Orientation-selective adaptation to first- and second-order patterns in human visual cortex

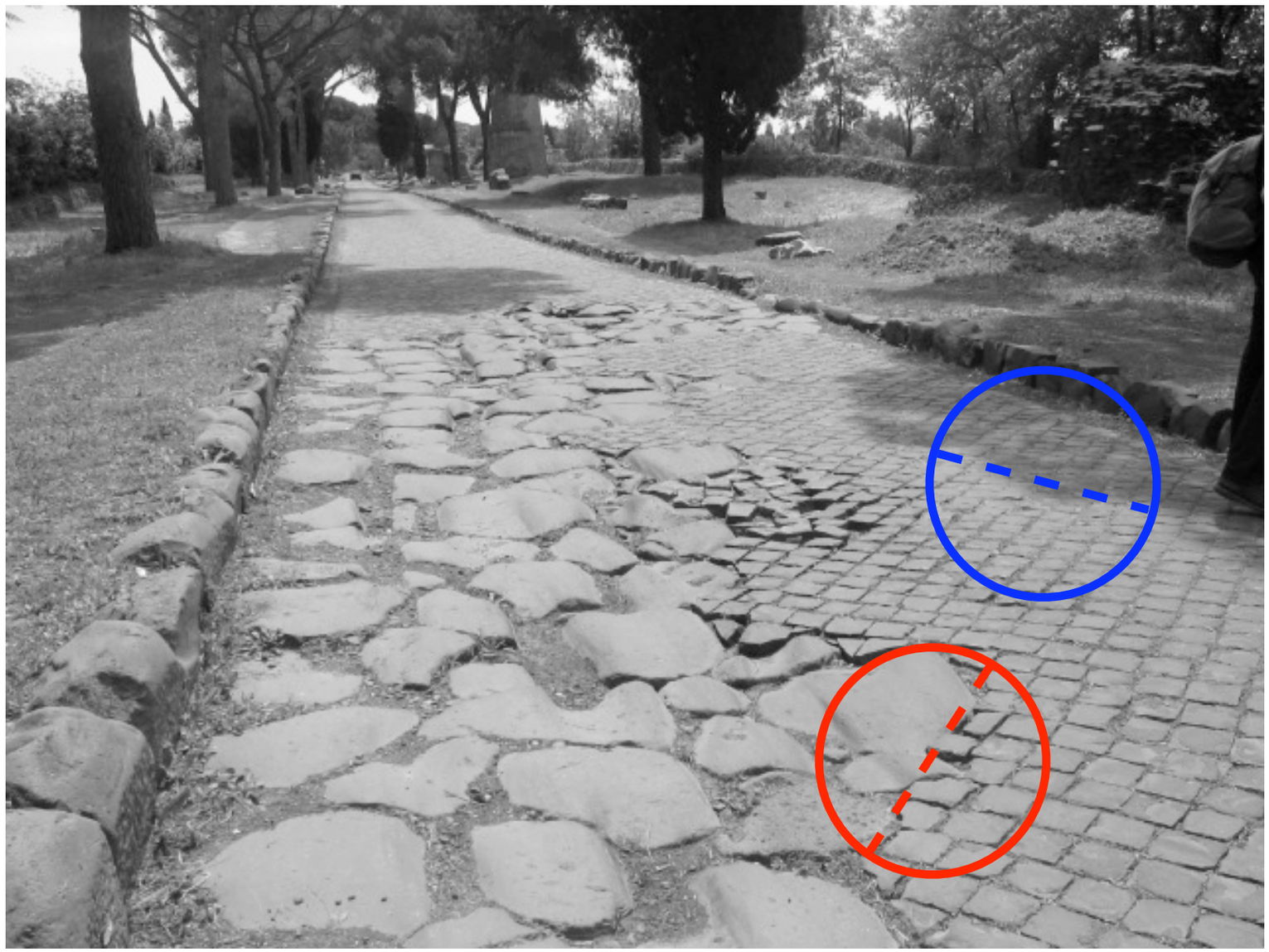
Jonas Larsson, Michael S. Landy, David J. Heeger

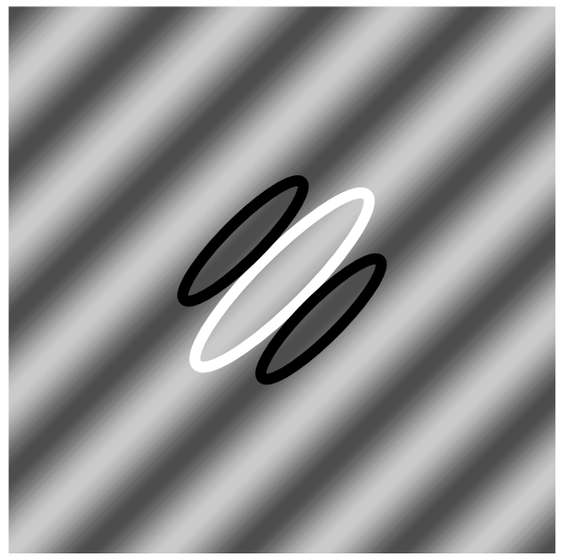
Department of Psychology &
Center for Neural Science,
New York University, USA

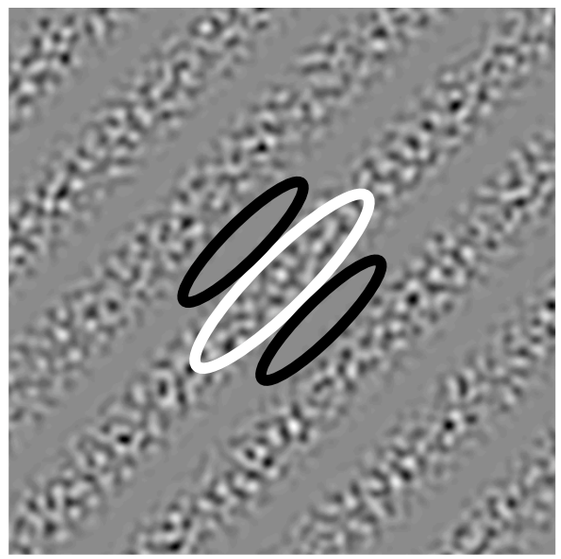
jonas@cns.nyu.edu

NYU

What are first- and second-order patterns?







