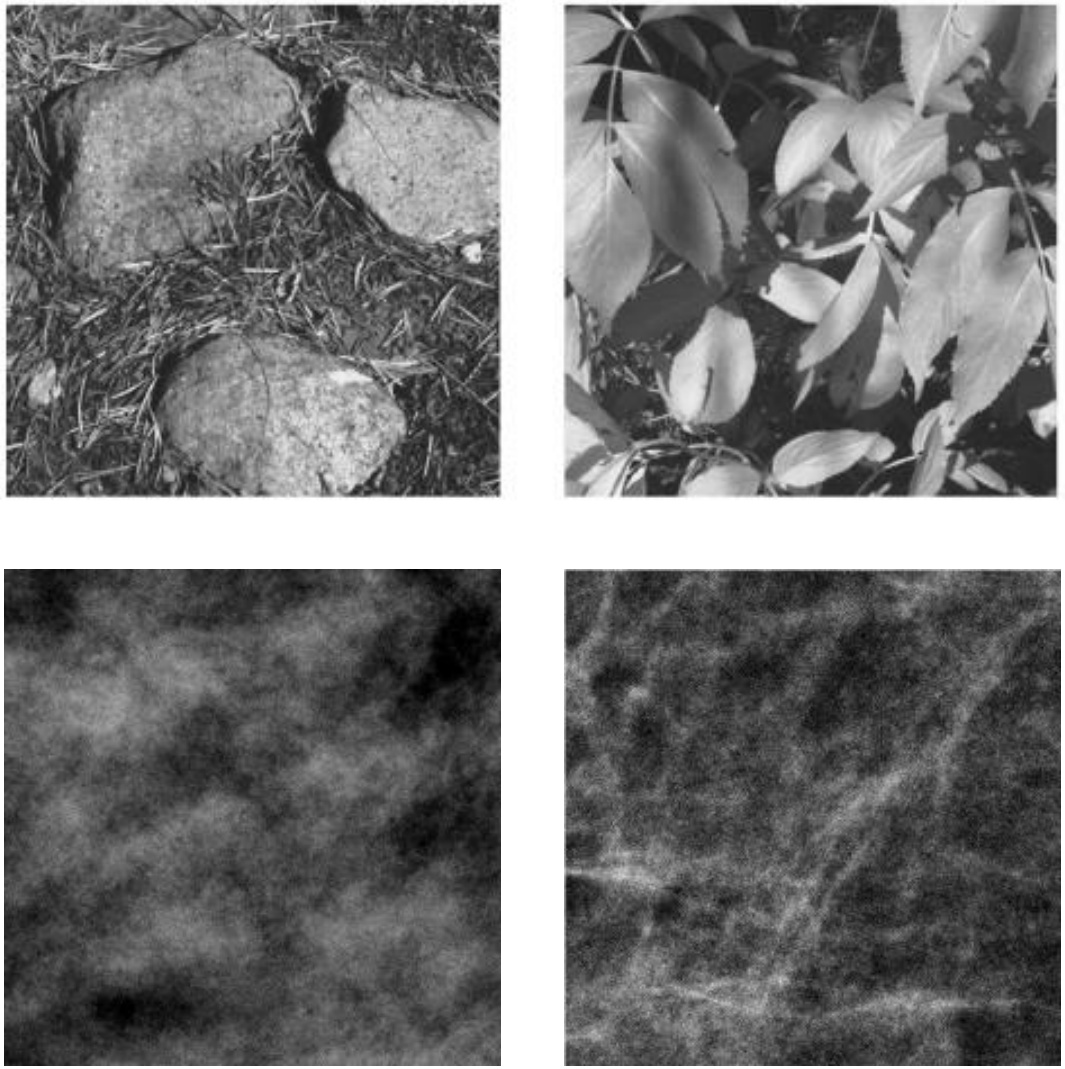




Adaptation to the characteristic blur in mammograms

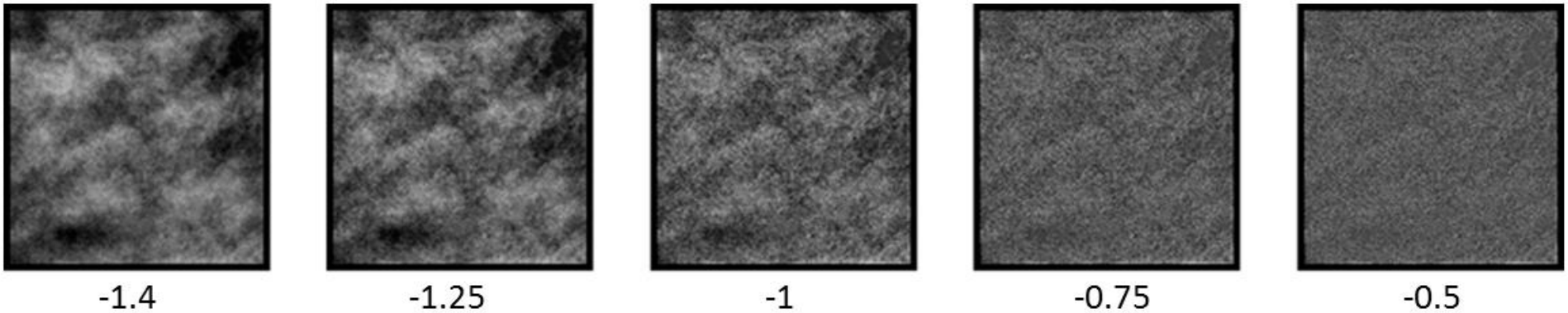


slope ~ -1.0



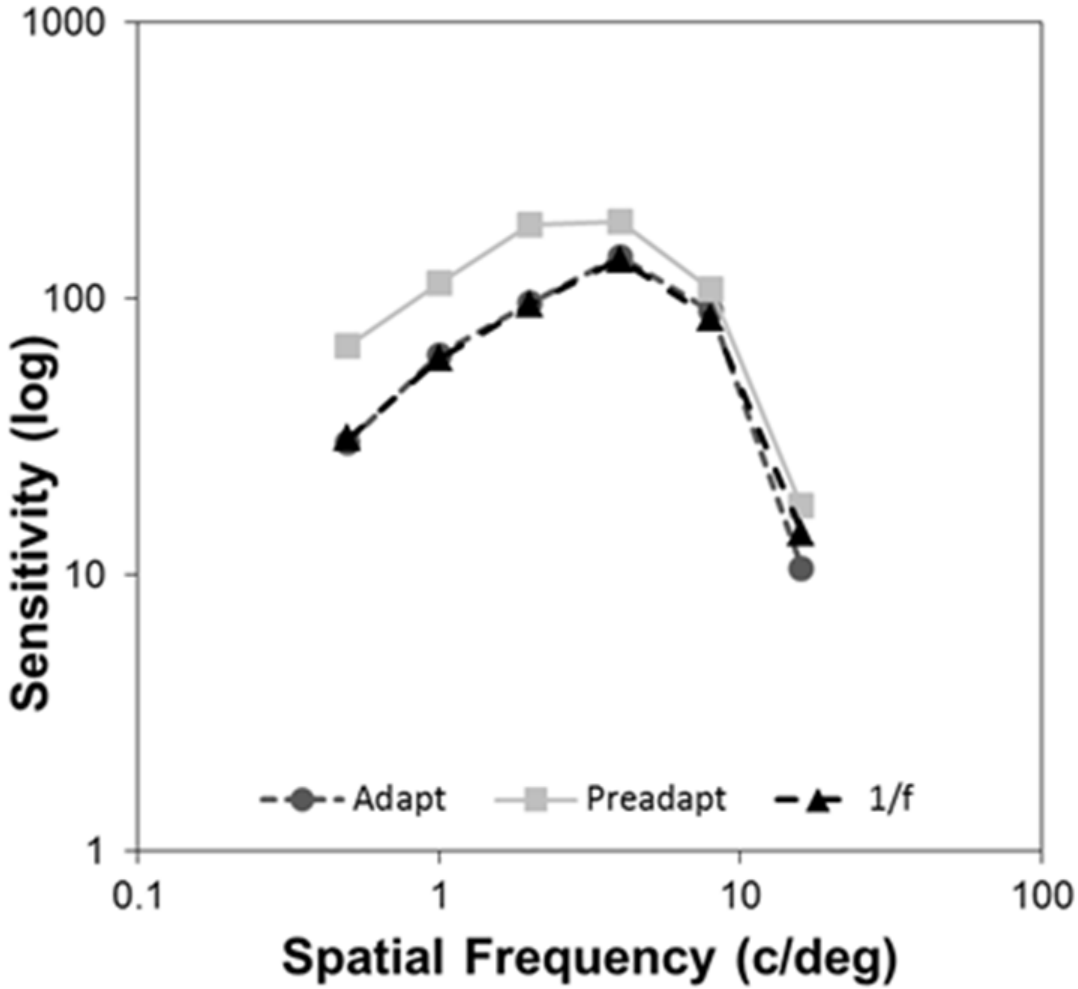
slope ~ -1.4

Adaptation to the characteristic blur in mammograms



