(1) covert attention

(2) effects on contrast sensitivity

(3) effects on spatial resolution

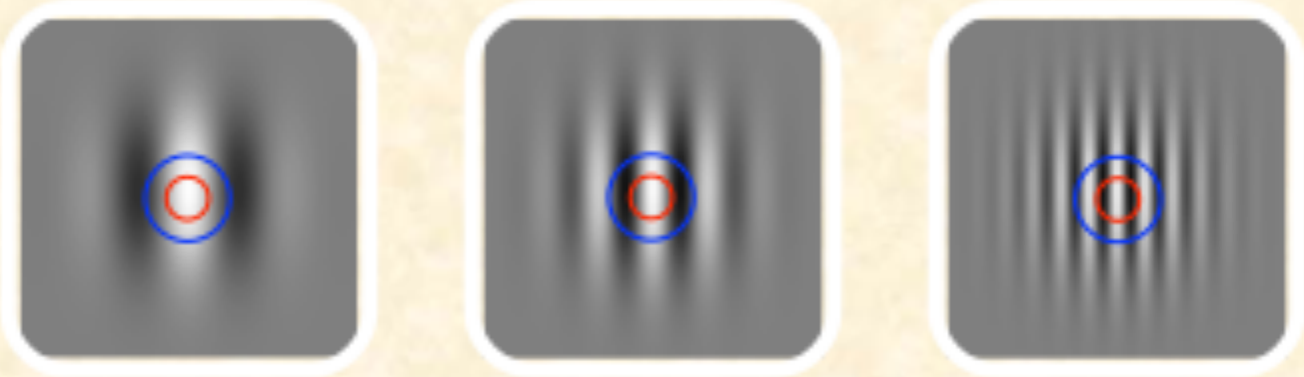
attention affects spatial resolution

1. definition
2. linking psychophysical and neurophysiological evidence - *NRN*, 2013
3. recent studies

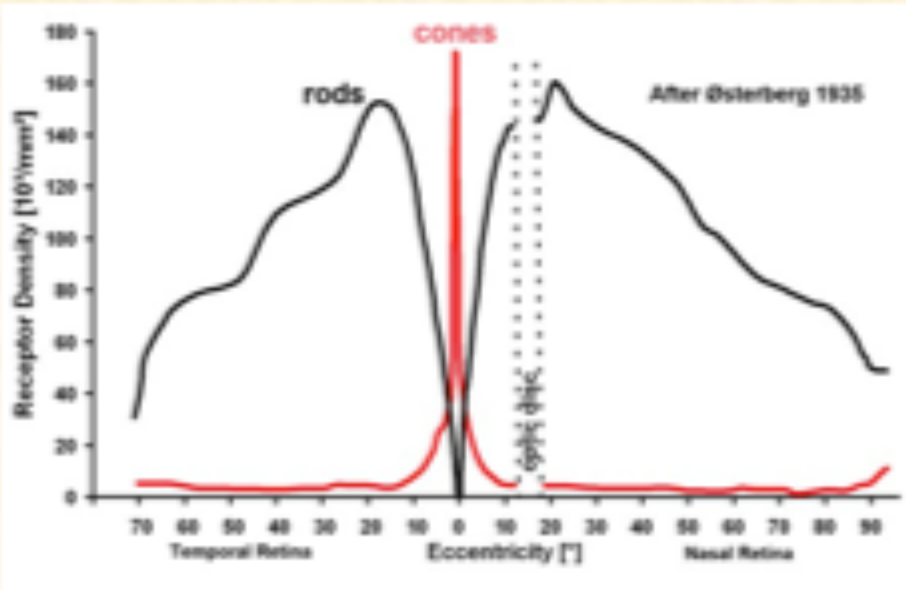
vision is limited by spatial resolution

- the ability to discriminate two nearby points in space
- depends on receptor size, number, and spacing

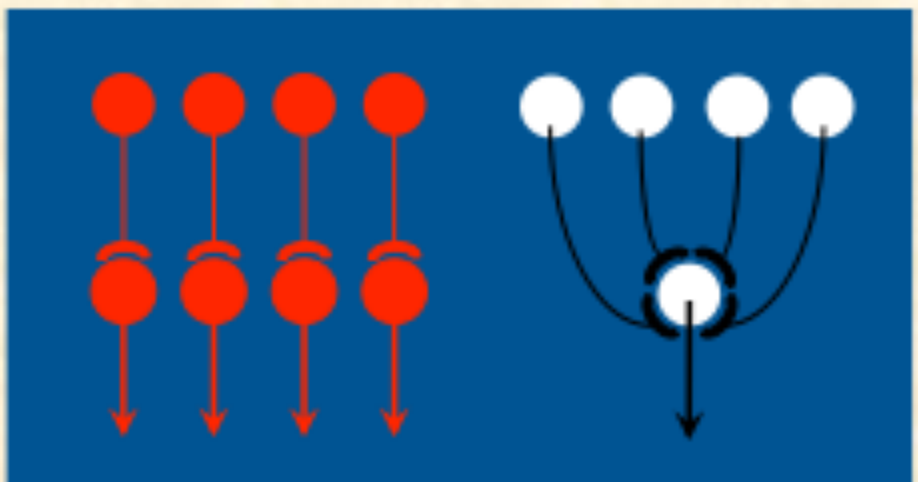
- average filter size inversely correlated with preferred spatial frequency

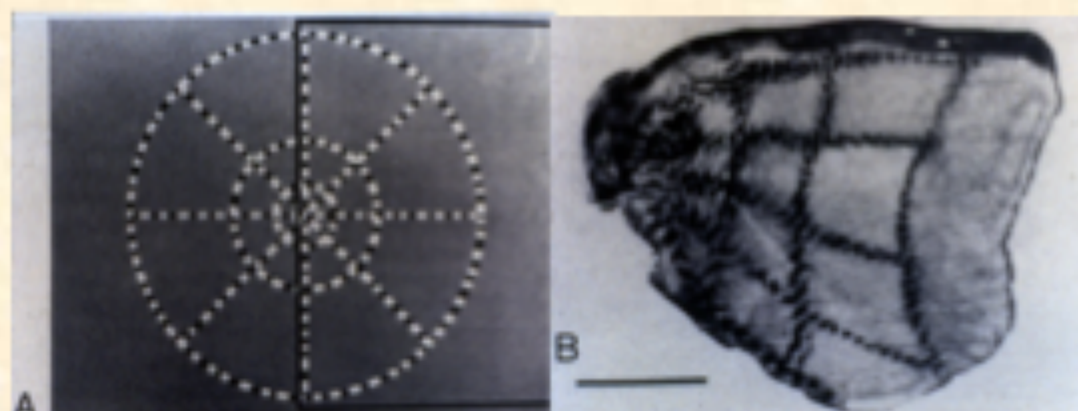


spatial resolution declines with eccentricity

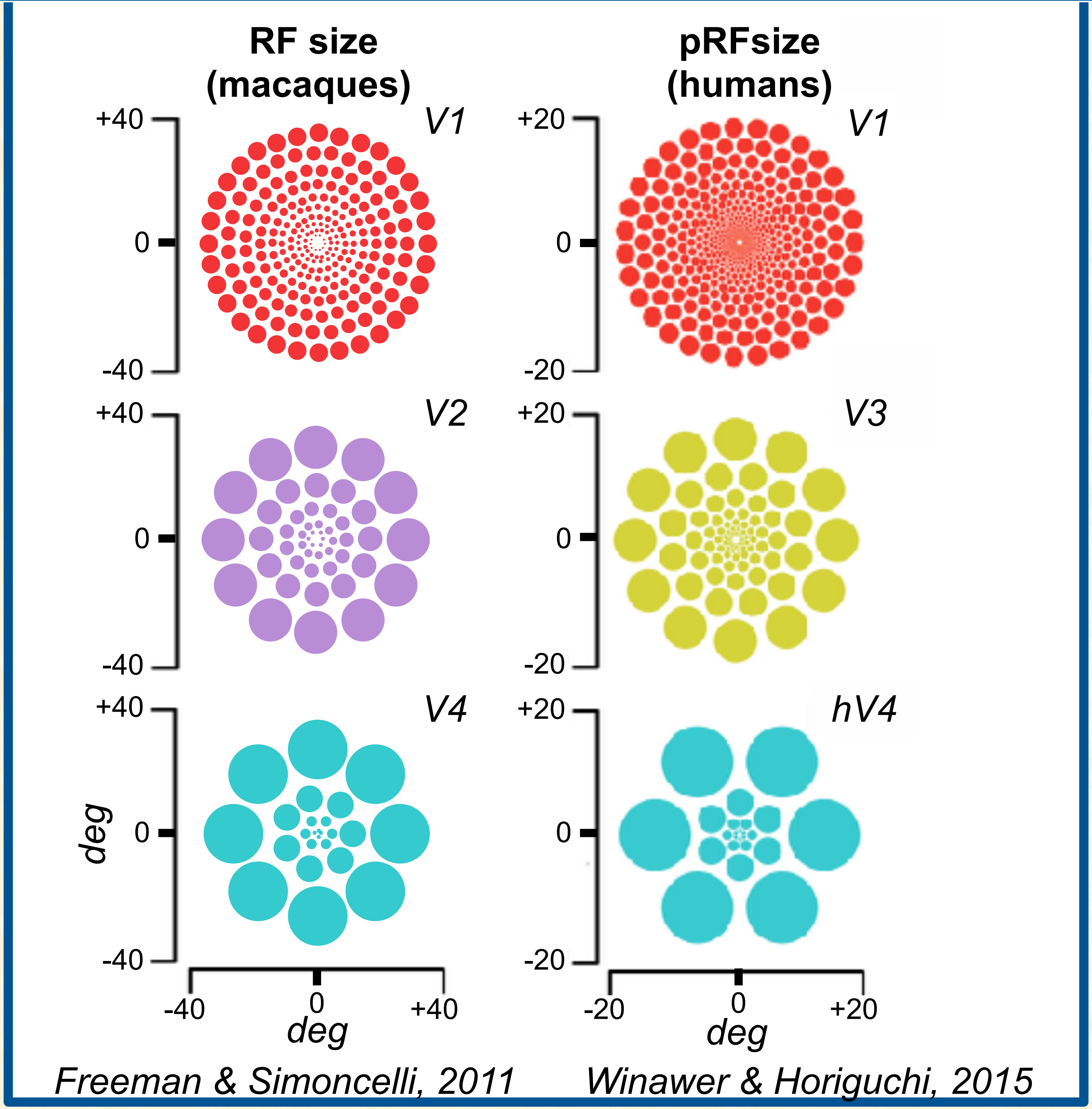


- retinal receptor density
- ganglion cell density
- mapping of photoreceptors
- receptive field size & density
- cortical magnification





spatial resolution declines with eccentricity



Carrasco & Barbot, 2015

attention and spatial resolution

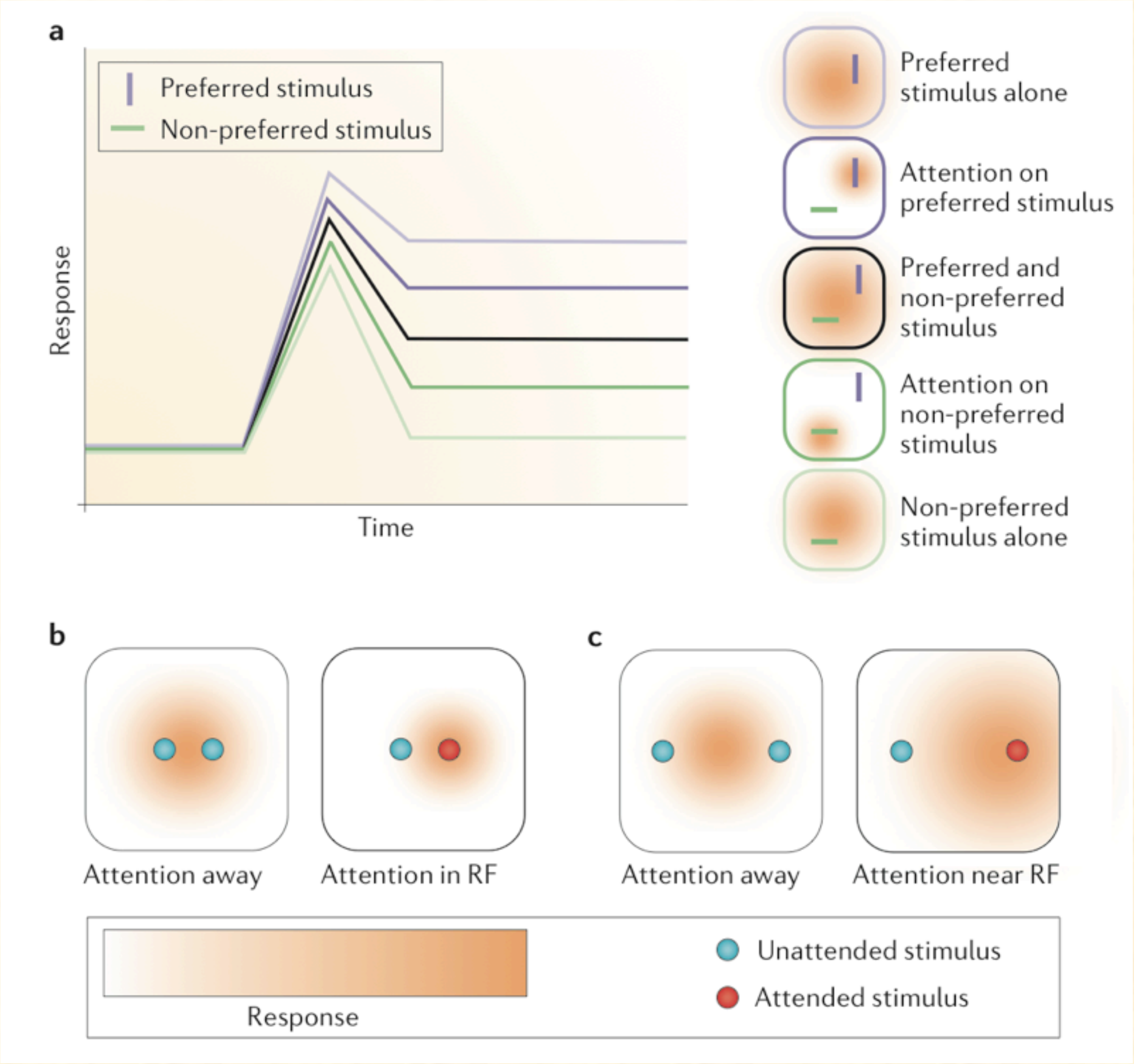
- benefits performance; e.g. visual search, acuity and crowding
- changes the appearance of spatial stimulus attributes; e.g. gap size

reviews: Carrasco & Yeshurun, PBR 2009
Carrasco, Vis Res 2011; Carrasco & Barbot, CSH: Cognition 2015

- changes receptive field size, structure and position
- linking psychophysical and neurophysiological evidence

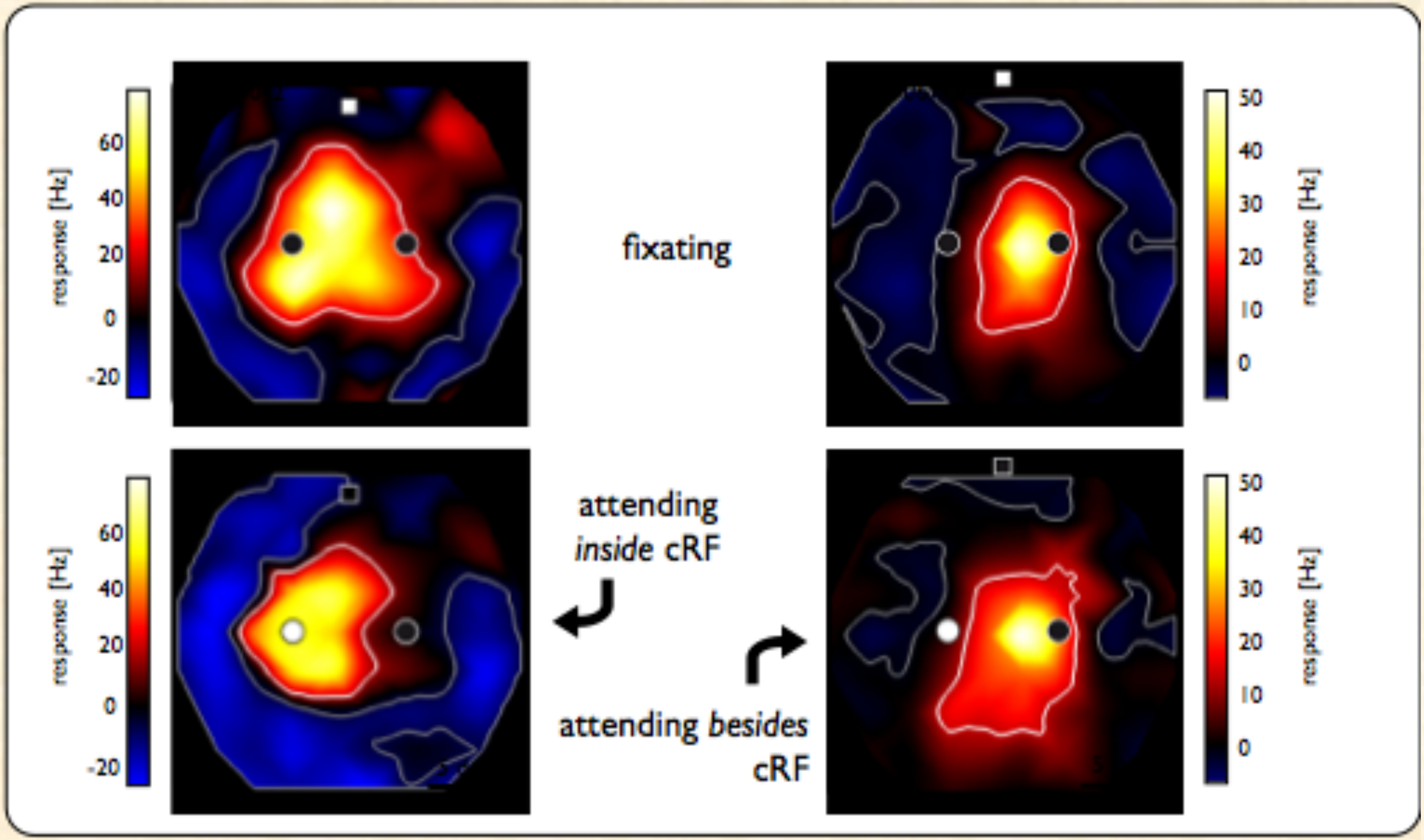
Anton-Erxleben & Carrasco, Nature Reviews Neurosci. 2013