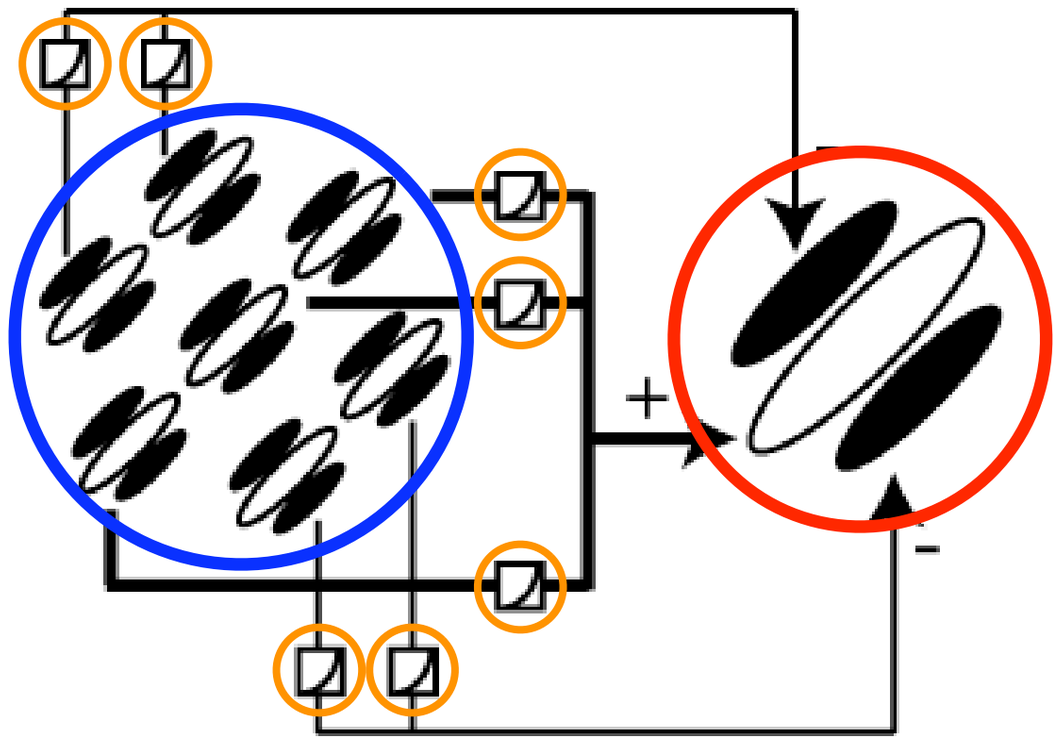
- First-order: vary in luminance; can be detected by linear filters
- Second-order: do not vary in luminance; cannot be detected by linear filters

Filter-rectify-filter (FRF) model of second-order vision

First stage: many small-scale linear filters

Rectify output of first stage filters

Second stage: Sum rectified output with large-scale linear filter



Predicts separate mechanisms for first- and second-order vision

Separate mechanisms?

- *Psychophysics*: different mechanisms for first- and second-order vision
- *Electrophysiology*: first-order neurons as early as V1; second-order neurons in extrastriate visual cortex of cats (area 18) and macaques (V2, V4, V5/MT)
- But many second-order neurons also selective for first-order patterns (cue invariance) - not predicted by FRF
- *Neuroimaging*: anatomical segregation of first- and second-order vision in humans? conflicting results

Open questions

- Anatomical segregation? Are any human visual areas *specialized* for first- or second-order vision?
- Multiple second-order mechanisms? Are *different* types of second-order patterns (contrast, orientation) processed by the *same* mechanism?
- Cue-invariance? Are there neurons that respond *both* to first- and second-order patterns?

Approach

- Adapt orientation-selective neurons
- Measure responses to adapted & orthogonal stimulus orientation with fMRI
- Event-related design
- Use independently identified visual area ROIs

Stimulus conditions

Unimodal

Cross-modal

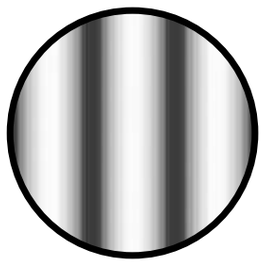
Adapter

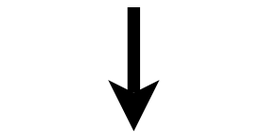
Probe

LM:LM

First-order

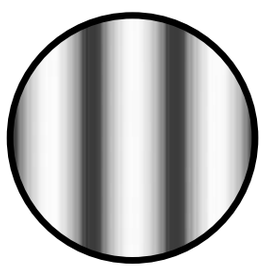
luminance





First-order

luminance



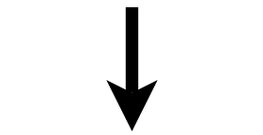
CM:CM

OM:OM

Second-order

contrast

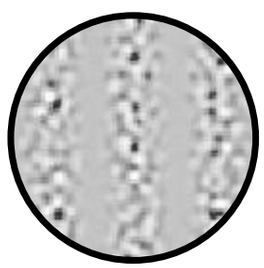
orientation

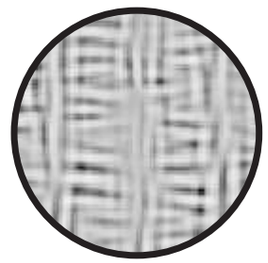


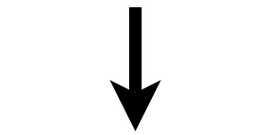
Second-order

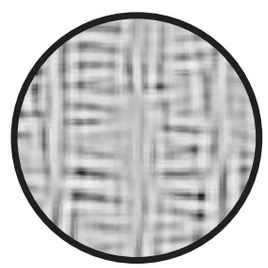
contrast

orientation





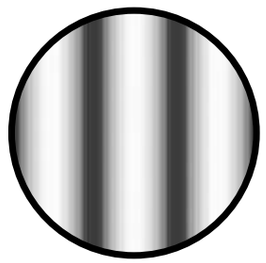


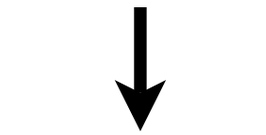


LM:OM

First-order

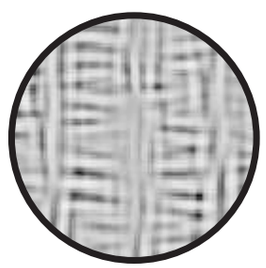
luminance





Second-order

orientation



Trial types

	Adapter orientation	*Probe orientation*
Parallel trials		
Orthogonal trials		
Blank trials		*blank screen*

Trial structure

Unattended perifoveal stimulus (1.5-5 deg)