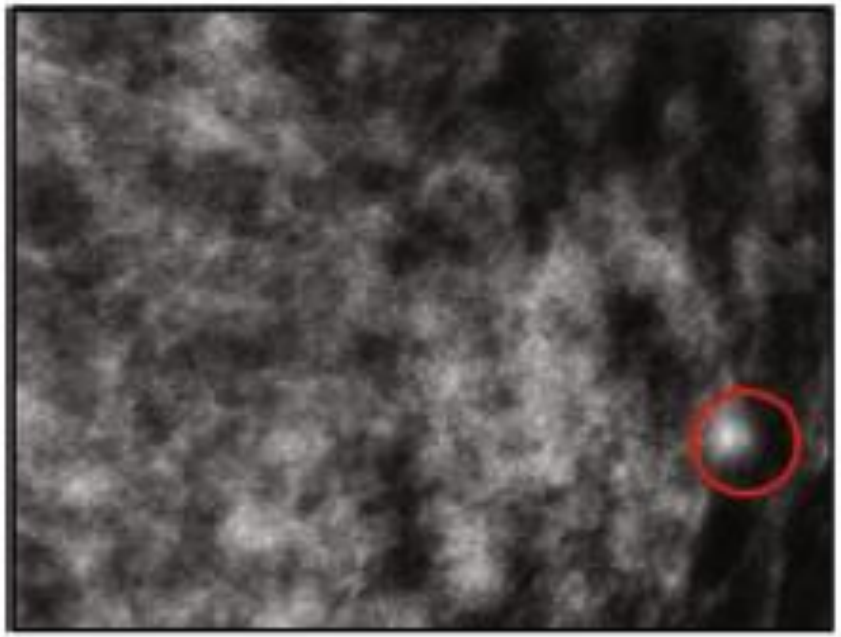
Kompaniez et al. Cog Res: Principles and Implications 2018

Adaptation to the images also leads to selective sensitivity losses at low spatial frequencies, biasing the contrast sensitivity function (CSF)