attention alters RF profiles



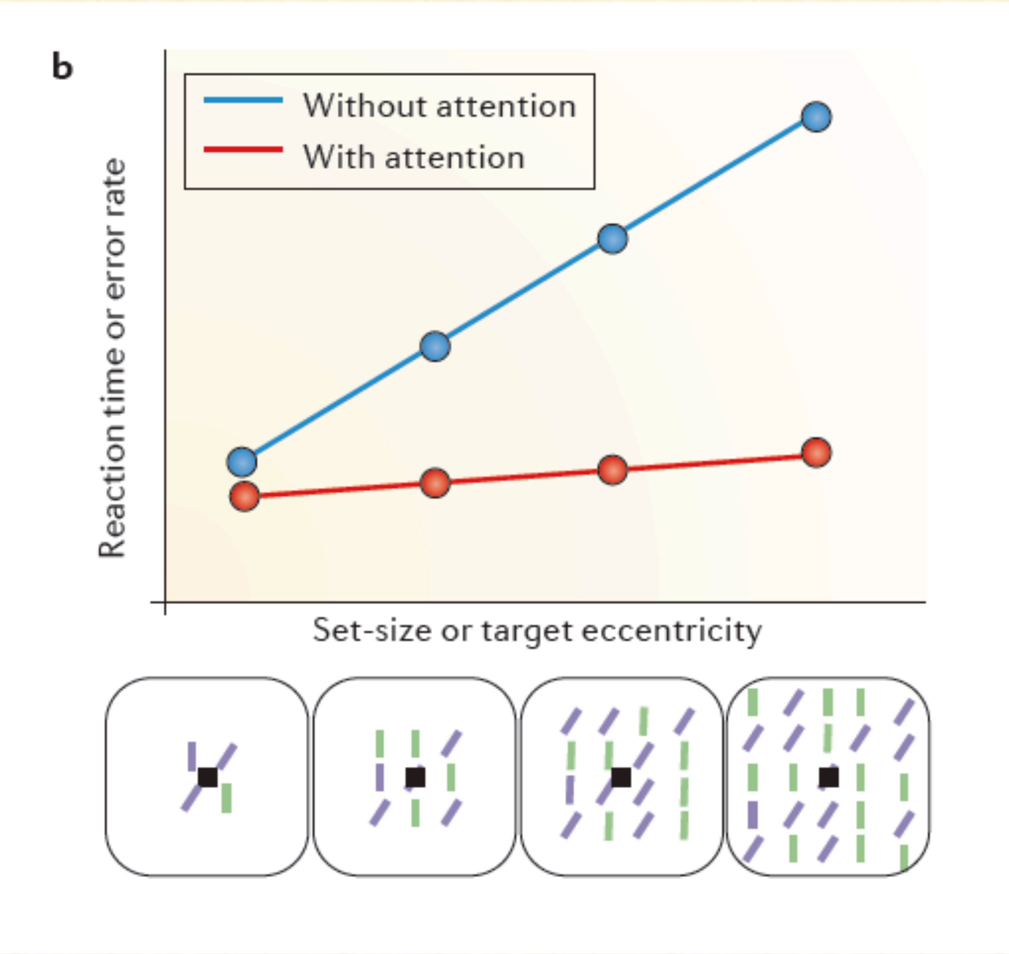
Anton-Erxleben & Carrasco, NRN 2013

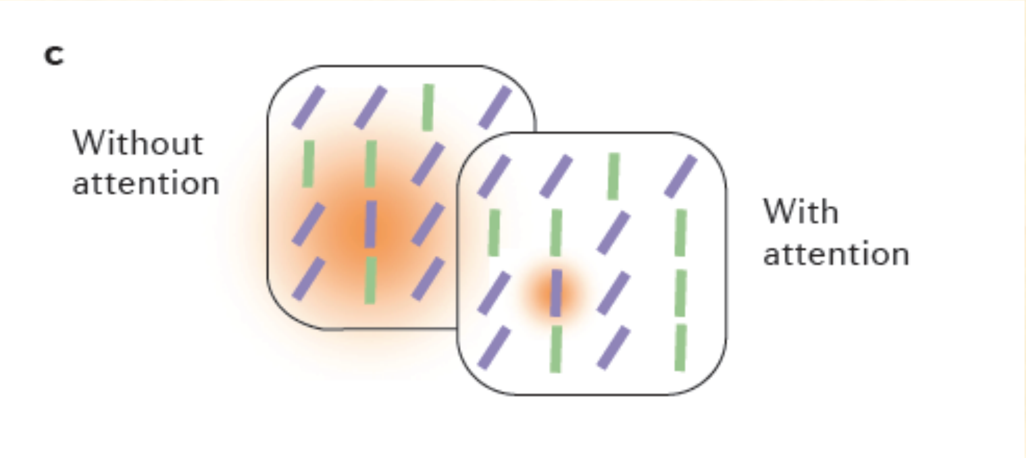
RFs can shrink or expand with attention



Wolmersdorf et al. 2006; Anton-Erxleben et al. 2009; Niebergall et al. 2011

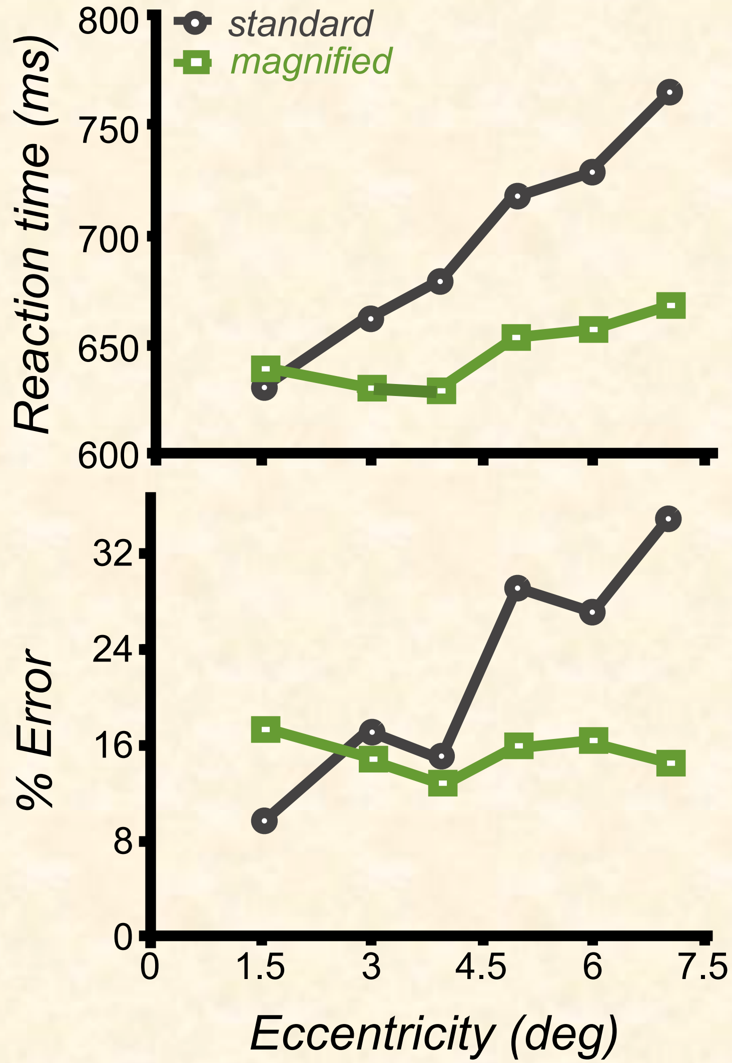
visual search



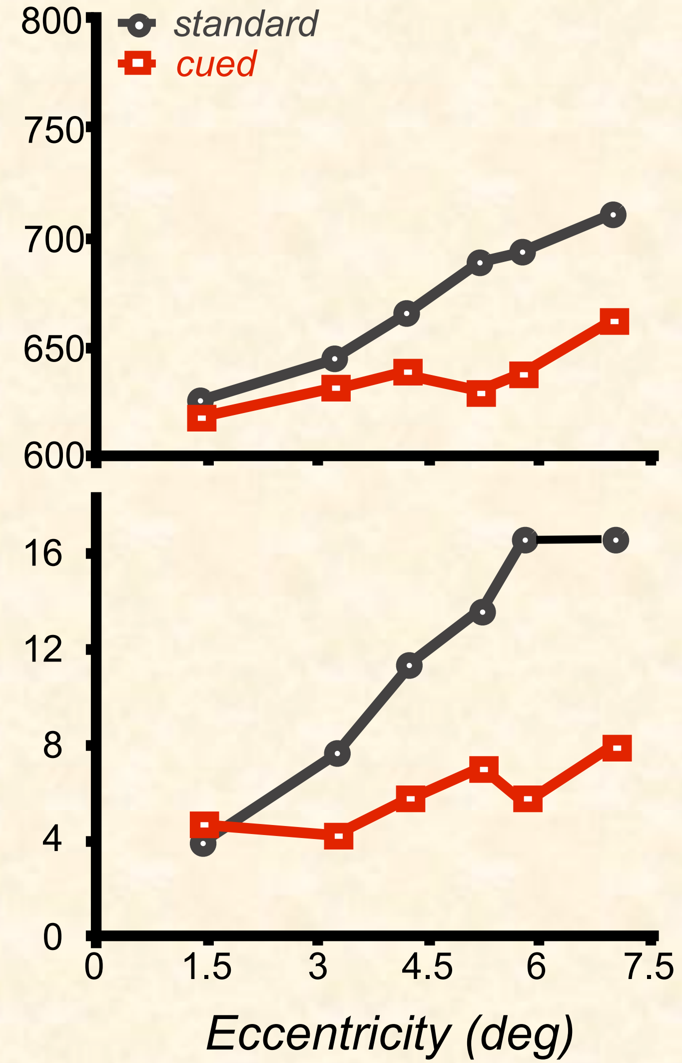


Anton-Erxleben & Carrasco, NRN 2013

SEARCH: cortical magnification & exogenous attention



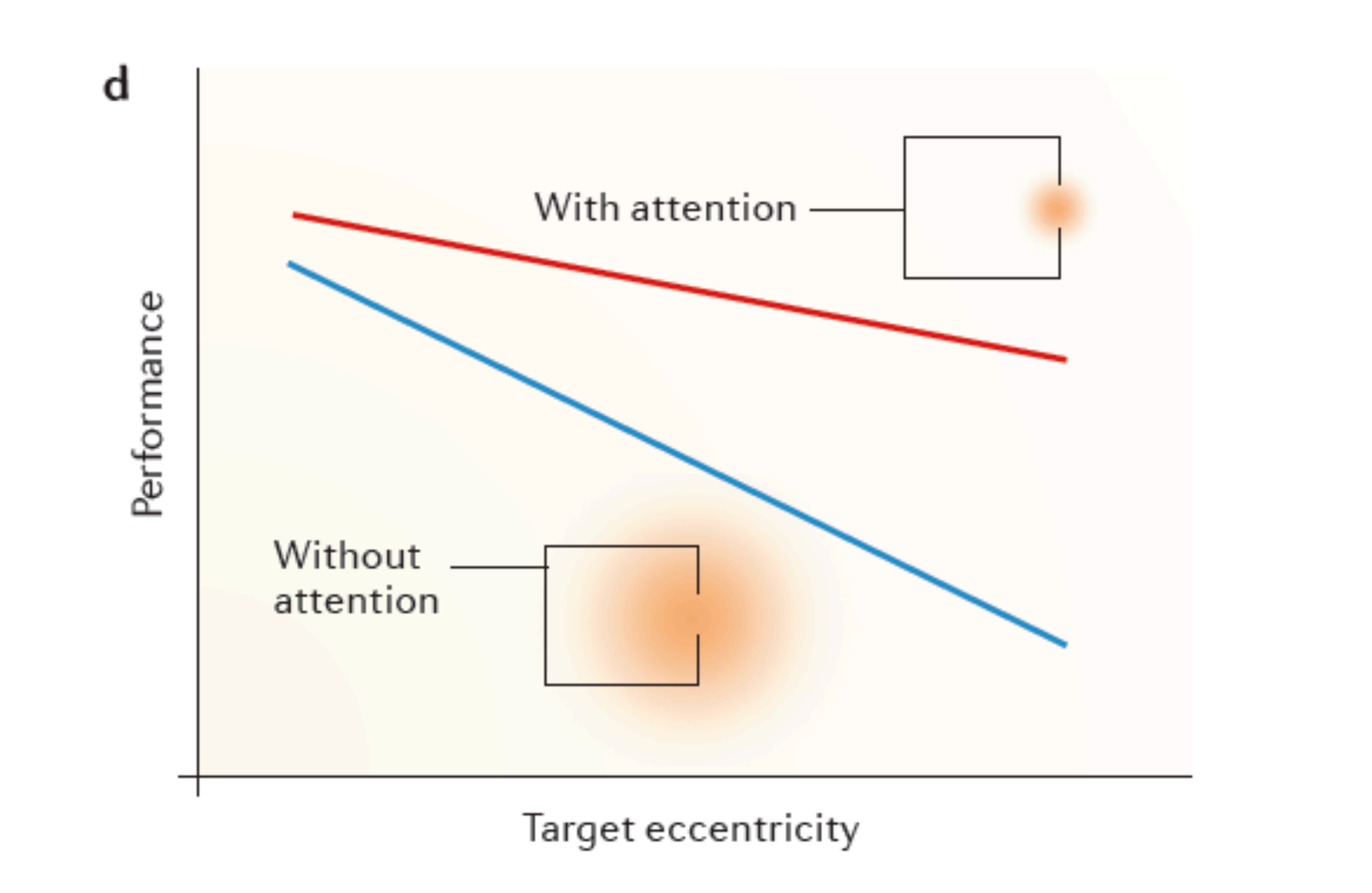
Carrasco & Frieder 1997



Carrasco & Yeshurun 1998

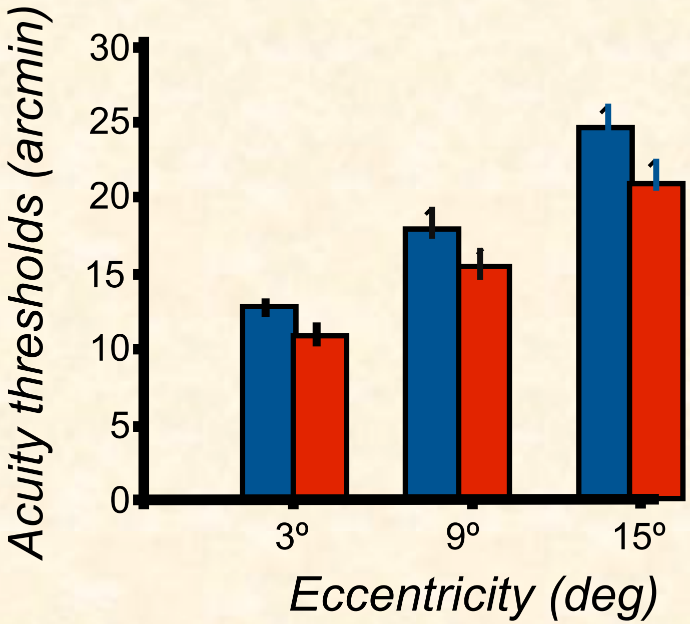
Carrasco & Barbot 2015

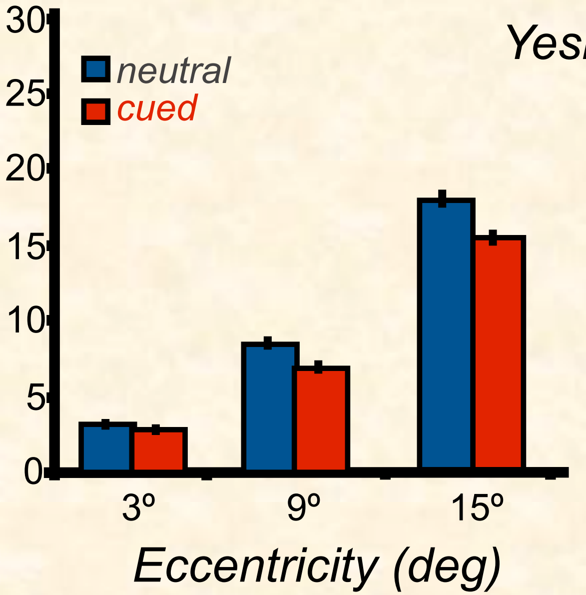
acuity



Anton-Erxleben & Carrasco, NRN 2013

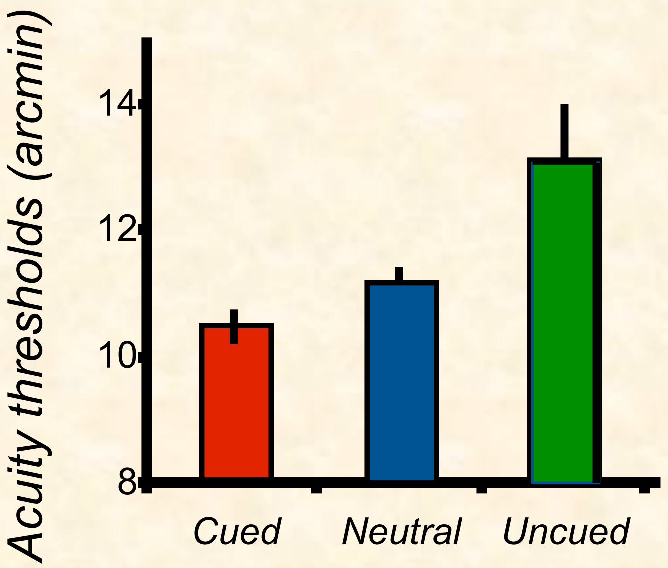
ACUITY: macaques humans

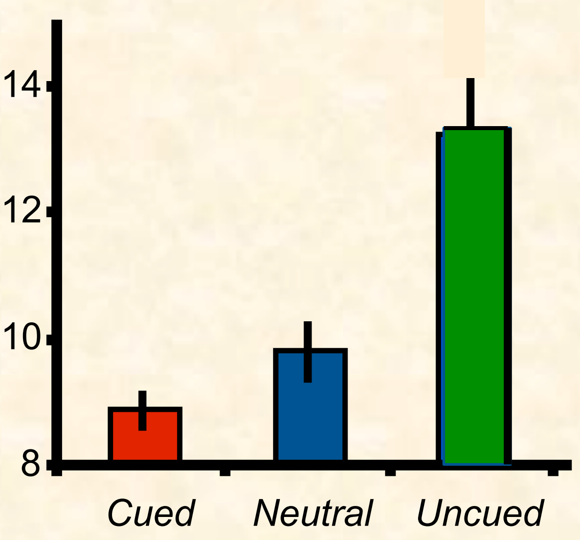




Yeshurun & Carrasco 1999
Golla et al. 2004

exogenous endogenous

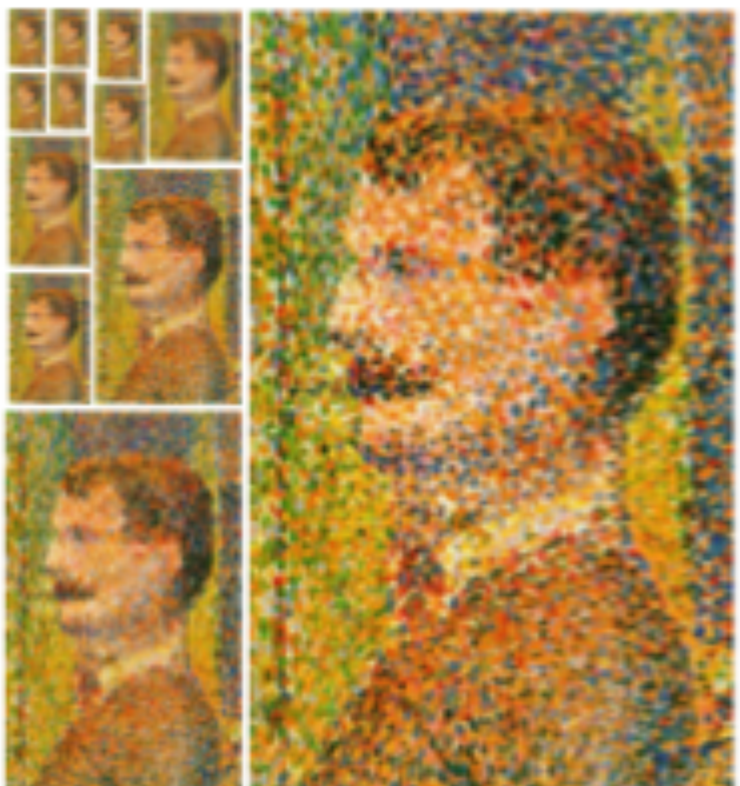


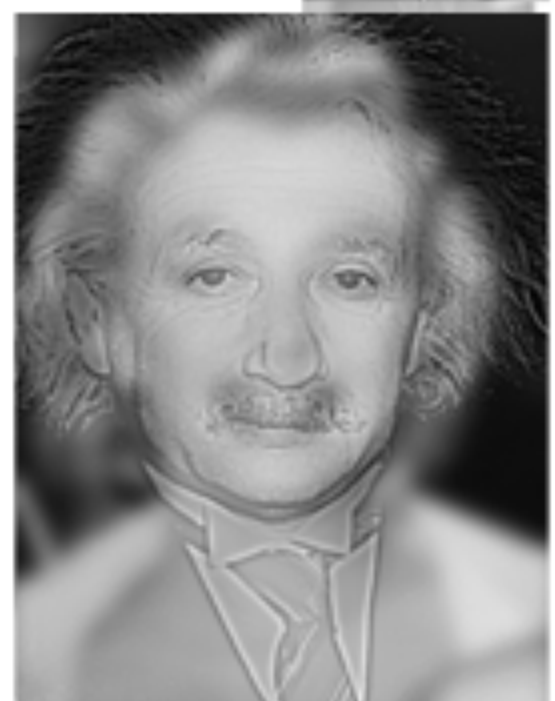


Montagna, Pestilli & Carrasco 2009

Carrasco & Barbot 2015

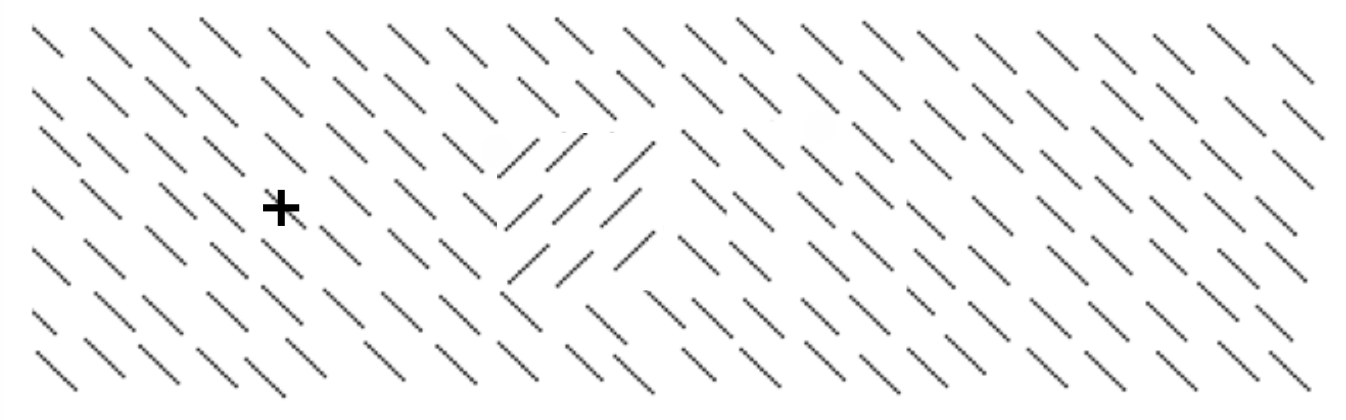
optimal resolution?

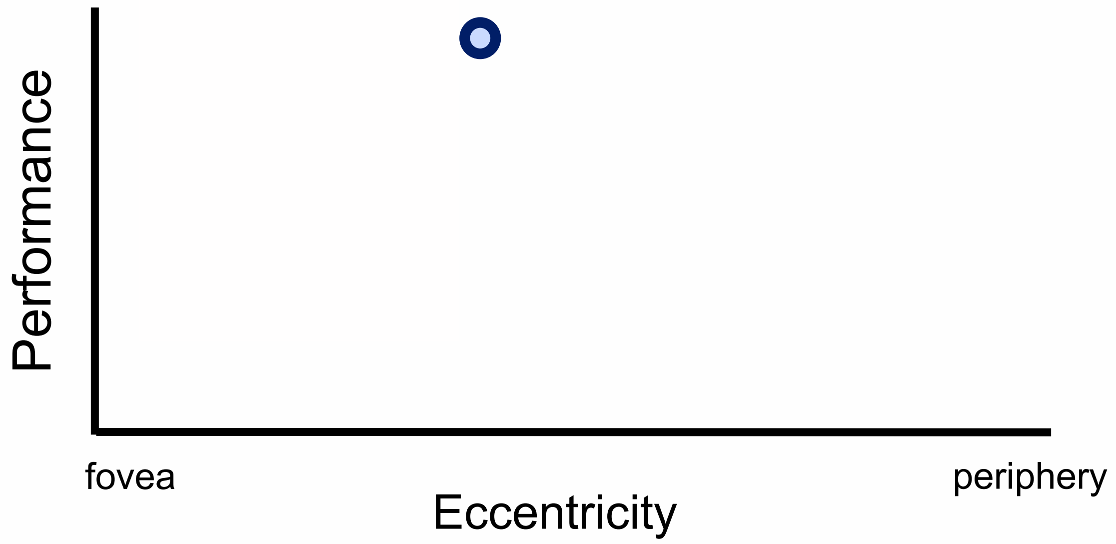




texture segmentation- performance f (resolution)

e.g., Gurnsey et al. 1996; Kehrer 1989, 1997; Morikawa 2000; Potechin & Gurnsey 2003





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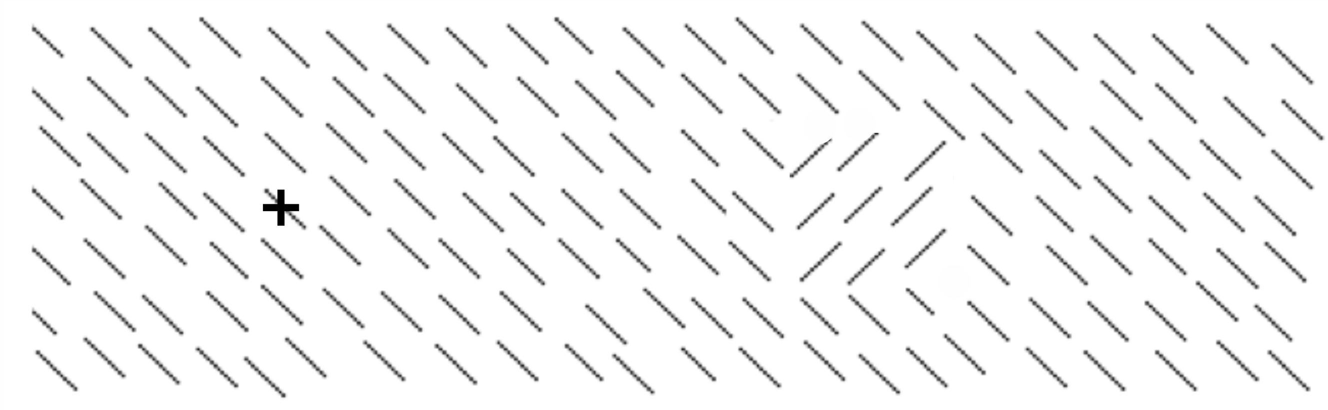

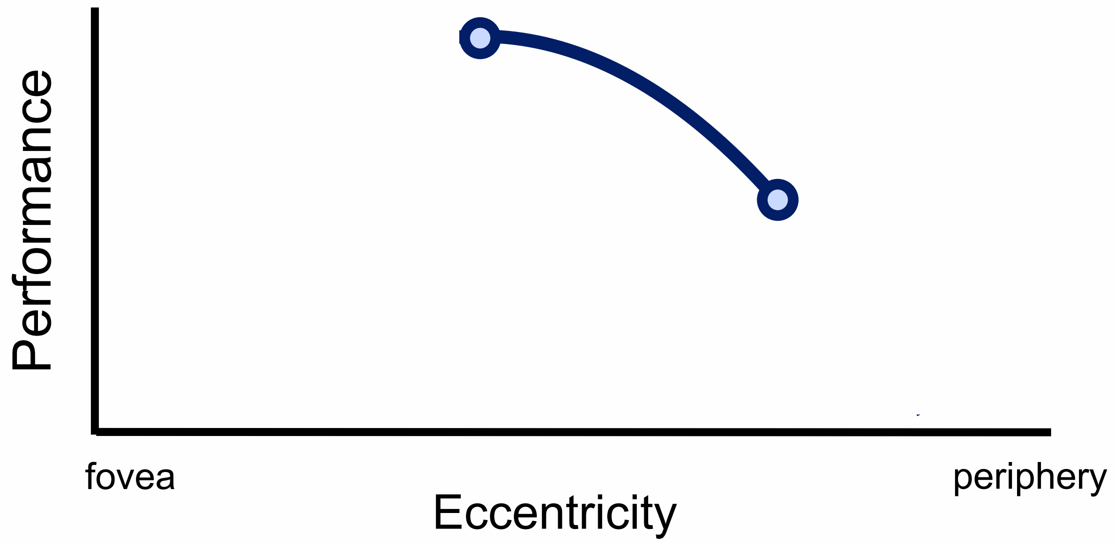

texture segmentation- performance f (resolution)