Adapter 4 s

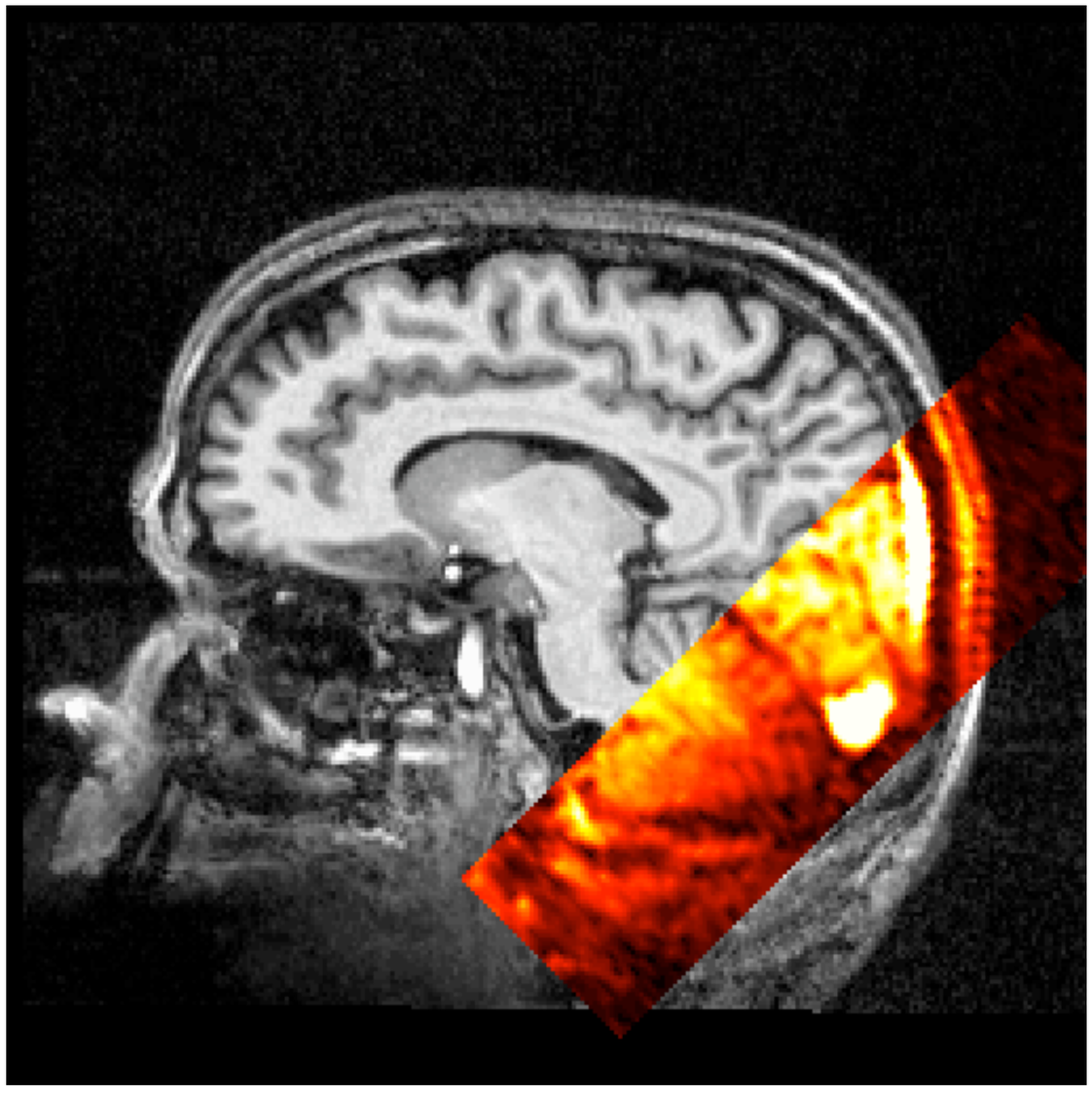
ISI 1 s

Probe 1 s

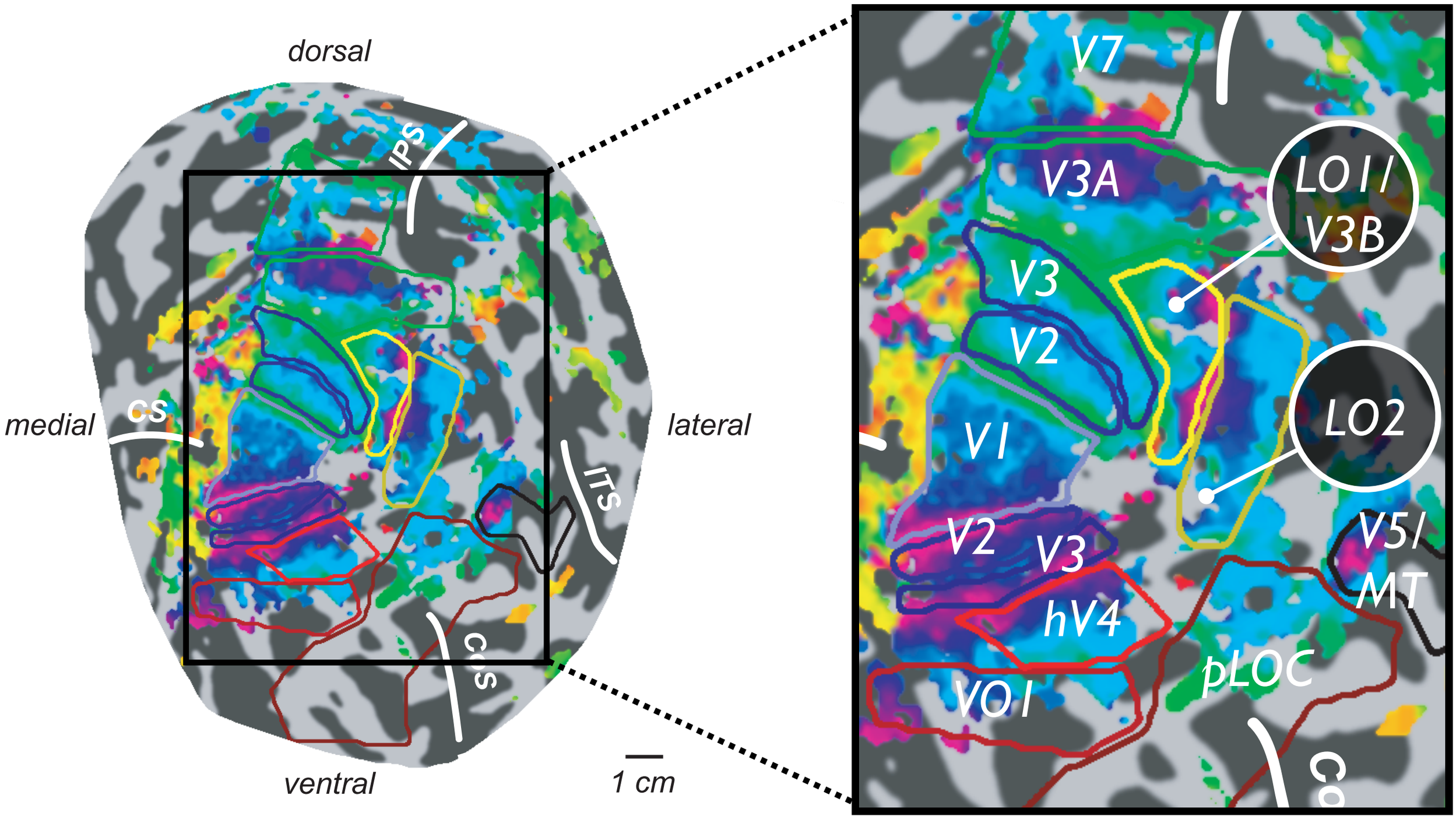
7.2 s

fMRI methods

- 3 subjects
- 8 scanning sessions per subject
- 280 trials per stimulus condition and trial type
- Siemens Allegra 3T, quadrature surface coil