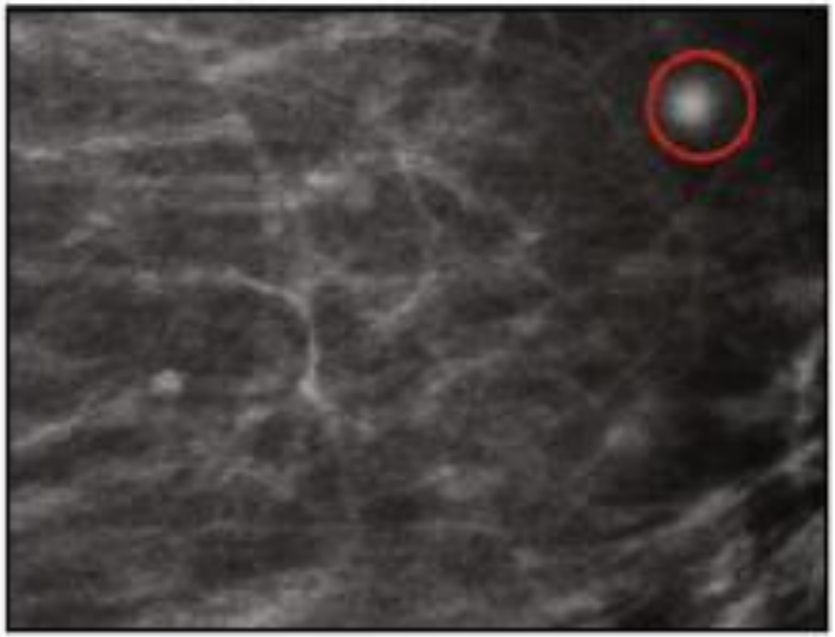


Adaptation and visual search in mammogram images

Mammograms with added targets (circled)