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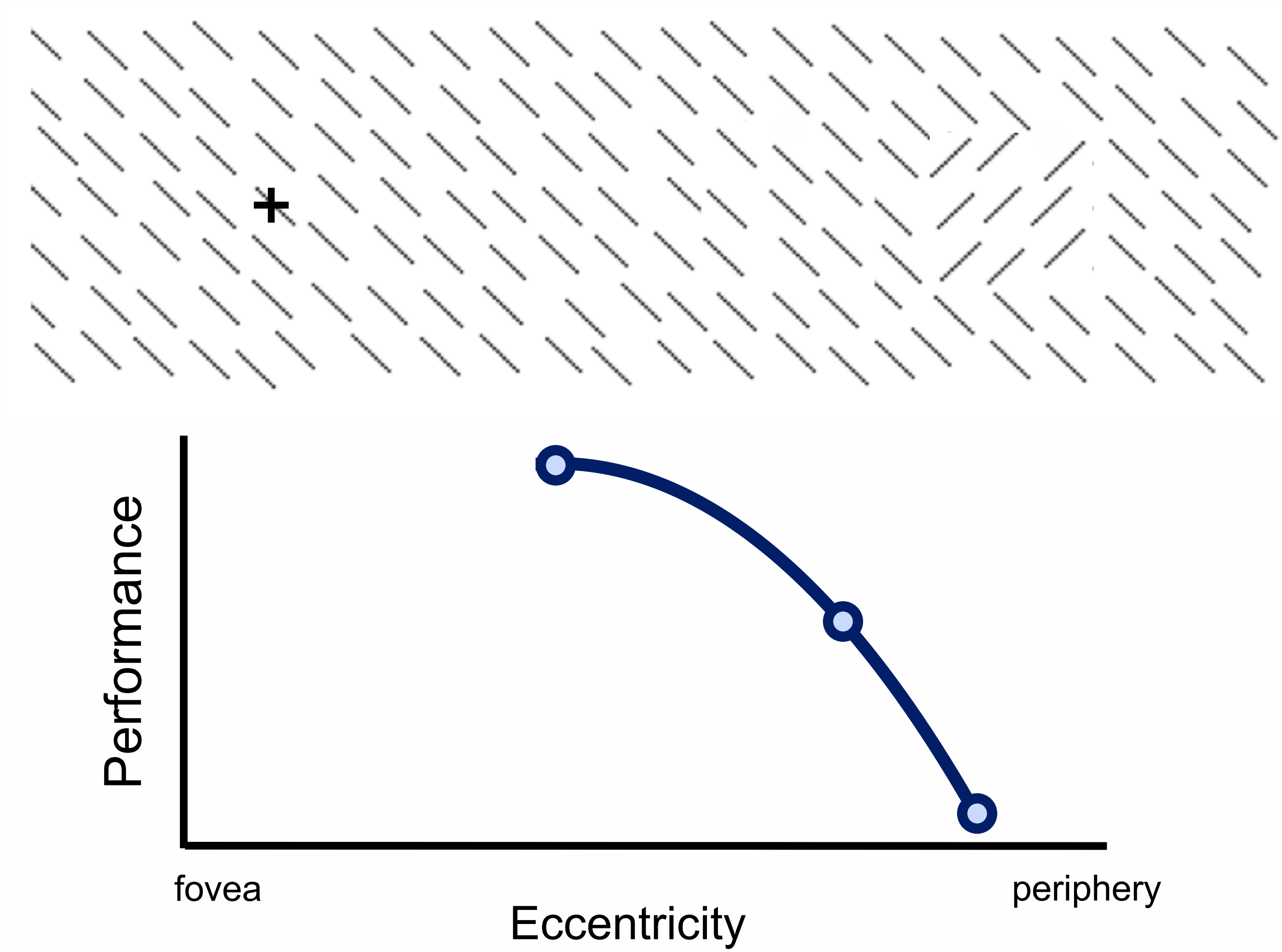
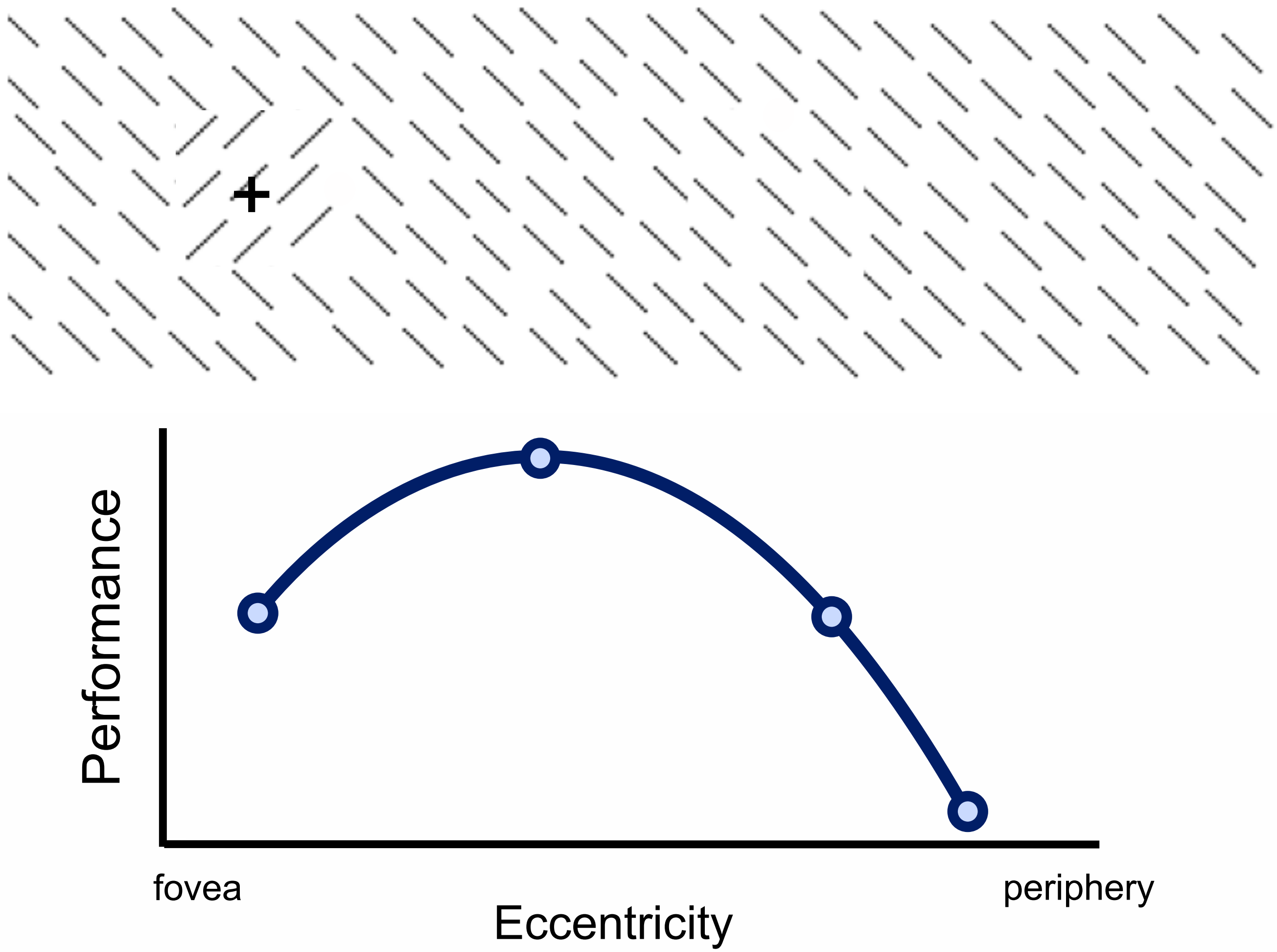


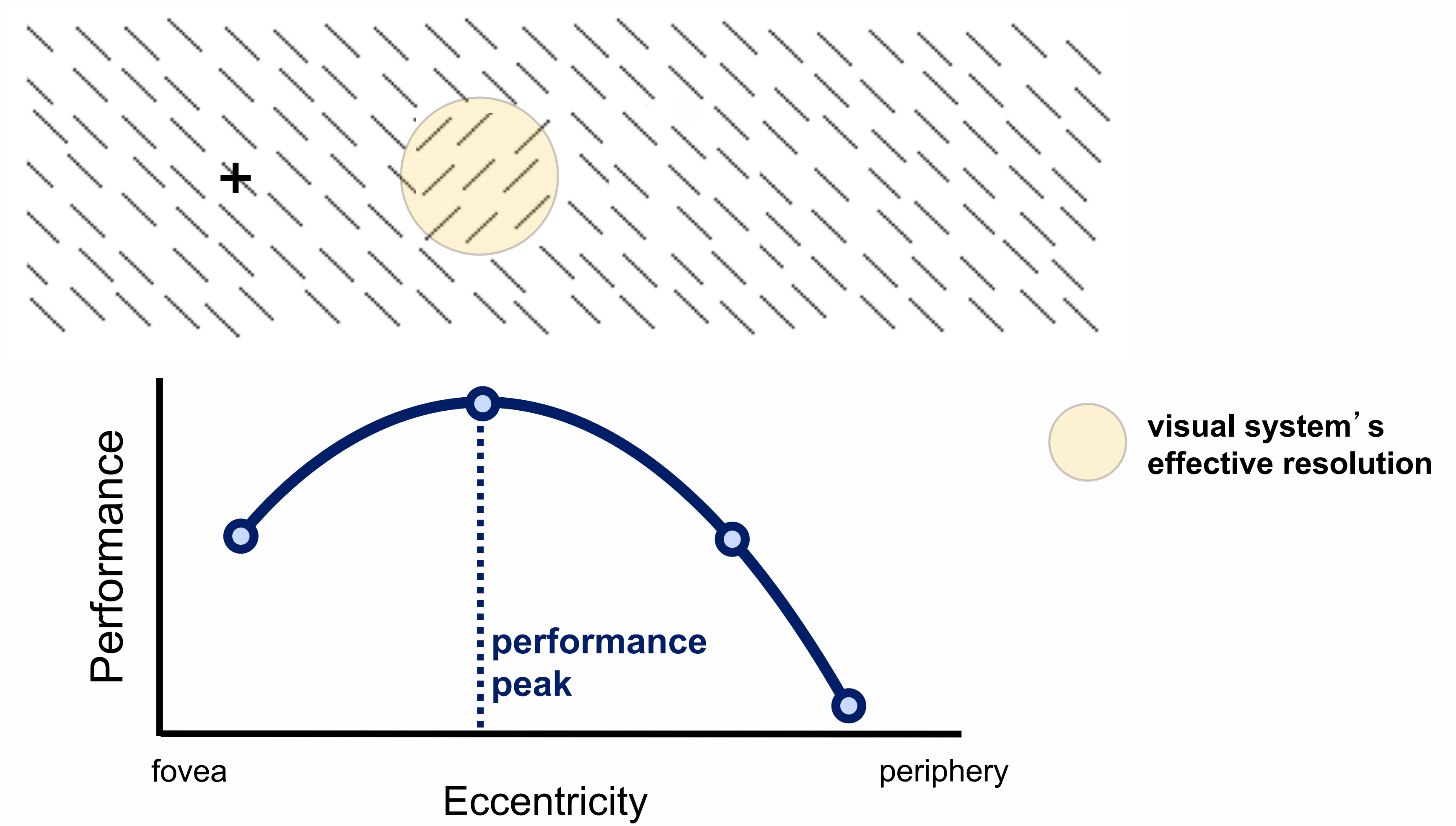
texture segmentation- performance f (resolution)

e.g., Gurnsey et al. 1996; Kehrer 1989, 1997; Morikawa 2000; Potechin & Gurnsey 2003



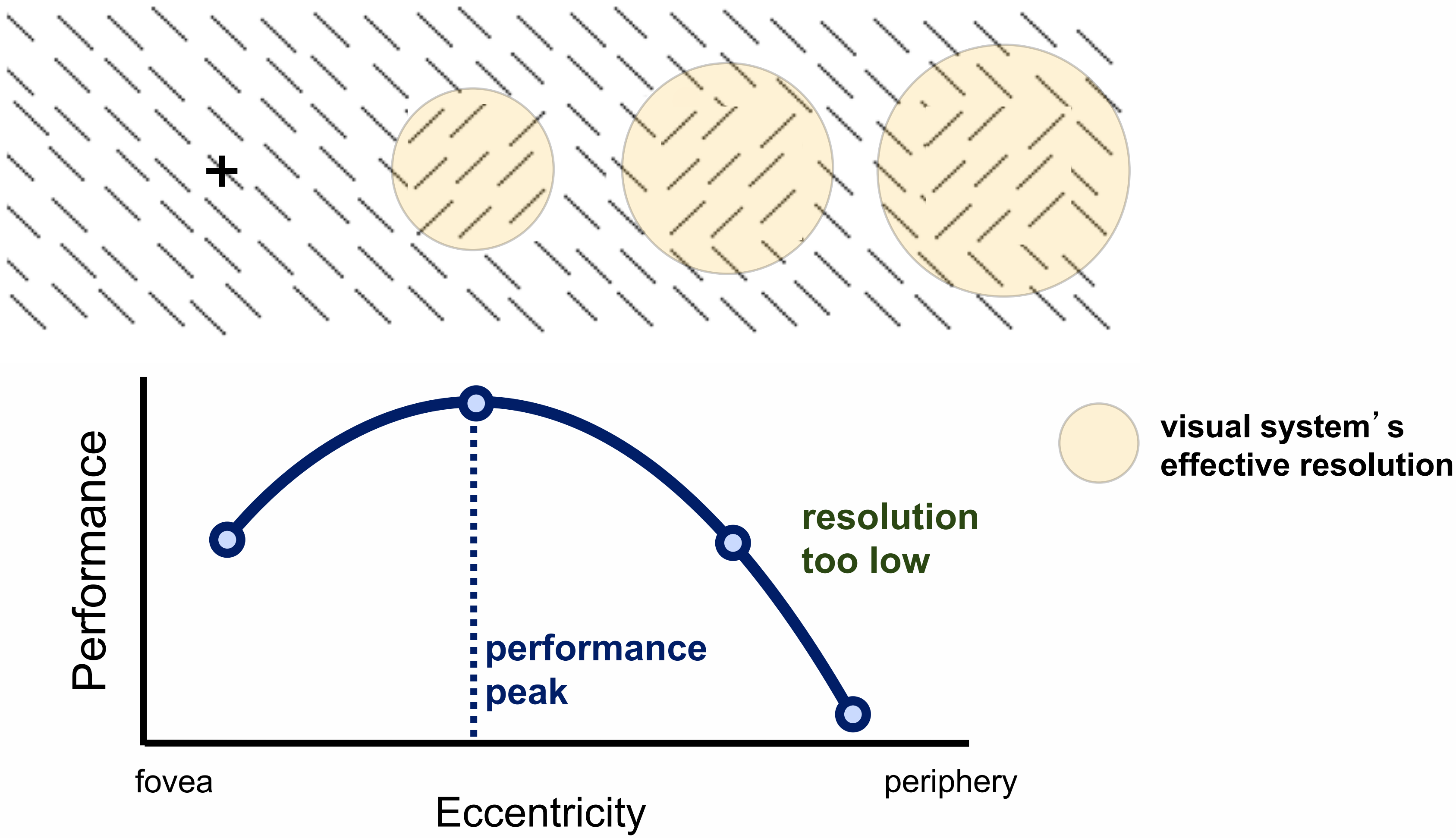
texture segmentation- performance f (resolution)

e.g., Gurnsey et al. 1996; Kehrer 1989, 1997; Morikawa 2000; Potechin & Gurnsey 2003



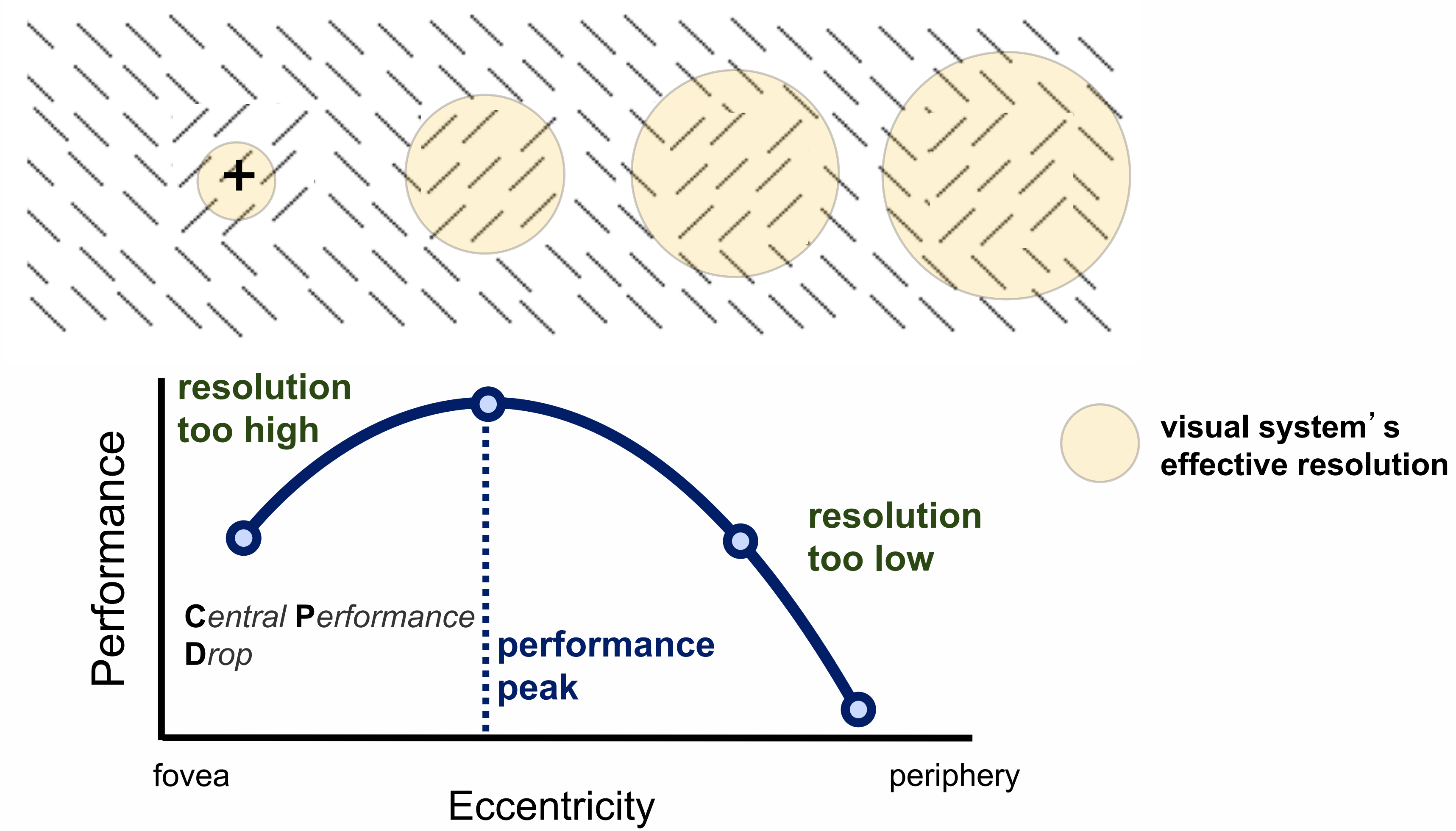
texture segmentation- performance f (resolution)

e.g., Gurnsey et al. 1996; Kehrer 1989, 1997; Morikawa 2000; Potechin & Gurnsey 2003



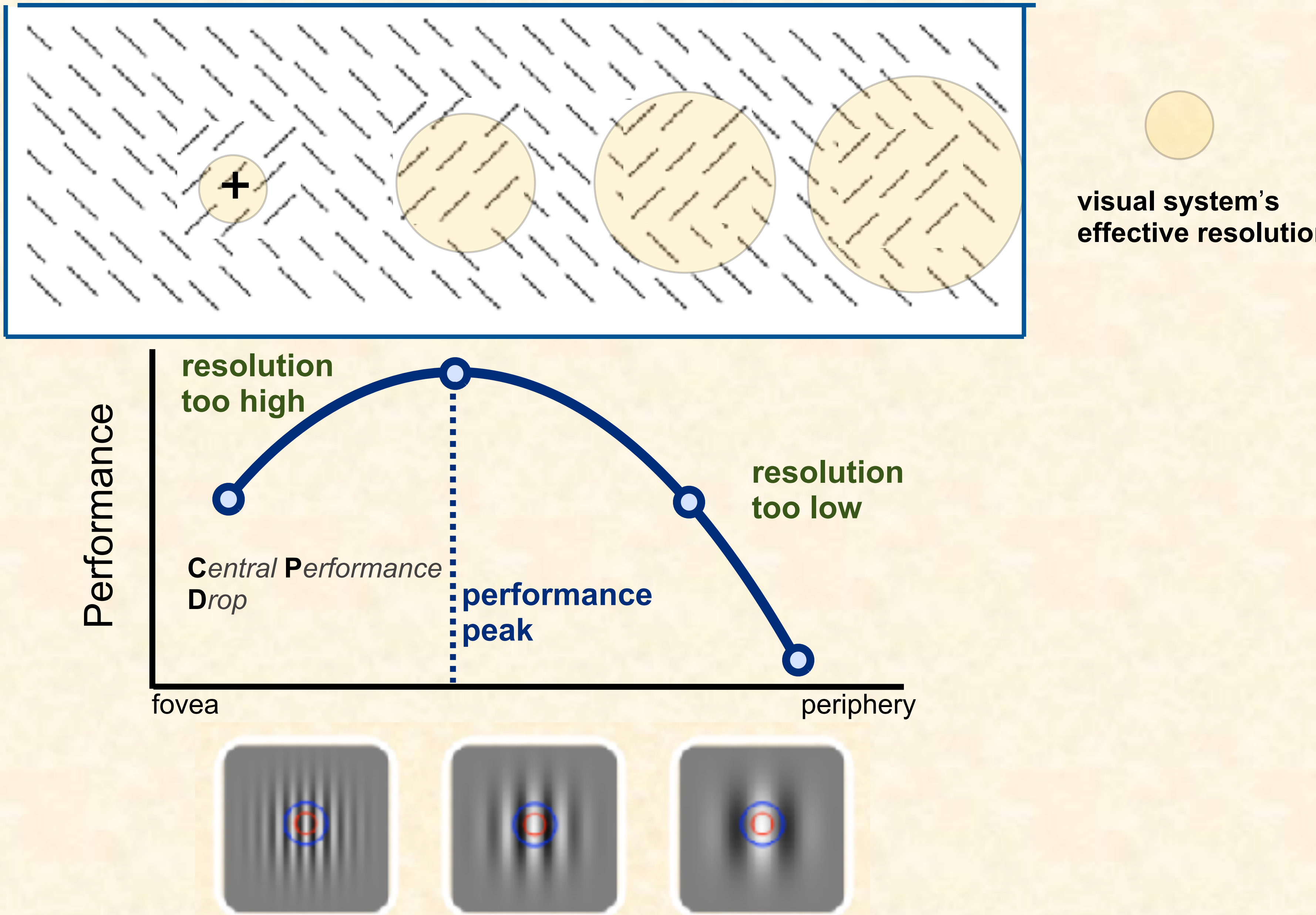
texture segmentation- performance f (resolution)

e.g., Gurnsey et al. 1996; Kehrer 1989, 1997; Morikawa 2000; Potechin & Gurnsey 2003