- BOLD EPI, 19 slices perpendicular to calcarine sulcus, TR=1.2s, TE=30ms, FA=75
- Bite bar & motion correction with FSL



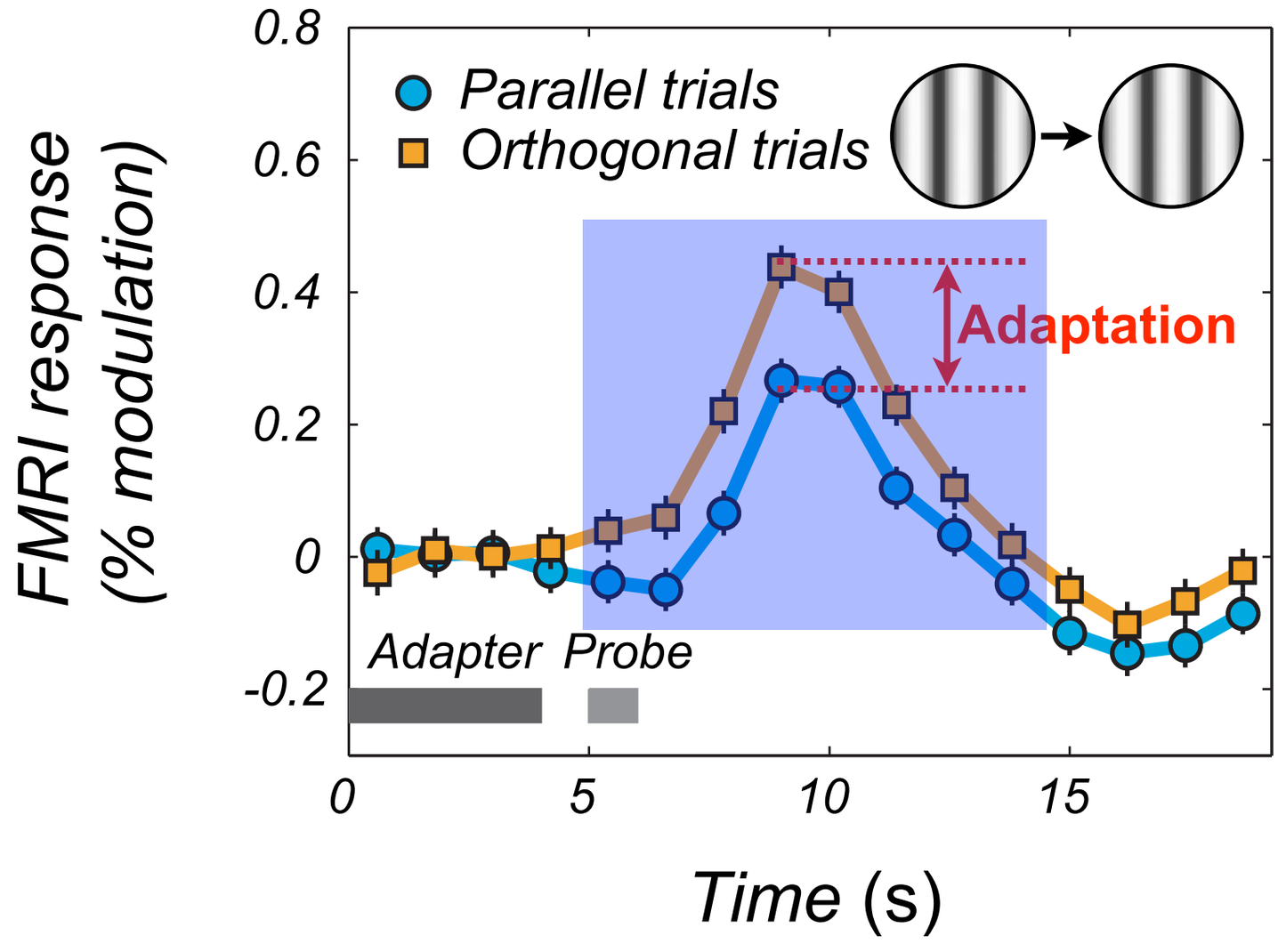
Visual area ROIs



Results:

Unimodal adaptation - first-order (LM:LM)