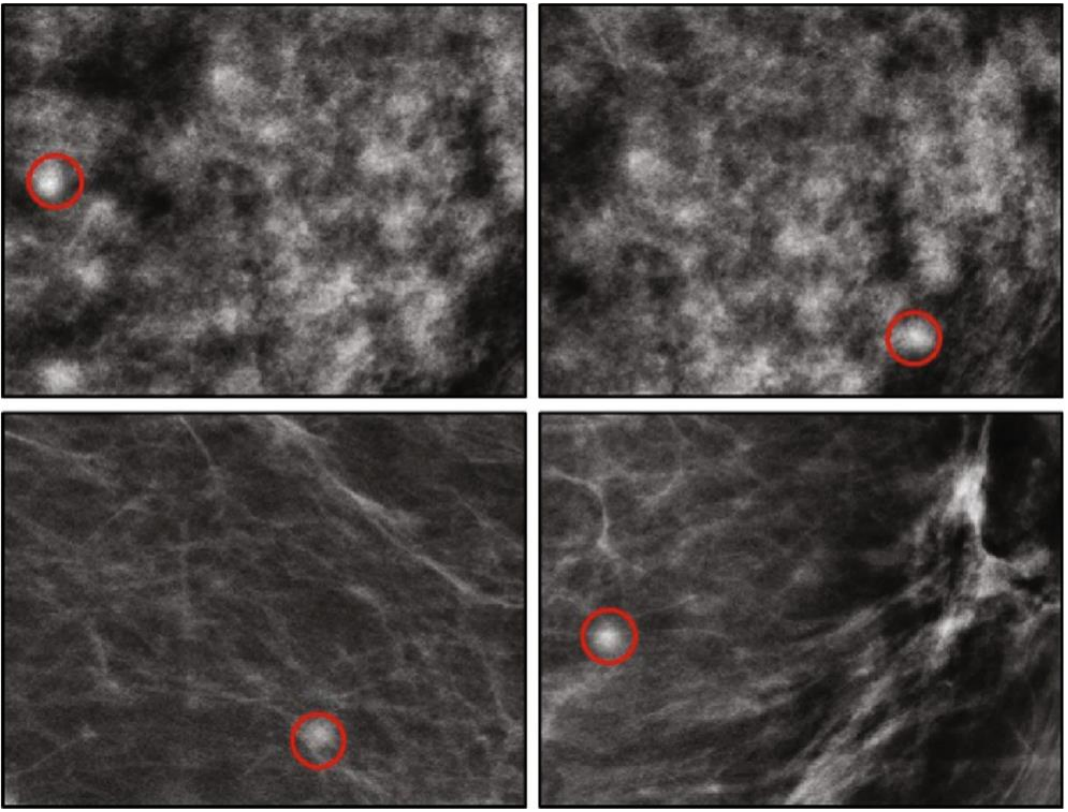
Dense Tissue

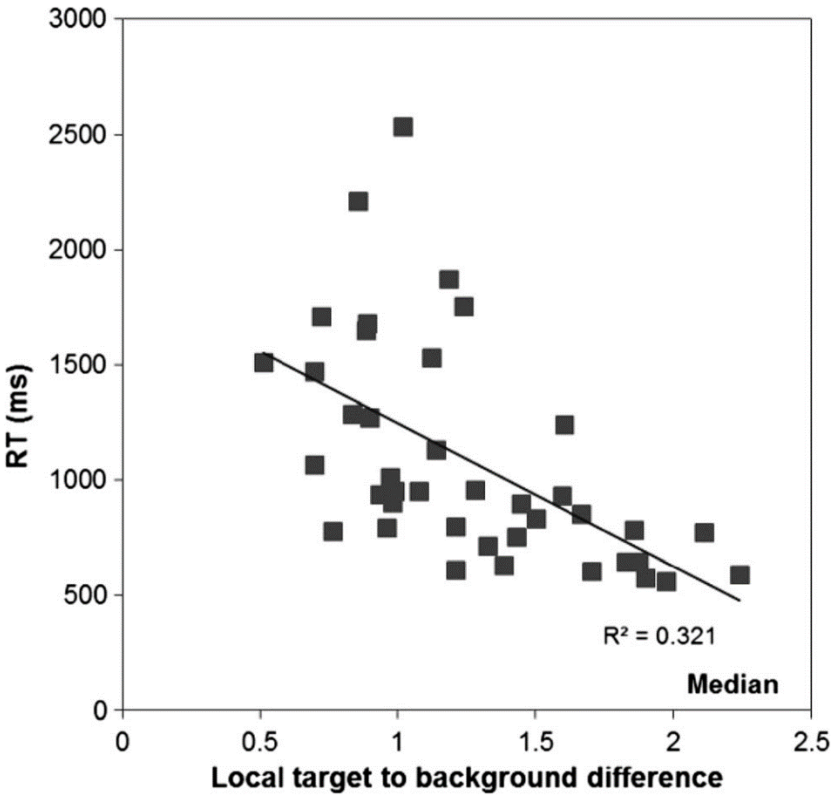