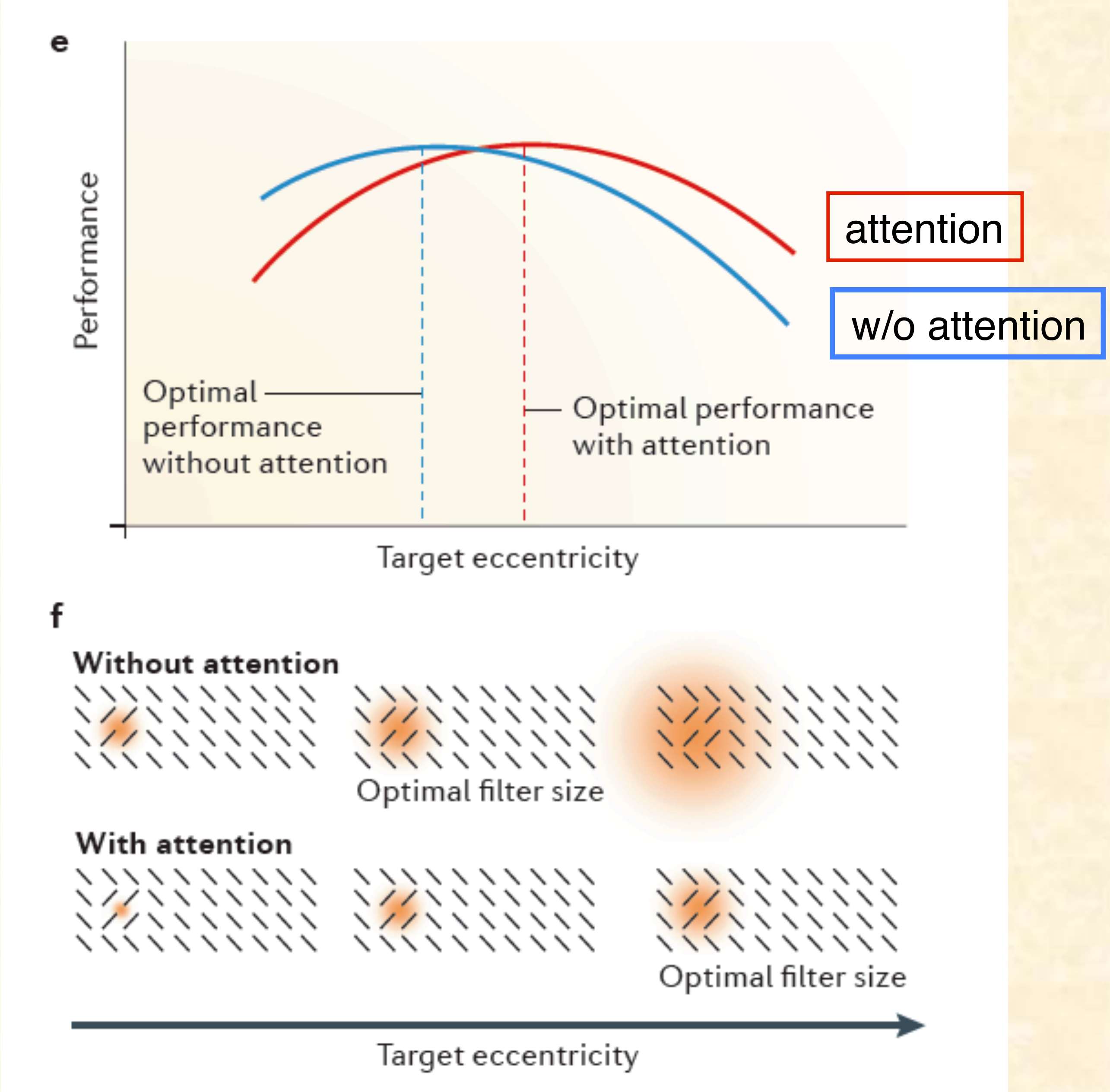


texture segmentation- performance f(resolution)

eg, Gurnsey et al. 1996; Kehrer 1989, 1997; Morikawa 2000; Potechin & Gurnsey 2003



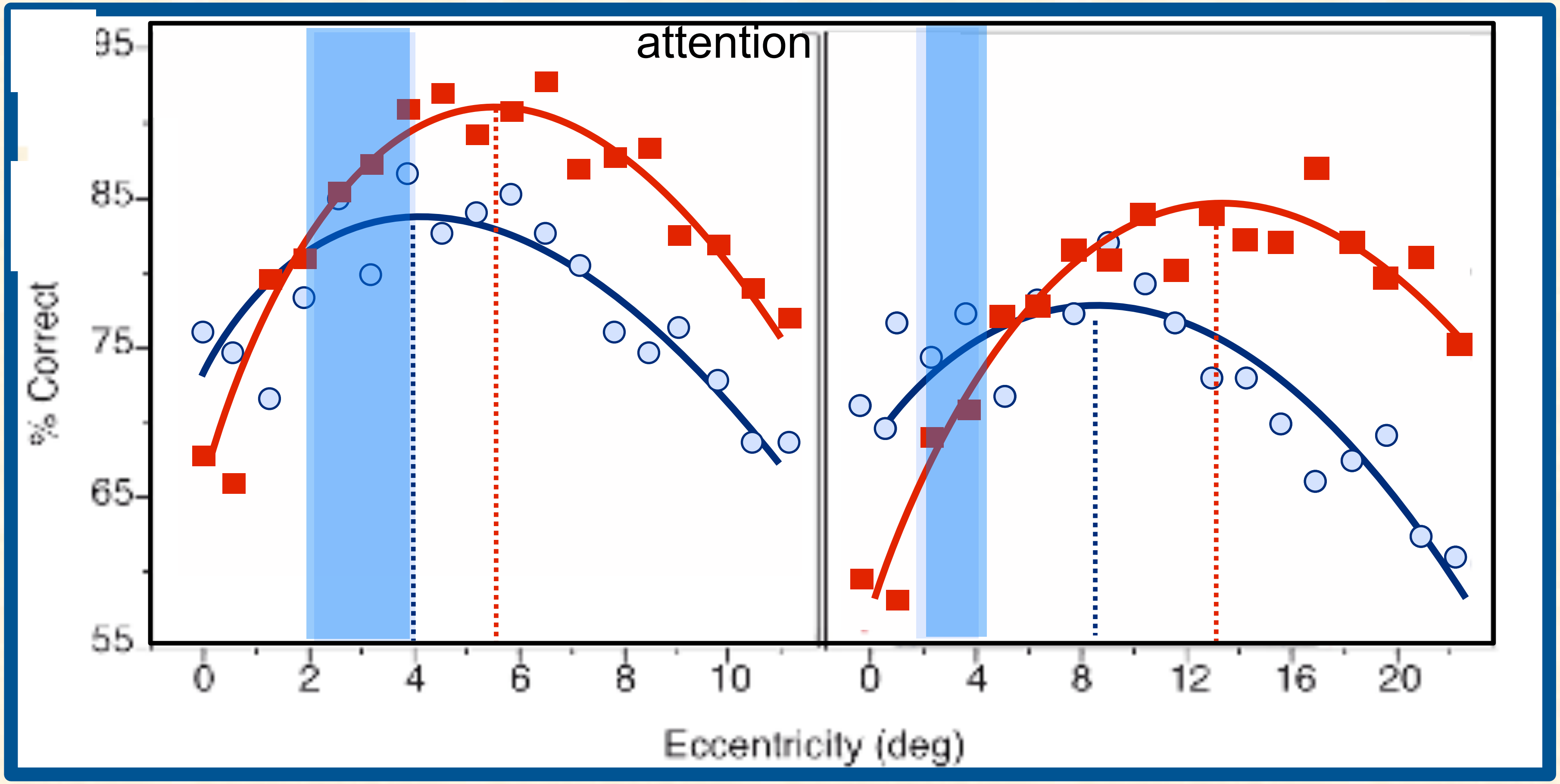
texture segmentation



exogenous attention improves or impairs performance by increasing resolution

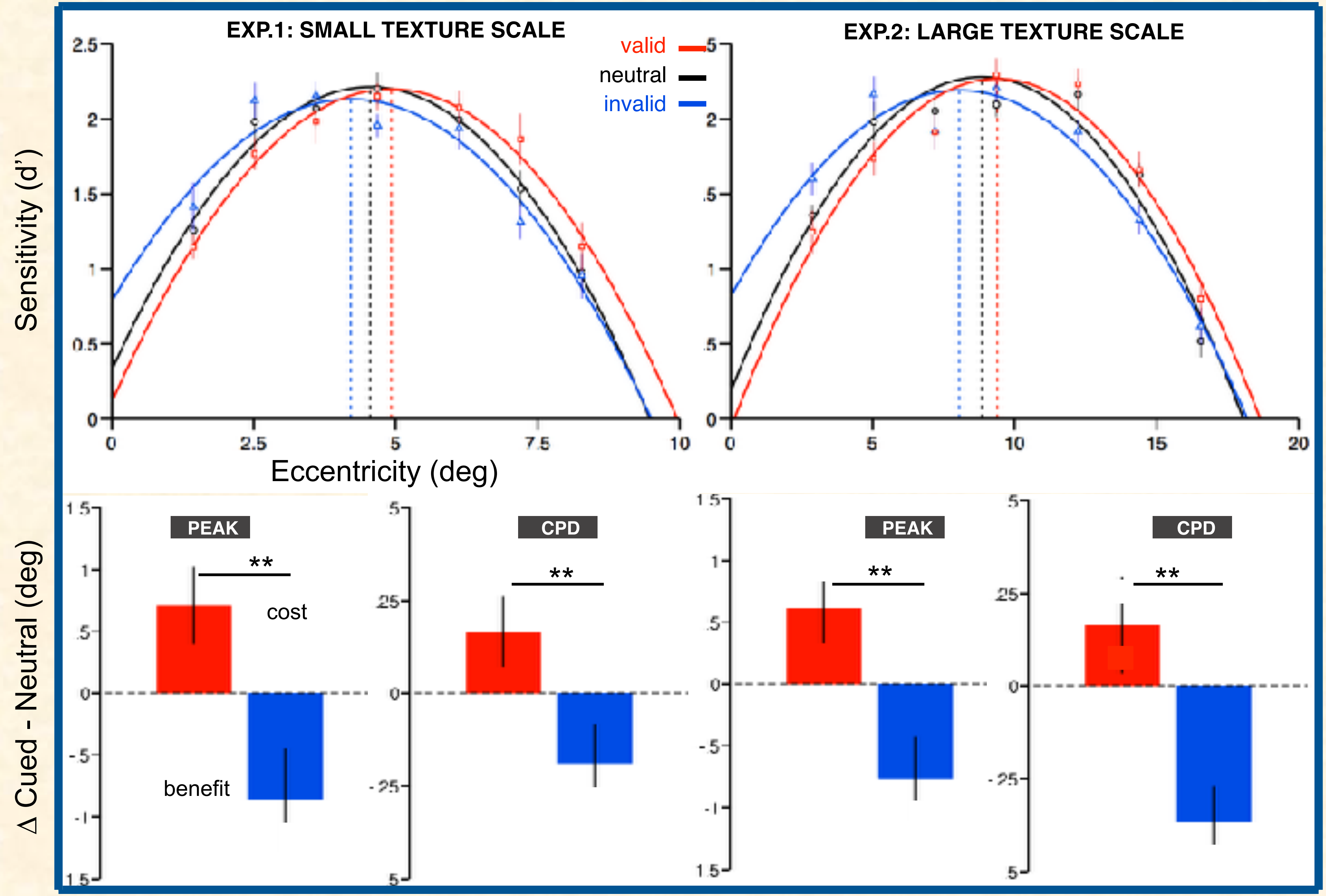
small texture scale
(viewing distance: 57 cm)

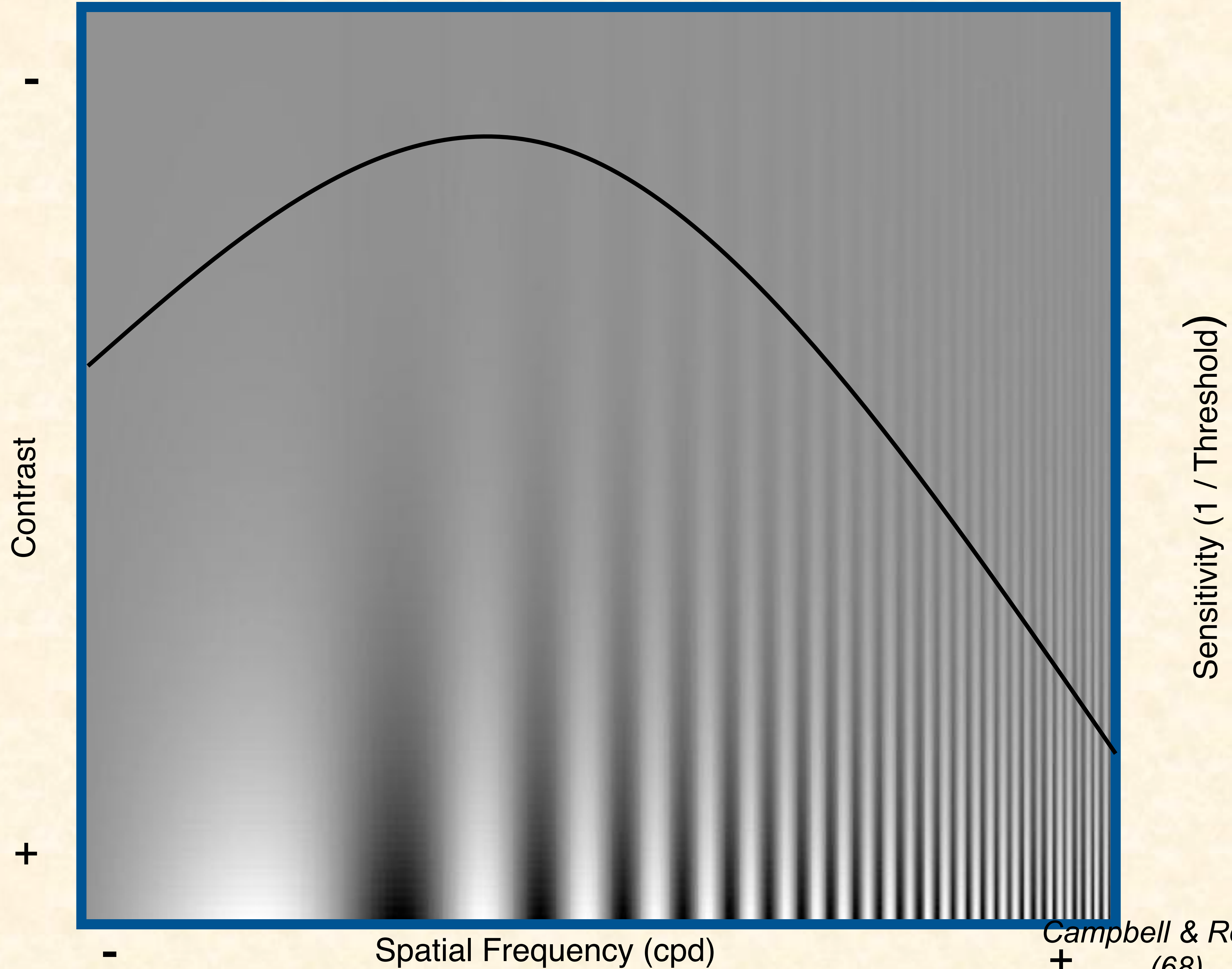
large texture scale
(viewing distance: 28 cm)



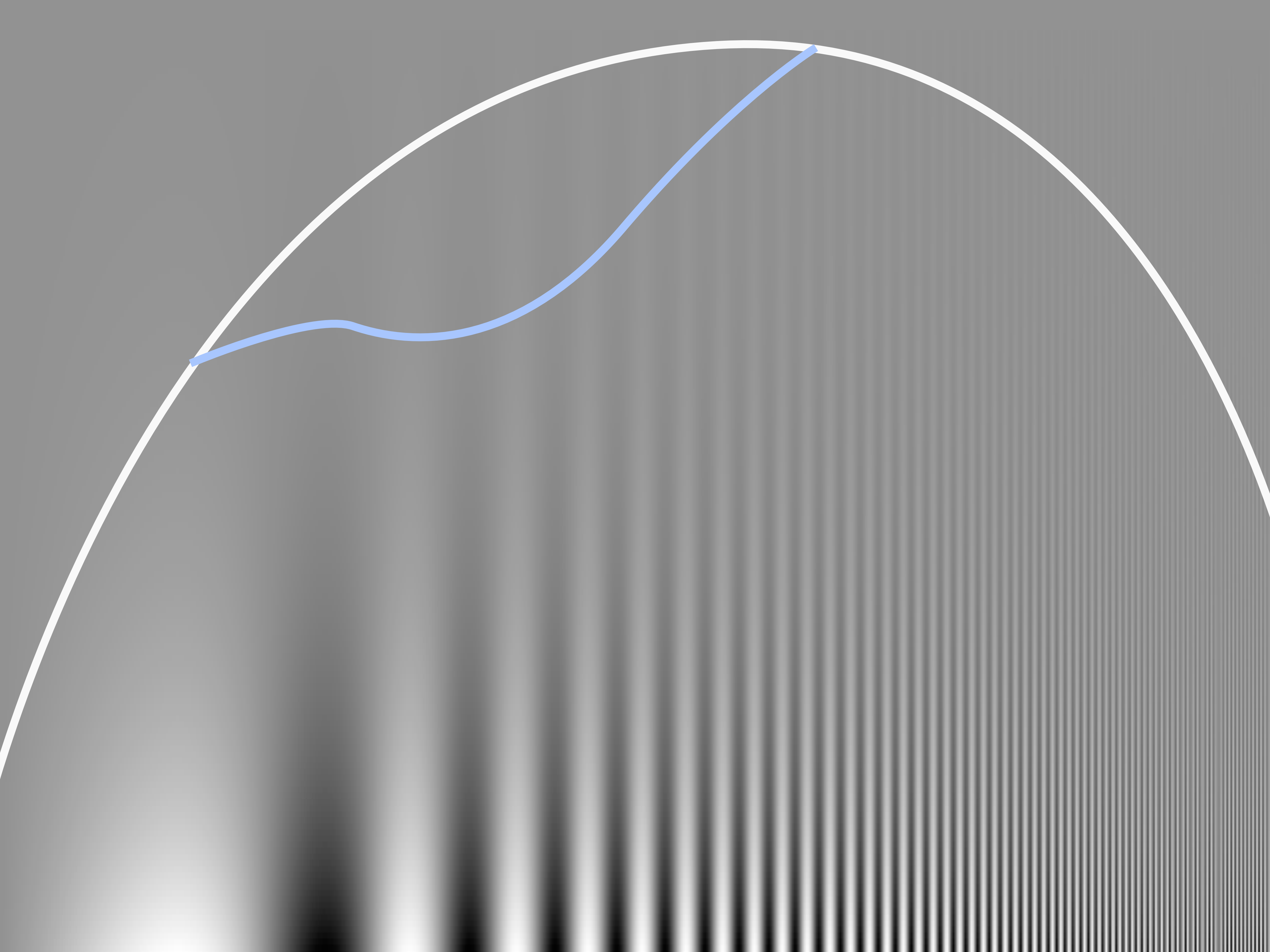
Yeshurun & Carrasco, Nature 1998

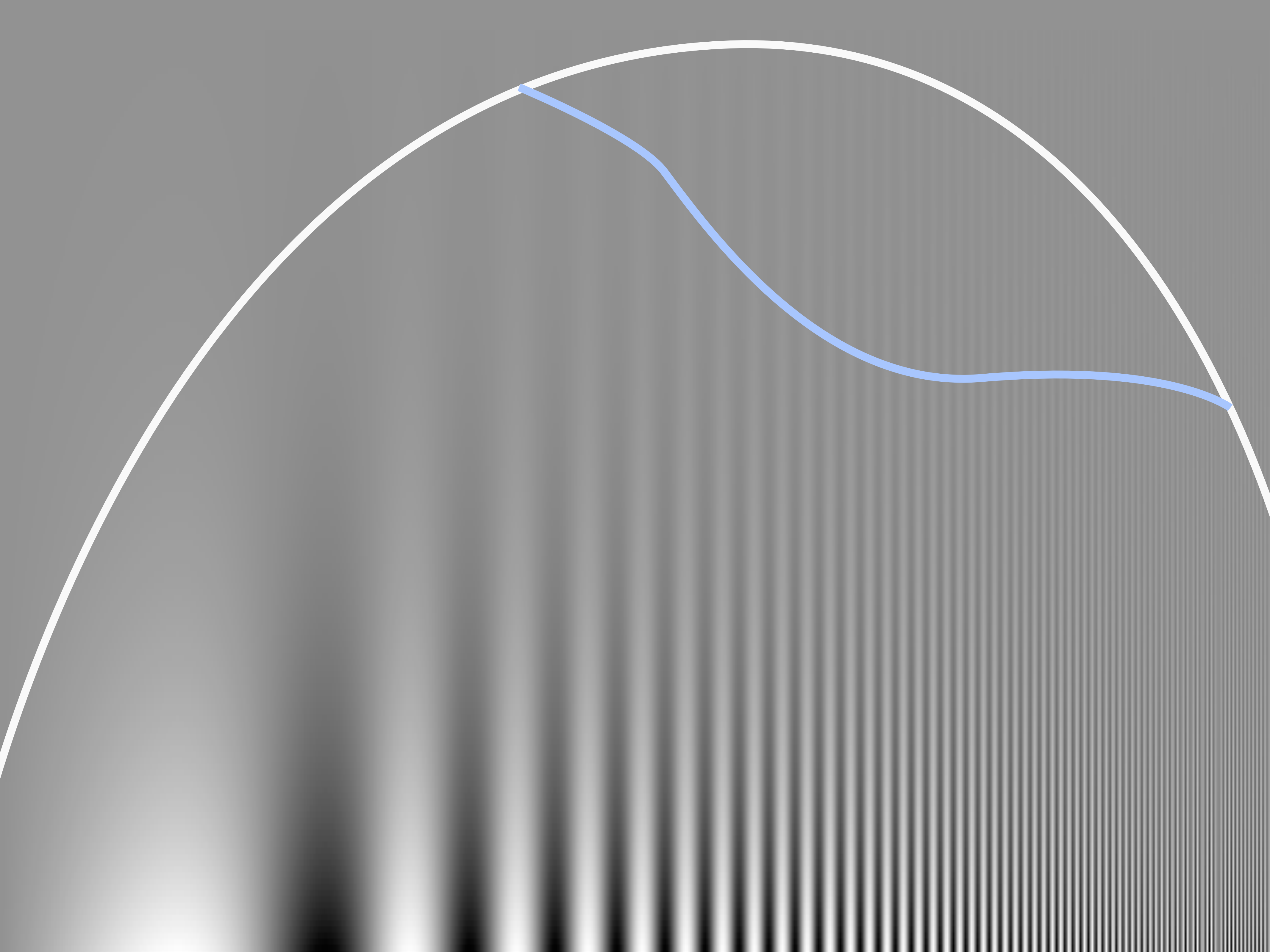
exogenous attention: resolution tradeoff