Orientation-selective adaptation to first-order patterns in V1

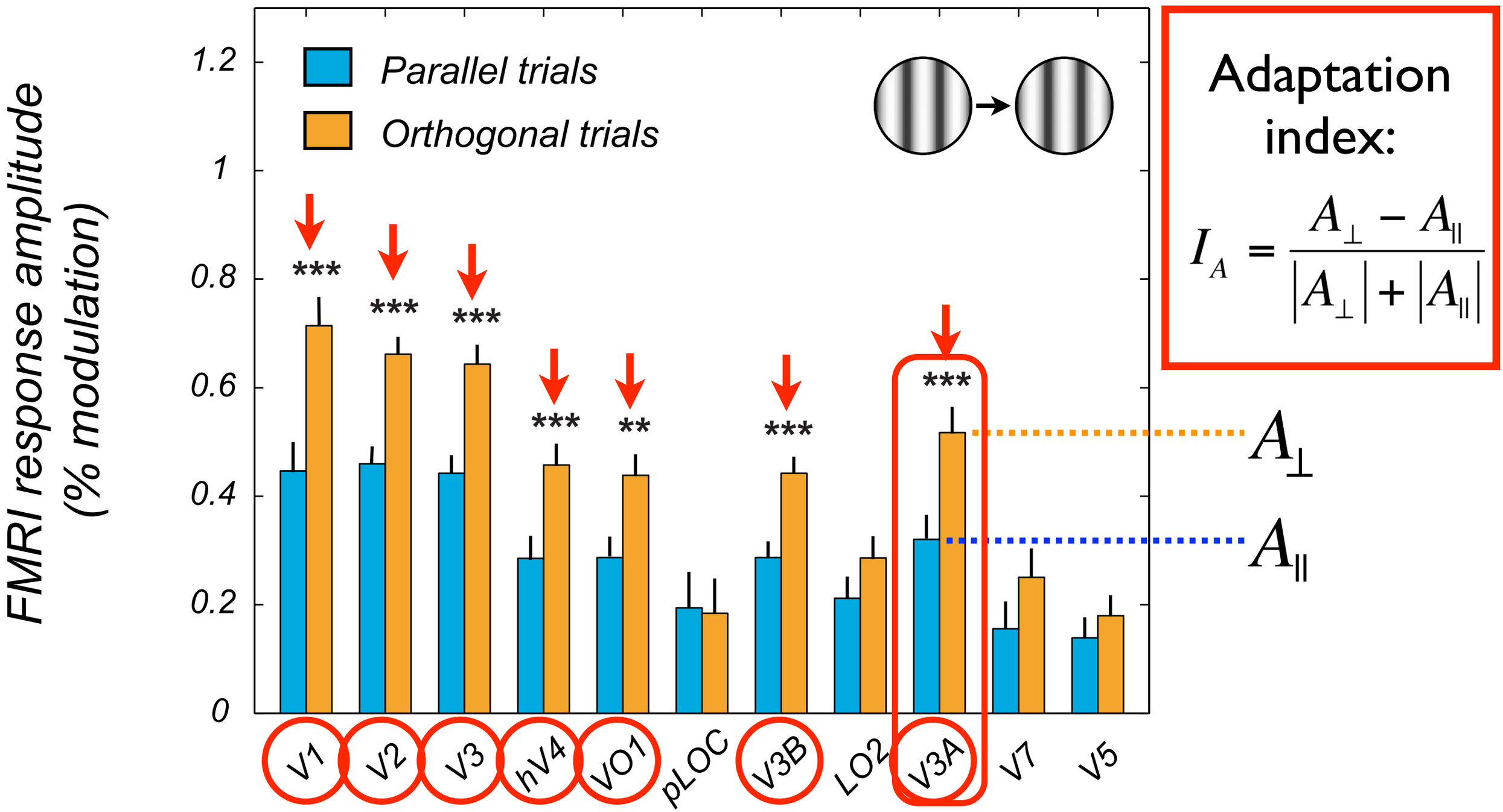


Response amplitude (A):

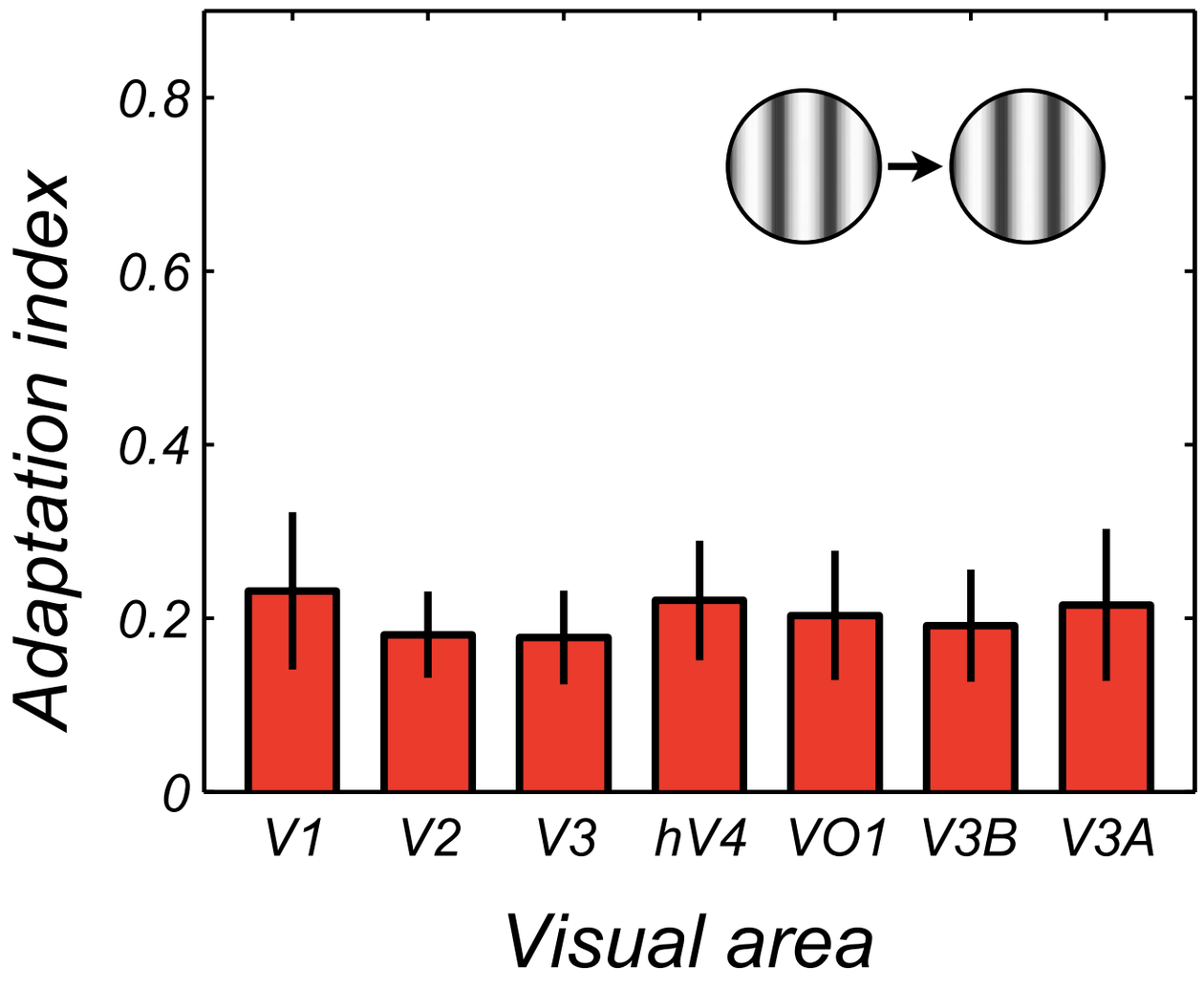
$$\bar{R} = \frac{1}{N}\sum_{i=1}^{N} R_i$$

$$A_i = \frac{R_i \bullet \bar{R}}{\left\|\bar{R}\right\|}$$

Adaptation to first-order patterns: luminance (LM:LM)