Fatty Tissue

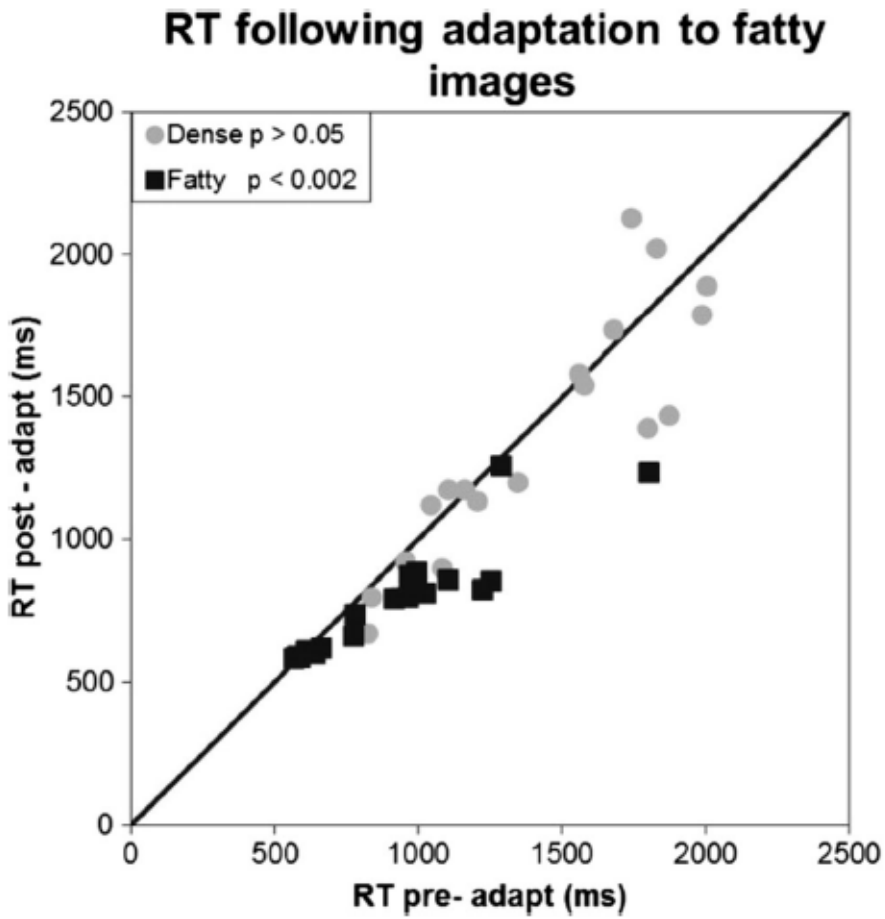
Kompaniez et al. Atten Percept Psychophys 2015