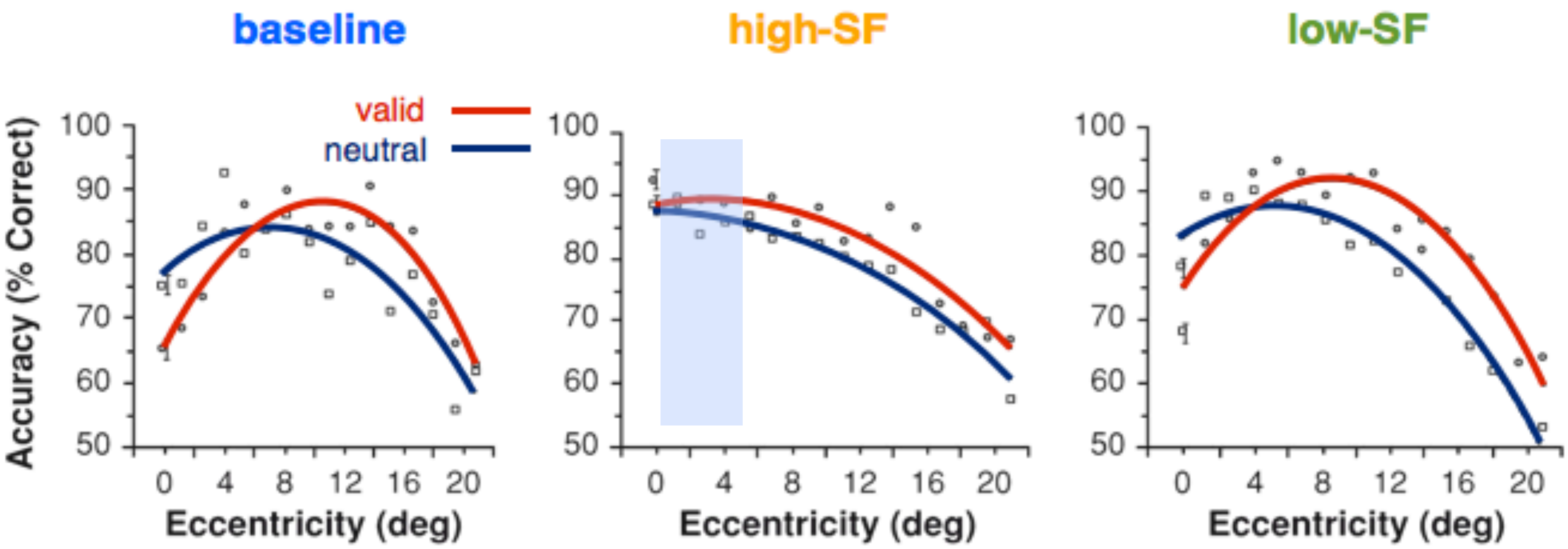


Campbell & Robson (68)





EXO: selective adaptation to spatial frequencies

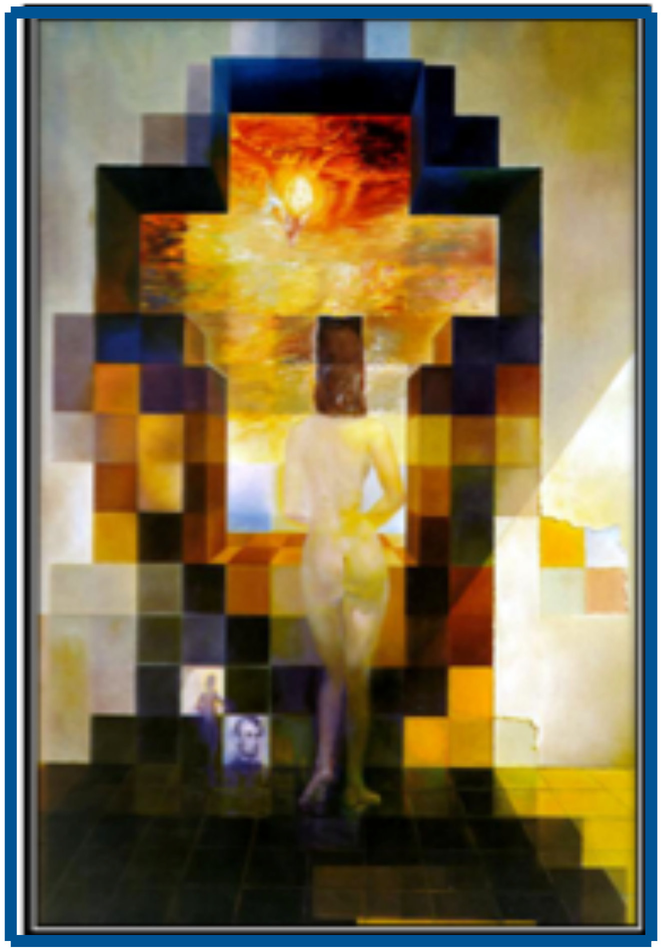


exogenous attention enhances resolution by increasing the sensitivity of small, high-SF filters

Carrasco, Loula & Ho, 2006

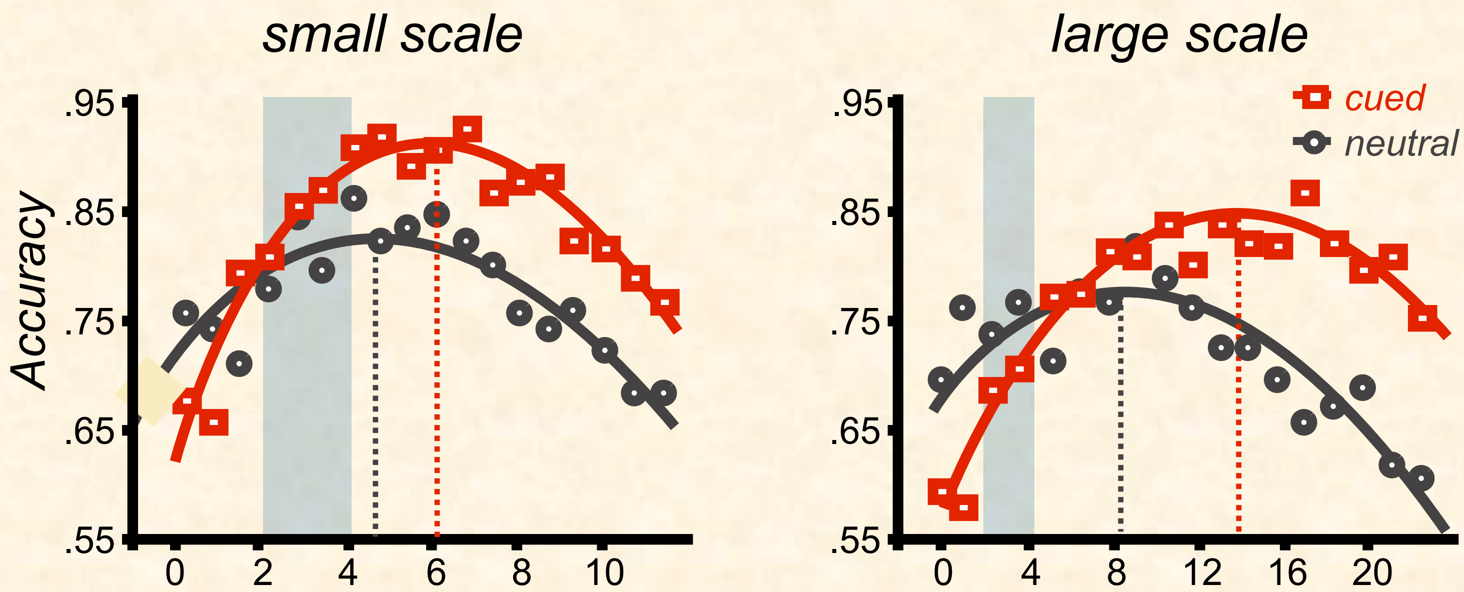
flexible resolution?

SEURAT



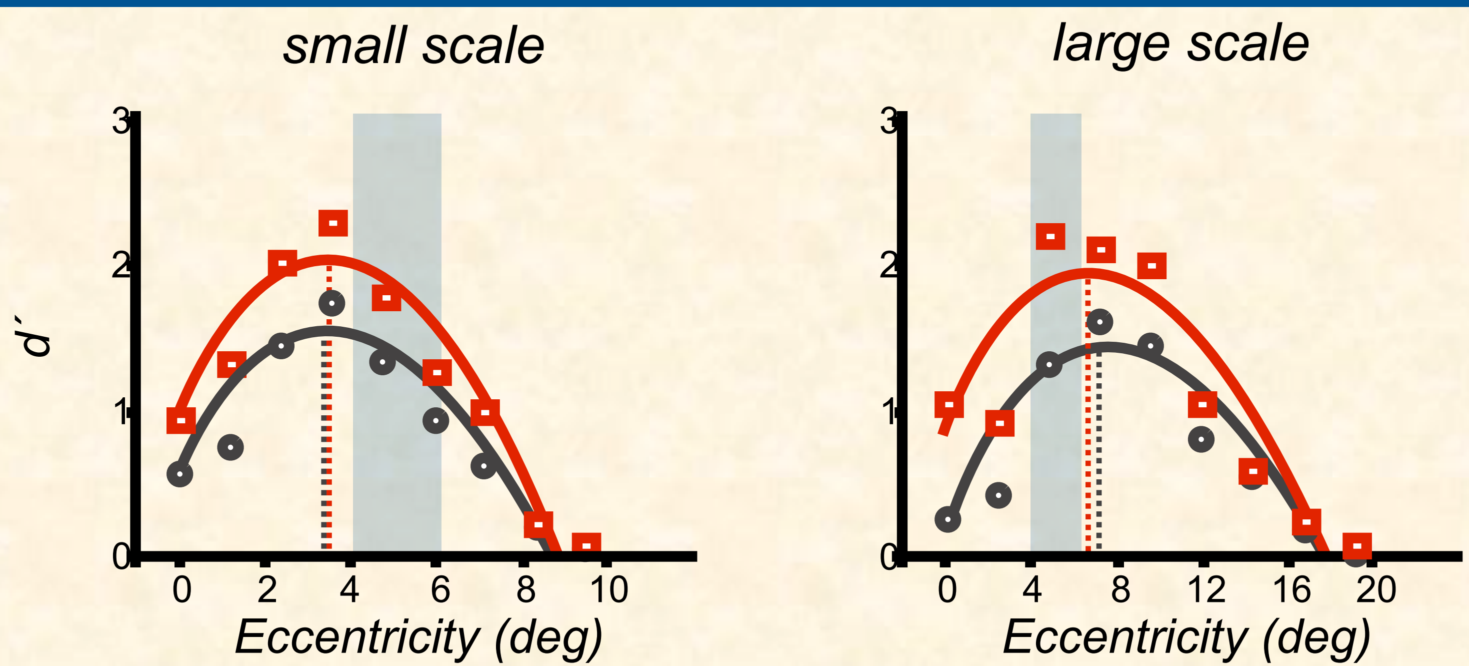
DALI

exogenous attention



Yeshurun & Carrasco, 1998

endogenous attention

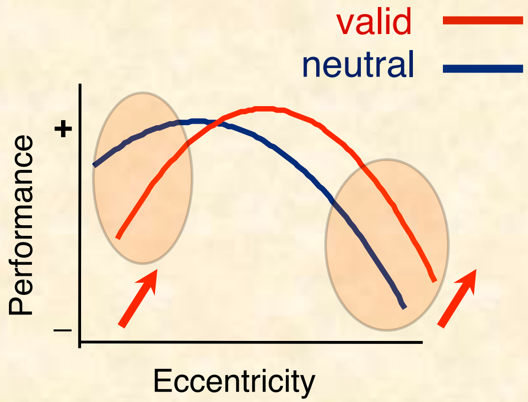


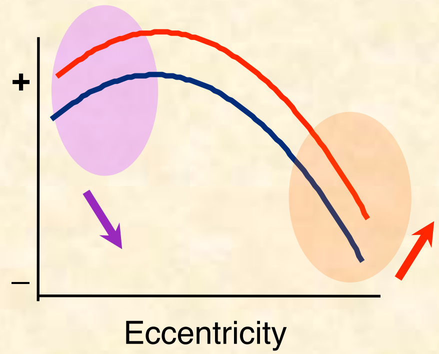
Yeshurun, Montagna & Carrasco, 2008

attention and spatial resolution

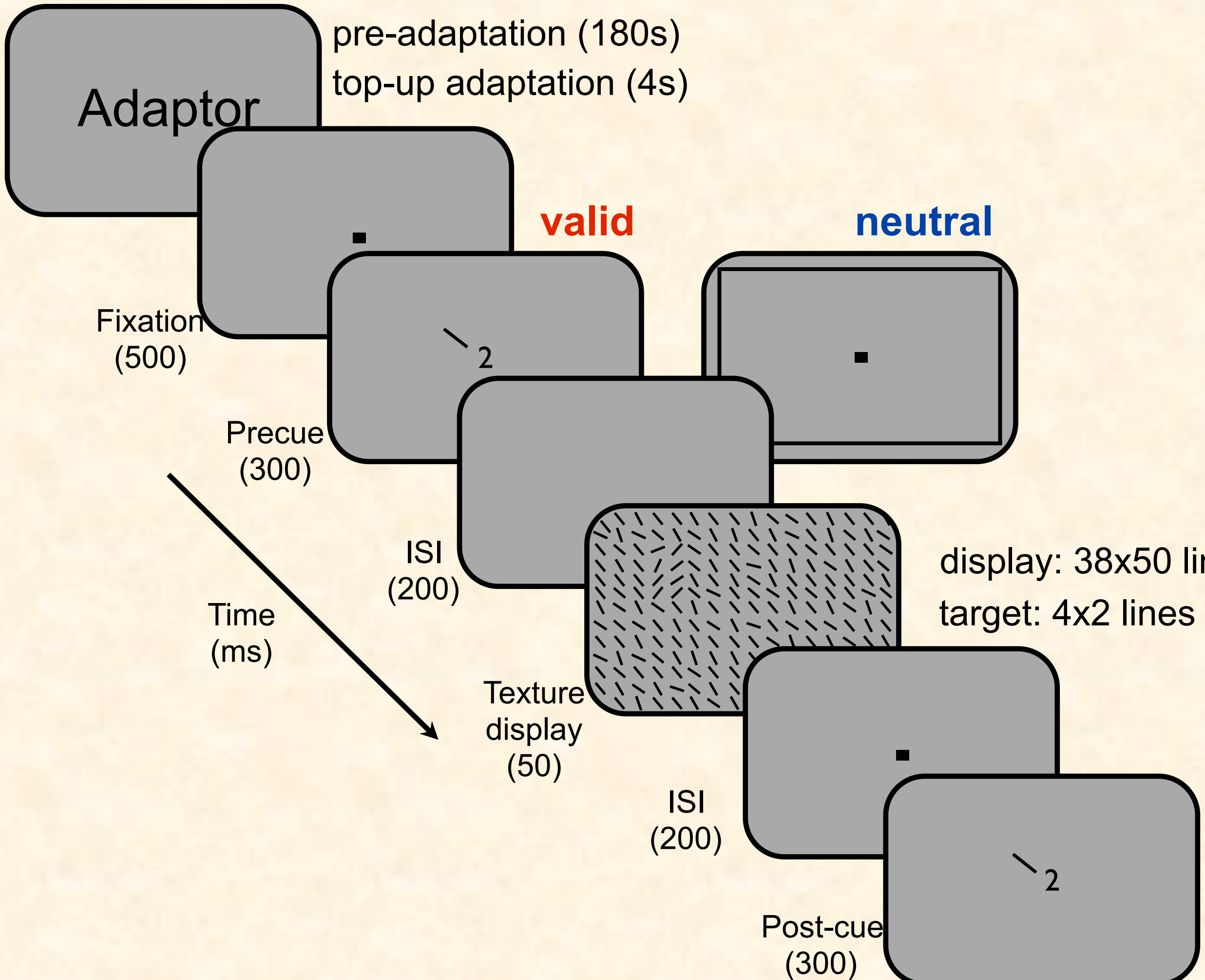
	EXOGENOUS	ENDOGENOUS
Performance at central locations	*impairs*	*improves*
Performance at peripheral locations	*improves*	*improves*
Spatial resolution	increases small filters' sensitivity	either increases or decreases?

AUTOMATICITY **FLEXIBILITY**



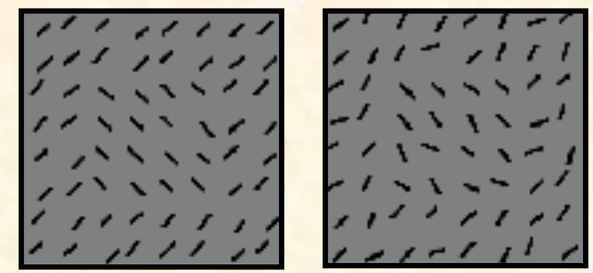


endogenous attention and texture segmentation



display: 38x50 lines

target: 4x2 lines



7 eccentricities (0–7 deg)

Yes-No Detection Task:

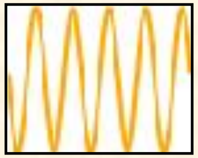
Q: Texture target present or absent?

n=12

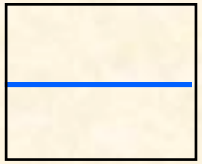
selective adaptation

vertical contrast modulator in carrier noise (6 cpd)

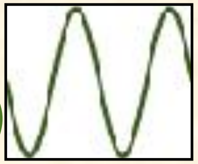
HIGH SFs (2 cpd)

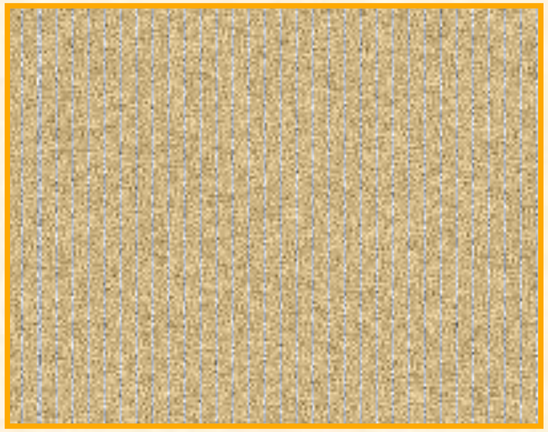


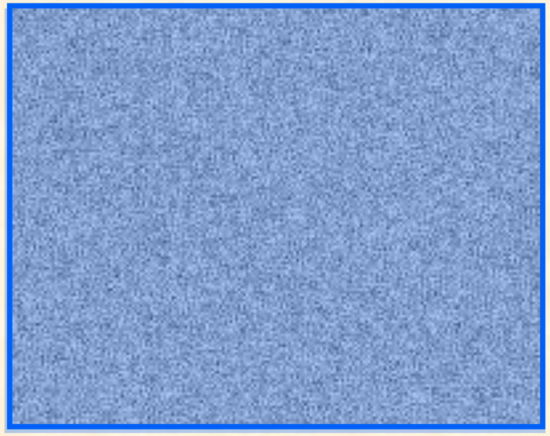
BASELINE (0 cpd)

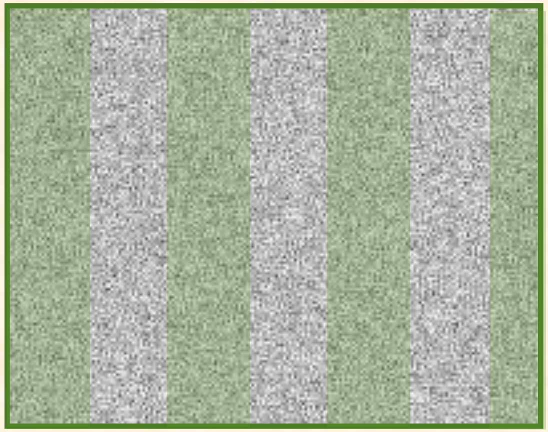


LOW SFs (0.18 cpd)