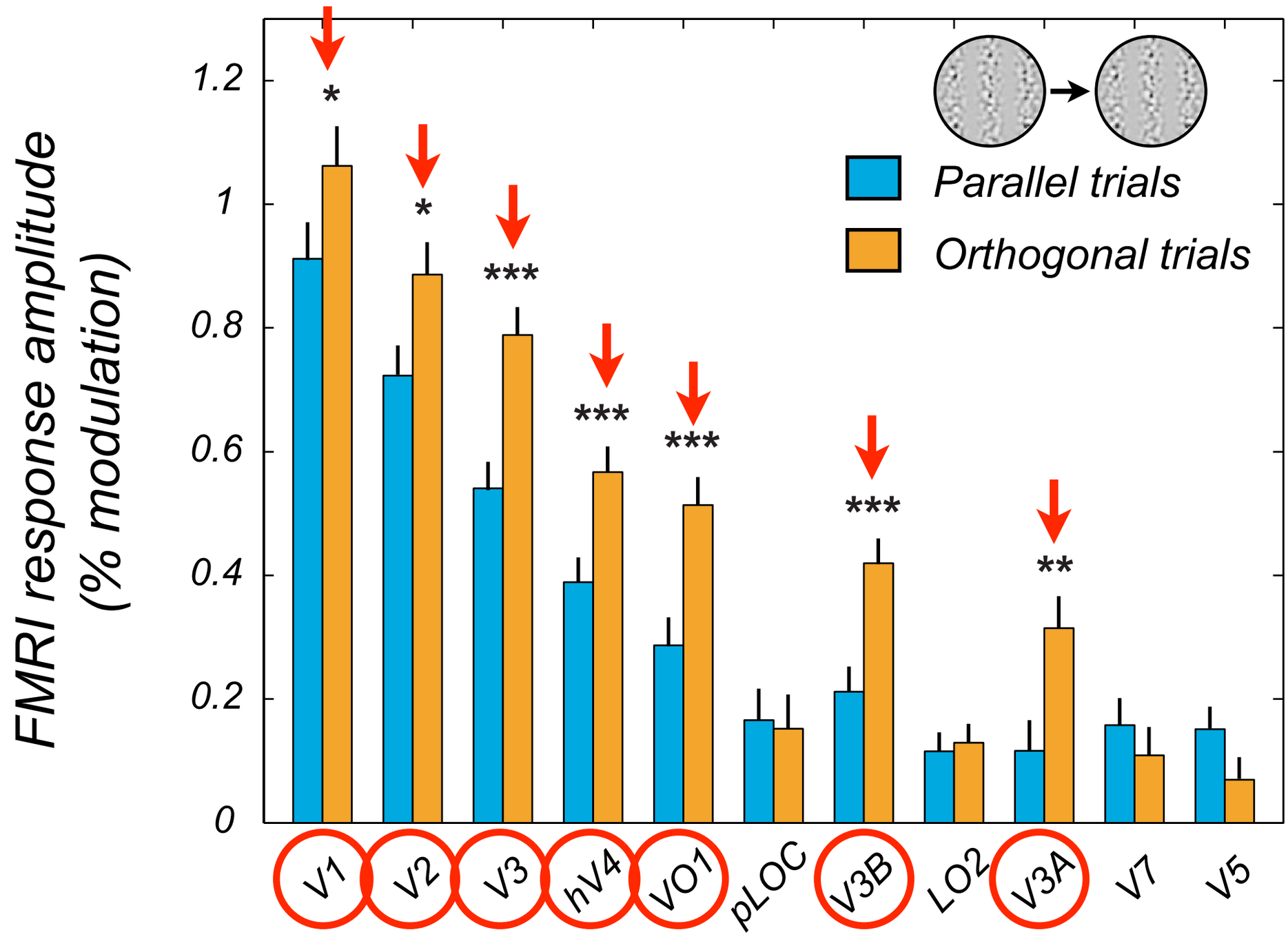
Adaptation indices: first-order patterns (LM:LM)