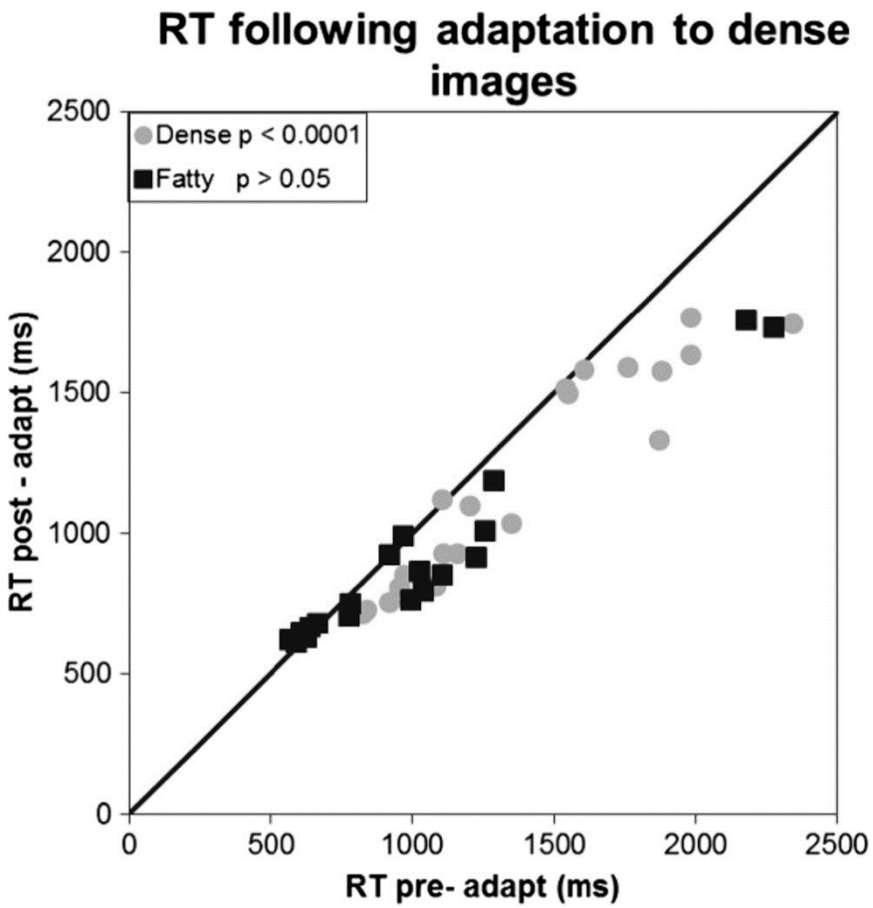
Search times are faster with higher contrast targets





Adaptation facilitates search for a “lesion” within the adapted tissue type – and thus is selective for texture





Adaptation and medical image perception

- Radiological images present unique visual properties of observers
- Adaptation to these properties can bias contrast sensitivity and visual appearance
- The adaptation may also enhance sensitivity to novel (suspicious) features in the images
- Protocols for inspecting medical images could be developed to control for and potentially harness visual adaptation to improve performance

Thank you!

Integrative Neuroscience
Center of Biomedical Research Excellence

Visual Perception Lab
University of Nevada Reno

NIH
National Eye Institute

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