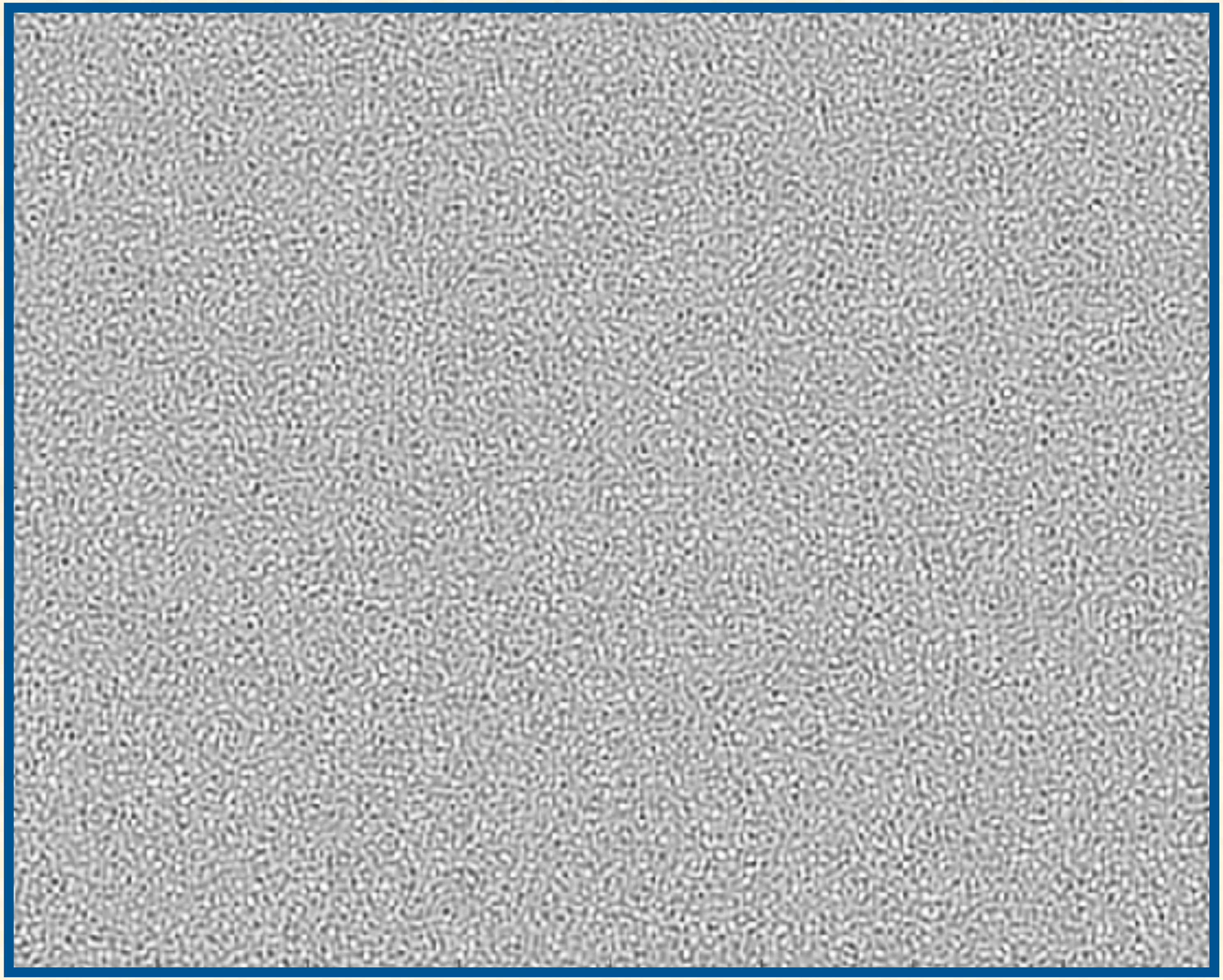




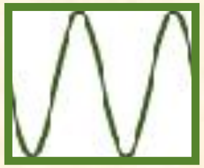


selective adaptation

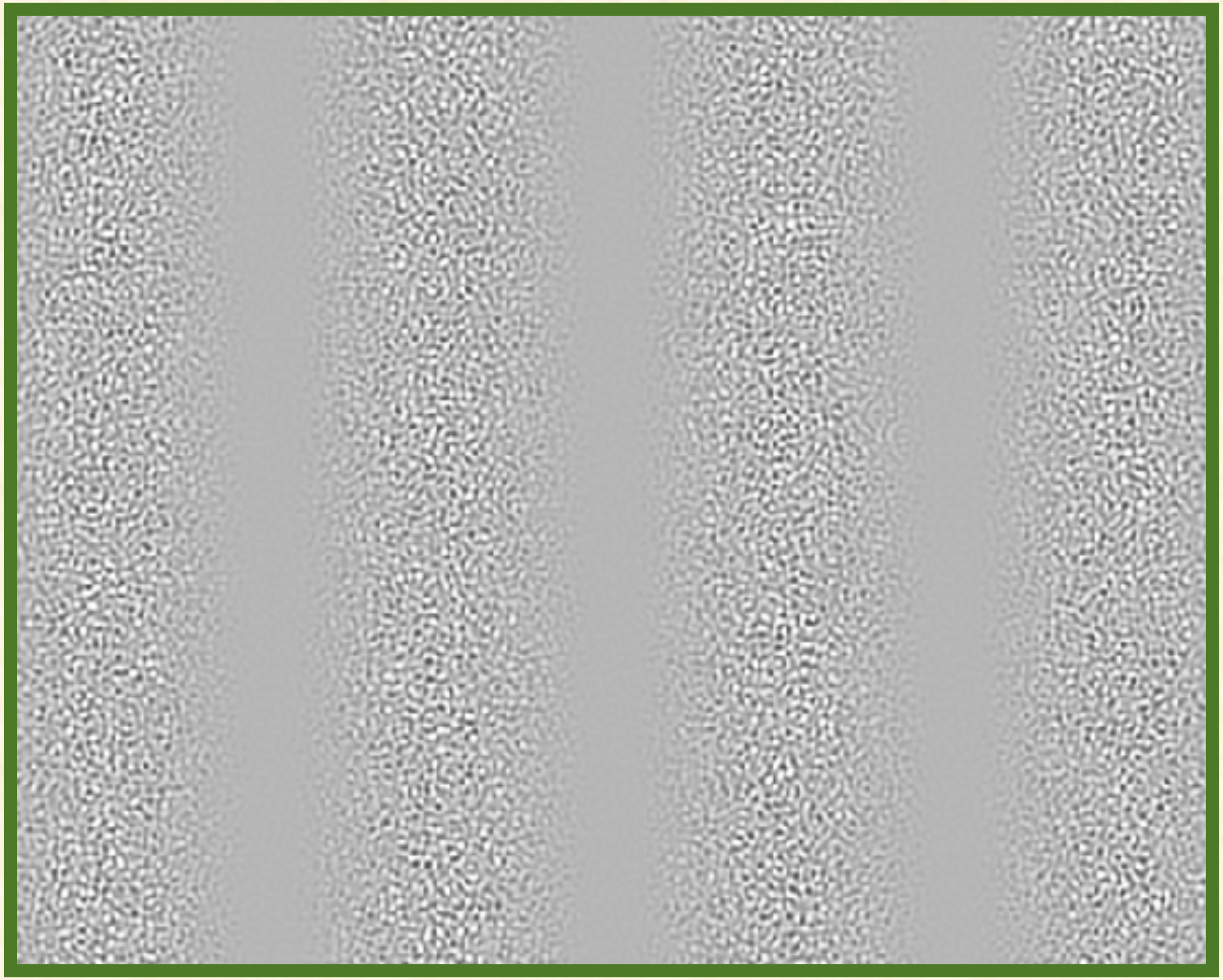
BASELINE



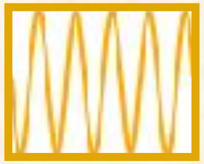
selective adaptation



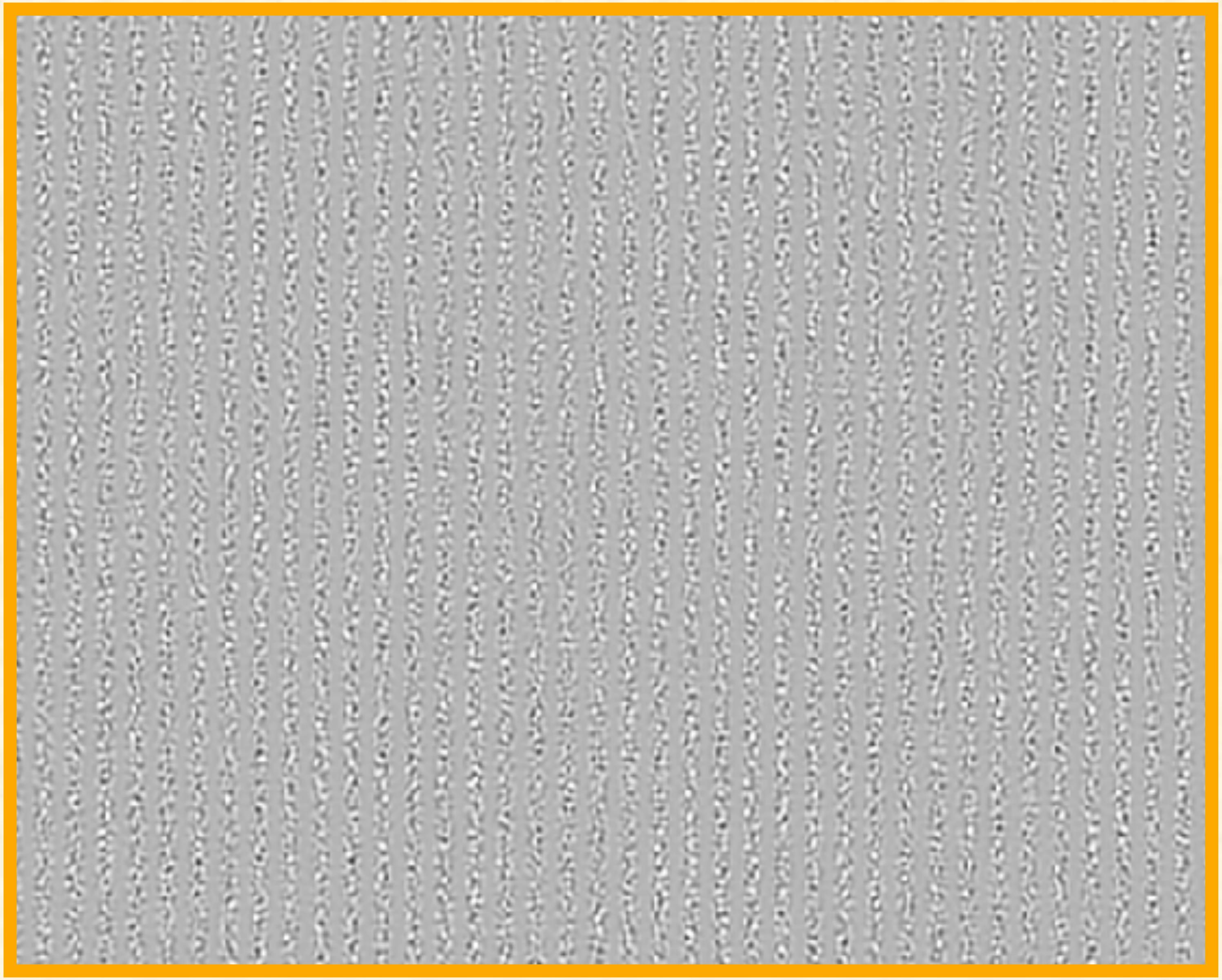
LOW SFs



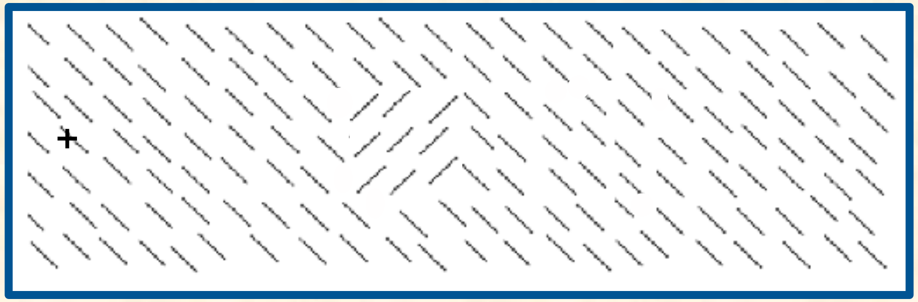
selective adaptation

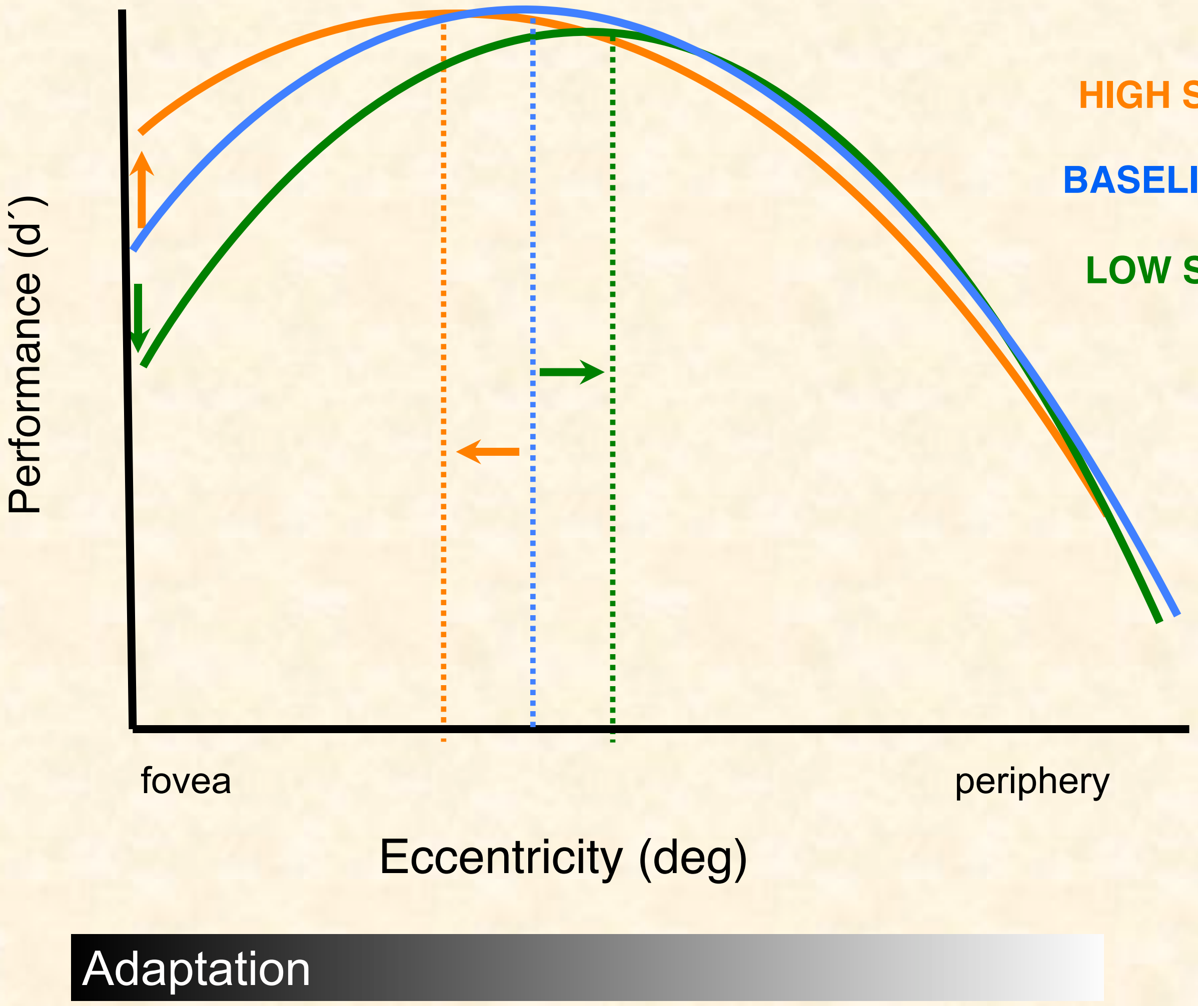


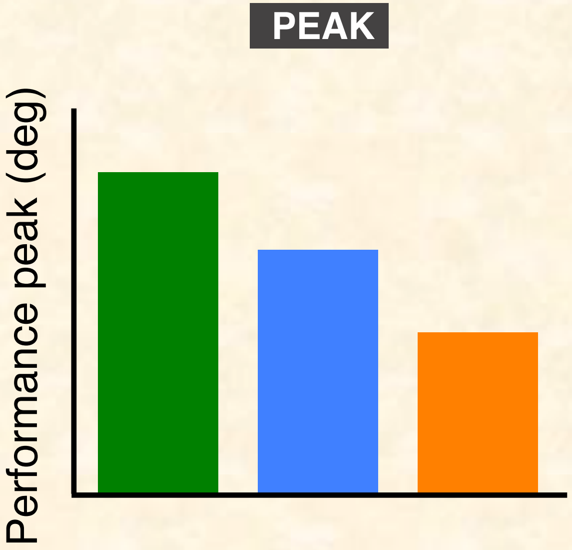
HIGH SFs

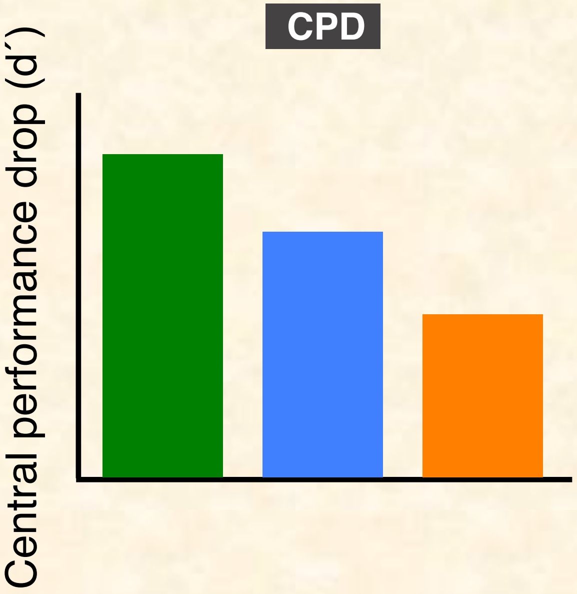


prediction: adaptation

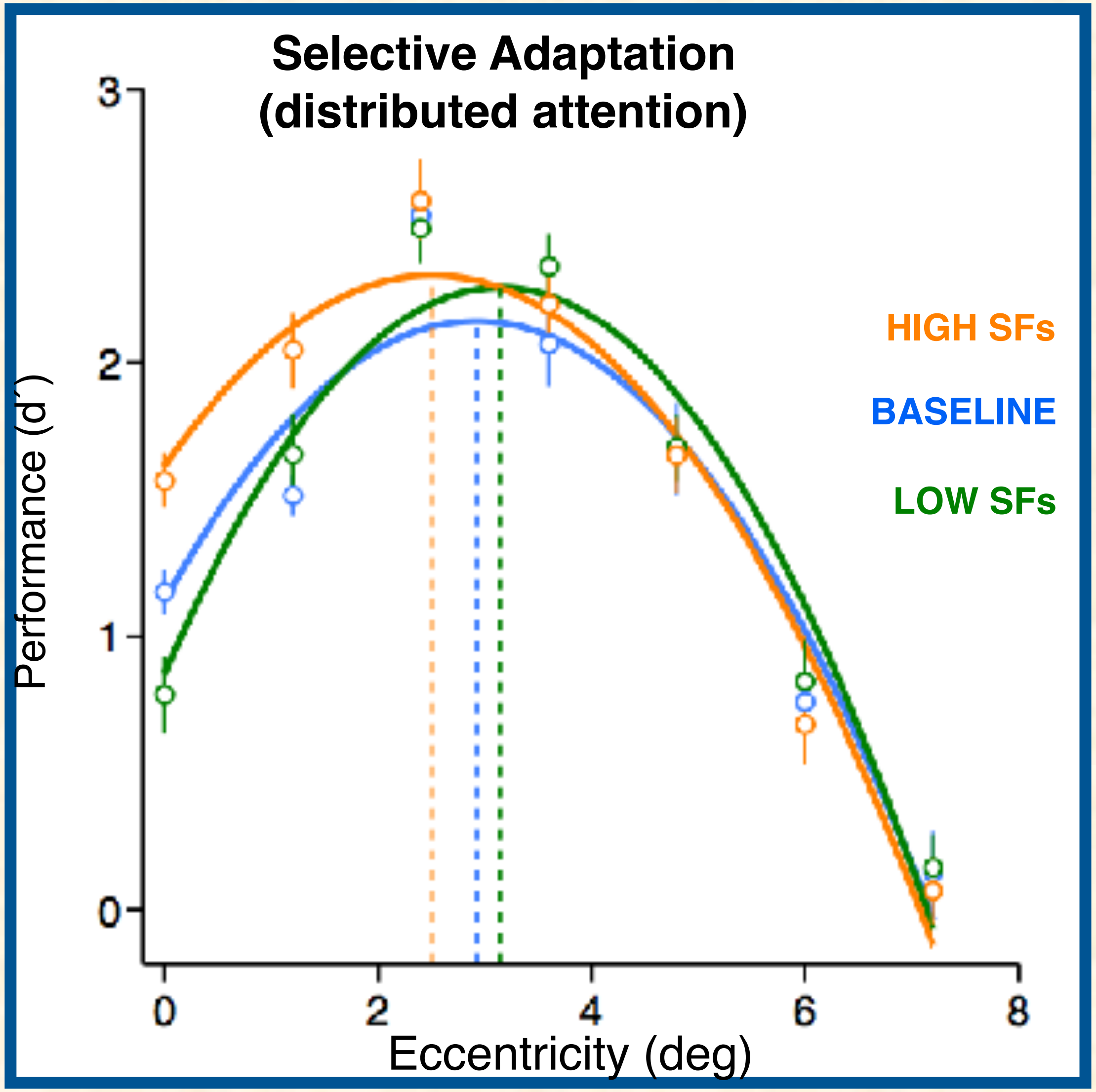


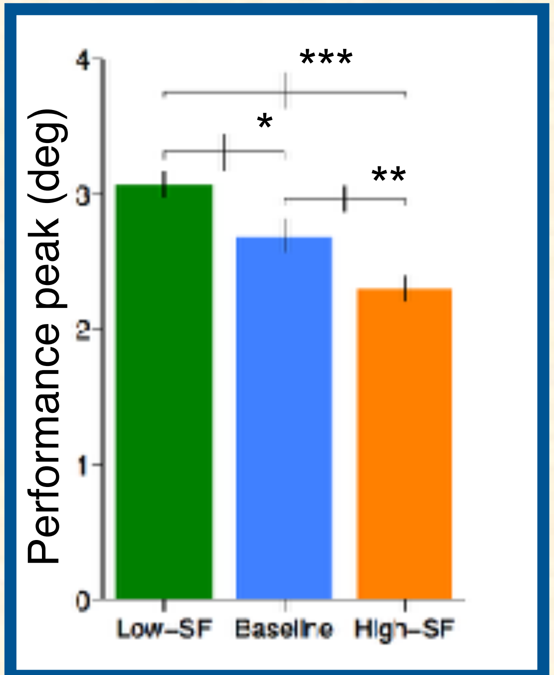


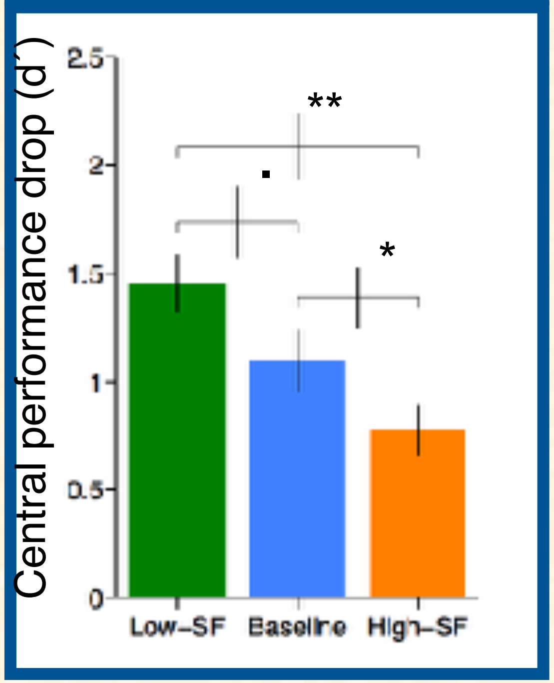




adaptation shifts peak and modulates CPD

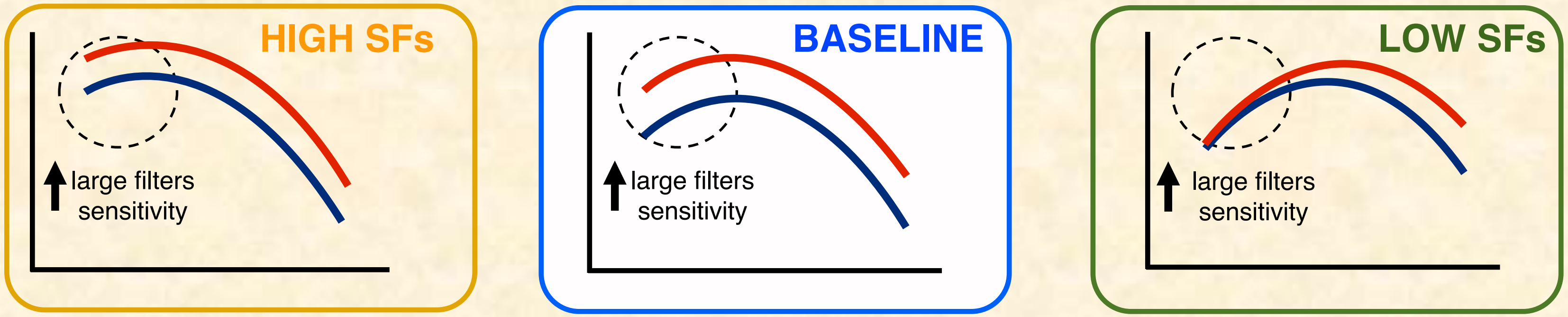


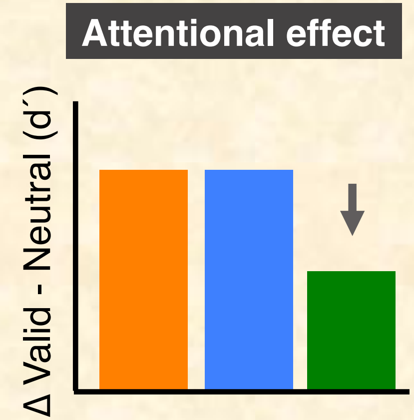




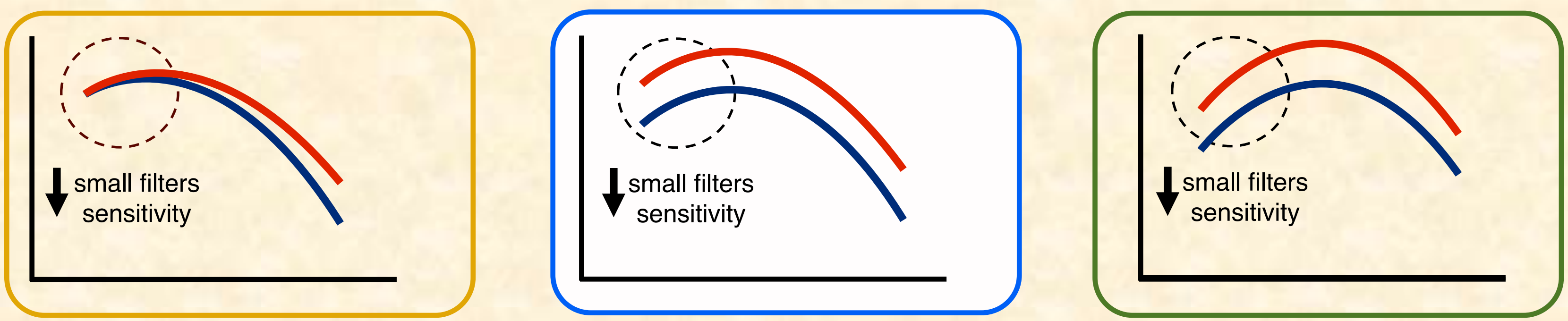
prediction: adaptation x attention

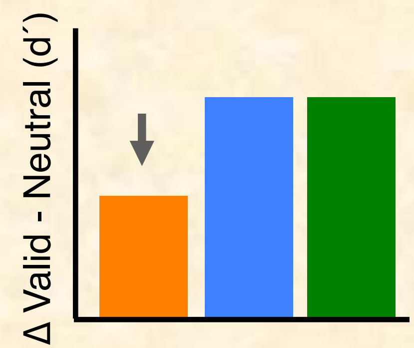
[H1] by increasing sensitivity of either small (lhigh SF) or large (low SF) filters