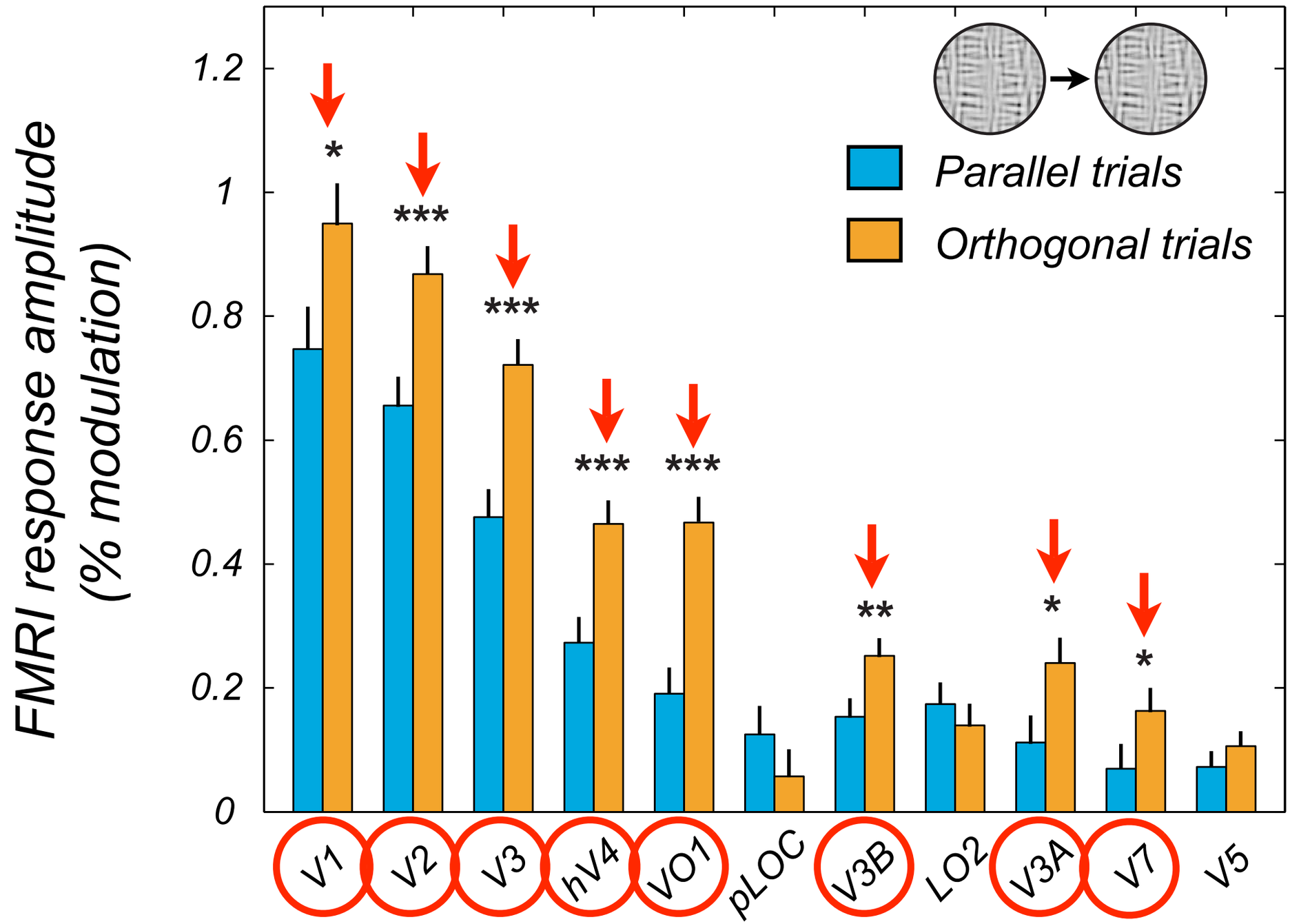
- Adaptation indices constant across visual areas
- No significant differences between V1 and extrastriate visual areas
- Adaptation in V1 can account for adaptation in extrastriate visual areas

Results:
Unimodal adaptation - second-order (CM:CM & OM:OM)

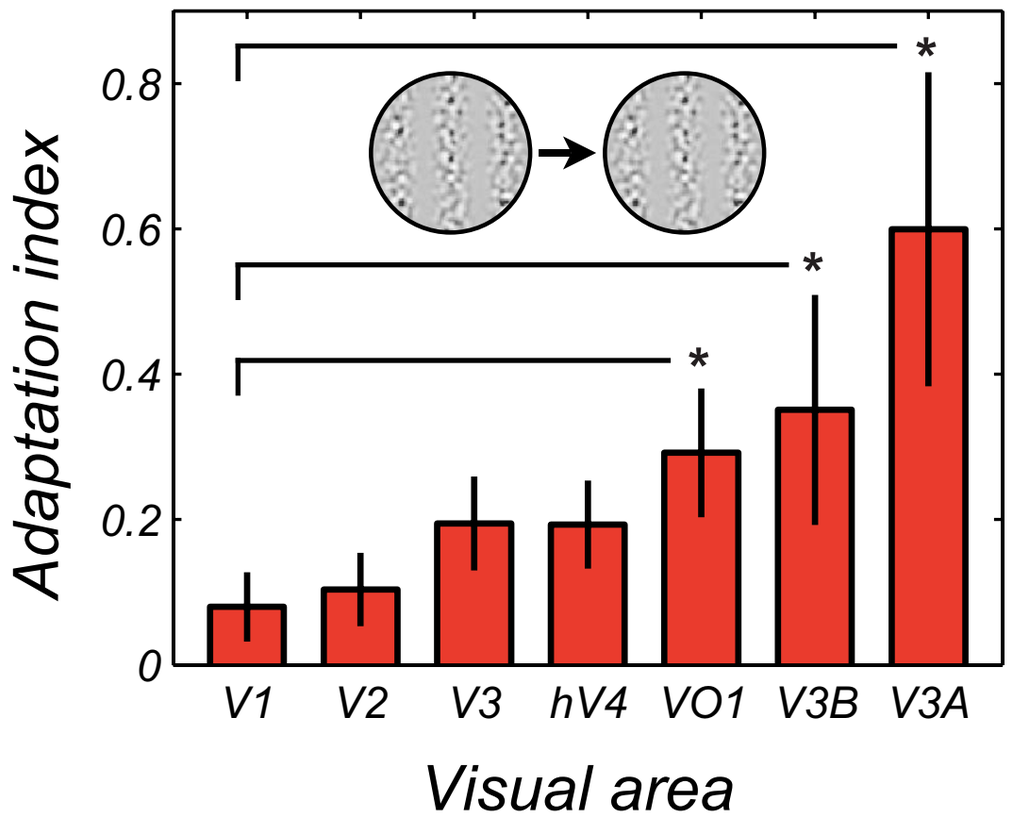
Adaptation to second-order patterns: contrast (CM:CM)