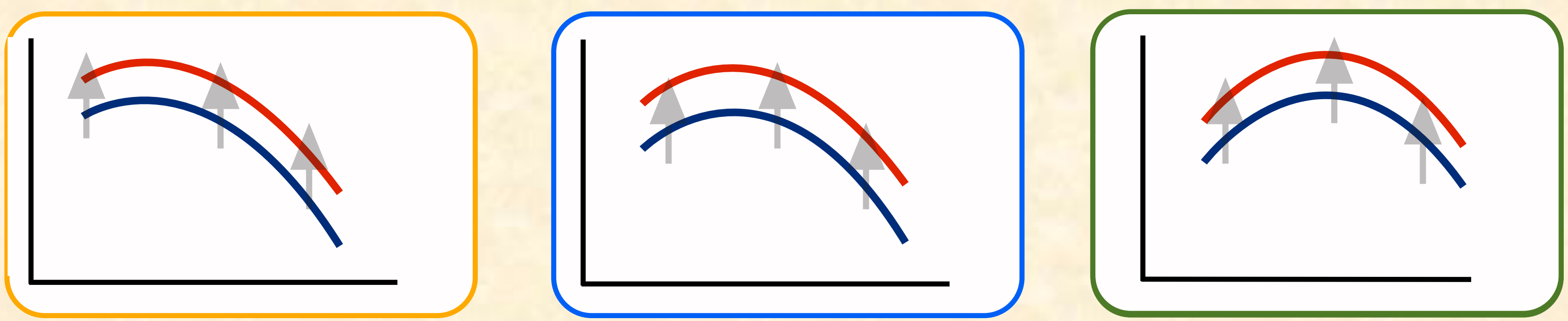


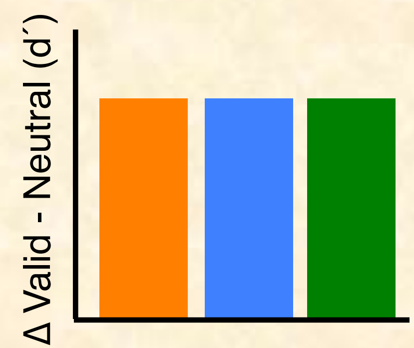
[H2] by either increasing or decreasing sensitivity of small (high SF) filters





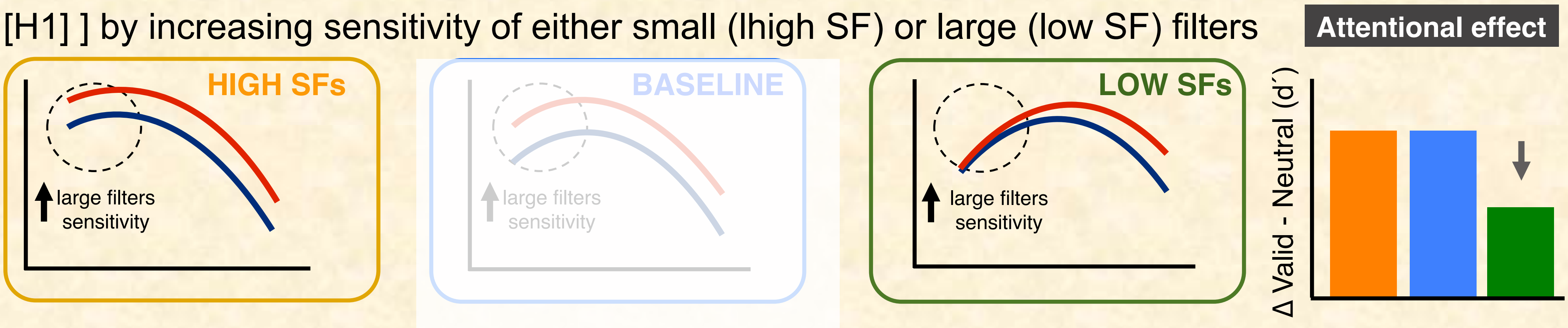
[H3] via a resolution-independent mechanism



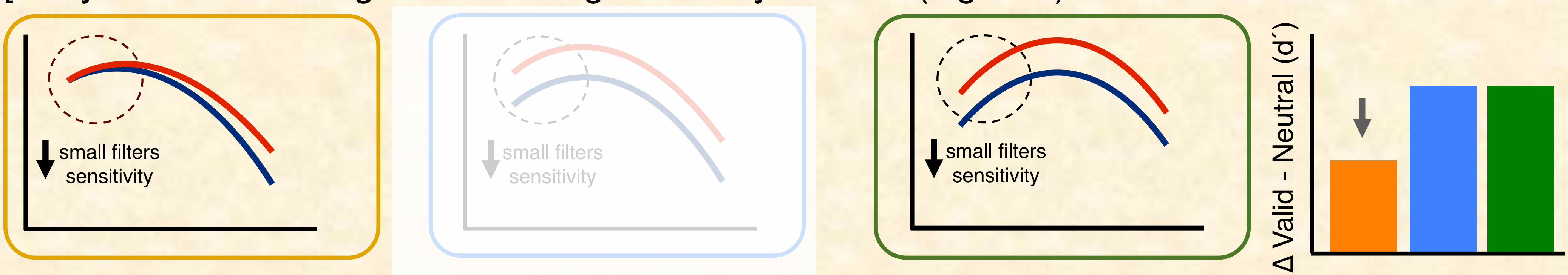


prediction: adaptation x attention

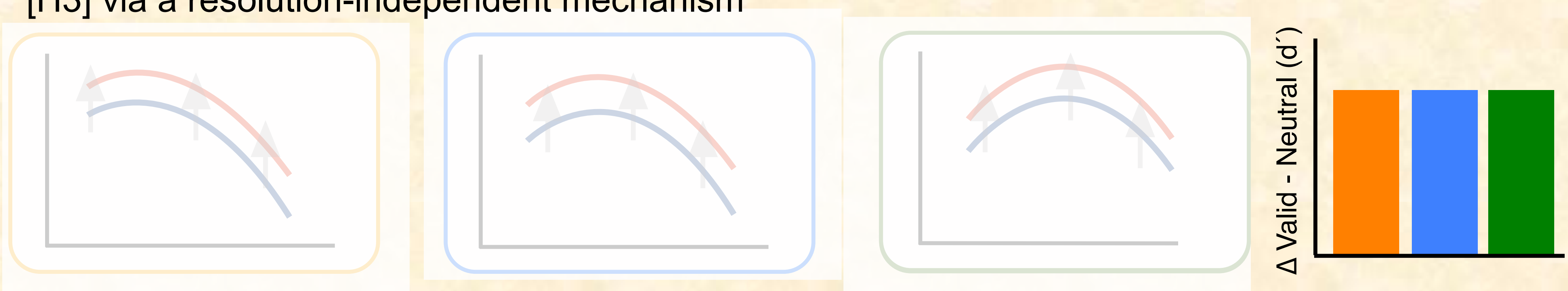
[H1]] by increasing sensitivity of either small (lhigh SF) or large (low SF) filters



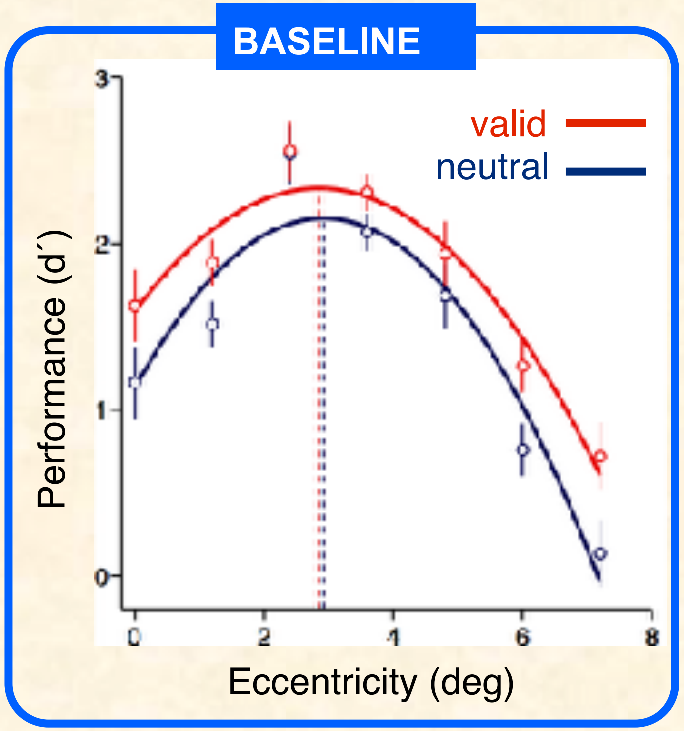
[H2by either increasing or decreasing sensitivity of small (high SF) filters

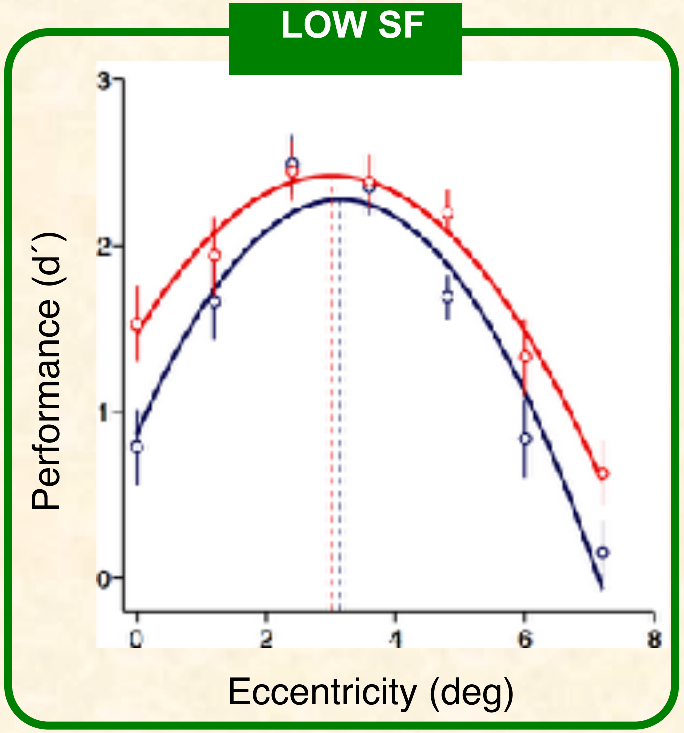


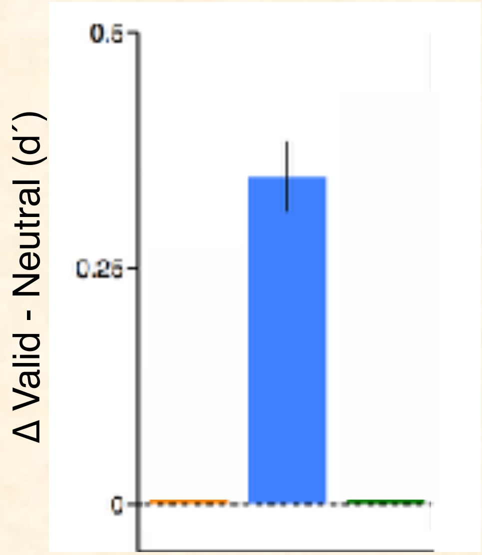
[H3] via a resolution-independent mechanism



adaptation interacts with attention



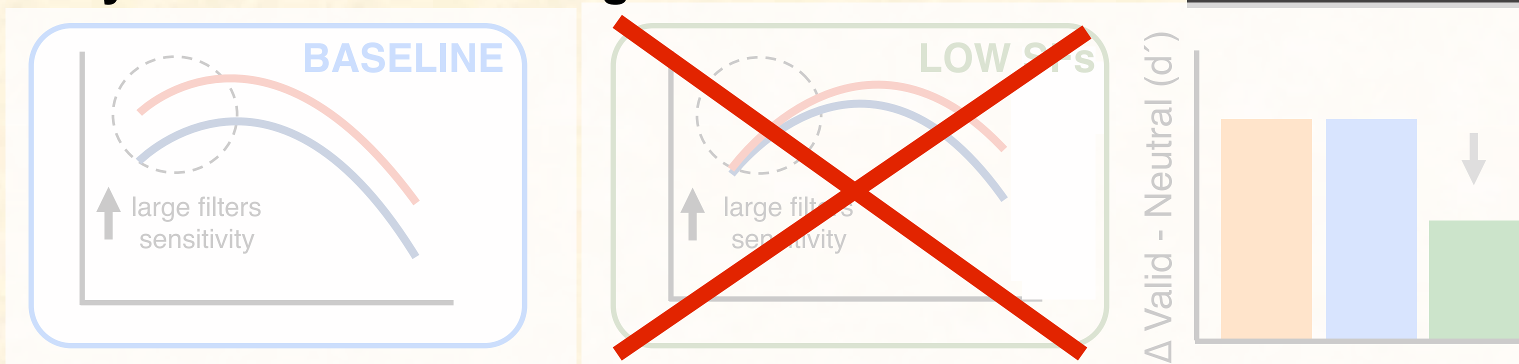




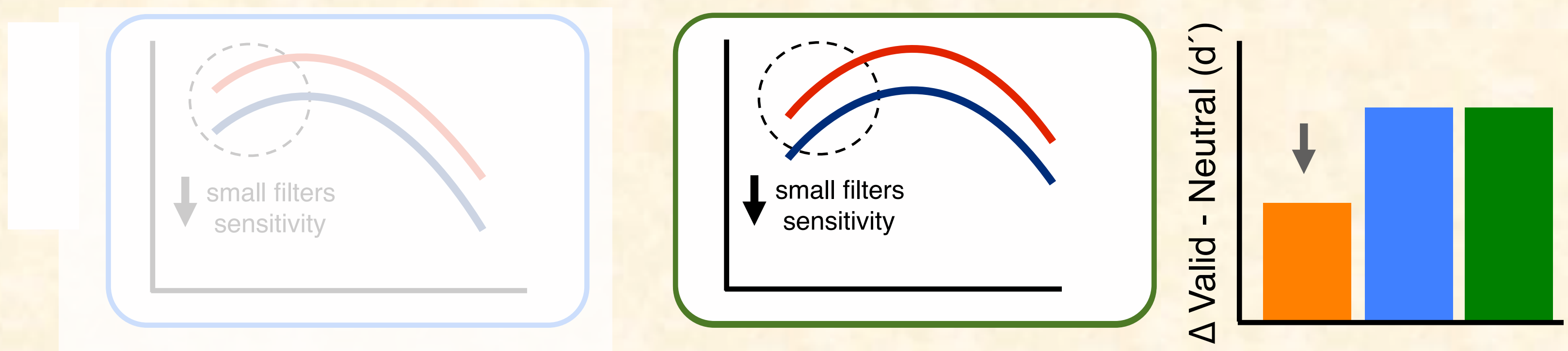
prediction: adaptation x attention

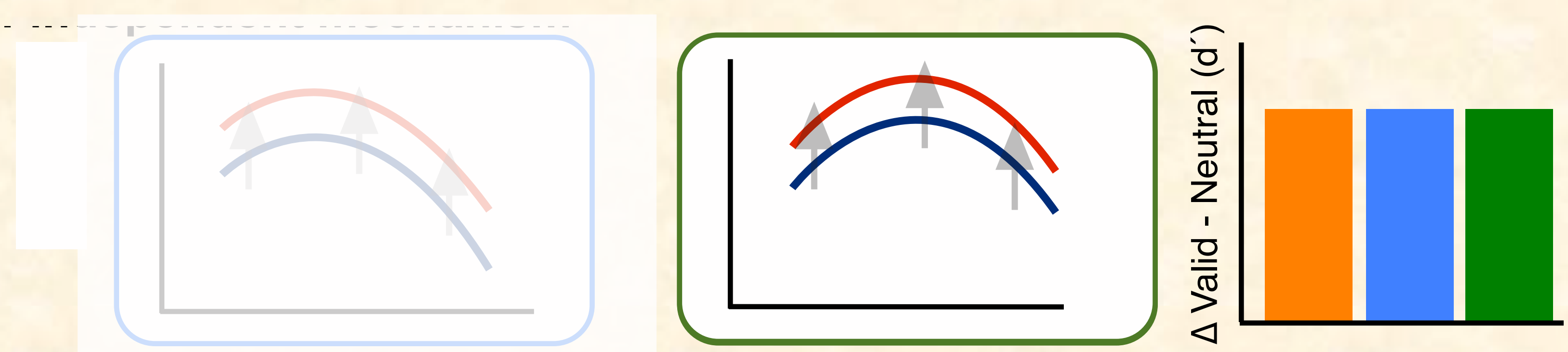
[H1] by increasing sensitivity of either small or large filters

Attentional effect

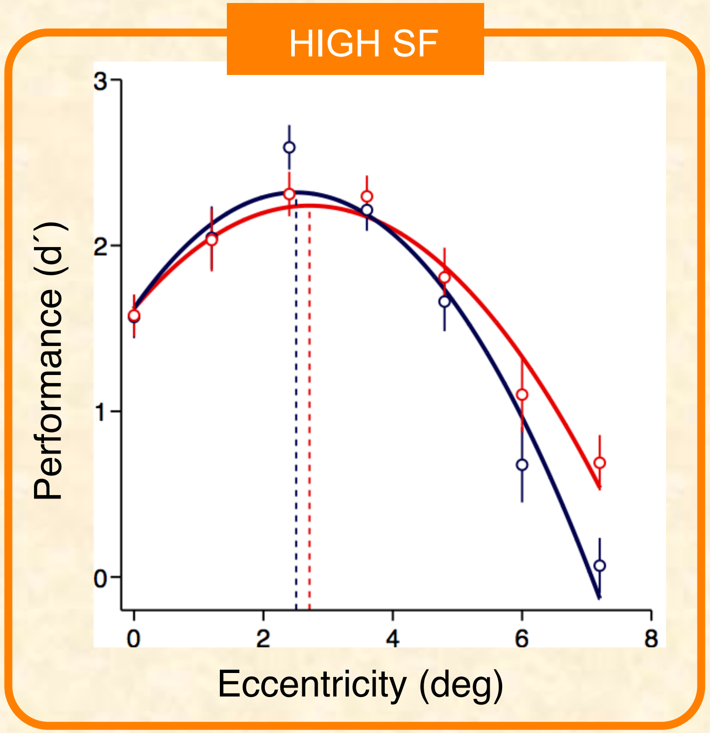


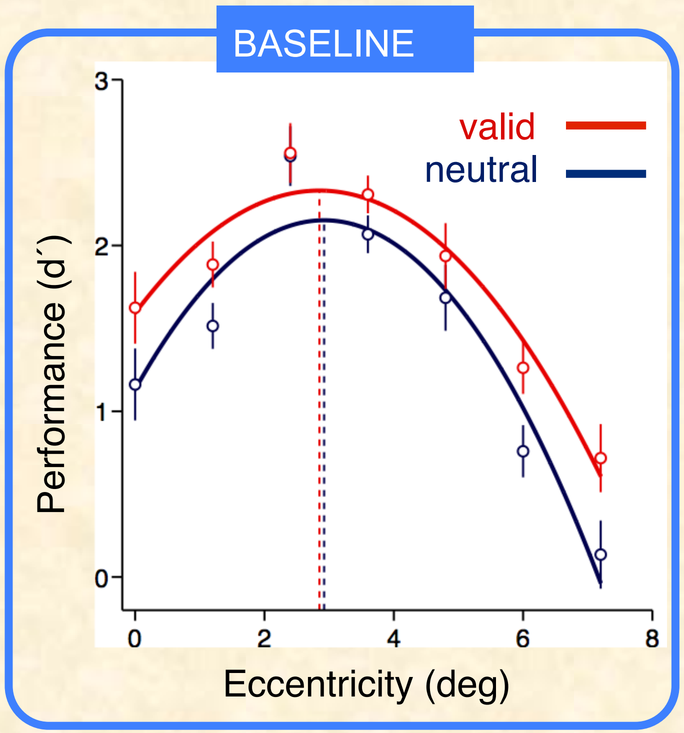
[H2] by either increasing or decreasing sensitivity of small filters

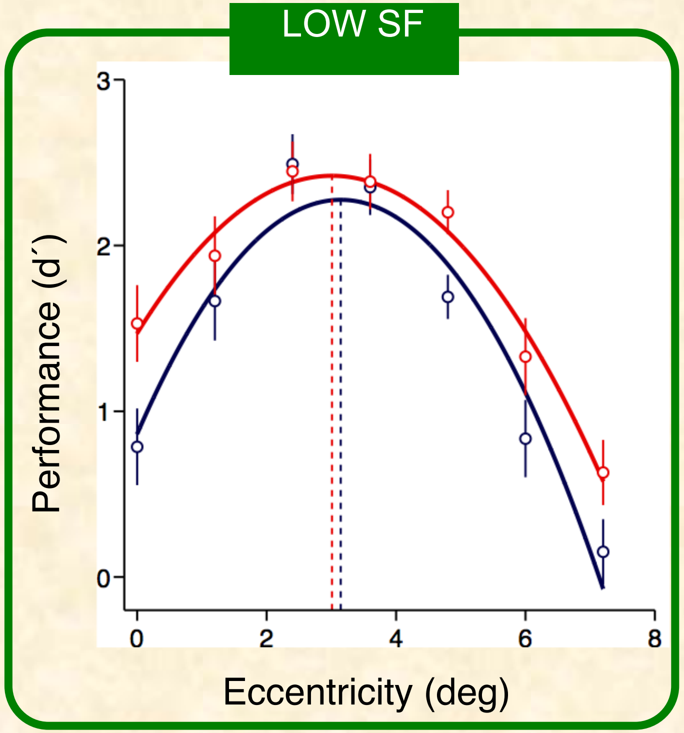


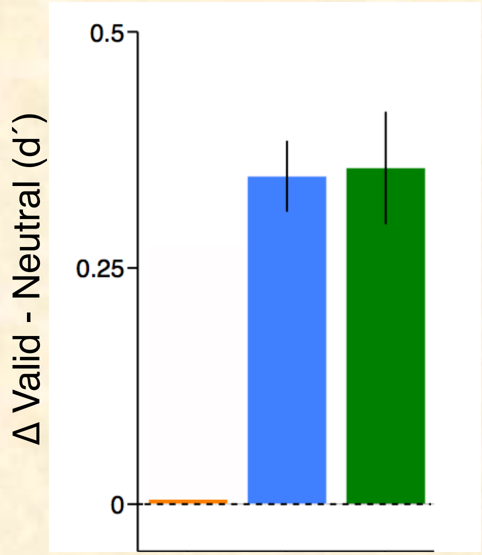


attention interacts with adaptation





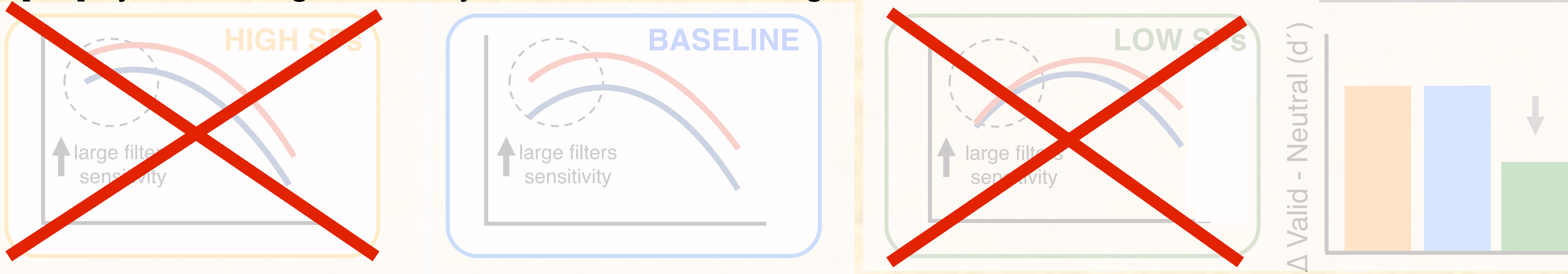




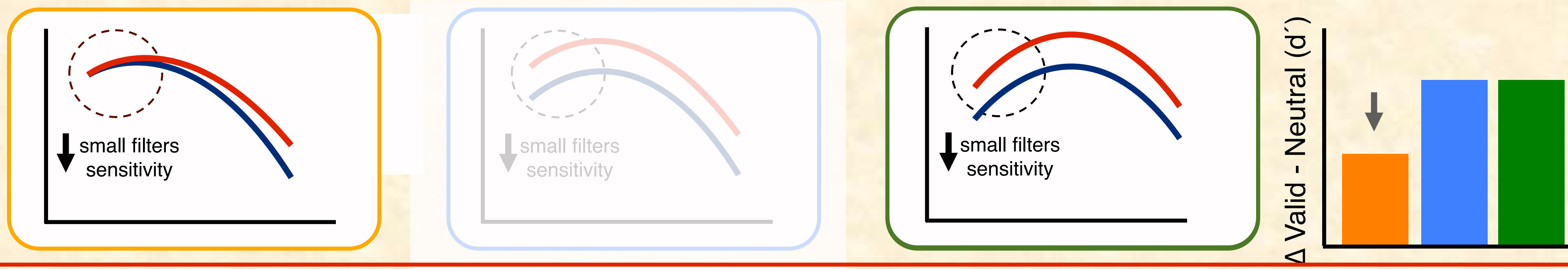
prediction: adaptation x attention

[H1] by increasing sensitivity of either small or large filters

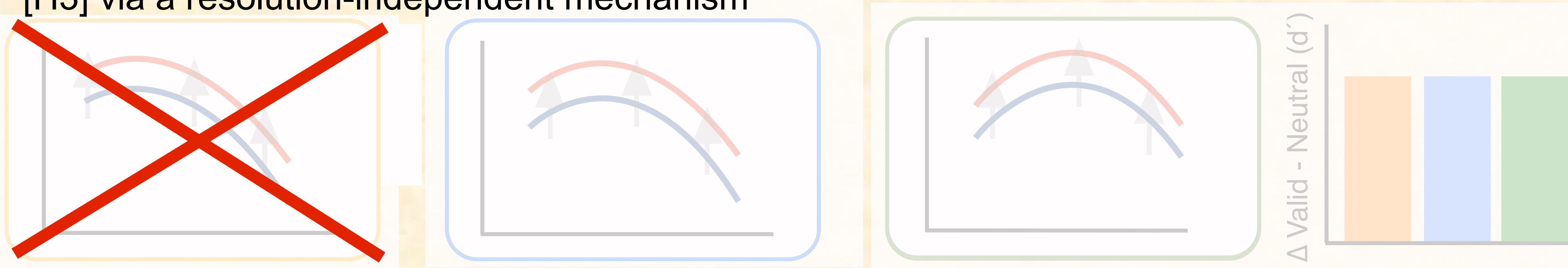
Attentional effect



[H2] by either increasing or decreasing sensitivity of small filters

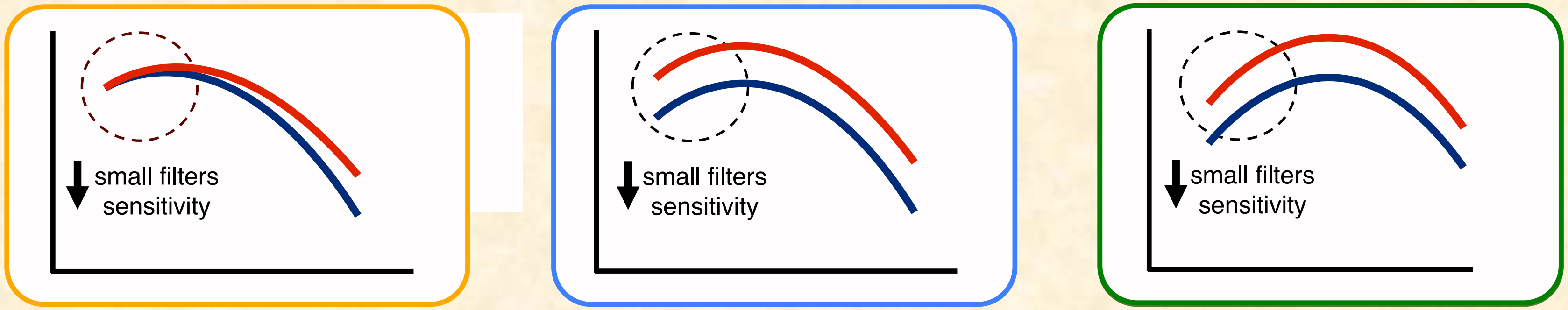


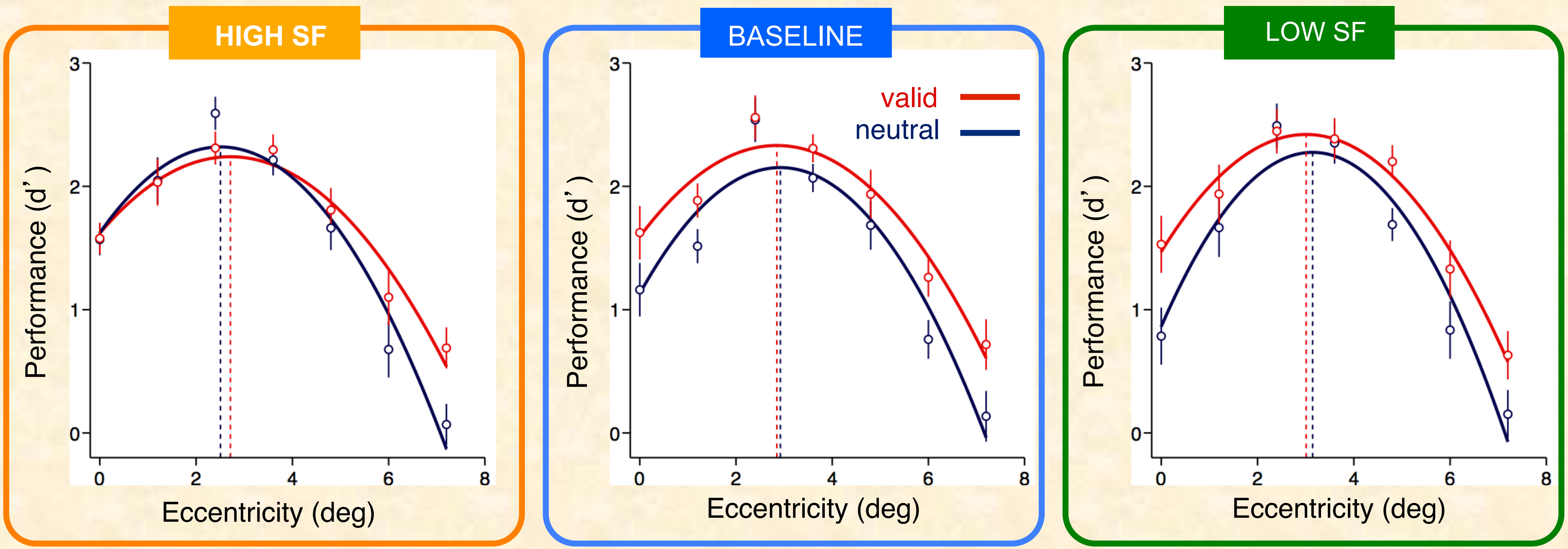
[H3] via a resolution-independent mechanism



small filters mediate the endo attention effect

[H2] by either increasing or decreasing sensitivity of small filters





Barbot & Carrasco (2017)

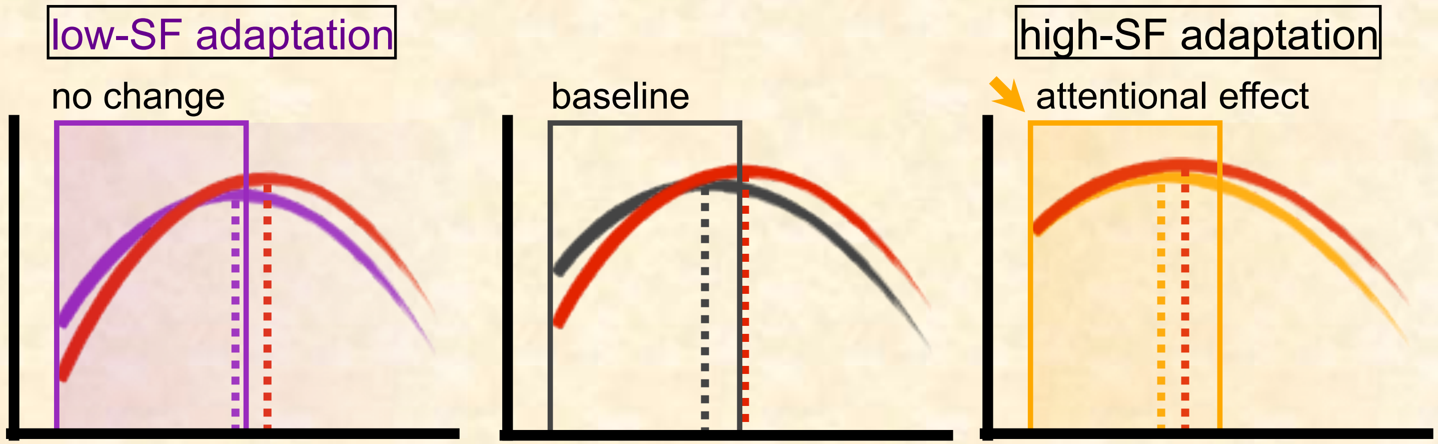
ENDO attention adjusts resolution to improve performance

- selective adaptation shifts the performance peak and modulates CPD, consistent with changes in the population's resolution
- adapting to high-SF, but not to low-SF, diminishes the CPD and silences attentional benefit at foveal and parafoveal locations
- attention modulates high-SF filters' sensitivity at central locations

Barbot & Carrasco (2017)

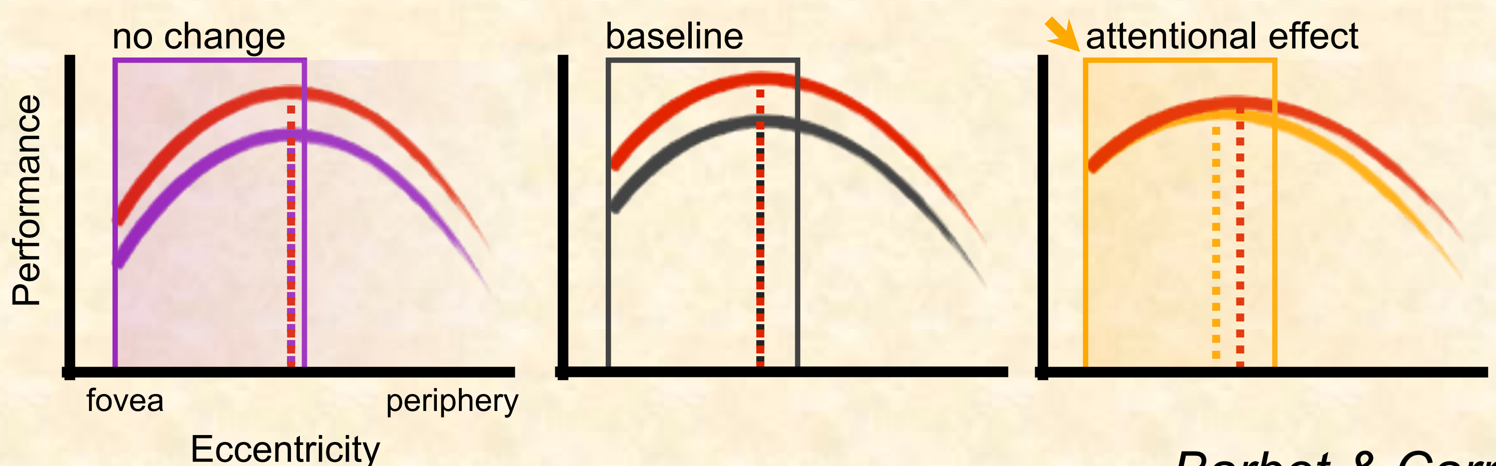
EXO ≠ ENDO attention

EXO attention increases resolution by increasing contribution of high-SF filters



Carrasco, Loula & Ho, 2006

ENDO attention decreases resolution by decreasing contribution of high-SF filters



Barbot & Carrasco, 2017

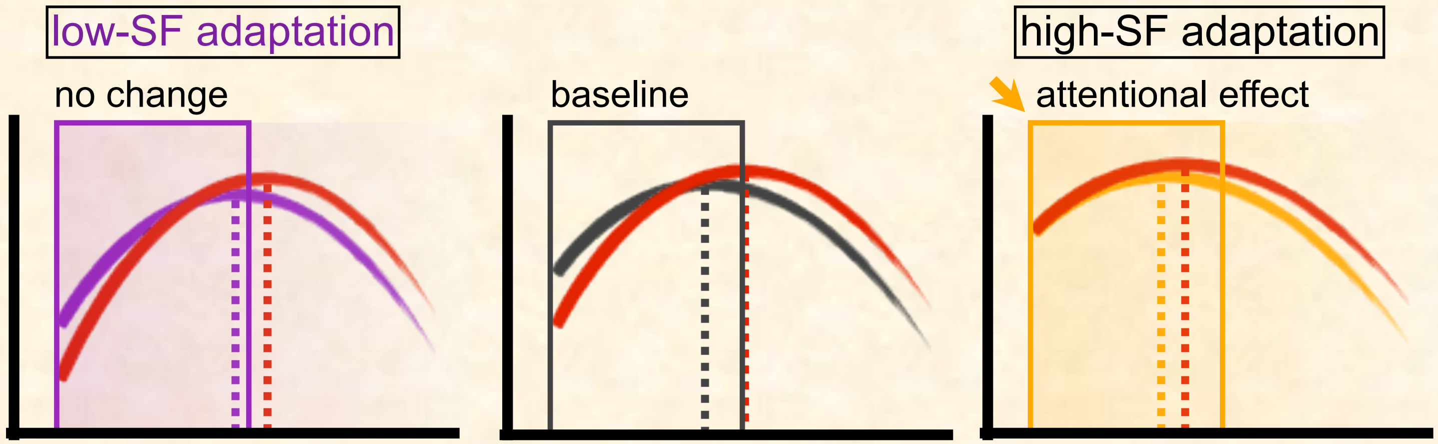
endogenous attention adjusts resolution to improve performance

- selective adaptation shifts the performance peak and modulates CPD, consistent with changes in the population's resolution
- adapting to high-SF silences attentional benefit at foveal and parafoveal locations

Barbot & Carrasco (2017)

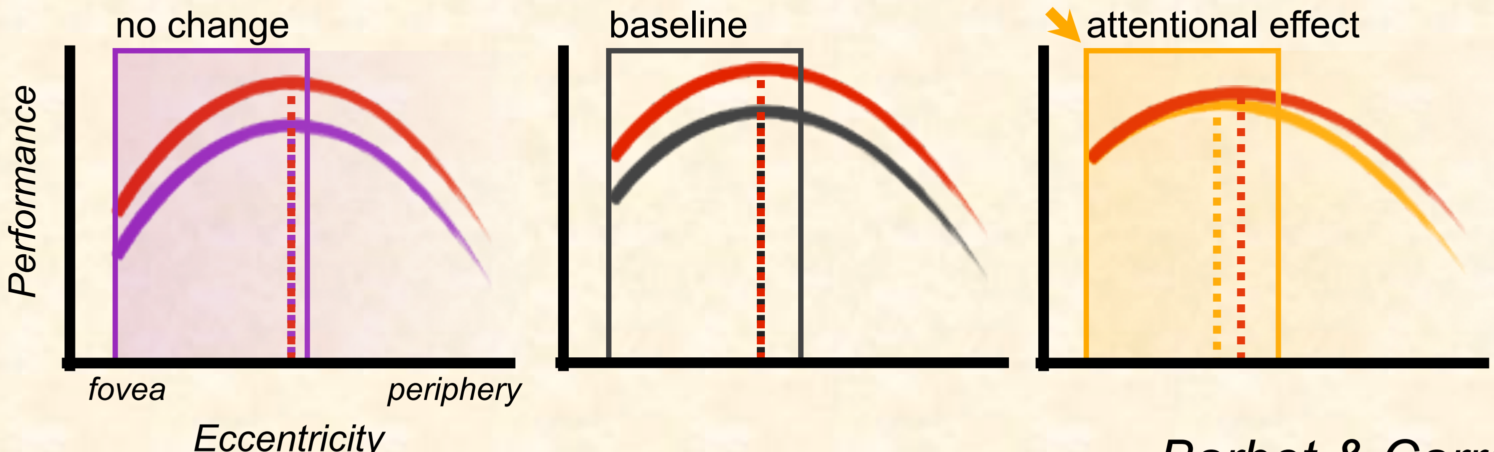
exogenous ≠ endogenous attention

Exogenous attention increases resolution by increasing contribution of high-SF filters



Carrasco, Loula & Ho, 2006

Endogenous attention decreases resolution by decreasing contribution of high-SF filters



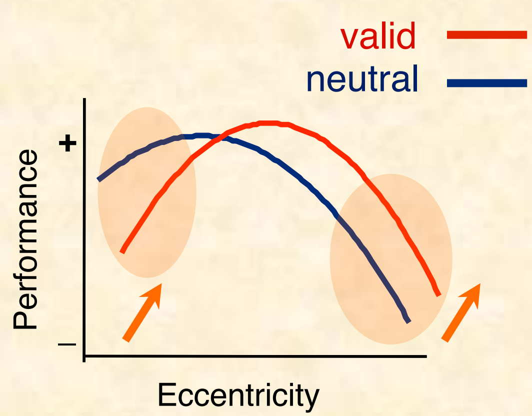
Barbot & Carrasco, 2017

attention and spatial resolution

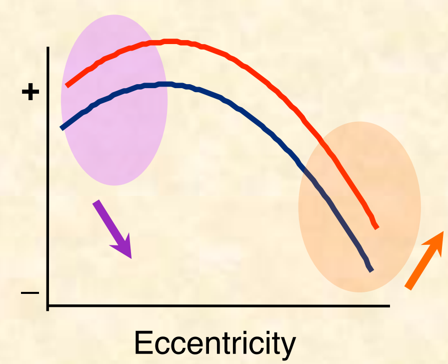
	EXOGENOUS	ENDOGENOUS
Performance at central locations	*impairs*	*improves*
Performance at peripheral locations	*improves*	*improves*
Spatial resolution	*increases* sensitivity	*increases* or *decreases* of small filters

AUTOMATICITY

FLEXIBILITY



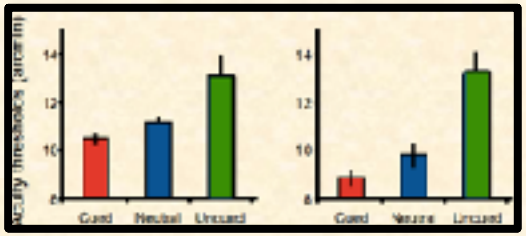
Carrasco, Loula & Ho, 2006

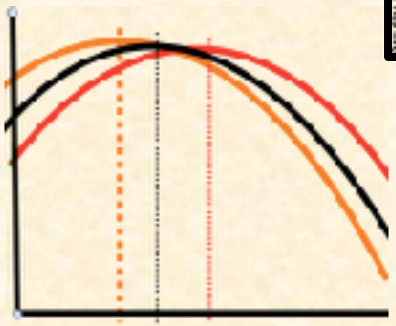


Barbot & Carrasco, 2017

covert attention helps overcome limitations of peripheral processing and restore visual performance

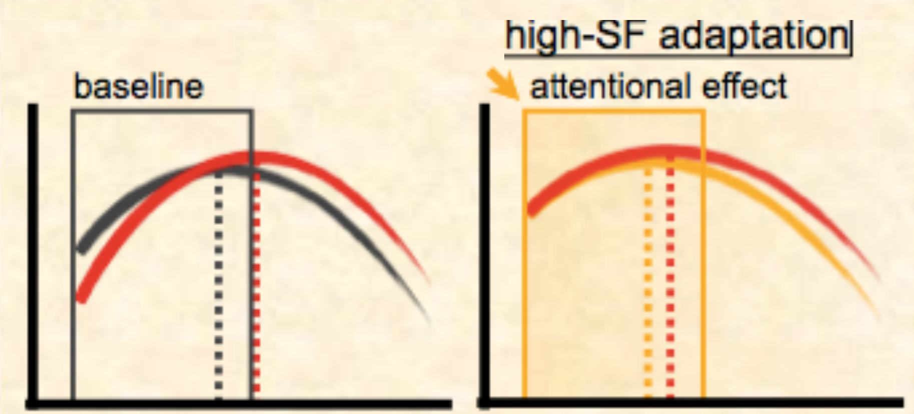
- **exogenous** attention <u>automatically</u> increases resolution (eg search, acuity), even when detrimental
- diverting **exogenous** attention decreases resolution and can improve performance!





- **endogenous** attention <u>flexibly</u> adjusts resolution per task demand to benefit performance

- **exogenous** and **endogenous** attention modulate sensitivity of the high-SF selective filters at a given eccentricity



RF position and size changes can qualitatively account for behavioral effects in performance

- concentrating processing resources at attended location (shift)
  - population receptive fields (pRFs) shift towards attended area through-out the visual field and the visual system *[Klein, Harvey & Dumoulin 2014]*
- reducing the area of spatial integration (shrinkage)
  - decreased spatial overlap in BOLD responses for adjacent locations, narrowing of the population's integration area *[Fischer & Whitney 2009]*
  - withdrawing attention from periphery results in larger pRFs and blurrier perceptual representation *[de Haas et al. 2014]*
- attention enhances the visual system's effective spatial resolution

Anton-Erxleben & Carrasco, NRN 2013