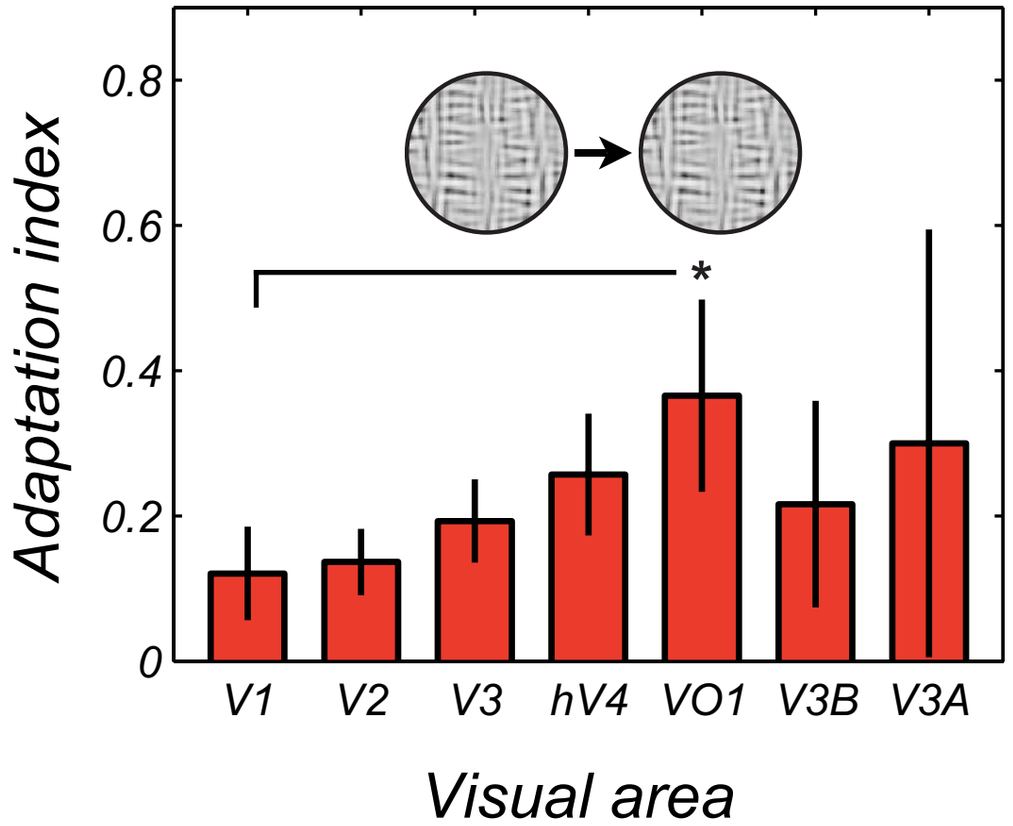


Adaptation to second-order patterns: orientation (OM:OM)



Adaptation indices: second-order patterns (CM:CM & OM:OM)



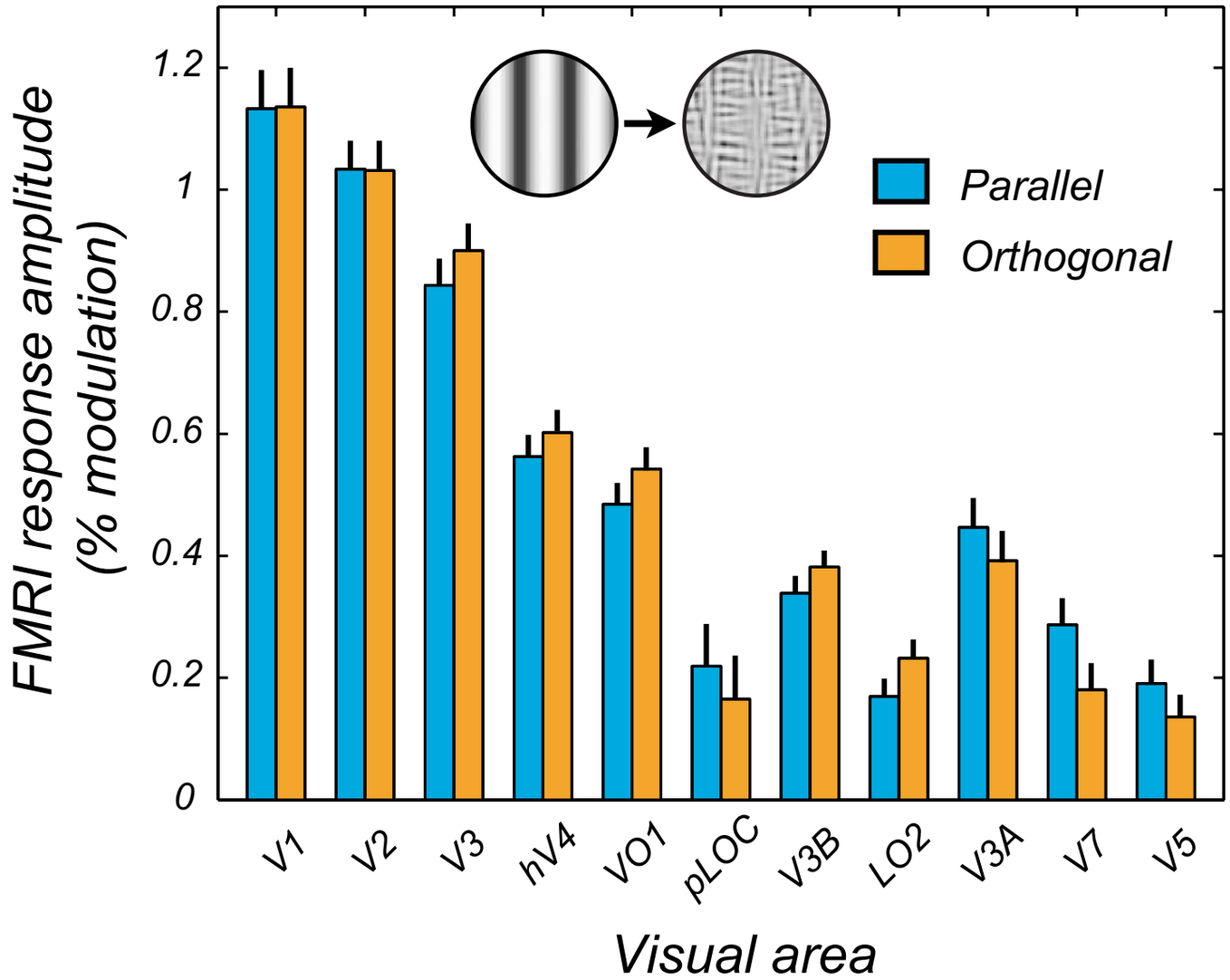


- Adaptation indices greater in extrastriate areas than in V1
- Suggests additional adaptation in extrastriate visual cortex

Cue invariance?

Cross-modal adaptation (LM:OM)

No consistent cross-adaptation between first- and second-order patterns (LM:OM)



Conclusions

- Results consistent with FRF model
- First-order neurons in V1
- FRF second-stage neurons both in V1 and extrastriate areas (feedback to V1?)
- Different second-order patterns processed in same visual areas
- No evidence of cue-invariant neurons
- Selective attention is not required for first- or second-order pattern adaptation

Acknowledgements

Center for Neural Science/ Department of Psychology:
Denis Schluppeck
Barbara Knappmeyer
Justin Gardner

NYU Center for Brain Imaging:
Keith Sanzenbach
Souheil Inati

jonas@cns.nyu.edu

NYU